TRINITY RIVER FLOW EVALUATION

Final Report

A report to the:

Secretary
U.S. Department of the Interior
Washington, D.C.

Prepared by:

U.S. Fish and Wildlife Service
Arcata Fish and Wildlife Office
1125 16th Street, Room 209
Arcata, CA 95521

and

Hoopa Valley Tribe
P.O. Box 417
Hoopa, CA 95546

In Consultation with:

U.S. Geological Survey
U.S. Bureau of Reclamation
National Marine Fisheries Service
California Department of Fish and Game

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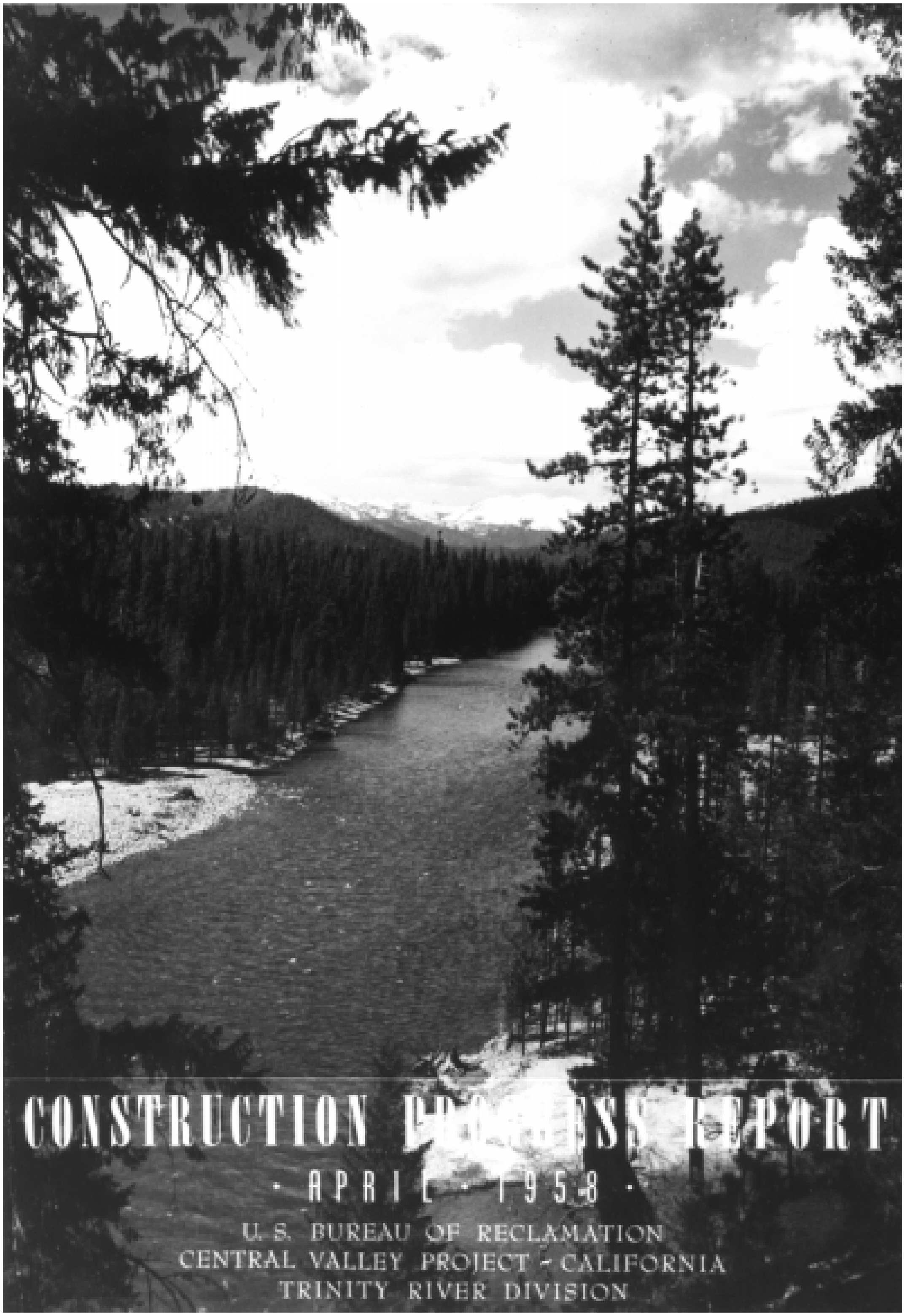

CONSTRUCTION PROGRESS REPORT

· APRIL · 1958 ·

U. S. BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
TRINITY RIVER DIVISION

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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PRIMARY AUTHORS

U.S. Fish and Wildlife Service

Joe Polos
Ann Gray
Paul Zedonis
Jeff Thomas
Tom Payne

Hoopa Valley Tribe

Robert Franklin
Bill Trush
Scott McBain

U.S. Geological Survey

Clair Stalnaker
Sam Williamson

U.S. Bureau of Reclamation

Rod Wittler

Chief Editor

Terry Rees (USGS)

Desktop Publishing

Brian R. Merrill

Electronic Publishing

USGS

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Individuals that assisted in preparation and review of the TRFE include: Mike Aceituno (USFWS), Bernard Aguilar (CDFG), Cindy Barry (USFWS), John Bartholow (USGS), Randy Bentin (CDFG), Scott Bergstrom (DOI Solicitor), Ted Boling (DOI), J. Craig Fischenich (USCE), Troy Fletcher (Yurok Tribe), J. Scott Foott (USFWS), Rowan Gould (USFWS), Bruce Halstead (USFWS), Mark Hampton (Northstate Resources), Dana Jacobsen (DOI Solicitor), Tom Kisanuki (USFWS), Matt Kondolf (UC-Berkeley), Richard Levin (Hoopa Valley Tribe), Dan Licht (USFWS), Amy Lind (USFS), Bob McCallister (CDFG), Rod McLeod (USFWS), Joe Membrino (Counsel, Hoopa Valley Tribe), Robert Milhouse (USGS), Tammy Newcomb (USFWS), Mike Orcutt (Hoopa Valley Tribe), Tim Randle (USBOR), Harry Rectenwald (CDFG), Russ Smith (USBOR), Gary Smith (CDFG), Dave Wegner, Peter Wilcock (Johns Hopkins Univ.), and Mark Zuspan (CDFG). Many of these individuals participated as subject matter experts in the series of meetings held in Eureka.

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CONVERSION FACTORS

This report uses English rather than metric units of measure. Water managers in the United States measure water in English units: TAF (thousand acre-feet) and cfs (cubic feet per second). The metric equivalents of these measures, dam^3 (cubic dekameters) and cms (cubic meters per second), are rarely used in the water industry and would have required conversion. The table below is provided for those who require the metric standard.

Quantity	To Convert from English Unit	To Metric Unit	Multiply English Unit by	To Convert to English from Metric Multiply Metric Unit by
Length	inches (in)	millimeters (mm)	25.4	0.03937
	inches (in)	centimeters (cm)	2.54	0.3937
	feet (ft)	meters (m)	0.3048	3.2808
	yards (yd)	meters (m)	0.9144	1.094
	miles (mi)	kilometers (km)	1.6093	0.62139
Area	square feet (ft^2)	square meters (m^2)	0.092903	10.764
	square miles (mi^2)	square kilometers (km^2)	2.59	0.3861
Volume	cubic feet (ft^3)	cubic meters (m^3)	0.028317	35.315
	cubic yards (yd^3)	cubic meters (m^3)	0.76455	1.308
	acre-feet (ac-ft)	cubic dekameters (dam^3)	1.2335	0.8107
	thousand acre-feet (TAF)	cubic dekameters (dam^3)	1233.5	0.0008107
Flow	cubic feet per second (cfs)	cubic meters per second (cms)	0.028317	35.315
Velocity	feet per second (ft/s)	meters per second (m/s)	0.3048	3.2808
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F - 32) /1.8	(1.8 x °C) + 32

ACRONYMS FOR THE TRINITY RIVER FLOW EVALUATION

ac-ft	acre-feet
AEAM	Adaptive Environmental Assessment and Management
AEAMP	Adaptive Environmental Assessment and Management Program
AMTG	Adaptive Management Technical Group
BETTER	Box Exchange Transport Temperature and Ecology of a Reservoir Model
BLM	U.S. Bureau of Land Management
BREACH	“Breach” model, (National Weather Service)
CDFG	California Department of Fish and Game
cfs	cubic feet per second
CRWQCB-NCR	California Regional Water Quality Control Board-North Coast Region
CSSC	California Species of Special Concern
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DEQ	Department of Environmental Quality
DMBRK	“Dam Break” model, (National Weather Service)
DOI	[U.S.] Department of the Interior
DWR	[California] Department of Water Resources
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	[U.S.] Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FLDWAV	“Flood wave” model, (National Weather Service)
FMP	Fishery Management Plan
FONSI	Finding of no significant impact
fps	foot-per-second or feet-per-second
HABTAE	Habitat Simulation Model
HEC	Hydraulic Engineering Center model (U.S. Army Corps of Engineers)
HSC	Habitat Suitability Criteria
HSI	Habitat Suitability Index
HVT	Hoopa Valley Tribe
IFIM	Instream Flow Incremental Methodology
KRTAT	Klamath River Technical Advisory Team
lbs	Pounds
LWD	Large Woody Debris
MESC	Midcontinent Ecological Science Center
NMFS	National Marine Fisheries Service
NPS	National Park Service
NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
OCAP	Operating Criteria and Procedures
PFMC	Pacific Fishery Management Council

PHABSIM	Physical Habitat Simulation Model
P.L.	Public Law
Program	Trinity River Basin Fish and Wildlife Program
PROSIM	Project Simulation Model
RAS	River Analysis System (model)
RFP	Request for proposals
RHABSIM	Riverine Habitat Simulation Model
R.	River
RM	river mile
RSL	Redwood Sciences Laboratory
SAB	Scientific Advisory Board
SALMOD	Salmonid Potential Production Model
Secretary	Secretary of the Interior
Service	U.S. Fish and Wildlife Service
SALUL	*Salix lucida ssp. lasiandra*
SMUD	Sacramento Municipal Utility District
SNTEMP	Stream Network Temperature Model
TAF	thousand acre-feet
Task Force	Trinity River Basin Fish and Wildlife Task Force
TCRCD	Trinity County Resource Conservation District
TMAT	Technical Modeling and Analysis Team
TMC	Trinity Management Council
TMG	Trinity Management Group
TRBFWTF	Trinity River Basin Fish and Wildlife Task Force
TRD	Trinity River Division
TRFE	Trinity River Flow Evaluation
TRFH	Trinity River Fish Hatchery
TRRP	Trinity River Restoration Program
TRNMOD	Water Management Policy Simulation Model for the Trinity River, CA
TSLIB	Time Series
USBOR	U.S. Bureau of Reclamation
USCE	U.S. Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USHOR	U.S. House of Representatives
Q	river discharge
WQRRS	Water Quality for River-Reservoir Systems model (U.S. Army Corps of Engineers)
WUA	weighted usable area
WY	water year
XS	cross section

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EXECUTIVE SUMMARY

When Congress authorized construction of the Trinity River Division (TRD) of the Central Valley Project (CVP) in 1955, the expectation was that surplus water could be exported to the Central Valley without harm to the fish and wildlife resources of the Trinity River. The TRD began operations in 1963, diverting up to 90 percent of the Trinity River's average annual yield at Lewiston, California. Access to 109 river miles of fish habitat and replenishment of coarse sediment from upstream river segments were permanently eliminated by Lewiston and Trinity Dams. Within a decade of completing the TRD, the adverse biological and geomorphic responses to TRD operations were obvious. Riverine habitats below Lewiston Dam degraded and salmon and steelhead populations noticeably declined.

In 1981, the Secretary of the Interior (Secretary) directed that a Trinity River Flow Evaluation (TRFE) study be conducted to determine how to restore the fishery resources of the Trinity River. This report is the product of that TRFE study. It provides recommendations to the Secretary to fulfill fish and wildlife protection mandates of the 1955 Act of Congress that authorized the construction of the Trinity River Division of the Central Valley Project, the 1981 Secretarial Decision that directed the U.S. Fish and Wildlife Service to conduct the TRFE, the 1984 Trinity River Basin Fish and Wildlife Management Act, the 1991 Secretarial Decision on Trinity River Flows, the 1992 Central Valley Project Improvement Act, and Federal Tribal trust responsibilities.

This report was compiled by teams of experts. After research and literature reviews were completed, they met to discuss the collective implications of their work. Individual chapters were then written and reviewed as a group. The purpose of each chapter was to:

- describe Congressional, Secretarial, and other actions taken to address the declines of the Trinity River fishery resources (Chapters 1 and 2);
- present the pre- and post-TRD biological and physical scientific knowledge of the Trinity River, including salmon and steelhead life histories and population trends, and changes in channel morphology and overall quality of fish habitat (Chapters 3 and 4);
- present the findings of studies conducted as part of the TRFE and the Trinity River Fish and Wildlife Restoration Program (Chapter 5);
- evaluate the effectiveness of the water volumes identified in the 1981 Secretarial Decision to restore fishery resources (Chapter 6).

The collective scientific effort led to:

- the conclusion that a modified flow regime, a reconfigured channel, and strategy for sediment management are necessary to have a functioning alluvial river (mixed-size rock, gravel, and sand deposited by river flow) that will provide the diverse habitats required to restore and maintain the fishery resources of the Trinity River (Chapter 7);
- instream flow, channel-rehabilitation, and fine and coarse sediment recommendations to address this conclusion (Chapter 8); and
- a recommendation to utilize an Adaptive Environmental Assessment and Management (AEAM) approach to guide future management and ensure the restoration and maintenance of the fishery resources of the Trinity River (Chapter 8).

Life History and Physical Requirements

The life histories of steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*) have two distinct phases, one in freshwater and the other in salt water. These species lay their eggs (spawn), hatch, and rear in freshwater. The adults lay their eggs in gravel of various preferred sizes (depending on species). The eggs incubate in the spaces between rocks of the river bed. After a period of time, small, fully formed fish ("fry") emerge from the gravel to begin their free-swimming life-stages. Young salmonids remain in the river of their birth for months to years (depending on species) before migrating to the ocean. Before they migrate, they undergo a physiological transformation (called smoltification) that allows them to survive in a saltwater environment. At that point, they are called "smolts". After the transformation, they migrate to saltwater. Salmon grow to their adult size in the ocean, returning in 2 to 5 years to the river of their birth to spawn.

Steelhead, coho salmon, and chinook salmon each require similar instream habitats for spawning, egg incubation, and rearing, although there are important differences. Timing of these habitat needs varies, thus optimizing population numbers and survival by minimizing competition among species. Common life-history requirements for these species include spawning gravels relatively free of fine sediments, adequate spawning habitat, low-velocity shelters for early life-stages, adequate rearing and feeding habitats with cover from predators, and appropriate flows and temperature conditions for migration to and from the ocean. For all species, spawning occurs in tails of pools and riffles where gravels are cleansed of fine sediment by high flows. Eggs and embryonic life stages develop in these well-percolated gravels for weeks until emerging as fry, which seek shallow, low-velocity shelters usually found along channel margins of gently sloping point bars and backwater areas. As they grow, habitat requirements change to faster and deeper riffle, pool, and run habitats, depending on the species. The habitats necessary for salmonids to complete all of their freshwater life stages were provided in the pre-TRD riverine environment; however, these conditions were radically changed by the operations of the TRD.

Changes of Riverine Habitats and Fish Populations Resulting from Construction and Operation of the TRD

Prior to the construction of the TRD, the Trinity River was an unregulated, meandering, dynamic alluvial river within a broad floodplain. Alluvial means "material deposited by running water." Dynamic means "that the alluvial material was frequently moved and the channel moved back and forth across the floodplain over time". Alluvial rivers are often characterized by a repeated, distinctive S-shaped channel pattern that is free to meander in the floodplain (alternate bar sequences). High flows periodically changed the size, shape, and location of river bars (submerged or exposed alluvial material). Flow regulation by the TRD removed nearly all high flows that were responsible for forming and maintaining dynamic alternate bar sequences. No longer scoured by winter floods downstream of the TRD, streambank (riparian) vegetation encroached into the river channel and formed riparian berms along the channel margins. Reduced flows, loss of coarse sediment, and riparian encroachment caused the mainstem river downstream from the TRD to change from a series of alternating riffles and deep pools that provided high-quality salmonid habitat to a largely monotypic run habitat confined between riparian berms (a trapezoid-shaped channel). The loss of alluvial features and diverse riverine habitats reduced the quantity and quality of salmonid habitats and the populations that relied upon them.

The available data indicate that in-river spawning populations of salmon and steelhead have dramatically declined since the construction of the TRD (Table ES1). Average spawning numbers of post-TRD naturally produced spring-run (return to the river in the spring) and fall-run (return to the river in the fall) chinook salmon represent a 68 percent reduction compared to the pre-TRD average. Large numbers of returning chinook salmon spawners observed since 1978 were typically hatchery-produced fish. Naturally produced fall- and spring-run chinook salmon account for an average of 44% and 32% of their respective spawning runs. This situation is not indicative of healthy spawning and (or) rearing conditions for naturally produced populations. The inriver coho salmon spawning population is predominantly of hatchery origin, with only 3 percent of the spawning coho attributable to natural production. While naturally produced fall-run steelhead make up a large portion of the inriver spawners (70 percent), this still represents a 53 percent reduction from pre-TRD estimates.

Table ES1. Pre- and Post-TRD Adult Salmon Returning to Spawn

Species	Pre-TRD Average[1]	Post-TRD Average for Naturally Produced Spawners[1]	Percent Reduction
Chinook Salmon (Spring-Run/Fall-Run)	38,600[2] (not available)	12,550 (1,550/11,000)	67%
Coho Salmon	5,000	200	96%
Steelhead	10,000	4,700	53%

[1] Pre- and Post-TRD adult salmon return data is presented in Chapter 3.

[2] Pre-TRD average number of chinook salmon returning to spawn was reduced by 9,000 to make pre- and post-TRD numbers more comparable, (i.e. the fish production that previously was provided above Lewiston and is included in the pre-TRD average of 47,600 chinook is now provided by the TRFH (returning adult requirements to provide eggs for the hatchery are 3,000 spring-run chinook and 6,000 fall-run chinook)).

Coho salmon that return to Klamath and Trinity Rivers are considered by the National Marine Fisheries Service (NMFS) to be part of the Southern Oregon/Northern California Coast Evolutionary Significant Unit (ESU) — one population for Federal Endangered Species Act (ESA) purposes. This ESU has been listed as threatened pursuant to the ESA. The final rule that listed the ESU recognized that various habitat declines affected coho salmon populations, including channel morphology changes, substrate changes, loss of off-channel rearing habitats, declines in water quality, and altered streamflows. The steelhead and chinook salmon populations of the Trinity River are being evaluated pursuant to the ESA and may warrant listing in the future.

Although the primary focus of this report is salmon and steelhead, pre-TRD wildlife populations have also been affected by changes in the riverine environment. Wildlife habitat features such as seasonally flooded marshes and side channels, shallow river margins, cold-water holding pools, and bank undercuts have been reduced or eliminated owing to TRD operations. Species that depend on flood-maintained habitats, such as the foothill yellow-legged frog (*Rana boylii*) and the western pond turtle (*Clemmys marmorata*), have been negatively impacted by TRD construction and operations.

Flow Evaluation Studies and Results

Several individual studies provided the needed information to make the recommendations in this report: (1) habitat preferences of salmon and steelhead and relative amounts of preferred habitats resulting from varying dam releases; (2) an evaluation of habitat availability and channel processes at channel-rehabilitation projects; (3) water and sediment interactions and river channel shape (fluvial geomorpholgy); (4) water temperature needs of salmon and steelhead and dam releases necessary to meet those needs; and (5) a juvenile salmon production model. The results of these studies are summarized below.

A study of the physical conditions (such as water depth, velocity, and structural elements) that support specific anadromous salmonid life stages (microhabitat) resulted in the development of site-specific habitat suitability criteria. Using these criteria, the relation between microhabitat and streamflow for riverine life-stages of chinook salmon, coho salmon, and steelhead were modeled. Results of physical habitat availability modeling on the Trinity River were used as a partial basis for making instream flow recommendations in conjunction with information on pre-TRD hydrology, fluvial geomorphology (streamflows needed to form and maintain the channel), sediment management, and water temperatures.

Several channel rehabilitation projects were evaluated to determine if these projects created the shallow, low velocity habitats required by young salmon and steelhead for rearing. Results indicated that restoring the gradually sloping bars provided stable amounts of rearing habitat throughout a wide range of flows - an improvement over conditions in the existing channel where the amount of available habitat fluctuates widely over the same range of flows. Rehabilitating the confined, trapezoidal channel to restore the pre-TRD channel morphology will provide high quality, stable habitat conditions that should greatly benefit young salmon and steelhead until they are ready to migrate to the ocean.

TRD operations disrupted the water and sediment interactions of the river, which changed the fish habitats below Lewiston Dam. To rehabilitate the complex habitats that were similar to those that existed in the pre-TRD alluvial channel, pre- and post-TRD water and sediment interactions were examined to determine what pre-TRD processes are absent in the post-TRD river and how these processes can be re-established. These processes are largely defined by a set of ten fundamental alluvial river attributes. These attributes are: (1) the channel morphology is spatially complex; (2) flows and water quality are predictably variable; (3) the channel-bed surfaces are frequently mobilized; (4) the channel-bed surfaces are periodically scoured and refilled; (5) fine and coarse sediment supplies are approximately balanced; (6) the channel location periodically migrates; (7) the channel has a functional floodplain; (8) the channel is occasionally "reset" during very large floods; (9) riparian plant communities are diverse and self-sustaining; and (10) the groundwater table (subsurface water level that surrounds rock, gravel and sand along the side of the river) fluctuates naturally with changing streamflows. Studies were conducted to identify dam releases required to re-establish the processes necessary to achieve many of these attributes (called fluvial geomorphological processes). Recovering the dynamic alluvial channel morphology similar to that which existed pre-TRD will restore the diverse habitats needed by the fish and wildlife.

Water temperature affects every aspect of the life of salmonids, including egg incubation, growth, maturation, competition, migration, spawning, and resistance to parasites, diseases, and pollutants. Operations of the TRD changed the thermal regime of the Trinity River, providing warmer water temperatures during the winter and colder water temperatures at Lewiston during the late spring/summer than were present at Lewiston prior to the TRD because water is released from the deep levels behind the dam. It was generally believed that the TRD would increase salmonid production due to more stable flows and cooler summer water temperatures provided by dam releases. This increased production was never realized. Most salmonid smolts outmigrated before summer water temperatures were unsuitable. Rearing juvenile salmonids remained in the cooler riverine habitats above Lewiston that were predominantly fed by snowmelt, or sought the cool layer of water at the base of pools throughout the mainstem (a stratified pool). Operation and construction of the TRD blocked these upstream habitats and altered flows such that pools no longer stratify. Temperature objectives were established for the Trinity River that are, in effect, to compensate for the loss of these necessary cool-water habitats. In order to examine the dynamic relation between meteorology, tributary hydrology, dam release temperatures and release magnitudes that all influence downstream water temperatures, a temperature model (SNTEMP) was calibrated specifically for the Trinity River. This model was used to examine water temperatures under various conditions and to help determine what flows were necessary to meet temperature objectives for outmigrating salmon during the spring and early summer. Simulations and measured data show that water temperatures throughout the Trinity River are influenced by dam releases during the spring. Increasing dam releases during the spring and early summer can improve temperature conditions in the river that promote better growing conditions and increase survival for ocean bound, outmigrating smolts. Because spring- and fall-run chinook salmon require cold water to survive and successfully spawn, but can no longer access cold-water areas above Lewiston Dam, there is a need to maintain a cold-water segment below Lewiston Dam. Dam releases can be effectively managed to provide holding areas that are the proper temperature for adult salmon and steelhead during the summer, fall, and winter.

A model, SALMOD, was developed to evaluate the effect of varying environmental conditions (flows, water temperature, habitat availability) on the number of naturally produced young-of-the-year chinook salmon in the Trinity River from Lewiston Dam downstream 25 miles. This model evaluated the potential numbers of fish (young-of-the-year chinook as an index) that could be produced under the four water volumes identified in the

1981 Secretarial Decision. In general, model results indicated that: (1) habitat conditions in the current channel severely limit the salmonid production potential of the Trinity River; and (2) increased rearing habitat is critical to restore and maintain salmonid populations.

Evaluation of the 1981 Secretarial Decision Volumes

The 1981 Secretarial Decision identified four volumes of water for evaluation: 140 thousand acre-feet (TAF), 220 TAF, 287 TAF, and 340 TAF. One acre-foot of water is the volume of water that would cover one acre to a depth of one foot (approximately 326,000 gallons - an average household uses between one-half and one acre-foot of water per year). Release schedules developed for each of the water volumes were assessed for their ability to meet criteria necessary to restore and maintain the fishery resources of the Trinity River: fish habitat requirements, summer/fall temperature criteria, smolt outmigration temperature requirements, and thresholds for geomorphological processes that create and maintain diverse fish habitats (alluvial river attributes). The flow releases from Lewiston Dam required to meet the criteria and accomplish specific objectives are described below:

1. Year-round releases of 300 cfs to provide suitable spawning and rearing habitat for salmon and steelhead within the existing channel;

2. Releases of 450 cfs from July 1 to October 14 to meet the summer/fall temperature objectives;

3. Spring/summer releases that would provide improved conditions for smolt outmigration; and

4. Releases necessary to achieve flow-related geomorphic processes that create and maintain river habitats.

The volumes of water identified in the 1981 Secretarial Decision were able to meet the fishery restoration criteria in varying degrees, although all criteria are not fully met even with the greatest volume, 340 TAF. The current water volume of 340 TAF is equal to the third driest year in the 84-year period of record at Lewiston, indicating that the river below Lewiston Dam has experienced a functional 35-year drought since TRD operations began. Habitat degradation and fine sedimentation, identified as reasons for the decline of these fishery resources, will continue under all 1981 Secretarial Decision volumes because of lack of sufficient water to address multiple needs within a single year. SALMOD results showed that peak production of chinook salmon will be reached at water volumes above those identified in the 1981 Secretarial Decision.

Fishery Restoration Strategy

The recommended strategy to rehabilitate salmonid habitat is a management approach that integrates riverine processes and instream flow-dependent needs. A fundamental conclusion of this and other studies is that the present channel morphology, a direct result of TRD construction and operation, is inadequate to meet salmonid production objectives. If naturally produced salmonid populations are to be restored and maintained, the habitats on which they depend must be rehabilitated.

Recommended future management to restore the fishery resources of the Trinity River must include reshaping selected channel segments, managing coarse and fine sediment input, prescribing reservoir releases to allow flow-related geomorphic processes to reshape and maintain a new dynamic channel condition, providing suitable spawning and rearing microhabitat, and providing favorable water temperatures for salmonids. This new channel morphology will be smaller in scale than that which existed pre-TRD, but it will exhibit the essential attributes of a dynamic alluvial river.

Recommendations

Rehabilitation of the mainstem Trinity River can best be achieved by restoring processes that provided abundant complex instream habitat prior to construction and operation of TRD. Restoring these processes requires releasing increased annual instream volumes in conjunction with variable reservoir release schedules, managing fine and coarse sediment supplies, and rehabilitating selected reaches of the mainstem channel. Studies performed as part of the TRFE identified three sets of flow-related management objectives: (1) releases to provide suitable salmonid spawning and rearing habitat; (2) releases to mimic the spring snowmelt hydrograph (the high flow in the spring resulting from the melting snowpack and the gradual decrease in flow following the peak) to satisfy flow-related geomorphic and riparian vegetation objectives necessary for the creation and maintenance of diverse salmonid habitats and assist smolt outmigration; and (3) releases to meet appropriate water-temperature objectives for holding/spawning adult salmonids and outmigrating salmonid smolts. Together, these recommended actions will rehabilitate the mainstem channel below Lewiston and provide the habitats necessary to restore and maintain the fishery resources of the Trinity River.

Water-Year Classification and Annual Instream Water Volumes

Variability is a keystone to the restoration strategy because no single annual flow regime can be expected to perform all functions needed to maintain an alluvial river system and restore and maintain the fishery resources. There are five water-year classes used in this study to describe the variability expected from year to year. They are Critically Dry, Dry, Normal, Wet, and Extremely Wet. In the restoration strategy outlined in this report, various flow-related geomorphic objectives and desired habitat conditions (microhabitat and temperature objectives) are targeted for each water-year class. Some processes and habitat conditions, such as favorable spawning and rearing microhabitat, are recommended for all water-year classes while others, such as floodplain inundation, are expected to be achieved only during the wetter water-year classes. Annual release schedules were developed by integrating the information on requirements to meet spawning and rearing microhabitat, flow-related geomorphic processes, and water temperature management objectives for the different water-year classes.

Inter-annual flow variability is achieved by recommending unique annual flow releases for each water year class. Recommended total instream water volumes range from 368.6 TAF in Critically Dry water years to 815.2 TAF in Extremely Wet water years (Table ES2). The average (weighted by water year class probability) water volume required for the Trinity River will be 594.5 TAF, an average increase of 254.5 TAF over the current water volume of 340 TAF.

Within Year (Seasonal) Flow Recommendations

Intra-annual changes in flow are often described by water managers, hydrologists and other scientists by a seasonal hydrograph. Flow levels fluctuate throughout the year based on weather conditions or managed water releases. The following summary is a description of recommended water releases from Lewiston Dam and the expected benefits downstream from the dam. The described seasonal water releases of the total water volume assigned to each water-year class are graphically depicted in Figure ES1.

In the present Trinity River channel, maintaining 300 cfs as the fall/winter baseflow provides suitable spawning habitat throughout the chinook salmon, coho salmon, and steelhead spawning seasons and provides habitat for rearing salmon and steelhead.

Since flow-related geomorphic management objectives require various flow levels, more comprehensive changes occur during wetter years. A list of the expected objectives that can be met by releases during the spring snowmelt hydrograph in different water-year classes is depicted in Table ES3. The short, 5-day, peak release during all water-year classes (except Critically Dry) provides sufficient duration to initiate targeted flow-related geomorphic processes and transport coarse bed material originating from tributaries in most years. The timing of the spring snowmelt peak release varies on the basis of historical timing, with the peak occurring later during wetter water years. The magnitude of releases to achieve flow-related geomorphic processes targeted for each water-year class varies, ranging from 1,500 cubic feet per second (cfs) in Critically Dry water years to 11,000 cfs in Extremely Wet water years. The recommended Extremely Wet and Wet spring snowmelt hydrographs also have two distinct segments while flows are decreasing after the spring snowmelt peak flow (referred to as the “descending limb of the spring snowmelt hydrograph”). These periods are separated by a short-duration “bench” at 6,000 cfs. The “bench” promotes transport of fine sediment once peak flows have mobilized the surface layer of the channelbed. Another “bench”, at 2,000 cfs, is recommended for Extremely Wet, Wet, and Normal water years to inundate portions of alternate bars during the time period when riparian vegetation releases seeds. This inundation

Table ES2. Recommended annual water volumes for instream release to the Trinity River in thousands of acre-feet (TAF), probability of occurrence, and Trinity Reservoir inflow thresholds.

Water-Year Class	Instream Volume (TAF)	Trinity Reservoir Inflow (TAF)	Probability of Occurrence
Extremely Wet	815.2	>2,000	0.12
Wet	701.0	1,350 to 2,000	0.28
Normal	646.9	1,025 to 1,350	0.20
Dry	452.6	650 to 1,025	0.28
Critically Dry	368.6	<650	0.12
Average (weighted by water-year probability)	594.5		

prevents riparian encroachment along the low-flow channel and provides suitable temperatures for chinook salmon smolts, which outmigrate later in the year than other salmonid species. A 36-day, 1,500-cfs "bench" during Critically Dry water years will discourage seedling germination on alternate bar flanks through inundation and provide some temperature benefits for outmigrating chinook salmon smolts. The rate of change for the descending limbs of the snowmelt hydrographs mimics natural receding snowmelt hydrograph rates.

Because of the long outmigration period for the three salmonid species combined, a variety of outmigrant temperature conditions are necessary throughout the spring/summer hydrographs. Recommended releases for Extremely Wet, Wet, and Normal water years provide optimal salmonid smolt temperatures (Table ES4). Marginal smolt temperatures will be provided throughout much of the outmigration period during Dry and Critically Dry water years. The lower releases during these year classes will allow mainstem water temperatures to warm earlier in the outmigration period, which will cue salmonids to outmigrate (warming temperatures are an important physiological signal to begin smoltification and outmigration) before water temperatures in the lower watershed are likely to become too warm to insure smolt survival. Following smolt temperature control releases, 450 cfs releases will be maintained to provide suitable temperature regimes for holding and spawning adult spring-run and fall-run chinook (Table ES5).

Channel Rehabilitation

Channel-rehabilitation activities are recommended along the mainstem Trinity River from Lewiston Dam to the North Fork Trinity River confluence. The intent of channel rehabilitation is to selectively remove the fossilized riparian berms (berms that have been anchored by extensive woody vegetation root systems and consolidated sand deposits) and recreate alternate bars. Channel rehabilitation is not intended to completely remove all riparian vegetation, but to remove vegetation at strategic locations to promote alluvial processes necessary for the restoration and maintenance of salmonid populations. The tightly bound berm material is hard to mobilize even at high flows, and mechanical berm removal is necessary. After selected berm removal, subsequent high-flow releases and coarse sediment supplementation will maintain these alternate bars and create a new dynamic channel. Specific channel rehabilitation recommendations vary by river segment between Lewiston Dam to the confluence of the North Fork Trinity River because the needs of channel rehabilitation change with tributary inputs of flow and sediment.

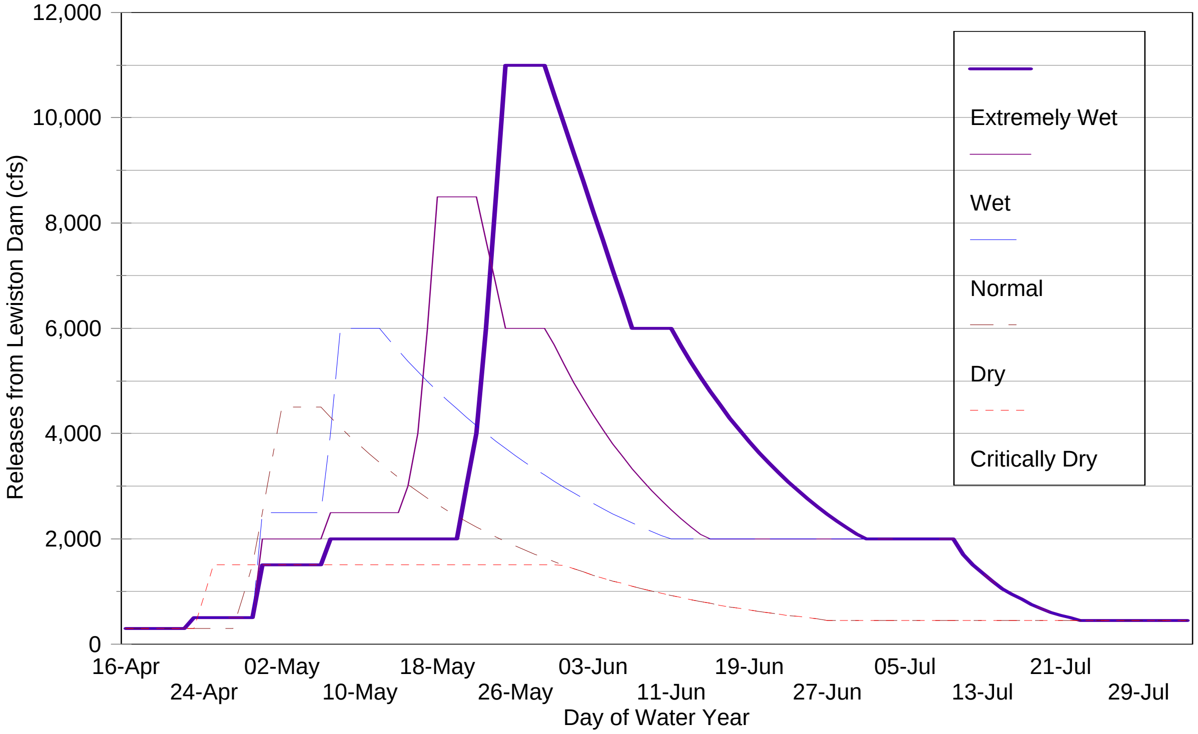

Figure ES1. Trinity River Flow Evaluation annual recommended hydrographs for each water year class: Extremely Wet, Wet, Normal, Dry, and Critically Dry. For all hydrographs, the recommended release from Lewiston Dam is 300 cfs from October 16 to April 8 and 450 cfs from August 1 to October 14.

The Service and Hoopa Valley Tribe identified 44 potential channel-rehabilitation sites, 3 potential side channel-rehabilitation sites, and 2 tributary delta maintenance sites. These sites are located where channel morphology, sediment supply, and high-flow hydraulics would encourage a dynamic, alluvial channel. A short implementation period for a significant number of these projects is recommended to evaluate whether they achieve their intended benefits: increasing the quality and quantity of salmonid habitat. Therefore, construction of 24 of the 44 channel-rehabilitation sites in the first 3 years of implementation is recommended. The remaining projects may proceed following evaluation by the AEAM program (see section on the AEAM program below).

Sediment Management

Sediment-management recommendations include: (1) immediate placement of more than 16,000 cubic yards of properly graded coarse sediment ($^{5}/_{16}$ to 5 inches) between Lewiston Dam and Rush Creek to restore the spawning gravel deficit caused by the elimination of upstream coarse sediment supply by the TRD; (2) annual supplementation of coarse sediment to balance the coarse sediment supply along the Lewiston Dam to Rush Creek segment; (3) reduction of fine sediment (< $^{5}/_{16}$ inch) storage in the mainstem by recommended flow releases; (4) prevention of fine sediment input from tributaries by mechanical removal from sedimentation ponds; and (5) reduction of fine sediment storage in the mainstem by mechanical removal. Channel-rehabilitation efforts also will remove large quantities (potentially up to 1 million cubic yards) of fine sediment stored in the riparian berms between Lewiston Dam and the North Fork Trinity River confluence.

Table ES3. Flow related geomorphic peak releases and durations with associated water-year classes and management objectives.

Peak Release (cfs)	Duration (days)	Water-Year Class	Management Objectives Achieved Through Flow Related Geomorphic Processes
1,500	36	Crit. Dry	• Prevention of germination/establishment of riparian vegetation low on alternate bars
4,500	5	Dry	• Mobilization of spawning gravels • Sand transport • All effects realized at lower flow level
6,000	5	Normal	• Channelbed surface mobilization • Significant mobilization of spawning gravels • Fine sediment movement • Channel migration • Floodplain inundation • Scour of 1-2 year old seedlings • Groundwater recharge of floodplain • All effects realized at lower flow levels
8,500	5	Wet	• Surface mobilization of alternate bars • Scour of bar margins • Coarse sediment movement • Scour of 2-3 year old seedlings • All effects realized at lower flow levels
11,000	5	Ext. Wet	• Significant scour of alternate bars • Large coarse sediment movement • Floodplain scour • Side-channel formation/maintenance • Sapling removal from alternate bars • All effects realized at lower flow levels

Table ES4. Water temperature objectives for the Trinity River salmonid smolts at the confluence of the Klamath and Trinity rivers for Extremely Wet, Wet, and Normal water year classes. These objectives are not met in Dry and Critically Dry water year classes because of the need to better synchronize Trinity River temperatures with those lower in the system.

Species	Temperature	Target Date
Steelhead	< 55.4ºF	May 22
Coho Salmon	< 59ºF	June 4
Chinook Salmon	< 62.6ºF	July 9

Table ES5. Water temperature objectives for the Trinity River during the summer, fall, and winter. Objectives are for the protection of holding and spawning salmon and steelhead.

	Temperature Objective Control Point	
Date	Douglas City (RM 92.2)	North Fork Trinity River (RM 72.4)
July 1 - September 14	60ºF	-
September 15 - September 30	56ºF	-
October 1 - December 31	-	56ºF

Adaptive Environmental Assessment and Management Program

The Trinity River Flow Evaluation Report, and the recommendations contained herein, are based on the best available scientific information compiled by a diverse group of scientists and engineers from various Federal, Tribal, and State agencies, and have been peer reviewed by outside experts and affected interests. Alluvial river systems are complex and dynamic. While our understanding of these systems and our predictive capabilities are extensive, some uncertainty over how the river and the fishery resources will react to the proposed recommendations still exists. Nonetheless, resource managers must make decisions and implement plans despite these uncertainties. AEAM provides a structured mechanism for fine-tuning management recommendations in relation to the recommended flows, sediment management, and channel rehabilitation activities.

Establishing an AEAM process for the Trinity River is recommended to guide future restoration activities. The proposed AEAM is an iterative 10-step process:

(1) Refine ecosystem goals and objectives;

(2) Monitor and assess the ecosystem baseline;

(3) Hypothesize biological/physical system behavior/response;

(4) Select future management actions;

(5) Implement management actions;

(6) Monitor the ecosystem response;

(7) Compare predictions with ecosystem response;

(8) Restate the ecosystem status;

(9) Use the adaptive process to evolve understanding of the ecosystem; and

(10) Assess continuing, modifying, or taking new actions.

Use of AEAM will assure restoration and maintenance of the fishery resources of the Trinity River and wise use of available water.

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CHAPTER 1 Introduction

1.1 Mandate

In 1955, Congress passed legislation (Public Law (P.L.) 84-386) (1955 Act) authorizing the construction of the Trinity River Division (TRD) of the Central Valley Project (CVP) to divert surplus water from the Trinity River into the Sacramento River. The 1955 Act also specifically authorized and directed the Secretary of the Interior (Secretary) to " . . . adopt appropriate measures to insure the preservation and propagation of fish and wildlife . . . " The U.S. House of Representatives report on the 1955 Act (USHOR, 1955) states:

> *. . . there is available for importation from the Trinity River, water that is surplus to the present and future needs of the Trinity and Klamath River Basins, and that surplus water, in the amount proposed in the Trinity division plan (704,000 acre-feet), can be diverted to the Central Valley without detrimental effect to the fishery resources.*

For the 10 years after the TRD became operational in 1964, an average of 88 percent (1,234 thousand acre-feet (TAF)) of the annual inflow was diverted into the Sacramento River Basin, with releases to the Trinity River ranging from 150 to 250 cubic feet per second (cfs) and a total annual instream volume of 120.5 TAF (TRBFWTF, 1977). These minimum releases were thought, at that time, to be adequate to sustain the fishery resources of the Trinity River. The releases identified as appropriate to protect the fishery resources below the TRD addressed primarily chinook spawning needs (Moffett and Smith, 1950). These minimum releases, however, did not address the fluvial geomorphic processes that maintain habitat, nor did these minimum releases provide habitat for other species or other life stages of salmonids. Following construction and

The 1955 Act authorized the TRD and directed the Secretary of the Interior to " . . . adopt appropriate measures to insure the preservation and propagation of fish and wildlife . . . " of the Trinity River.

operation of the TRD, rapid and unexpected changes in the river morphology caused the degradation of fish and wildlife habitat.

> Following construction and operation of the TRD, rapid and unexpected changes in the river morphology caused the degradation of fish and wildlife habitat, and salmonid populations noticeably decreased.

Within a decade of completion of the TRD, salmonid populations had noticeably decreased (Hubbel, 1973). Increased flow releases and habitat rehabilitation projects were identified as necessary to restore the fishery resources (TRBFWTF, 1977). On January 14, 1981, Secretary Cecil Andrus issued a Secretarial Decision and supporting documents (1981 Secretarial Decision, Appendix A) that directed the U.S. Fish and Wildlife Service (Service) to conduct the Trinity River Flow Evaluation (TRFE) Study. The mandate of this study was to determine how to restore anadromous fish populations in the Trinity River Basin.

The 1981 Secretarial Decision directed the Service to submit a report summarizing the effects of minimum releases and other actions in restoring Trinity River salmon and steelhead populations. The report was to address habitat availability over a range of instream water volumes (140 TAF to 340 TAF), and the need to maintain, increase, or decrease these volumes. The report was also to recommend specifically what actions should be continued, eliminated, or implemented to mitigate fish population declines attributable to the TRD.

1.2 Purpose of the Trinity River Flow Evaluation Report

This report provides recommendations to the Secretary of the Interior designed to fulfill fish and wildlife protection mandates of the 1955 Act, the 1981 Secretarial Decision, 1984 Trinity River Basin Fish and Wildlife Management Act, 1991 Secretarial Decision, the 1992 Central Valley Project Improvement Act, and the federal trust responsibility to restore and maintain the Trinity River fishery resources.

This report:

- describes Congressional, Secretarial, and other actions taken to address the declines of the Trinity River fishery resources;
- presents the current scientific knowledge of the Trinity River, including changes in channel morphology and overall quality of fish habitat; and
- concludes that a new channel configuration, with accompanying adaptive management of releases, will provide water temperature control and sediment transport needed to create the dynamic habitat required to restore and maintain the fishery resources of the Trinity River Basin.

The science at the time of the 1981 Secretarial Decision focused on single species management. In response to an increasing awareness and understanding of river ecosystems and fishery habitats, additional studies that addressed channel morphology, sediment, water temperature, and

> The 1981 Secretarial Decision directed the U.S. Fish and Wildlife Service to conduct the Trinity River Flow Evaluation Study to determine how to restore fish populations in the Trinity River Basin, and to recommend specifically what actions should be continued, eliminated, or implemented to mitigate fish population declines attributable to the TRD.

other ecosystem processes were initiated. This report makes management recommendations based on information provided in the following studies:

- Salmonid Microhabitat
- Channel Rehabilitation Microhabitat
- Fine Sediment Transport and Spawning Gravel Flushing
- Investigations of the Alluvial River Attributes
- Flow-Water Temperature Relations
- Chinook Salmon Potential Production

> "This report provides recommendations to the Secretary of the Interior designed to fulfill fish and wildlife protection mandates . . . "

Integrating the results of these studies provides the scientific basis necessary to satisfy Secretarial and Congressional mandates. Fundamentally, this report acknowledges that native fish and wildlife species evolved and adapted to the fluvial processes and habitats characteristic of the pre-disturbance Trinity River, and restoring salmonid populations must be founded on rehabilitating and managing fluvial processes that create and maintain habitats vital to anadromous fish.

Subsequent chapters are summarized below:

Chapter 2: Background: Water Management and Fishery Restoration Activities chronicles events leading up to the 1981 Secretarial Decision and subsequent legislative and administrative actions addressing restoration efforts in the Trinity River Basin. The Trinity River Division of the Central Valley Project facilities also are described.

> "The science at the time of the 1981 Secretarial Decision focused on single species management. In response to an increasing awareness and understanding of river ecosystems and fishery habitats, additional studies that addressed channel morphology, sediment, water temperature, and other ecosystem processes were initiated."

Chapter 3: Fish and Wildlife Background presents detailed descriptions of the life histories and habitat requirements of Trinity River anadromous salmonids, as well as other fish and semi-aquatic species that live in the Trinity River.

Chapter 4: A Historical Perspective to Guide Future Restoration describes the general physical, hydrological, and biological setting of the Trinity River prior to and after construction of the TRD— specifically, the hydrology, fluvial geomorphology, and riparian communities of the Trinity River. Specific alluvial river attributes that link natural riverine processes necessary to rehabilitate salmonid habitat are presented.

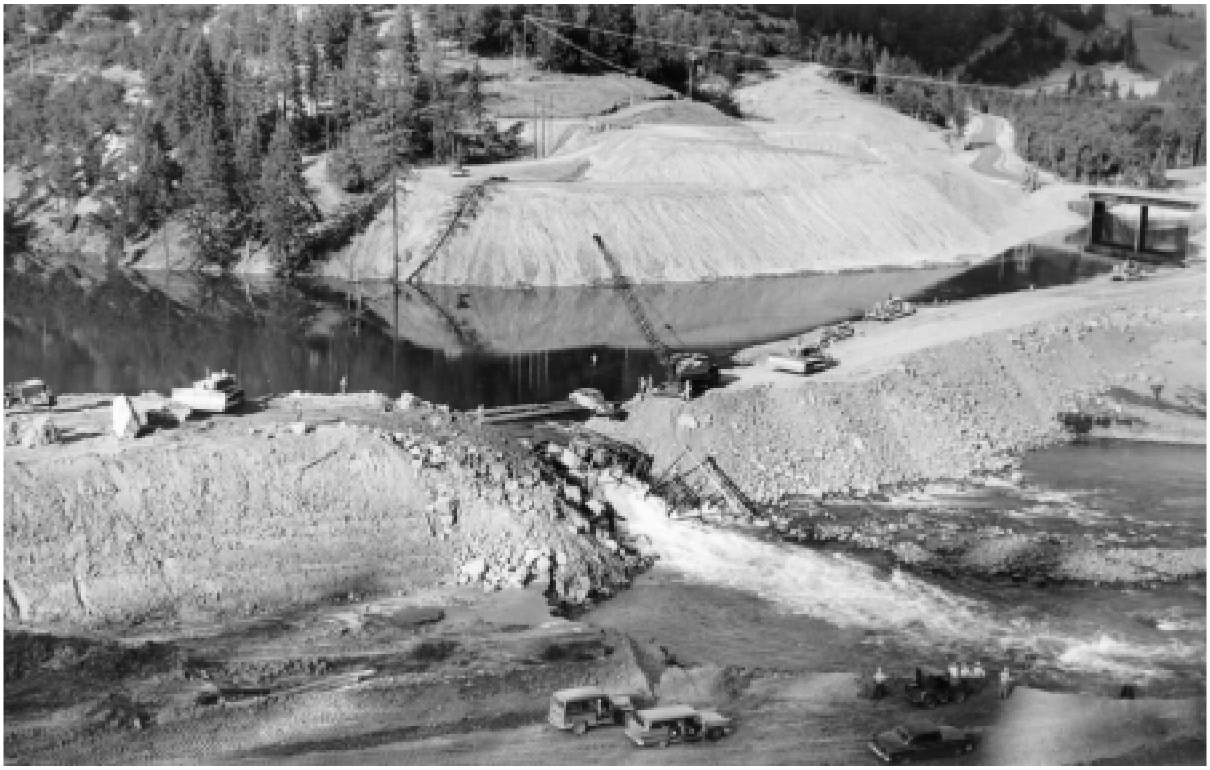
Chapter 5: Study Approaches and Results describes individual studies, conducted as a part of the Flow Evaluation, and other studies, conducted under the Trinity River Restoration Program, that addressed restoration and maintenance of the habitat necessary to the fishery resources of the Trinity River.

Chapter 6: Evaluation of the 1981 Secretarial Decision Volumes evaluates annual instream volumes of 140, 220, 287, and 340 TAF, as identified in the 1981 Decision.

Chapter 7: Restoration Strategy presents the overall strategy necessary to rehabilitate the mainstem Trinity River and restore its fishery resources.

Chapter 8: Recommendations presents recommended flow regimes, sediment, and channel rehabilitation actions necessary to restore and maintain the Trinity River fishery resources. Management objectives and recommendations to achieve these objectives are presented. Also included is a recommendation to establish an Adaptive Environmental Assessment and Management program to guide future restoration activities and modify management recommendations.

Restoring salmonid populations must be founded on rehabilitating and managing fluvial processes that create and maintain habitats vital to anadromous fish.



CHAPTER 2 Background: Water Management and Fishery Restoration Actions

2.1 Authorization, Construction, and Facilities of the Trinity River Division

The Trinity River, located in northwest California, is the largest tributary to the Klamath River (Figure 2.1). Water export and energy generation from the Trinity River were envisioned as early as 1931, when plans for diverting Trinity River water to the Sacramento River were included as part of the California State Water Plan (TRBFWTF, 1977). Plans involving the Trinity River Division were removed from the California State Water Plan in 1945 (USBOR, 1952), but these plans were subsequently adopted and refined by the U.S. Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers. In 1949, Reclamation released preliminary plans to develop the Trinity River as part of the CVP. In 1953, the Secretary transmitted to Congress the reports and findings of the Department's agencies regarding the proposed plan.

The TRD was authorized by an act of Congress on August 12, 1955, (P.L. 84-386). Section 1 of the 1955 Act provided for the construction, operation, and maintenance of the TRD. Section 2, however, specifically authorized and directed the Secretary to " . . . adopt appropriate measures to insure the preservation and propagation of fish and wildlife[.]" Congress stated that an average annual supply of 704 TAF of water, considered surplus to the present and future needs of the Trinity River Basin, could be exported from the Trinity River Basin to the Central Valley " . . . without detrimental effect on the fishery resources . . . " (H.R. Rep. No. 602, 84th Cong., 1st Sess. 4-5 (1955); S. Rep. No. 1154, 84th Cong., 1st Sess. 5 (1955)). Reclamation completed the Trinity River Division in 1964.

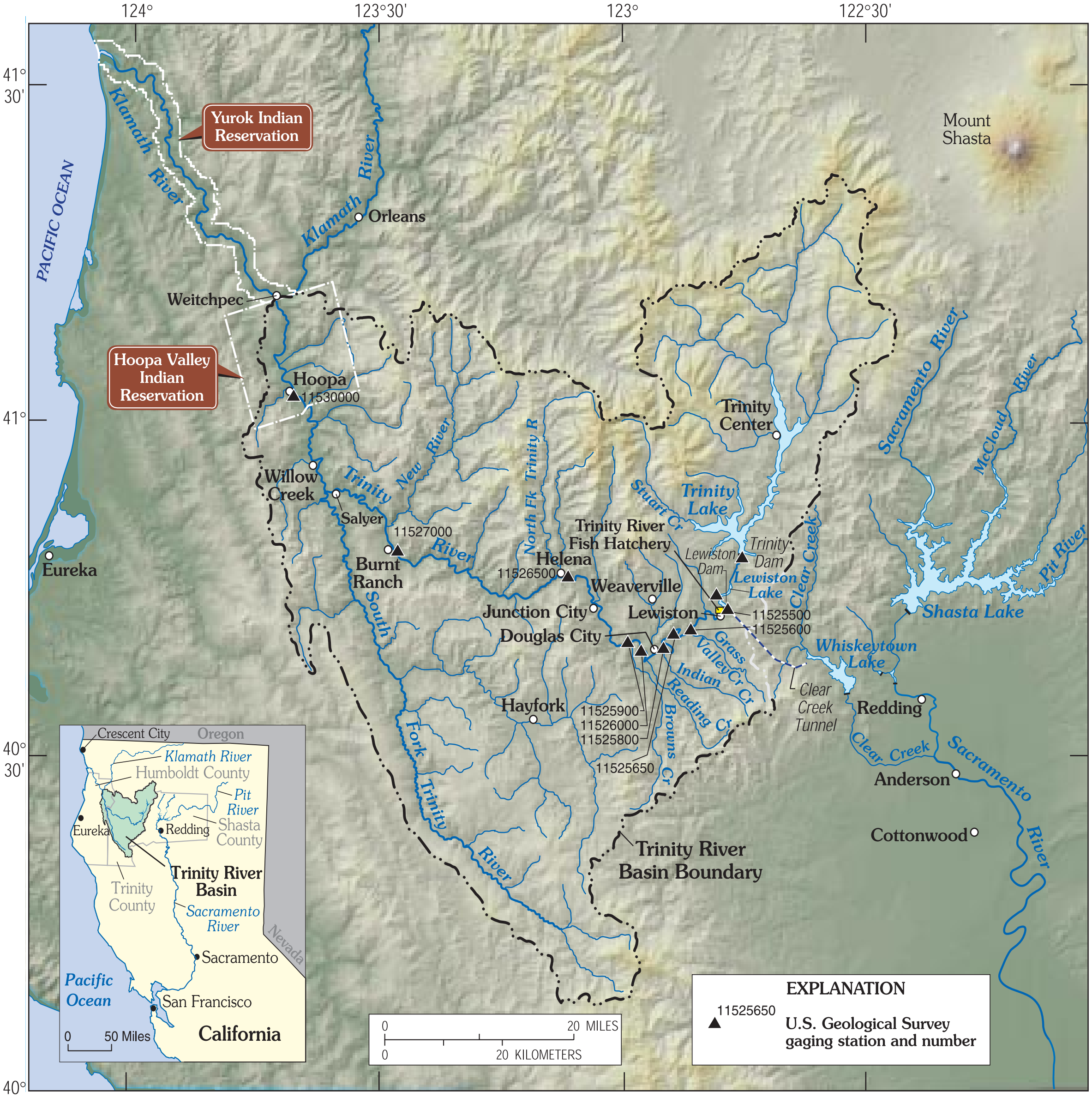


Figure 2.1. The Trinity River Basin and adjacent area in northwestern California.

The Shasta (authorized in 1935 and completed in 1945) and Trinity River Divisions of the Central Valley Project store and transfer water resources of the Trinity and northern Sacramento River basins to the Central Valley (Figure 2.2). Water from the Trinity River Basin is stored, regulated, and diverted through a system of dams, reservoirs, tunnels, and powerplants. The system diverts the water south into Clear Creek, the Sacramento River, and the Central Valley of California. A brief description of pertinent facilities is presented below.

Trinity Dam and Lake: Trinity Dam regulates flows and stores water for various uses. Completed in 1962, Trinity Dam is an earthfill structure 538 feet high with a crest length of 2,450 feet. The dam forms Trinity Lake, which

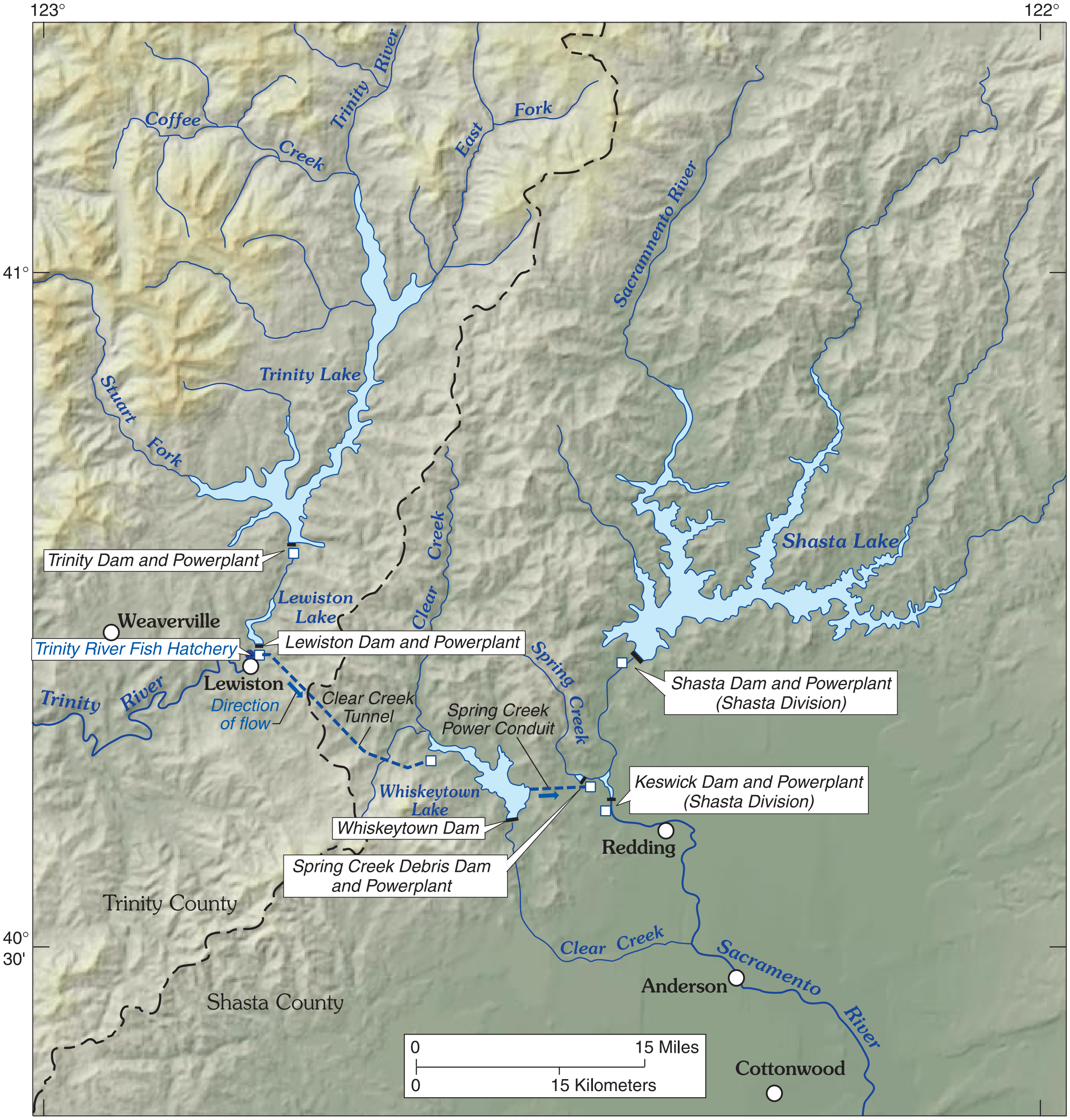


Figure 2.2. Trinity River and Shasta Division of the Central Valley Project.

has a storage capacity of 2,448,000 acre-feet. The lake offers recreation facilities for camping, boating, water skiing, swimming, fishing, and hunting.

Trinity Powerplant: Trinity Powerplant at Trinity Dam has two generators with a total capacity of 105,556 kilowatts (Figure 2.2).

Lewiston Dam and Lake: Lewiston Dam is about 8 miles downstream from Trinity Dam. The dam creates an afterbay to Trinity Powerplant and regulates releases into the Trinity River. Lewiston Dam is an earthfill structure 91 feet high and 754 feet long, forming a reservoir with a storage capacity of 14,660 acre-feet. The trans-basin diversion begins at Lewiston Lake via Clear Creek Tunnel to Whiskeytown Lake.

Lewiston Powerplant: Lewiston Powerplant at Lewiston Dam has one generator with a capacity of 350 kilowatts (Figure 2.2).

Trinity River Fish Hatchery: The Trinity River Fish Hatchery (TRFH), operated by the California Department of Fish and Game (CDFG), has a production capacity of roughly 40 million salmonid eggs. It is located immediately downstream from Lewiston Dam. The hatchery was constructed and operated to help mitigate for lost production from habitats upstream from the TRD.

Clear Creek Tunnel: Clear Creek Tunnel, 17.5 feet in diameter and 10.7 miles long, conveys up to 3,200 cfs from Lewiston Lake to Judge Francis Carr Powerhouse and Whiskeytown Lake. It is the conduit for the trans-basin diversion.

Judge Francis Carr Powerhouse: Judge Francis Carr Powerhouse, on Clear Creek, has two generators with a total capacity of 141,444 kilowatts.

"Over the first 10 years of full TRD operations, water years (WY) 1964-1973, 88 percent of the inflow of the Trinity River (averaging annually 1,234 of 1,396 TAF) into Trinity Lake was diverted into the Sacramento River Basin."

Whiskeytown Dam and Lake: Located on Clear Creek, Whiskeytown Dam stores Clear Creek runoff and diverted Trinity River flows discharged from Judge Francis Carr Powerhouse. The dam is an earthfill structure 282 feet high with a crest length of 4,000 feet. Whiskeytown Lake has a capacity of 241,100 acre-feet and provides recreation facilities for picnicking, camping, swimming, boating, water skiing, fishing, and hunting. The Spring Creek Tunnel diverts water from Whiskeytown Lake to the Spring Creek Powerhouse and Keswick Dam on the Sacramento River.

2.2 Early Operation of TRD

Over the first 10 years of full TRD operations, water years (WY) 1964-1973, 88 percent of the inflow of the Trinity River (averaging annually 1,234 of 1,396 TAF) into Trinity Lake (formerly Clair Engle Reservoir) was diverted into the Sacramento River Basin. Until 1974, Reclamation operated the TRD to release a minimum flow into the Trinity River ranging from 150 to 250 cfs for fishery resource purposes, pursuant to provisions of the 1955 Act. Studies supporting the 1955 Act determined that an annual instream fishery volume of 120.5 TAF was necessary to maintain or improve the fish and wildlife resources (TRBFWTF, 1977). The original release schedule and annual instream volume focused primarily on providing fish habitat for spawning chinook (Moffett and Smith, 1950). Within a decade of the completion of the TRD, salmonid populations had noticeably decreased (Hubbel, 1973).

2.3 Trinity River Basin Fish and Wildlife Task Force

The decline of the salmon and steelhead populations led to the formation in 1971 of the Trinity River Basin Fish and Wildlife Task Force (TRBFWTF). Members included Federal, State, Tribal, and local agencies. This Task Force developed the Trinity River Basin Comprehensive Action Program (TRBFWTF, 1977) to halt the degradation of fish and wildlife habitat in the Basin and formulate a long-term management program for the Trinity River.

2.4 Increased Flow Regimes in the 1970's

In 1973, the California Department of Fish and Game (CDFG) requested that Reclamation release an annual volume of 315 TAF into the Trinity River to " . . . reverse the steelhead and fall-run king [chinook] salmon declines." (TRBFWTF, 1977). In 1974, CDFG began a 3-year experiment to determine the effects of this increased streamflow on salmon and steelhead populations, but a combination of flood and drought conditions resulted in the annual instream flows totaling 705 TAF in 1974, 275 TAF in 1975, and 126 TAF in 1976. Since the 3-year experiment could not be completed as designed, no formal evaluation of the flows was made.

In 1978, the Service conducted a microhabitat study investigating the relation between streamflows and anadromous fish habitats in the Trinity River (USFWS, 1980a). The study concluded that substantial gains in fish habitat for specific life stages would be achieved if the annual instream flow regime were raised to 287 TAF. Ultimately, the study concluded that an instream flow regime of 340 TAF would be necessary after a stream restoration program was implemented. The report noted that, in some cases, habitat gains for some life stages would occur at the expense of habitat reduction for other life stages.

> “ . . . the [1980] EIS concluded that insufficient streamflow was the most critical limiting factor, and that increased flows would result in immediate improvement in fish habitat and fish runs . . . ”

An Environmental Impact Statement (EIS), prepared in 1980, addressed the Department of the Interior’s proposal to restore salmon and steelhead populations by increasing streamflows in the Trinity River (USFWS, 1980b). The EIS determined that an 80 percent decline in chinook salmon and a 60 percent decline in steelhead populations had occurred since the commencement of TRD operations. The EIS further estimated the total salmonid habitat loss in the Trinity River Basin to be 80 to 90 percent. The EIS concluded that the fundamental factors causing the decline in fishery resources were insufficient streamflow, streambed sedimentation, and inadequate regulation of fish harvest. While recognizing that full restoration of the fisheries must address each of those factors, the EIS concluded that insufficient streamflow was the most critical limiting factor, and that increased flows would result in immediate improvement in fish habitat and fish runs; thus, an increase in flows was deemed a necessary first step in restoring Trinity River fishery resources.

2.5 Secretarial Decision of 1981

Supported by the 1980 EIS, Secretary Cecil Andrus issued a Secretarial Decision on January 14, 1981, that directed the Service to conduct the Trinity River Flow Evaluation to evaluate the effects on fish habitat by increasing annual instream releases to 140 TAF in critically dry water years, 220 TAF in dry water years, and 340 TAF in normal or wetter water years, and to recommend long-term flow releases. On the same date, the Secretary affirmed an agreement (Appendix B) between the Service and Reclamation (then the Water and Power Resources Service) concerning the flow evaluation. The agreement stated that the Trinity River Flow Evaluation Report would: (1) summarize the effectiveness of flow restoration and other measures, including intensive stream and watershed management programs, in rebuilding Trinity River salmon and steelhead stocks; (2) address the adequacy of habitat at specific instream releases discussed above and the need to maintain, increase, or decrease the 340 TAF flow regime; (3) recommend measures to mitigate fishery habitat impacts attributable to the TRD; and (4) recommend appropriate flows and other measures necessary to better maintain favorable instream habitat conditions.

2.6 Congressional Responses in the 1980’s to Declining Fish and Wildlife Resources

One of the first congressional responses to the decline of the Trinity River fishery resources was the enactment of the Trinity River Stream Rectification Act in 1980 (P. L. 96-335) to control sand deposition from the degraded watershed of Grass Valley Creek, a tributary to the Trinity River (Figure 2.1). However, by 1984, Congress had concluded that the reduction in streamflows below Lewiston Dam was a principal cause of the drastic reduction in fish populations.

In 1984, Congress passed the Trinity River Basin Fish and Wildlife Management Act, P. L. 98-541 (1984 Management Act). In this Act, Congress found that the TRD's operations substantially reduced instream flows in the Trinity River, resulting in degraded fish habitat (pools, spawning gravels, and rearing areas) and consequently a drastic reduction in anadromous fish populations. Congress further found that construction of the TRD reservoirs contributed to reductions in the terrestrial wildlife populations historically found in the Basin because habitat was inundated by the reservoirs. Congress also found that factors not related to the TRD, including watershed erosion and fishery harvest management practices, had significantly reduced the Basin's fish and wildlife populations. A similar Act, the Klamath River Basin Conservation Restoration Area Act 16 U.S.C § 460ss et seq.9(P.L. 99-552), was passed in 1986 for the entire Klamath River Basin. This companion Act provided additional authority to the Secretary "... to implement a restoration program in cooperation with State and local governments to restore anadromous fish populations to optimum levels in both the Klamath and Trinity River Basins." Id. § 460ss(9).

The 1984 Management Act directed the Secretary to develop a management program to restore fish and wildlife populations in the Basin to levels approximating those that existed immediately before TRD construction began. The Act statutorily established the Trinity River Fish and Wildlife Task Force as an advisory committee to the Secretary. The Act directed the Secretary to use the fish and wildlife management program prepared in 1983 by the prior-existing Task Force to develop a fish and wildlife restoration program (Program). The Act further directed that the Program include efforts aimed toward the rehabilitation of fish habitat in the Trinity River and its tributaries, modernization and increased effectiveness of the TRFH, monitoring of fish and wildlife populations and the effectiveness of rehabilitation work, advising the Pacific Fisheries Management Council (PFMC) on salmon harvest management plans, and "other activities as the Secretary determines to be necessary to achieve the long-term goal of the program."

Congress reauthorized the 1984 Act in 1996 (P.L. 104-143) and, among other things, amended its goal to clarify that the management program is intended to aid in the resumption of fishing activities (recreational, non-tribal commercial, and Tribal) and that restoration will be measured not only by returning salmon and steelhead spawners but also by the ability of dependent Tribal and non-tribal fishers to participate fully in the benefits of restoration through enhanced harvest opportunities. Additionally, the 1984 Management Act was amended to clarify that the TRFH should not impair efforts to restore and maintain naturally reproducing anadromous fish stocks within the Basin.

A major component of the Program has been a watershed rehabilitation program to reduce fine sediment input, primarily decomposed granite, from tributaries of the upper Trinity River below Lewiston Dam (TCRCD and NRCS, 1998). Construction of Buckhorn Debris Dam on Grass Valley Creek in 1990, pursuant to P. L. 96-335, and the purchase and rehabilitation of portions of the Grass Valley Creek watershed in 1993, have assisted in

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the reduction of sand input into the mainstem Trinity River. The Bureau of Land Management (BLM) and the United States Forest Service (USFS) also have undertaken substantial watershed rehabilitation activities to reduce erosion (BLM, 1995).

"Since the implementation of the Program, more restrictive management of commercial, sport, and Tribal fisheries has greatly reduced the harvest impacts on fall chinook from the Klamath Basin (which includes Trinity stock) from the levels that occurred in the late 1970's and early 1980's."

The Program has provided estimates of the annual run sizes of salmonids (spring and fall chinook salmon, coho salmon, and steelhead) in the Trinity River. This information has been used to manage the Klamath Basin fisheries. Since the implementation of the Program, more restrictive management of commercial, sport, and Tribal fisheries has greatly reduced the harvest impacts on fall chinook from the Klamath Basin (which includes Trinity stock) from the levels that occurred in the late 1970's and early 1980's (KRTAT, 1986; PFMC, 1988). These reductions also would have reduced harvest impacts on Trinity River spring chinook salmon stocks. The impacts that ocean fisheries have on Trinity River coho have been greatly reduced since 1994, when ocean fishery management was modified to protect Oregon coastal coho salmon stocks (PFMC, 1995).

2.7 Increased Flow Regimes in the 1990's

Four of the first six years of the Trinity River Flow Evaluation Study were designated as dry water years under criteria established in the 1981 Secretarial Decision, due to drought conditions in California from 1986 through 1990. As a result, the Hoopa Valley Tribe filed an administrative appeal seeking Secretarial intervention to resolve issues pertaining to dry-year flow reductions. In July 1990, the Secretary directed the Service to review Trinity River flows as originally described by the 1981 Secretarial Decision. In January 1991, the Service developed an environmental assessment (EA) tiered to the 1980 EIS that analyzed the environmental impacts of a proposal to provide " . . . at least 340 TAF for each dry or wetter water year and 340 TAF in each critically dry year, if at all possible." This 1991 EA was adopted by the Secretary, and a Finding of No Significant Impact (FONSI) was made (Secretarial Decision on Trinity River Flows, 1991; Appendix C).

2.8 Central Valley Project Improvement Act

In 1992, Congress enacted the Central Valley Project Improvement Act, Title XXXIV of P.L. 102-575 (CVPIA). Among other purposes described in section 3402 of the CVPIA, Congress intended the statute " . . . to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River Basins . . . " and " . . . to address impacts of the Central Valley Project on fish, wildlife, and associated habitats." The CVPIA includes several provisions related to the TRD such as Section 3406(b)(19) addressing carry-over storage and Section 3406(e)(4) addressing studies evaluating the need for temperature control devices at Trinity Dam and Reservoir. In order to meet the Federal Government's trust responsibility to protect the fishery resources of the Hoopa Valley Tribe, as well as to meet the fishery restoration goals of the 1984 Act, section 3406(b)(23) of the CVPIA directed the Secretary to provide annual instream flow releases into the Trinity River of not less than 340 TAF for the purposes of fishery restoration, propagation, and maintenance pending the completion of the study directed by Secretary Andrus. This section further required that the Trinity River Flow Evaluation Study be completed " . . . in a manner which insures the development of recommendations, based on the best available scientific data, regarding permanent instream fishery flow requirements and Trinity River Division operating criteria and procedures for the restoration and maintenance of the Trinity River fishery."

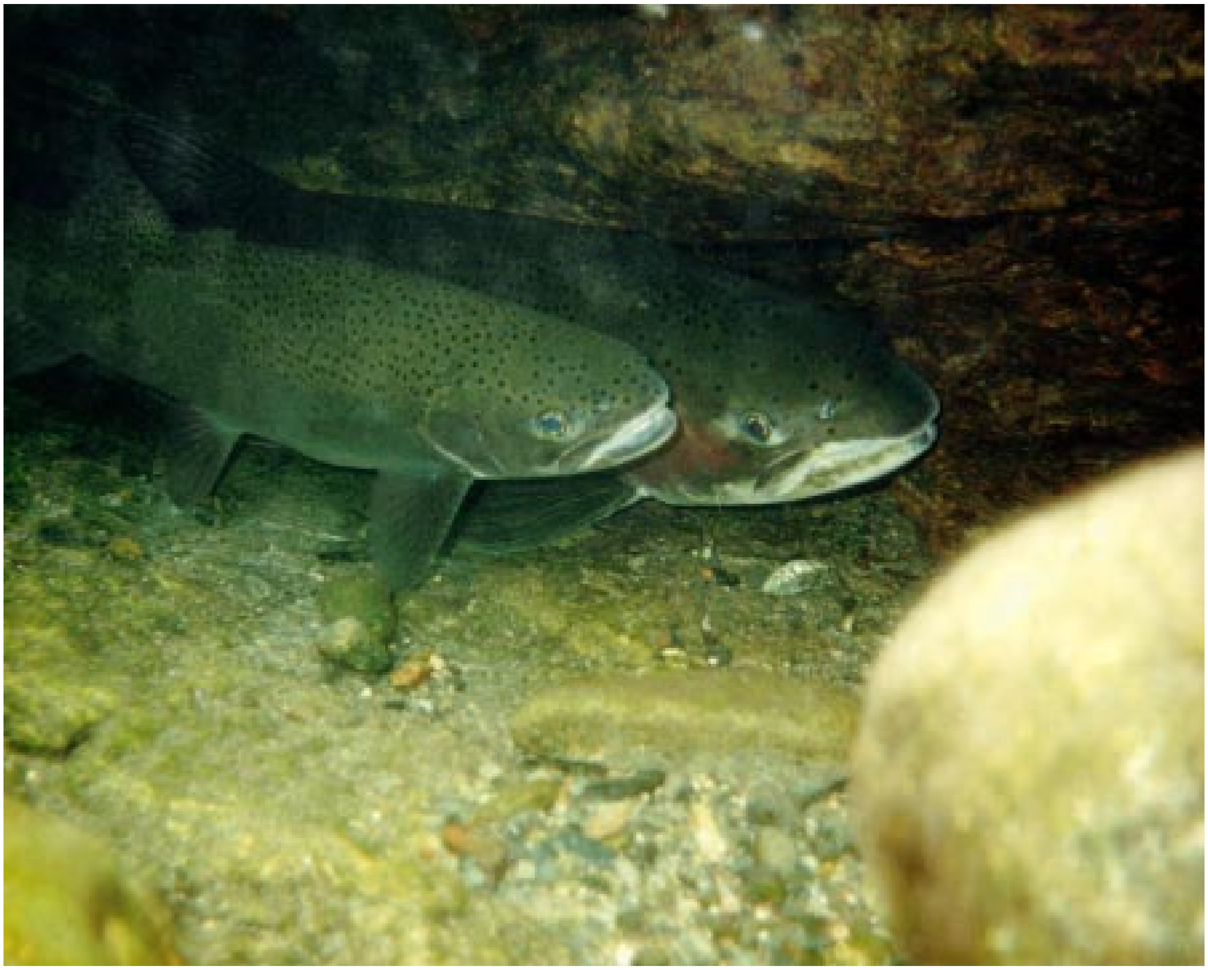
> "In order to meet the Federal Government's trust responsibility to protect the fishery resources of the Hoopa Valley Tribe, as well as to meet the fishery restoration goals of the 1984 Act, section 3406(b)(23) of the CVPIA directed the Secretary to provide annual instream flow releases into the Trinity River of not less than 340 TAF for the purposes of fishery restoration, propagation, and maintenance. . . ."

If both the Secretary and the Hoopa Valley Tribe concur in the recommendations, the Secretary shall implement them accordingly. If the Hoopa Valley Tribe and the Secretary do not concur, then the minimum releases of 340 TAF shall continue unless increased by Congress, by judicial decree, or by an agreement between the Secretary and the Hoopa Valley Tribe.

2.9 Tribal Trust Responsibility

The 1981 Secretarial Decision directed the Trinity River Flow Evaluation Study based on the conclusion that the Secretary's statutory responsibilities, as well as the Federal trust responsibility to the Hoopa Valley and Yurok tribes, " . . . compel restoration of the river's salmon and steelhead resources to pre-project levels." In 1993, the Department of the Interior's Solicitor elaborated on the Federal Government's trust responsibility to the Hoopa Valley and Yurok Tribes (DOI, 1993). The Solicitor stated that the Hoopa Valley and Yurok Tribes' reserved fishing rights include the right to harvest quantities of fish on their reservations sufficient to support a moderate standard of living, and that the Tribes' reserved fishing rights include the right to fish for ceremonial, subsistence, and commercial purposes. Because of the depressed condition of the fishery, the Tribes are entitled, under the Solicitor's Opinion, to 50 percent of the harvest. The Ninth Circuit Court of Appeals concluded that the Federal Government's trust responsibility includes the duty to preserve the Hoopa Valley and Yurok Tribes' fishing rights (Parravano v. Babbitt, 70 F.3d 539, 546-47 (9th Cir. 1995) cert. denied, 116 S.Ct. 2546 (1996)). One of the expected results of the restoration measures recommended in this Trinity River Flow Evaluation Report, including instream flows from the TRD, is to meet the Secretary's trust responsibility to restore and maintain the Tribal fisheries.

> "...the Hoopa Valley and Yurok Tribes' reserved fishing rights include the right to harvest quantities of fish on their reservations sufficient to support a moderate standard of living, and that the Tribes' reserved fishing rights include the right to fish for ceremonial, subsistence, and commercial purposes."



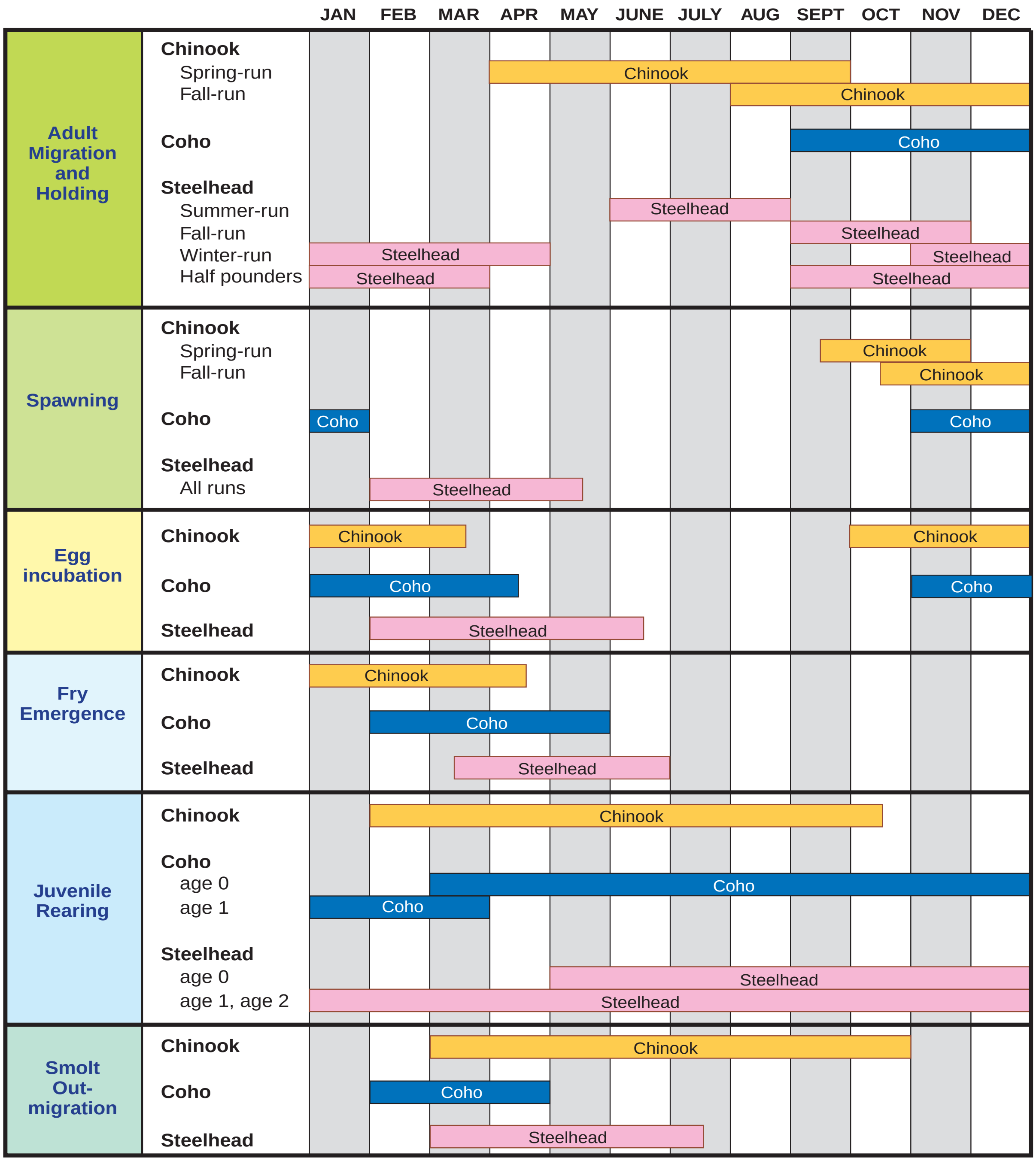
CHAPTER 3 Trinity River Fish and Wildlife Background

3.1 Fish Resources

Commercial, Tribal, and sport fisheries depend on healthy populations of steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*). The following sections describe the habitat requirements and life histories of these fish species and document their decline. Any recommended measures to restore and maintain the Trinity River fishery resources must consider these life histories and habitat requirements.

The life histories of anadromous species have two distinct phases, one in freshwater and the other in salt water. Newly hatched young remain in the river of their birth for months to years before migrating to the ocean to grow to their adult size. Adult salmonids return from the ocean to their natal rivers to spawn. Although steelhead, coho salmon, and chinook salmon require similar instream habitats for spawning, egg incubation, and rearing, the timing of their life history events varies (Figure 3.1). Published values

> "Commercial, Tribal, and sport fisheries depend on healthy populations of steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*)."



* A small percentage of chinook in the Trinity River overwinter and outmigrate at age 1, similar to coho age 1 life history.

Figure 3.1. Diagram of the timing and duration of various life-history events for chinook salmon, coho salmon, and steelhead in the Trinity River.

for each species' life history requirements are presented in Tables 3.1 to 3.3; depth and velocity (microhabitat) requirements and temperature requirements by life stage are discussed in Sections 5.1 and 5.5.

3.1.1 General Habitat Requirements and Life Histories

Anadromous adult salmonids enter the river from the ocean and hold until they are ready to spawn. Some species, such as spring-run chinook and summer steelhead, enter the river months prior to spawning; these fish hold in deep pools for protection from predators and for cool thermal refuge during the summer. Once spawning begins, salmonids construct redds (spawning areas) in gravel. Adult salmonids select a spawning site with appropriate gravel size, water velocities, and depth (refer to Section 5.1 for species-specific data for Trinity River salmonids). The size of the gravel selected by the fish is typically related to the size of the fish constructing the redd. Adult salmonids deposit eggs into the redd where they incubate in the spaces between gravel particles. Clean spawning gravels are important because fine sediment accumulation in the redd can affect the oxygen supply to the eggs, decreasing survival and (or) emergence success (Tagart, 1984). Conversely, good subgravel flows provide high levels of dissolved oxygen, resulting in increased egg survival to hatching (Shaw and Maga, 1943; Wickett, 1954; Shelton, 1955; Shelton and Pollock, 1966; Healey, 1991). Incubation time for eggs and egg survival rates are dependent on water temperature, with warmer water supporting faster hatching times (Alderdice and Velsen, 1978). Redd scour, often associated with flooding, can increase egg mortality (Gangmark and Bakkala, 1960), but scour is necessary to maintain clean high-quality spawning gravels (McBain and Trush, 1997).

"Clean spawning gravels are important because fine sediment accumulation in the redd can affect the oxygen supply to the eggs, decreasing survival and emergence success. …scour is necessary to maintain clean high-quality spawning gravels."

After hatching, the sac fry remain within the gravel interstitial spaces for 4 to 10 weeks to avoid predation and dislodgement by high flows (Dill, 1969). After the egg sac is absorbed, the fish emerge from the gravel and are referred to as "fry" (total length < 2 in. for purposes of this report). Fry commonly occupy shallow waters with little or no velocity (refer to Section 5.1 for species-specific data for Trinity River salmonids), and use cover such as undercut banks, woody debris, overhanging vegetation, and the interstitial spaces between cobbles. Fry tend to disperse downstream with flow increases and (or) with high fry densities (Lister and Walker, 1966; Major and Mighell, 1969; Healey, 1980). Increased flows disperse fry, but extreme flow fluctuations during the emergence period can be detrimental to the year-class (Coots, 1957).

During the next life-history stage, the juvenile or "parr" stage, juveniles spend from several months to 3 years growing in freshwater, depending on the species. As fry and juveniles grow larger, habitat preferences change. Juveniles move from stream margins and begin to use deeper water areas with slightly faster water velocities (specific depths and velocities for Trinity River salmonid lifestages are presented in Section 5.1). Individual rearing

"Upon reaching a species-specific size, juvenile salmonids undergo smolting, a physiological metamorphosis that prepares them for outmigration from the river and for growth and survival in the ocean. . . . increased smolt survival may subsequently increase the numbers of returning adults."

Table 3.1. Specific parameters for chinook salmon life-history requirements from published literature.

Chinook Salmon Life History Requirements			
Spawning Requirements			Citation(s)
	Redd sizes	36 - 108 ft^2	Bjornn & Reiser 1991
	Territory sizes	144 - 216 ft^2	Burner 1951
	Gravel sizes	0.5 - 4.0 in.	Bjornn & Reiser 1991
	Velocities*	0.33 - 6.2 ft/sec 0.1 - 5.0 ft/sec	Healey 1991 Bjornn & Reiser 1991
	Depths*	0.16 - 23+ ft ≥ 0.78 ft	Healey 1991 Bjornn & Reiser 1991
	Eggs buried to depths	0.6 - 2.0 ft 0.65 - 1.4 ft	Healey 1991 Bjornn & Reiser 1991
Fry Rearing Requirements	Depths*	shallow, stream margins	Chapman & Bjornn 1969, Everest & Chapman 1972
	Velocities*	little to none	Chapman & Bjornn 1969, Everest & Chapman 1972
Juvenile Rearing Requirements	Depths*	0.5 - 4.0 ft	Bjornn & Reiser 1991
	Velocities*	0 - 3.9 ft/sec	Everest & Chapman 1972 Bjornn & Reiser 1991
	Optimal rearing temperatures**	44.6 - 57.2 ºF	Rich 1987, Bell 1991
Smolt Requirements	Optimal smolting temperatures**	< 59 ºF	Clarke et al. 1981, Pereira & Adelman 1985, Baker et al. 1995

* indicates information specific to the Trinity River is further detailed in Section 5.1.
** indicates a more detailed discussion of temperature requirements is presented in Section 5.5.

fish tend to stay within the same area (several feet) of the stream (Edmundson et al., 1968; Reimers, 1968), occupying faster flowing water during the day and moving to the slower velocity stream margins at night (Edmundson et al., 1968). Usually, chinook salmon rear in the river for only a few months. Coho salmon, however, rear for 1 year and steelhead rear in the river for 1 to 3 years; consequently both require overwinter habitats. These habitats consist of areas with clean cobbles and gravels, with low or no velocity to avoid displacement by winter storm floods.

Upon reaching a species-specific size, juvenile salmonids undergo smolting, a physiological metamorphosis that prepares them for outmigration from the river and for growth and survival in the ocean. The timing of smolting is crucial for smolt survival. Fish size, water temperature, flow, and photoperiod interactively determine the readiness to smolt (Wedemeyer et al.,

Table 3.2. Specific parameters for coho salmon life-history requirements from published literature. LWD = large woody debris.

Coho Salmon Life History Requirements			
Spawning Requirements			Citation(s)
	Redd sizes	16 - 30 ft^2	Bjornn & Reiser 1991
	Territory sizes	126 ft^2	Burner 1951
	Gravel sizes	1.5 - 5.4 in. 0.5 - 4.0 in.	Briggs 1953 Bjornn & Reiser 1991
	Velocities*	1.0 - 2.5 ft/sec	Briggs 1953
	Depths*	≥ 0.6 ft 0.33 - 0.67 ft	Bjornn & Reiser 1991 Briggs 1953
	Eggs buried to depths	0.6 - 1.3 ft	Briggs 1953
Fry Rearing Requirements	Depths*	shallow, stream margins	Hartman 1965, Allen 1969
	Velocities*	little or no velocity	Hartman 1965, Allen 1969
	Optimal rearing temperatures**	44.6 - 62.6 ºF	Brett 1952, Bell 1991
Juvenile Rearing Requirements	Depths*	> 1.0 ft	Bjornn & Reiser 1991
	Velocities*	< 1.0 ft/sec	Bjornn & Reiser 1991
	Overwintering requirements	lg. pools w/LWD, undercut margins and debris near riffle margins	Hartman 1965, Bustard & Narver 1975
	Optimal rearing temperatures**	44.6 - 62.6 ºF	Brett 1952, Bell 1991
Smolt Requirements	Optimal smolting temperatures**	44.6 - 53.6 ºF	Clarke et al. 1981, McMahon 1983

* indicates information specific to the Trinity River is further detailed in Section 5.1.
** indicates a more detailed discussion of temperature requirements is presented in Section 5.5.

1980; Hoar, 1988). If flows and habitat are managed to facilitate timely and successful smolting, increased smolt survival may subsequently increase the numbers of returning adults (Raymond, 1979).

The rate at which a smolt migrates out of the river is related to smolt size, flows, temperature, and photoperiod (Hoar, 1988). Increasing streamflows and increasing water temperatures tend to increase the rate of smolt migration. The rate of smolt movement also increases from early in the season to late in the season as temperatures rise and photoperiod lengthens (Raymond, 1968; Cramer and Lichatowich, 1978).

Table 3.3. Specific parameters for steelhead life-history requirements from published literature.

Steelhead Life History Requirements			
Spawning Requirements			Citation(s)
	Redd sizes	47 - 58 ft^2	Bjornn & Reiser 1991
	Gravel sizes	0.25 - 5.0 in.	Barnhart 1986
	Velocities*	0.75 - 5.1 ft/sec	Barnhart 1986
	Depths*	0.3 - 5.0 ft	Barnhart 1986
	Eggs buried to depths	8 - 12 in.	Bjornn & Reiser 1991
Fry Rearing Requirements	Depths*	shallow, stream margins; 0.25 - 1.2 ft	Hartman 1965 Barnhart 1986
	Velocities*	little or no velocity	Hartman 1965
	Optimal rearing temperatures**	50 - 64.4 °F	Hokanson et al. 1977, Bell 1991
Juvenile Rearing Requirements	Depths*	< 0.5 - 2.5 ft 0.8 - 1.6 ft	Bugert & Bjornn 1991 Barnhart 1986
	Velocities*	< 0.05 - 1.0 ft/sec	Bugert & Bjornn 1991
	Overwintering requirements	boulder-rubble stream margins ~ 1.0 ft deep, low velocity	Everest & Sedell 1983
	Optimal rearing temperatures**	50 - 64.4 °F	Hokanson et al. 1977, Bell 1991
Smolt Requirements	Optimal smolting temperatures**	< 55.4 °F	Kerstetter & Keeler 1976, Zaugg 1981

* indicates information specific to the Trinity River is further detailed in Section 5.1.
** indicates a more detailed discussion of temperature requirements is presented in Section 5.5.

Depending on species, adults typically return to their natal streams to spawn at 3 to 6 years of age. Some salmon return at 2 years of age and are referred to as "jacks" (Leidy and Leidy, 1984). Although jacks are capable of spawning, most are male and do not contribute to the production potential of the spawning escapement. Steelhead, unlike salmon, do not always die after spawning, and may make three to four spawning migrations (Barnhart, 1986; Leidy and Leidy, 1984).

Each salmonid species requires slightly different microhabitats for each life stage and similar microhabitats are used by different species at different times of the year. This segregation of timing and microhabitats reduces competition between species (Bjornn and Reiser, 1991). The life histories of each species (Figure 3.1) are outlined below, with descriptions of the habitat components and lifestage timing critical to the growth and survival of each species.

3.1.1.1 Chinook Salmon

Chinook salmon are the largest Pacific salmon (Moyle, 1976). Trinity River chinook salmon populations are composed of two races, spring-run and fall-run (Leidy and Leidy, 1984). Spring-run chinook salmon ascend the river from April through September, with most fish arriving at the reach below Lewiston (RM 111.9) by the end of July. These fish remain in deep pools until the onset of the spawning season, which typically begins the third week of September, peaks in October, and continues through November (CDFG,1992a, 1992b, 1994a, 1995, 1996a, 1996b). The fall-run chinook salmon migration begins in August and continues into December (CDFG, 1992a, 1992b, 1994a, 1995). Fall-run chinook salmon begin spawning in mid-October, activity peaks in November, and continues through December. The first spawning activity usually occurs just downstream from Lewiston Dam. As the spawning season progresses into November, spawning extends downstream as far as the Hoopa Valley (USFWS, 1988, 1989,1990, 1991; HVT, 1996).

> "Each salmonid species requires slightly different microhabitats for each life stage and similar microhabitats are used by different species at different times of the year. This segregation of timing and microhabitats reduces competition between species."

Emergence of spring- and fall-run chinook salmon fry begins in December and continues into mid-April (Leidy and Leidy, 1984). Juvenile chinook salmon typically leave the Basin (outmigrate) after a few months of growth in the Trinity River. Outmigration from the upper river, as indicated by monitoring near Junction City (RM 79), begins in March and peaks in early May, ending by late May or early June (Glase, 1994a). Outmigration from the lower Trinity River, as indicated by monitoring near Willow Creek (RM 24), peaks in May and June, and continues through the fall (USFWS, 1998).

3.1.1.2 Coho Salmon

Coho salmon migrate up the Trinity River and Klamath River from mid-September through January and spawn from November through January (Leidy and Leidy, 1984). Emergence of coho salmon fry in the Trinity River begins as early as late February and continues through March (Glase, 1994a; USFWS, 1998).

After their emergence from the gravel, fry use cobbles or boulders for cover and typically defend a territory (Allen, 1969). Suitable territories may be extremely important for coho salmon juveniles, as Larkin (1977) found that the abundance of coho salmon may be limited by the availability of these appropriate habitats.

In the summer, coho salmon parr reside in pools and near instream cover, such as large woody debris, over-hanging vegetation, and undercut banks (Sandercock, 1991). Overwintering habitat is essential for coho salmon because juvenile coho salmon remain in the Trinity River Basin for their first winter and into the following spring. Preferred overwintering habitats are large mainstem, backwater, and secondary channel pools containing large woody debris, and undercut margins and debris near riffle margins (Hartman, 1965; Bustard and Narver, 1975). Instream residency occurs throughout the upper mainstem from Lewiston downstream to at least the confluence with the North Fork.

Outmigration of 1-year-old coho salmon smolts begins in February and continues through May. Peak outmigrations occur in May in the Trinity River near Willow Creek (USFWS, 1998). Outmigrant monitoring on the mainstem Trinity near Junction City and Willow Creek from 1992 to 1995 indicated that natural coho salmon smolt production is low and typically represents less than 3 percent of the total annual coho salmon smolt catch (Glase, 1994a).

3.1.1.3 Steelhead

The National Marine Fisheries Service (NMFS) recognizes two ecotypes of steelhead based on sexual maturity at the time of river entry (NMFS, 1994). Steelhead that enter the river in an immature state and mature several months later are termed "stream-maturing"; these are the summer-run steelhead. "Ocean-maturing" steelhead enter the river system while sexually mature and spawn shortly thereafter; ocean-maturing steelhead are referred to as "winter-run" steelhead. Portions of both groups may enter freshwater in spring or fall and are then called "spring-" or "fall-run" steelhead (Barnhart, 1986).

In addition to runs of adult steelhead, the Klamath and Trinity Rivers also support a run of immature steelhead known as "half-pounders", which spend only 2 to 4 months in the ocean before returning to the river in late summer and early fall (Barnhart, 1986). Half-pounders feed extensively in freshwater and are highly prized by sport anglers. Half-pounders overwinter in the river without spawning before returning to the ocean, and return as mature adults during subsequent migrations. Half-pounders have a very limited geographic distribution and are known to exist only in the Rogue, Klamath-Trinity, Mad, and Eel river systems.

Steelhead enter the Klamath-Trinity Rivers throughout most of the year. Summer-run adults enter the stream between May 1 and October 30 (Barnhart, 1986) and hold in the river for several months before spawning. Summer-run steelhead commonly reach Lewiston (RM 112.0) by early June and continue to arrive through July. They enter major tributary streams by August (Leidy and Leidy, 1984) and remain in deep pools until they spawn in February (Barnhart, 1986). Winter-run steelhead enter the river between November 1 and April 30 and hold in relatively high-velocity habitats, such as riffles and runs. They spawn in April and May (Barnhart, 1986). Summer- and winter-run steelhead, therefore, are isolated temporally and spatially. They do not interbreed because summer-run adults generally use areas that are farther upstream than areas used by winter-run adults (Barnhart, 1986).

Spawning of all steelhead races in the Trinity River typically begins in February, peaks in March or April, and ends in early June (Leidy and Leidy, 1984). After emergence from spawning gravel, steelhead fry and juvenile steelhead use habitats similar to those of juvenile salmon, although rearing steelhead prefer higher velocities than do salmon of similar size. Everest and Sedell (1983) identified key winter habitat for steelhead as areas with boulder-rubble stream margins that are approximately 12 inches deep with low to near zero water velocities.

Outmigration of steelhead smolts from the Trinity River above Junction City (RM 79.6) begins in early spring of their second or third year and peaks in late April and early May (Glase, 1994a). Outmigration near Willow Creek (RM 24) begins in late March and early April, peaks in early May, and continues throughout June (USFWS, 1998).

3.1.1.4 Summary of Habitat Requirements

Although the three species of anadromous salmonids that inhabit the Trinity River have unique habitat preferences and timing for their spawning, growth, and outmigrating life stages, these species share common life-history requirements that should be considered when making crucial decisions regarding restoration of the fisheries:

1. Spawning pairs require adequate space to construct and defend their redd, which commonly is associated with unique instream habitat features;
2. Spawning gravels with a low percentage of fine sediment facilitate adequate subgravel flow through the interstitial spaces in the redd,

increasing successful egg hatch and sac fry survival. Excessive sand and silt loadings reduce the survival of eggs and sac fry, as well as fry emergence success;

3. Salmonid fry require low-velocity, shallow habitats— and, as they grow, a variety of habitat types are required that include faster, deeper water and instream cover;

4. Because of their extended residency in the Basin, coho salmon and steelhead must have abundant overwintering habitat composed of low-velocity pools and interstitial cobble spaces; and

5. Smolt survival is a function of fish size, water temperatures in the spring and early summer, and streamflow patterns.

3.1.2 Abundance Trends

Pre-TRD data on salmon abundance in the Trinity Basin are sporadic (See Appendix D). The most continuous data set available is that for post-TRD fall-run chinook. Data for steelhead and coho salmon commonly are unavailable or of poor quality: the adults of these species spawn during high flows, making the operation of fish-counting weirs and other standard methodologies at best inaccurate (or impossible) in some years. Another factor confounding the assessment of adult returns is the number of hatchery-produced fish that elect not to re-enter the hatchery but instead spawn in the river. This behavior artificially inflates annual inriver spawning escapements, so that the naturally produced spawning populations appear larger than they are. The following sections describe the data available for pre- and post-TRD populations, and when available, the relative numbers (proportions) of hatchery-produced and naturally produced fish contributing to the inriver spawning escapement. For the purposes of this evaluation, the term “inriver spawners” and “inriver spawning escapement” refers to fish that spawn in the Trinity River and excludes fish that return to the TRFH. “Naturally produced” refers to fish whose parents were inriver spawners; “hatchery-produced” refers to fish whose parents were spawned at TRFH.

3.1.2.1 <u>Chinook Salmon</u>

Information specific to the Trinity River chinook salmon populations prior to the construction of the TRD is sparse (Table 3.4). The Tribes along the banks of the lower Trinity and Klamath Rivers have always depended extensively on abundant populations of salmon and steelhead for their subsistence, commercial,

Table 3.4. Pre-TRD salmonid abundance information available for the Trinity River. No distinction was made between spring- and fall-run chinook for these estimates.

Species	Year(s)	Number of Fish	Location/Reach	Type of Data
Chinook salmon	1912	141,000	Klamath Estuary	Harvest
Chinook salmon	1944, 1945, 1955, 1956, 1963	average = 47,600 (min = 19,000, max = 75,600)	Trinity R., above the North Fork and above Lewiston	Spawning escapements (see Appendix E for more details)
Chinook salmon	1944, 1945, 1955, 1956, 1963	average = 18,834 (min = 10,000, max = 30,134)	Trinity R., above the North Fork to Lewiston	Spawning escapements (see Appendix E for more details)
Coho salmon	historic estimate	5,000	Trinity R., above Lewiston	Spawning escapement (USFWS/CDFG, 1956)
Steelhead	historic estimate	10,000	Trinity R., above Lewiston	Spawning escapement (USFWS/CDFG, 1956)

and ceremonial uses. Thousands of salmon were harvested annually (Hewes, 1942). In the mid-1800's, spring-run chinook salmon were considered the most abundant race in the Klamath Basin. After gold was discovered in the Klamath and Trinity Rivers, canneries began operating along the Klamath estuary in the late 1800's. At the harvest peak in 1912, approximately 141,000 salmon were harvested and canned. In 1915, approximately 72,400 chinook salmon were harvested from the Klamath River and its tributary streams. By the early 1900's, over-harvesting had reduced the spring-run populations to low levels, making the fall-run chinook the dominant run in the Basin (Snyder, 1931).

"The Tribes along the banks of the lower Trinity and Klamath Rivers have always depended extensively on abundant populations of salmon and steelhead for their subsistence, commercial, and ceremonial uses."

Historical (pre-TRD) estimates of fall-run chinook salmon entering the Trinity River were made by various investigators, and data for some years were reinterpreted using different methods, leaving large discrepancies in estimates for the same year. Hamaker (1997) reviewed historical run-sizes in the literature (Appendix D) and found that pre-TRD spawning escapement estimates for the Trinity River upstream from the North Fork Trinity River confluence that were not affected by the TRD ranged from 19,000 to 75,600 chinook salmon, with an average escapement of 47,600 (Table 3.4). Estimates for spawning escapements from the North Fork Trinity River confluence to Lewiston ranged from 10,000 to 30,134 chinook salmon, averaging 18,834. These North Fork to Lewiston estimates exclude the 1963 escapement because spawner distribution was affected by the TRD that year.

For the period 1982 to 1995, total inriver spawning escapement (jacks and adults) in the Trinity River Basin above Willow Creek ranged from 5,249 to 113,007 and averaged 35,230 (Appendix E, Table E.1). Spawning escapement of adult (jacks excluded) fall-run chinook salmon ranged from 4,867 to 92,548 fish and averaged 25,359 during this period. Substantial numbers of these inriver spawners were hatchery-produced. Based on ad-clip rates observed at the TRFH and the Willow Creek weir from 1982 to 1995, the proportion of inriver spawners (jacks and adults; adult-only information is unavailable) that are naturally produced ranged from 10 to 94 percent, and averaged 44 percent. After removing the numbers of hatchery-produced fall-run chinook salmon, the inriver spawning escapement (jacks and adults) of naturally produced fall-run chinook salmon ranged from 2,348 to 41,663 and averaged 11,044.

The post-TRD proportion of inriver fall-run chinook spawners that are naturally produced ranged from 10 to 94 percent, and averaged 44 percent.

Comparisons between pre- and post-TRD averages are problematic (Figure 3.2) because: (1) few complete pre-TRD estimates exist; (2) only fish spawning in the river above the North Fork were estimated prior to TRD; and (3) those estimates do not distinguish between spring- and fall-run chinook, although Snyder (1931) indicates that the fall-run chinook was the dominant run in the Klamath River estuary by the 1930's. The post-TRD average (35,230) for spawning fish is 12,300 less than the average pre-TRD spawning escapement (47,600). If the numbers of straying hatchery fish that spawn in the river are removed, the post-TRD average for naturally produced fish (11,044) is less than a quarter of the average pre-dam estimate and only slightly more than half the minimum pre-TRD spawning escapement (19,000). Hatchery-origin fish commonly constitute a large part of the fish spawning inriver, but increases of naturally produced fish do not follow in subsequent

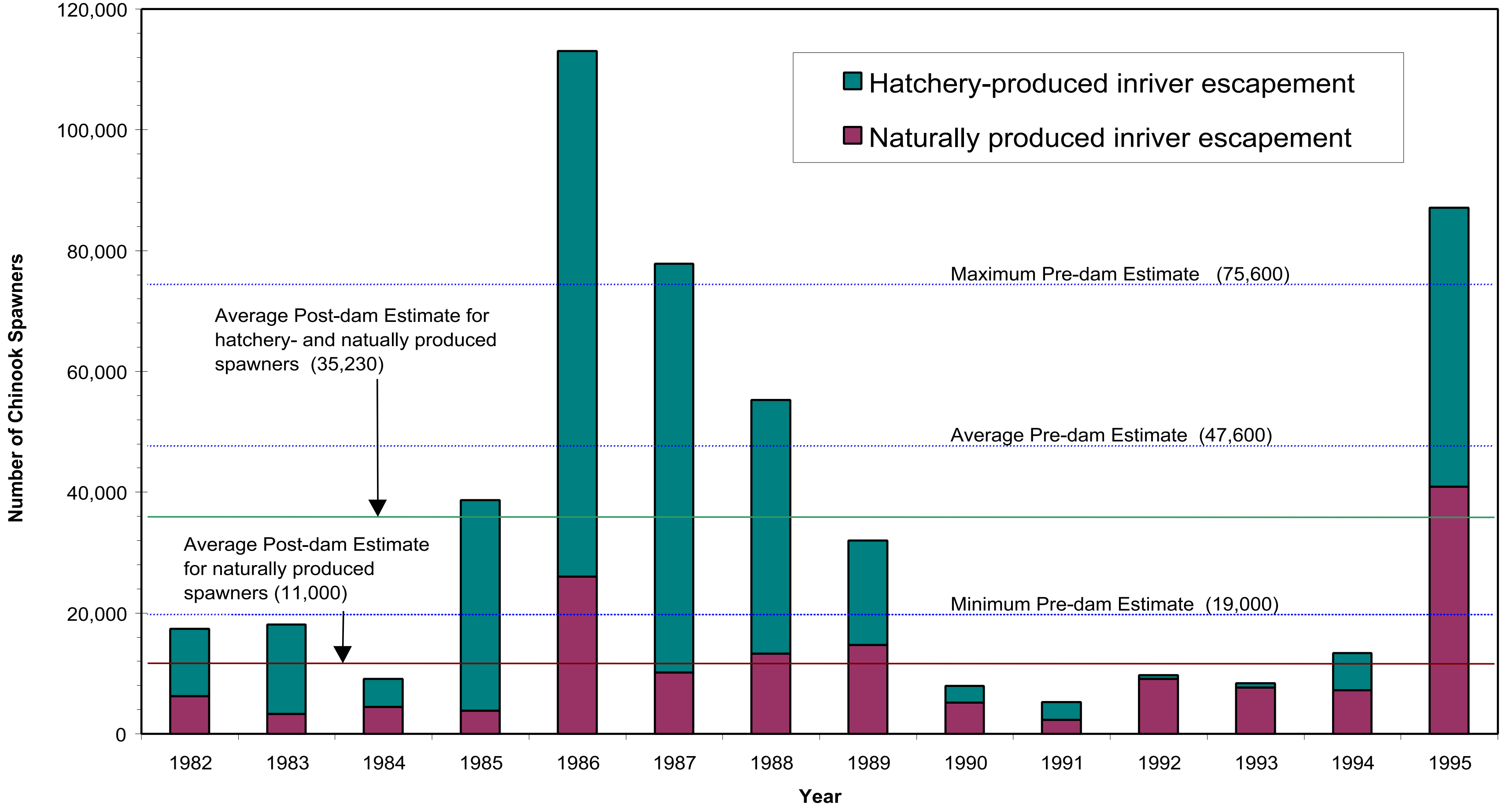


Figure 3.2. Post-TRD fall-run chinook inriver spawner escapements (1982-1995) and the proportion of inriver spawners that were naturally and hatchery-produced in the Trinity River above Willow Creek, compared to historical estimates (1944, 1945, 1955, 1956, and 1963).

years. Offspring of hatchery-produced fish are indistinguishable from offspring of naturally produced fish because neither are marked; therefore, the offspring of any fish spawning in the river is naturally produced. From 1986 to 1989, large numbers of fish spawned inriver, but very few naturally produced fish returned in 1988 to 1994, indicating that in that time frame relatively few progeny of these inriver spawning escapements survived to return as adults.

From 1978 to 1994, numbers of spring-run chinook salmon spawners (jacks and adults) above Junction City ranged from 1,360 to 39,570 and averaged 9,800 (Table 3.5). From 1982 to 1994, the naturally produced component of the inriver spawners ranged from 0 to 100 percent and averaged 32 percent. During this period, numbers of naturally produced spring-run chinook salmon ranged from 0 to 6,214 and averaged 1,551 fish. Spring-run chinook salmon that spawned in the North Fork Trinity River, New River, and South Fork Trinity River were not included in these estimates because these tributaries are below the Junction City Weir.

> "…the naturally produced component of the inriver spring-run chinook spawners ranged from 0 to 100 percent and averaged 32 percent."

3.1.2.2 Coho Salmon

Information on coho salmon in the Trinity River prior to TRD construction is sparse. Moffett and Smith (1950) reported that coho salmon were usually observed in the Hoopa Valley by October, but that they were not common in the Trinity River above Lewiston. Other information suggests that coho salmon adults and juveniles did use habitat in the Trinity River above Lewiston: Approximately 5,000 adult coho salmon migrated past Lewiston prior to TRD construction according to USFWS/CDFG (1956) (Table 3.4). Additionally, fingerling coho salmon were rescued from an irrigation diversion in 1949, 1950, and 1951 near Ramshorn Creek, which enters the Trinity River approximately 42 miles upstream from Lewiston (USFWS/CDFG, 1956).

Between the time that the TRD was completed (1964) and 1977, two coho salmon escapements were estimated for the Trinity River upstream from the North Fork. In 1969 and 1970, the CDFG estimated the coho salmon run at 3,222 and 5,245 fish, respectively (Smith, 1975; Rogers, 1973 as cited by Hubbell 1973). Since 1978, the inriver spawners of coho salmon (jacks and adults) in the Trinity River above Willow Creek have ranged from 558 to 32,373, and averaged 10,192 fish (Table 3.5; Appendix E, Table E.4). From 1991 to 1995, the naturally produced contribution to the inriver escapement ranged from 0 to 14 percent, and averaged 3 percent. Adjustments to the inriver spawner escapement that exclude hatchery-produced coho salmon indicated that an average of 202 naturally produced coho salmon returned annually (Appendix E, Table E.4); i.e., the Trinity River inriver coho salmon population is predominantly of hatchery origin.

> The Trinity River coho salmon inriver spawning escapement is predominantly of hatchery origin.

3.1.2.3 Steelhead

Estimating run sizes of Trinity River steelhead has always been difficult because many steelhead enter the river after fall rains increase flow beyond the operational limits of fish-counting weirs; steelhead that migrated from late fall to late spring were therefore often missed in fish-counting operations. Prior to TRD construction, USFWS/CDFG (1956) estimated that 10,000 steelhead migrated past Lewiston (Table 3.4), but no estimates were made for the river below Lewiston. At one time, spawning was extensive in many tributaries, and considerable mainstem spawning occurred in some years prior to TRD construction (Moffett and Smith, 1950). However, mainstem spawning adults were considered to be a minority of the overall population (USFWS/CDFG, 1956).

Table 3.5. Post-TRD average spawning escapements (jacks and adults) for the Trinity River. Note: all averages are calculated on annual values and can not be directly derived from the information presented in this table.

Species	Average Inriver Escapement (hatchery - and naturally produced spawners)	Average Inriver Escapement (naturally produced spawners)	Average Hatchery Percentage of the Inriver Spawners	River Reach
Fall-Run Chinook	35,231	11,044	56	Willow Creek to Lewiston Dam
Spring-Run Chinook	9,800	1,550	68	Junction City to Lewiston Dam
Coho	10,190	200	97	Willow Creek to Lewiston Dam
Fall-Run Steelhead	9,160	4,724	30	Willow Creek to Lewiston Dam

Steelhead spawning surveys in the Trinity River and several tributaries between North Fork Trinity River and Lewiston in 1964 provided an estimate of 7,449 to 8,684 fish (LaFaunce, 1965). LaFaunce (1965) stated that these surveys provided minimal estimates of steelhead abundance because of the short duration of the surveys (March 30 to May 12) and the inability to separate multiple redds. A 1972 steelhead spawning survey indicated that steelhead use of several tributaries below Lewiston had declined since 1964 (Rogers, 1973). The number of steelhead using tributaries below Lewiston in 1964 was likely to have been greater than the number prior to TRD construction because fish that reared in areas upstream from Lewiston were now precluded from their natal habitats and forced to spawn in the downstream tributaries. Potentially, over time, steelhead numbers may have declined toward levels that could normally be sustained by these tributaries below the dams.

CDFG produced 12 estimates of steelhead escapement upstream from Willow Creek from 1980 to 1995, and estimated the hatchery contribution to the in-river spawner escapement in six of these years (Appendix E, Table E.5). In-river spawner escapement in the Trinity River Basin above Willow Creek ranged from 1,977 to 28,933 and averaged 9,160 (Table 3.5). The contribution of naturally produced steelhead to the in-river spawner escapement ranged from 57 to 88 percent and averaged 70 percent for the six years for which data were available (Appendix E). Adjustments to the annual in-river escapement to exclude hatchery-produced steelhead indicated that escapement of naturally produced steelhead ranged from 1,176 to 14,462 and averaged 4,724 (Table 3.5). However, the data collected to generate these estimates only account for the fall-run and the early portion of the winter-run and therefore assess only a portion of the Trinity River steelhead population.

> "The contribution of naturally produced steelhead to the in-river spawner escapement ranged from 57 to 88 percent and averaged 70 percent . . . "

The healthiest populations of summer-run steelhead in the Trinity River Basin are in the North Fork Trinity River and New River (Appendix E, Table E.6). Canyon Creek and the South Fork Trinity River also support small populations of summer-run steelhead.

3.1.2.4 Summary of Abundance Trends

Current populations of naturally produced Trinity River anadromous salmonids are at low levels. The large spawning escapements since 1978 were typically dominated by hatchery-produced fish that spawned in the natural areas of the Trinity River and are not indicative of healthy spawning and rearing conditions in the Trinity River. Typically, more fish spawn in the river than are spawned at the hatchery (see Appendix E), but fewer fish that were spawned in the river as eggs survive to return as adults. This poor survival probably indicates poor habitat conditions for early life stages (eggs, fry, and juvenile), assuming that hatchery-produced and naturally produced fish are subjected to the same environmental conditions from smolt to adult. The relatively large contribution of hatchery-produced fish can be attributed to their increased survival during incubation and early life stages (egg, fry, and juvenile) under controlled hatchery conditions.

An indicator of the poor condition of the freshwater habitat of the Trinity River is the status of coho salmon, whose extended freshwater life history makes them more dependent than chinook salmon on freshwater habitat for rearing. On May 6, 1997, the National Marine Fisheries Service (NMFS) issued a final rule listing the coho salmon that return to Klamath and Trinity Rivers, the Southern Oregon/Northern California Coast Evolutionary Significant Unit (ESU), as threatened, pursuant to the Endangered Species Act (ESA) (62 Fed. Reg. 24588). The final rule estimated that California populations of coho salmon — fewer than 10,000

> "Current populations of naturally produced Trinity River anadromous salmonids are at low levels. The large spawning escapements since 1978 were typically dominated by hatchery-produced fish that spawned in the natural areas of the Trinity River and are not indicative of healthy spawning and rearing conditions in the Trinity River."

naturally producing adults — could be less than 6 percent of their abundance in the 1940's. The final rule also noted that large hatchery programs are an issue. The final rule recognized that various habitat declines affected coho salmon populations, including channel morphology changes, substrate changes, loss of off-channel rearing habitats, declines in water quality (e.g., elevated water temperatures), and altered streamflows. On November 25, 1997, NMFS proposed that critical habitat be designated for coho salmon in the Trinity River (62 Fed. Reg. 62741).

Steelhead populations in the Klamath and Trinity Rivers were also proposed as threatened pursuant to the ESA (62 Fed. Reg. 43937), and controversy delayed the final decision until February 1998 (62 Fed. Reg. 43974). NMFS determined that Klamath Mountains Province ESU steelhead did not warrant listing at the time, but do warrant classification as a candidate species (63 Fed. Reg. 13347). NMFS will reevaluate the status of steelhead within 4 years to determine if listing is warranted. The chinook salmon of this ESU are also candidate species pursuant to the ESA.

3.1.3 Fish Disease Monitoring

The Service's California-Nevada Fish Health Center has conducted disease surveys on both naturally produced and hatchery-origin salmonids produced in the Trinity River since 1991 (Foott, 1996; pers. comm.). Samples were collected from juvenile salmonids at the TRFH prior to release. A second set of samples was collected from both hatchery and naturally produced salmonids captured in an outmigrant trap located 90 miles downstream, near Willow Creek.

Several pathogens were detected, including infectious hematopoietic necrosis virus (IHNV), Erythrocytic Inclusion Body Syndrome (EIBS) viral inclusions, *Renibacterium salmoninarum*, *Nanophyetus salmonicola metacercaria*, and *glochidia* (larval mollusks). High infestations of the *N. salmonicola metacercaria* have consistently been observed in both hatchery and natural salmonids captured in the outmigrant trap and there is considerable concern that these infestations may negatively affect survivability of salmon smolts (Foott and Walker, 1992).

The parasitic trematode, *N. salmonicola*, infects multiple hosts during its life cycle. The initial host for the parasite is a freshwater snail, probably *Oxytrema* or *Juga* species. Once in the snail, the larvae develop into cercariae. The cercariae burrow out of the snail when ready and begin their search for their secondary host, a fish. When contact is made with a fish, the cercariae burrow into the fish and enter the bloodstream. Once in the bloodstream, the parasites will usually travel to the kidney, heart, or gills where they develop into cysts.

> Currently, Trinity River coho salmon are listed as threatened pursuant to the Endangered Species Act, and chinook salmon and steelhead are candidate species. The final rule that listed coho salmon recognized that various habitat declines affected coho salmon populations, including channel morphology changes, substrate changes, loss of off-channel rearing habitats, declines in water quality (e.g., elevated water temperatures), and altered streamflows.

There is considerable concern that high infestations of the *N. salmonicola* metacercaria may negatively affect survivability of salmon smolts.

Nanophyetus infection rates in Trinity River juvenile chinook salmon collected in the spring and fall were as high as 2,500 and 5,000 cysts per gram of kidney, respectively (Foott and Walker, 1992). Hatchery salmon, which were free of *Nanophyetus* infections at the hatchery, had *Nanophyetus* infections that were nearly equal to naturally produced chinook salmon after exposure to the trematode in the river for only 2 weeks. Although not proven conclusively, there is a good possibility that an inverse relationship exists between the severity of *Nanophyetus* infections and salt-water survival (Free et al., 1997).

The low-flow releases prevalent below the TRD during the spring migration period have improved conditions favoring *N. salmonicola* survival (Foott, 1996, pers. comm.). Low flows increase the time for outmigrating salmon to exit the river system, thus increasing their exposure to *Nanophyetus cercariae.* Lower flows and reduced water velocities also enhance conditions necessary for free-swimming cercaria to locate and infect fish (Foott, 1996, pers. comm.). It seems likely that the elimination of high spring flows, through the operation of the TRD, has improved conditions for the survival and reproduction of snail populations, which could lead to increased numbers of *N. salmonicola* than occurred historically.

3.1.4 Other Fish Species in the Trinity River

Although the primary focus of the TRFE is on anadromous salmonids, the fish community in the Trinity River is composed of several additional species (Table 3.6). Several native species are of biological, cultural, and economic significance, and their life histories and habitat requirements are briefly outlined here to illustrate the diversity of habitat required by the fish community.

Pacific Lamprey (*Entosphenus tridentatus*) are harvested by the Hupa, Karuk, and Yurok Indians and remain an integral part of their culture today. Pacific lamprey are a parasitic species of anadromous lamprey native to the Trinity River. Adult Pacific lamprey migrate upstream and spawn during the spring (Moyle, 1976). Eggs are deposited in pits excavated in gravel and cobble substrates, which are usually associated with run and riffle habitats similar in character to salmon spawning areas. The eggs hatch into a non-parasitic larval stage, referred to as an “ammocoete”. Ammocoetes drift downstream into slow-water habitats, where they burrow into sand or silt substrates. They spend from 4 to 5 years in freshwater, where they feed on organic detritus. The juveniles metamorphose into the adult form just prior to seaward migration, at which time they become parasitic. Adults remain in the ocean usually 6 to 18 months before they begin their spawning migration.

Green Sturgeon (*Acipenser medirostris*) are harvested by the Tribal fisheries in the lower Klamath and Trinity Rivers and these fish have cultural significance to the Hupa, Karuk, and Yurok Indians. From 1982 through 1992, the harvest of green sturgeon on the Yurok Indian Reservation was fairly consistent, averaging just under 300 fish (Craig and Fletcher, 1994). Green sturgeon migrate up the Klamath and Trinity Rivers between late February and July to spawn. Gray’s Falls (RM 43) is believed to be the upstream limit of sturgeon migration in the Trinity River. Sturgeon spawn from March through July, peaking mid-April to mid-June (Emmett et al., 1991). Juvenile green sturgeon are found in the Trinity River near Willow Creek from June through September (USFWS, 1998), and appear to outmigrate during their first summer to the lower river or estuary, where they rear for some time before moving to the ocean.

Table 3.6. Fish species found in the Trinity River.

Common name	Scientific Name
Pacific lamprey*	*Entosphenus tridentatus*
Green sturgeon*	*Acipenser medirostris*
American shad	*Alosa sapidissima*
Brown trout	*Salmo trutta*
Steelhead/rainbow trout*	*Oncorhynchus mykiss*
Coho salmon*	*Oncorhynchus kisutch*
Chinook salmon*	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Kokanee salmon	*Oncorhynchus nerka*
Golden shiner	*Notemigonus crysoleucas*
Speckled dace*	*Rhinichthys osculus*
Minnows	*Pimephalus spp.*
Klamath smallscale sucker*	*Catostomus rimiculus*
Threepine stickleback	*Gasterosteus aculeatus*
Black crappie	*Pomoxis nigromaculatus*
Sunfish spp.	*Lepomis spp.*
Largemouth bass	*Micropterus salmoides*
Sculpin*	*Cottus spp.*

* indicates species native to the Trinity River.

Speckled Dace (*Rhinichthys osculus*) are a native species common throughout the Trinity River and its tributaries. Speckled dace are most abundant in cobble-strewn riffles, where they hide during the day and feed at night (Moyle, 1976). Speckled dace are small fish (< 6 inches), and few live beyond their third winter. Adults spawn during the spring, and fry are common during late spring and summer months in shallow edgewaters with moderate current.

Klamath Smallscale Suckers (*Catostomus rimiculus*) are most abundant in slow-run and pool habitats (Moyle, 1976). Suckers spawn during the spring in run habitats and tributary streams. Fry and juvenile suckers have been observed in the mainstem in slow edgewater habitats in both the mainstem and side channels by Service biologists during late spring and summer months.

3.2 Wildlife Resources

Although the primary focus of the TRFE is on anadromous salmonids, the Trinity River is important to many species of wildlife. Riparian habitats in unregulated rivers in northwestern California support diverse vertebrate and invertebrate communities. These species are adapted to and depend on annual flood events to create river and floodplain habitats, such as seasonally flooded marshes and side channels, early successional willow vegetation, and shallow, low water-velocity areas along the main channel (i.e., backwater and edgewater pools) (Wilson et al., 1991; Lind et al., 1995; Reese, 1996; Reese and Welsh, 1998). Many wildlife species also have adapted their breeding, migration, and foraging cycles (Table 3.7) to the natural flow cycles of the river (Lind et al., 1996). Growth, development, behavior, and survival of ectothermic animals (amphibians, reptiles, invertebrates) are highly dependent on temperature. Thus, the timing and temperature of water releases could have significant effects on many species.

Little pre-TRD information exists on riparian-associated wildlife species in the Trinity River Basin. Many sensitive wildlife species occur in riparian habitats along the mainstem Trinity River today and likely occurred prior to the construction of the Trinity and Lewiston Dams: foothill yellow-legged frog (California species of special concern [CSSC]); western pond turtle (CSSC); bald eagle (Federal ESA-listed threatened); osprey (CSSC); yellow warbler (CSSC); willow flycatcher (State threatened); yellow-breasted chat (CSSC); and black-capped chickadee (CSSC) (Wilson et al., 1991; Lind et al., 1995; BLM, 1995). There are also three bat species (pallid, little brown myotis, and Townsend's western big-eared [CSSC]) that are typically associated with riparian habitats, but their historical and current status in the Trinity River Basin is unknown (BLM, 1995).

Two sensitive and highly aquatic species have been studied in the Trinity River Basin: the foothill yellow-legged frog (*Rana boylii*) and the western pond turtle (*Clemmys marmorata*) (Lind et al., 1995; Reese, 1996; Reese

Table 3.7. Annual cycles of amphibians and reptiles along the mainstem Trinity River (compiled by A. Lind, USDA Forest Service - 11/95). See footnotes on next page.

	Landscape use													
Month	PGS [i] larvae	PGS adults	RSN larvae	RSN adults	WTO egg/tad	WTO toads	PTF egg/tad	PTF frogs	FYF egg/tad	FYF frogs	BLF all life stgs	WPT females	WPT males	Garter Snakes
Jan-Feb[ii]	tribs/ river, in substrate	on land, active ?	sloughs & river	on land, active ?	-------[iii]	on land, inactive ?	-------	on land, active ?	--------	on land, inactive ?	sloughs, marshes	on land, hibernating	on land, hibernating	on land, hibernating
March	tribs/ river, in substrate	tribs, breeding	sloughs & river	sloughs, breeding	-------	river	sloughs & vern pools	river & other riparian	-------	sloughs & river	sloughs, marshes	moving to river	moving to river	on land, active ?
April	tribs/ river, in substrate	tribs, breeding	sloughs & river	sloughs, breeding	river, slow margins (eggs)	river, slow margins	sloughs & vern pools	river & other riparian	river, bar margins (eggs)	river, bar margins	sloughs, marshes	in or near river	in or near river	riparian & river shore
May	tribs & river	tribs, breeding	sloughs & river	sloughs, breeding	river, slow margins (eggs)	river, slow margins	sloughs & vern pools	river & other riparian	river, bar margins (eggs)	river, bar margins	sloughs, marshes	nesting, land (25%)	main river channel	riparian & river shore
June	tribs & river	on land, inactive	sloughs & river	sloughs, breeding	river, slow margins (eggs)	river, slow margins	sloughs & vern pools	river & other riparian	river, bar margins (eggs)	river, bar margins	sloughs (eggs)	nesting, land (50%)	main river channel	riparian & river shore
July	tribs & river	on land, inactive	sloughs & river	on land, inactive	river, slow margins	river shore & margins	sloughs & vern pools	river & other riparian	river, bar margins	river shore & margins	sloughs (eggs)	nesting, land (25%)	main river channel	riparian & river shore
August	tribs & river	on land, inactive	sloughs & river	on land, active ?	river, slow margins	river shore & margins	-------	river & other riparian	river, bar margins	river shore & margins	sloughs, marshes	main river channel	main river channel	riparian & river shore
Sept	tribs & river	on land, inactive	sloughs & river	on land, active ?	river, slow margins	river shore & margins	-------	river & other riparian	river, bar margins	river shore & margins	sloughs, marshes	moving onto land	moving onto land	riparian & river shore
Oct	tribs & river	on land, inactive	sloughs & river	on land, active ?	-------	river shore & margins	-------	river & other riparian	river, bar margins	sloughs & river	sloughs, marshes	on land, hibernating	on land, hibernating	riparian & river shore
Nov-Dec[2]	tribs/ river, in substrate	on land, active ?	sloughs & river	on land, active ?	-------	on land, inactive ?	-------	on land, active ?	-------	on land, inactive ?	sloughs, marshes	on land, hibernating	on land, hibernating	on land, hibernating

Table 3.7 cont.. Annual cycles of amphibians and reptiles along the mainstem Trinity River (compiled by A. Lind, USDA Forest Service - 11/95).

Footnotes: (for Table 3.7)

i. Info on annual cycles was derived as follows for each species (eg., PGS) and life stage (eg., adult)
PGS - Pacific giant salamander (*Dicamptodon tenebrosus*) - literature (see below)
RSN - rough-skinned newt (*Taricha granulosa*) - literature and pitfall trapping (Welsh, unpublished data)
WTO - western toad (*Bufo boreas*) - literature and field notes (Lind, unpublished data)
PTF - Pacific treefrog (*Hyla regilla*) - literature and field notes (Lind, unpublished data)
BLF - bullfrog (*Rana catesbeiana*) - literature and field notes (Lind, unpublished data)
FYF - foothill yellow-legged frog (*Rana boylii*) - literature and field surveys (Lind, unpublished data)
WPT - western pond turtle (*Clemmys marmorata*) - radio telemetry study (Reese, unpublished data)

ii. Detailed information is not provided for November through February because most species are on land and inactive in the Trinity Basin during these months.

iii. ----- indicates that this life stage does not exist at this time of year.

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> "Riparian habitats in unregulated rivers in northwestern California support diverse vertebrate and invertebrate communities. These species are adapted to and depend on annual flood events to create river and floodplain habitats."

and Welsh, 1998; Reese and Welsh, in press). Foothill yellow-legged frogs are active during spring, summer, and fall along the river margins and in flowing side channels, and probably hibernate in the winter. Eggs are deposited between April and June in shallow, low-velocity areas along rocky, sparsely vegetated river bars (Lind et al., 1996). Upon metamorphosis, most juveniles migrate upstream, probably as a compensating mechanism for downstream drift of larvae (CDFG, 1994b). Surveys of foothill yellow-legged frogs on the Trinity River found that their distribution is related to the distribution of early successional riparian and gravel-bar habitats (Lind et al., 1996). Greater numbers of frogs were found in reaches farther downstream from the dam, where the gravel bar habitats are in greater abundance. The loss of open, rocky, shallow river bars in the upper river has probably contributed to a decline in foothill yellow-legged frog populations (Lind et al., 1996), and the absence of these habitats may deter young frogs from migrating upstream where habitat is less suitable.

Yellow-legged frog egg and larvae survival depends on timing and volume of runoff events (Lind et al., 1996). From the onset of oviposition, yellow-legged frogs require a minimum of 15 weeks to metamorphose (CDFG, 1994b), and are extremely vulnerable to fluctuating flows during this period. Unhatched eggs subjected to a high-flow event are generally washed away (Lind et al., 1996). Larve that hatch prior to a high-flow event are more likely to survive depending on the rate of fluctuation. Rapidly ascending or descending water levels can decrease survival because larvae have difficulty tracking rapidly changing water levels and cannot find appropriate habitat before they are washed away or stranded (Lind et al., 1996).

It is suspected that yellow-legged frogs use environmental cues such as temperature and rainfall patterns to initiate or suspend breeding activities (Lind et al., 1996). Thus, in an unregulated river the frogs are effectively able to avoid depositing eggs during periods of highly fluctuating flows, which are so detrimental to eggs and larvae. On the Trinity River, however, yellow-legged frogs are often subjected to releases that are not in sync with their environmental cues, resulting in high egg and larvae mortality (Lind et al., 1996).

In summer, water temperatures of TRD releases are generally lower than what yellow-legged frogs have adapted to on the Trinity River. Low temperatures retard egg and larvae development, and prolong the period in which they are vulnerable to fluctuating flows and to predators.

Since the construction of TRD, yellow-legged frogs in the upper river have been subjected to decreasing habitat availability, unpredictable timing and volume of releases, and lower summer water temperatures. Thus, frogs have probably had to deposit eggs in faster, deeper water more vulnerable to scouring flows; oviposition has often occurred during periods when eggs and

> "Greater numbers of frogs were found in reaches farther downstream from the dam, where the gravel bar habitats are in greater abundance. The loss of open, rocky, shallow river bars in the upper river has probably contributed to a decline in foothill yellow-legged frog populations."

larvae are likely to be washed away or stranded; and the eggs and larvae have taken longer to develop in the cooler water extending the vulnerable period. Also, upstream migration may have been reduced due to sparse upstream habitat.

Since the construction of TRD, the loss of alternate point bars has resulted in fewer deep pool microhabitats used for refuge and also has reduced shallow edgewater used for rearing by western pond turtles.

Western pond turtles are found in and along pool and glide habitats of the main channel, and smaller hatchlings and juveniles are found in backwater pools, shallow river margins, and side channels with vegetation. The lower end of side channels (the alcove) is often scoured during large floods, providing deep slow-velocity pool habitat adjacent to the main channel. These pools are important foraging and thermoregulation sites for western pond turtles (Reese, 1996). Backwater eddies (a common attribute of alcoves) trap logs and other debris, which are used for aerial basking by western pond turtles when air temperatures are greater than water temperatures (CDFG, 1994b). The limited mixing of backwater areas with the mainstem allows surface temperatures to get considerably higher in backwater areas than the mainstem during the summer. This warm surface layer is utilized by western pond turtles for "water basking" when air temperatures become too warm for aerial basking. Mats of submergent vegetation commonly associated with backwater areas are particularly attractive to western pond turtles because they maintain even warmer surface-water temperatures, help turtles maintain their position, and provide immediately accessible cover (CDFG, 1994b). Standing water associated with more isolated backwater areas also provide an abundance of nekton (zooplankton fauna), a major food source for juvenile pond turtles (CDFG, 1994b).

Cooler summer water temperatures probably also affect western pond turtles by slowing growth, and by altering behavior and habitat selection (Lind, pers. comm.). Cooler water temperatures may shorten the turtles' active period, increase aerial basking activity, or force turtles to seek warmer waters in shallower or more isolated backwaters. Warmer winter water temperatures would also affect pond turtles, which may overwinter on land or in water, or remain active in water during the winter depending on temperatures (CDFG, 1994b).

Since the construction of TRD, the loss of alternate point bars has resulted in fewer deep pool microhabitats used for refuge and also has reduced shallow edgewater used for rearing. Densities of western pond turtles in the mainstem Trinity River (2.6 turtles/acre) are very low in comparison to densities on the unregulated South Fork Trinity River (5 turtles/acre) and unregulated Hayfork Creek (up to 300 turtles/acre), a tributary to the South Fork Trinity River (Reese, 1996; Reese and Welsh, in press). In addition, the age structure for these two locations differs from that of the mainstem, which has a more adult-biased population than either of the other two (Reese, 1996; Reese and Welsh, in press). These differences indicate population declines on the mainstem owing to changes resulting from the dams.

In summary, downstream from Lewiston Dam, there have been many changes in riverine and riparian habitats owing to TRD operations. Habitat features such as seasonally flooded marshes and side channels, shallow river margins, cold-water holding pools, and bank undercuts have been reduced or eliminated.

"Habitat features such as seasonally flooded marshes and side channels, shallow river margins, cold-water holding pools, and bank undercuts have been reduced or eliminated. Species that depend on flood-maintained habitats (e.g., foothill yellow-legged frogs, western pond turtles) have been negatively impacted by reductions in flows."

Species that depend on flood-maintained habitats (e.g., foothill yellow-legged frogs, western pond turtles) have been negatively impacted by reductions in flows. The post-project reductions in summer water temperatures (Section 4.3.6) may also affect development rates and other physiological functions of ectothermic wildlife such as amphibians and reptiles (BLM, 1995).

CHAPTER 4 A Historical Perspective to Guide Future Restoration

Describing the present Trinity River system, including its salmonid populations, is relatively easy. Describing its historical condition is more difficult, but possible. Few scientists made detailed measurements of Trinity River ecosystem processes before TRD construction began (pre-TRD). Historical data consist of several sets of aerial photographs, data collected at USGS gaging stations, personal accounts, and a few administrative reports. Aerial photos show that the mainstem below Lewiston had morphological features typical of alluvial rivers; therefore, the geomorphologists' knowledge of contemporary alluvial rivers can be applied to the former mainstem channel. Basic life-history requirements of woody riparian species are known. Similarly, habitat preferences and physiological limitations for salmon and other aquatic species can be determined from present-day studies. By applying present-day knowledge to the past, we can chart the future. A fishery-restoration strategy pursued in this way sidesteps simply treating symptoms: it attempts to remedy causes for the decline of the fishery resources of the Trinity River. A map of the Trinity River from Lewiston Dam to the North Fork Trinity River confluence is shown in Figure 4.1 and the sites discussed are listed in Table 4.1.

4.1 The Trinity River Ecosystem Before the Trinity River Division

When the TRD was constructed in the early 1960's, the Trinity River mainstem was anything but pristine. Undisturbed conditions did not exist anywhere owing to extensive human disturbance to the active channel, floodplain, and hillslopes. The pre-European mainstem from the uppermost section of present-day Trinity Lake to the North Fork Trinity River confluence had extensive floodplains in any reach unconfined by valley walls. Beginning in the mid-1800's gold miners first placer-mined the Basin, sluicing entire hillsides into the

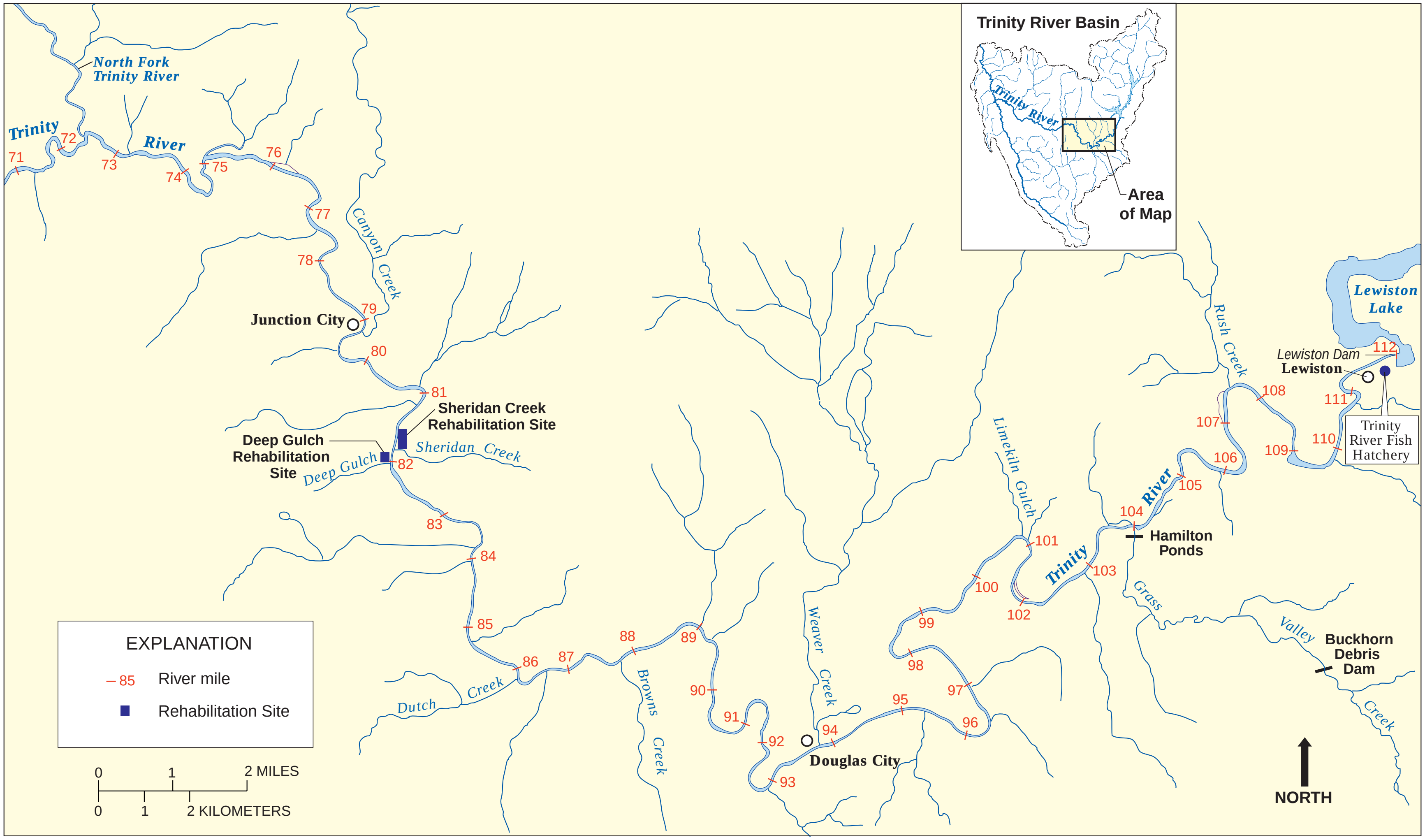

Figure 4.1. The Trinity River mainstem and tributaries from Lewiston to the confluence of the North Fork Trinity River. River mile is the number of river miles upstream from the Trinity River's confluence with the Klamath River.

Table 4.1. Detailed list of Trinity River landmarks downstream from Trinity Dam.

Name	Description	River Mile
Trinity Dam	Storage dam	120.0
Lewiston Dam	Re-regulation and diversion dam	111.9
Dam Site	Sediment budget monitoring site	111.5
Trinity River @ Lewiston	USGS continuous streamflow gaging station (1911-present)	110.9
New Lewiston Bridge	Bridge crossing the Trinity River	110.8
Deadwood Creek	Tributary	110.8
Deadwood Creek @ Lewiston	Sediment budget monitoring site, HVT continuous streamflow gaging station (1997-present)	110.8
Lewiston Cableway	USGS cableway, mainstem sediment transport monitoring site	110.2
Old Lewiston Bridge	Bridge crossing the Trinity River	109.95
Sawmill	Channel morphology monitoring site	108.6
Rush Creek	Tributary	107.5
Rush Creek near Lewiston	Sediment budget monitoring site, HVT continuous streamflow gaging station (1996-present)	107.5
Gold Bar	Channel morphology monitoring site	106.3
Dark Gulch	Tributary	105.9
Bucktail Bank Rehabilitation	Bank rehabilitation project	105.6
Gravel Plant	Channel morphology monitoring site	105.5
Browns Mountain Bridge	Bridge crossing the Trinity River	105.05
Bucktail	Channel morphology monitoring site	104.6
Grass Valley Creek	Tributary	104.0
Trinity House Gulch	Tributary	103.7
Ponderosa Pool	Sand storage monitoring site	103.6
Tom Lang Pool	Sand storage monitoring site	102.8
Poker Bar Bridge	Bridge crossing the Trinity River	102.4
Reo Stott Pool	Sand storage monitoring site	102.0
Society Pool	Sand storage monitoring site	101.3
China Gulch	Tributary	100.95
Limekiln Gulch	Tributary	100.9
Limekiln Bank Rehabilitation	Bank rehabilitation project	100.2
Steel Bridge	Channel morphology monitoring site	99.2
Steel Bridge Pool	Sand storage monitoring site	99.0
Steel Bridge Bank Rehabilitation	Bank rehabilitation project	98.8
Trinity River blw Limekiln Gulch	USGS continuous streamflow gaging station (1981-1991)	98.3
Limekiln Cableway	Sediment transport monitoring site, HVT streamflow gaging station (1998-present)	98.3
MacIntyre Gulch	Tributary	96.95
Vitzthum Gulch	Tributary	96.3
Indian Creek	Tributary	95.3

Table 4.1 continued.

Name	Description	River Mile
Indian Creek near Douglas City	Sediment budget monitoring site, HVT continuous streamflow gaging station (1997-present)	95.3
Indian Creek	Channel morphology monitoring site	95.2
Weaver Creek nr Douglas City	USGS continuous streamflow gaging station (1959-1969)	93.8
Weaver Creek	Tributary	93.8
Hwy 299 Bridge	Bridge crossing the Trinity River	93.7
Reading Creek	Tributary	92.9
Douglas City Campground	Channel morphology monitoring site	92.8
Trinity River @ Douglas City	HVT continuous streamflow gaging station (1996-present)	92.2
Steiner Flat Bank Rehabilitation	Bank rehabilitation project	91.8
Steiner Flat	Channel morphology monitoring site	91.7
Lorenz Gulch	Tributary	89.3
Dutton Creek	Tributary	89.0
Browns Creek nr Douglas City	USGS continuous streamflow gaging station (1957-1967)	87.8
Browns Creek	Tributary	87.8
Trinity River near Douglas City	USGS continuous streamflow gaging station (1945-1951)	87.7
Maxwell Creek	Tributary	86.8
Dutch Creek	Tributary	86.3
Carr Creek	Tributary	85.3
Bell Gulch Bank Rehabilitation	Bank rehabilitation project	84.0
Bell Gulch	Tributary	84.0
Soldier Creek	Tributary	83.8
Deep Gulch Bank Rehabilitation	Bank rehabilitation project	82.2
Deep Gulch	Tributary	82.0
Sheridan Crk Bank Rehabilitation	Bank rehabilitation project	82.0
Sheridan Creek	Tributary	81.8
Upper Sky Ranch	Channel morphology monitoring site	81.6
Mill Creek	Tributary	81.2
Oregon Gulch	Tributary	80.9
Lower Sky Ranch	Channel morphology monitoring site	80.4
Dutch Creek Road Bridge	Bridge crossing the Trinity River	79.6
McKinney Creek	Tributary	79.6
Trinity River @ Junction City	HVT streamflow gaging station (1995-present)	79.6
Canyon Creek	Tributary	79.1
Canyon Creek	Channel morphology monitoring site	79.0
Jim Smith Bank Rehabilitation	Bank rehabilitation project	78.5
Conner Creek	Tributary	77.3
J & M Tackle	Channel morphology monitoring site	76.9
Wheel Gulch	Tributary	76.2
Valdor Gulch	Tributary	75.1
Pear Tree Gulch	Tributary	73.15
Pear Tree Bank Rehabilitation	Bank rehabilitation project	73.1
North Fork Trinity River	Tributary	72.4
North Fork Trinity River	DWR/USGS continuous streamflow gaging station (1912, 1913, 1957-1980)	72.4
Trinity River nr Burnt Ranch	USGS continuous streamflow gaging station (1932-40, 1957-present)	48.6
Trinity River at Hoopa	USGS continuous streamflow gaging station (1912, 1913, 1917, 1918, 1932-present)	12.4
Klamath River	Mouth of Trinity River	0.0

A historical perspective guides future restoration by identifying and understanding interrelationships between natural channel conditions and fishery production, and placing that understanding in the context of specific changes induced by the TRD. Managers can begin understanding the direct and indirect impacts of certain management actions to the river, how that impact propagated to the fishery, and then prescribing alternative management activities (restoration) to reverse those negative impacts.

tributaries, then later (from the early 1900's to the early 1950's) dredged most of the natural river channel, often from one valley wall to the other. Most floodplain and terrace features were destroyed, leaving extensive tailings. Although greatly increased sediment supply into the mainstem created chronic turbidity, salmon and steelhead populations were abundant. Physical evidence of pre-TRD channel conditions was uncovered from aerial photographs, interpretation of remnant channel features, and inspection of the USGS gaging station cableway cross-section records at Lewiston (RM 110.2) (McBain and Trush, 1997).

4.1.1 An Alluvial River Morphology

Although the river corridor had been greatly altered by gold mining, the Trinity River mainstem remained morphologically diverse. The Trinity River mainstem was, and still is, a mix of distinct channel morphologies, both alluvial and bedrock-controlled. Many channel reaches from Lewiston downstream to the North Fork Trinity River were alluvial, where the river had the capability of shaping its channelbed and banks. The pre-TRD Trinity River was resilient: Left to wander among the mine tailings, the mainstem reshaped portions of these tailing fields into a meandering channel typical of normally functioning alluvial rivers (Figures 4.2 and 4.3). The channel migrated or avulsed (rapid abandonment of channel to another location) across the valley floor over time, occupying all locations within the valley at some time. The mainstem had extensive floodplains and a meandering river corridor in its least confined reaches downstream from Dutch Creek (RM 86.3), as well as in partially confined channel reaches closer to Lewiston. Other reaches were variably influenced by depositional features composed mostly of cobbles or small boulders derived from bedrock outcrops.

An alluvial channel morphology is maintained in a "dynamic quasi-equilibrium" where sediment routed through the channel roughly equals the sediment supplied. Sediment is transported through or stored within the channel (dynamic), but the channel morphology fluctuates only narrowly over time (quasi-equilibrium). Knighton (1984) states, "no exact equilibrium is implied but rather a quasi-equilibrium manifests in the tendency of many rivers to develop an average behavior." Long- and short-term changes to sediment supply or flow regime initiate adjustments in channel morphology and the channel's "average behavior" (Lane, 1955). Although a dynamic quasi-equilibrium is not universal among rivers, the concept provides a useful baseline to evaluate alluvial processes before the TRD. In a nearby alluvial river, the South Fork Trinity River, alluvial features show signs of frequent, roughly annual mobilization, although overall morphology often appears unchanged between major floods. Pre-TRD aerial photographs of the mainstem Trinity River are similar.

Unregulated alluvial rivers are continually renewed through fluvial processes that shape and maintain the channelbed topography. A prevalent feature of low-gradient alluvial rivers, such as the Trinity River, is an alternate bar sequence. An alternate bar sequence consists of two point bars, opposite and longitudinally offset from one another, connected by a transverse bar (riffle) (Figures 4.4 and 4.5). Alternate bars, often referred to as "riffle-pool sequences", are composed of an

Figure 4.2. Trinity River near Junction City (RM 79.6) showing pre-TRD (1961) riparian communities at a discharge of 192 cfs.

aggradational lobe near the thalweg (the deepest part of the channel), a crossover (riffle), and an adjacent scour hole (pool). On a broader spatial scale, two alternate bars form a complete channel meander with a wavelength roughly equaling 9 to 11 bankfull channel widths (Leopold et al., 1964). Alternate bar features are readily apparent in pre-TRD aerial photographs (Figures 4.2, 4.3, and 4.4), even in reaches confined by bedrock valley walls such as the Trinity River near the confluence with Browns Creek (RM 87.8) (Figure 4.6). Typical pre-TRD meander wavelengths ranged from 2,500 feet to 4,000 feet, sinuosity values ranged from 1.0 to 1.2, and the radius of curvature for meanders varied on the basis of the degree of bedrock confinement.

During low flows the channel meanders through the alternating point bars, but during high flows the bars become submerged and the flow pattern straightens. During these periods of high energy, bedload is mostly transported across the face of these alternating point bars rather than along the thalweg. In contemporary unregulated alluvial rivers, alternate bar surfaces show signs of

Figure 4.3. Trinity River at Junction City (RM 79.6) in 1960 illustrating alternate point bar sequences at a discharge of 5,000 cfs.

frequent mobilization, but overall bar shape and elevation commonly appear unchanged in sequential aerial photographs between major floods.

Pre-TRD channel geometry was reconstructed by McBain and Trush (1997) using remnant floodplain/terrace features at Steiner Flat (RM 91.7) and at the USGS gaging station cross section at Lewiston (RM 110.2). Steiner Flat, a partially alluvial and partially confined channel reach that did not suffer major alteration due to gold mining, provided a reasonable site to assess pre-TRD channel morphology. On the basis of a reconstructed channel cross section, the pre-TRD bankfull channel width was estimated to be approximately 280 feet (Figure 4.7). At the Lewiston gaging station cableway cross section, the pre-TRD bankfull channel width was 250 feet and average bankfull depth was 7.5 feet (Figure 4.8).

Figure 4.4. Trinity River near Lewiston (RM 112.0) circa 1960, prior to the construction of TRD. Note alternate bar sequences and large floodplain.

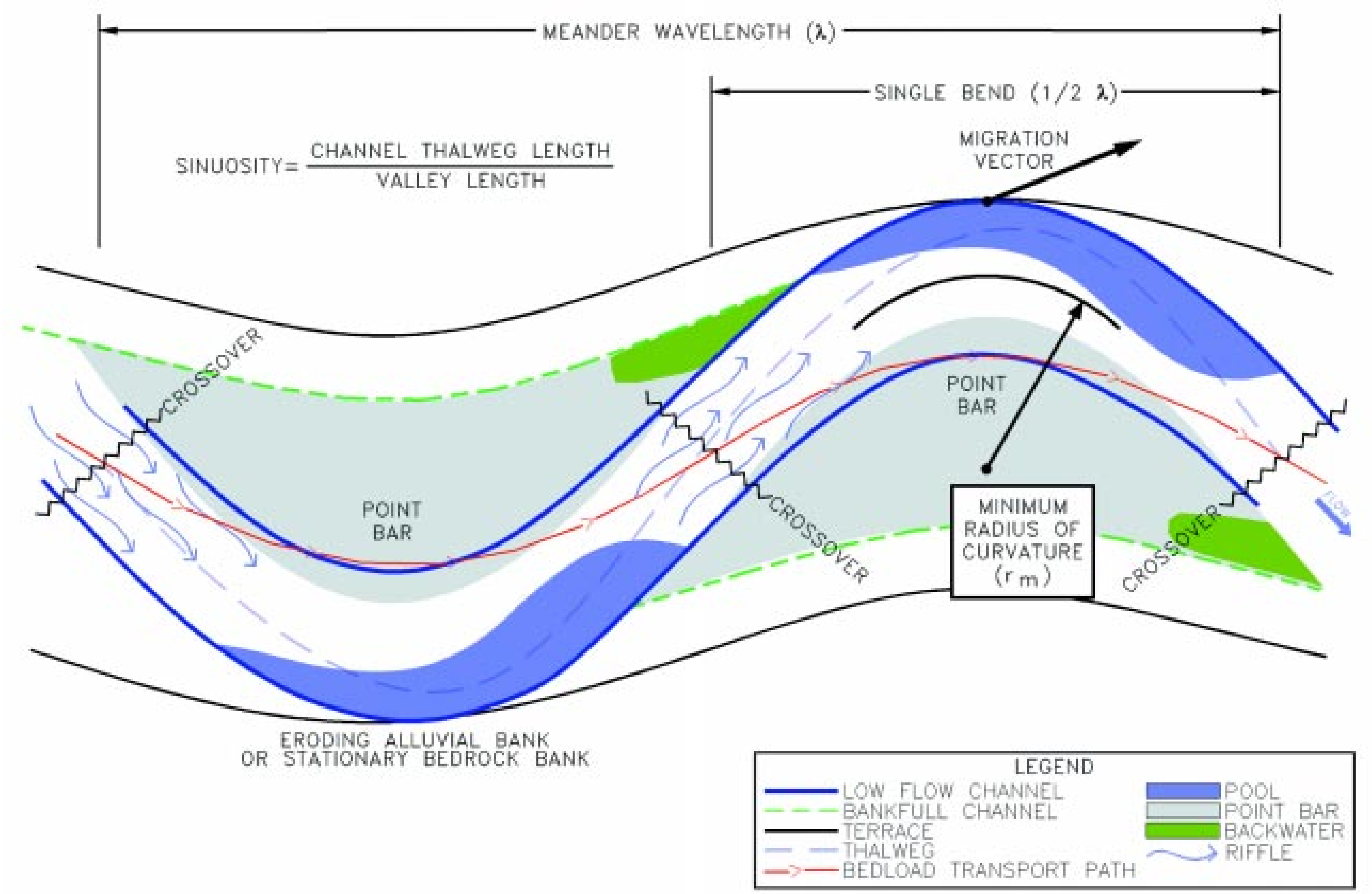

Figure 4.5. Idealized alternate bar sequence in an alluvial channel.

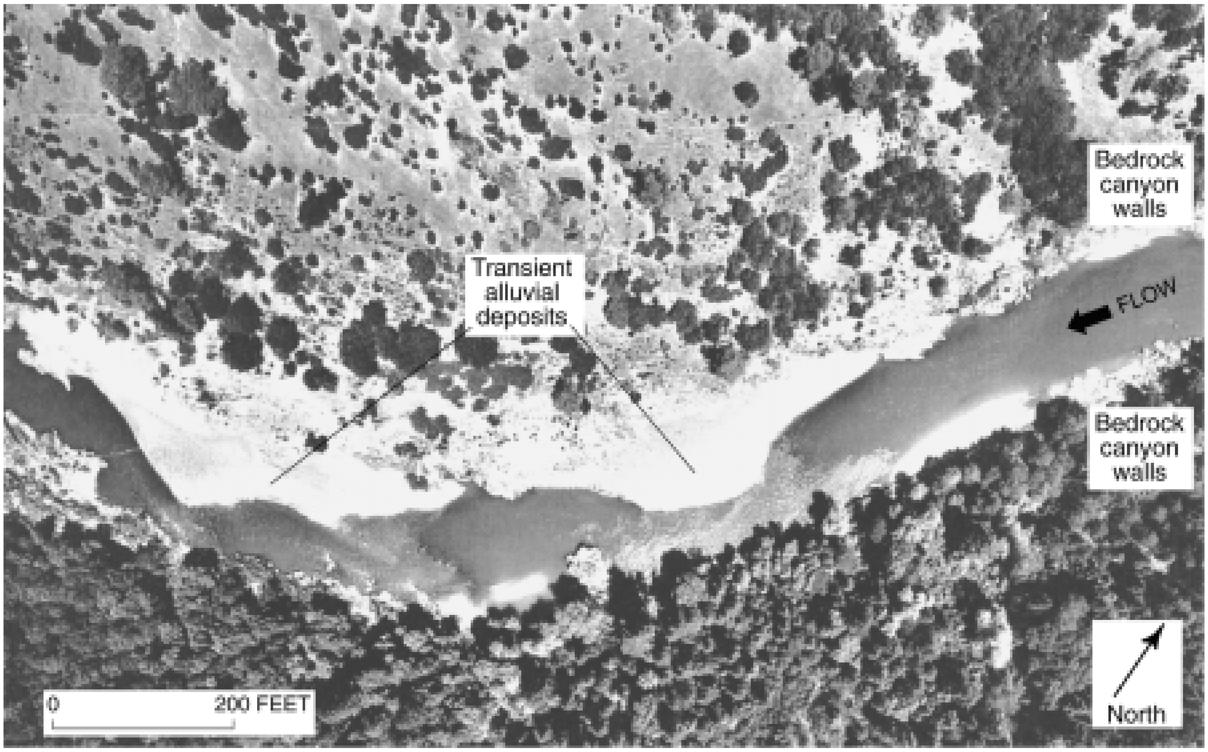

Figure 4.6. Trinity River at Browns Creek (RM 87.8) in 1961, illustrating alternate bar sequences at a discharge of 192 cfs.

4.1.2 Alternate Bars and Habitat

In the absence of extensive historical physical-habitat data, the role of alternate bars in creating habitat in contemporary alluvial river ecosystems was used as a guide to characterizing habitat availability in the historical mainstem. The topographic diversity of the pre-TRD channelbed surface generated diverse anadromous salmonid habitat at any given flow (Figure 4.9). For example, the steep riffle face of alternate bars, at winter and summer baseflows, provided widely varying water velocities and depths over short distances (a few feet). This hydraulic complexity created physical habitat for several age classes of juvenile salmonids. At typical baseflows, an alternate bar sequence on the mainstem provided adult holding areas, preferred spawning substrates, early-emergence slack water, and winter/summer juvenile rearing habitats (Figure 4.9). As baseflows varied within and among seasons, most if not all these habitats remained available although differing in proportion. Even in bedrock-influenced channel reaches, other macro-alluvial features, such as mid-channel bars and (or) point bars, generated similar habitat complexity. Associated features such as undercut banks, side channels, and backwater alcoves all contributed to a physical mosaic that collectively provided habitat for all salmonid freshwater life stages. In this report, alternate bars are considered to be discrete, physically definable units of salmonid habitat; this usage is similar to the traditional use of pools and riffles as habitat units by fisheries scientists.

The alternate bar morphology provides velocity, substrate, and topographical diversity over a wide range of flows, which is critical for providing high quality salmonid habitat.

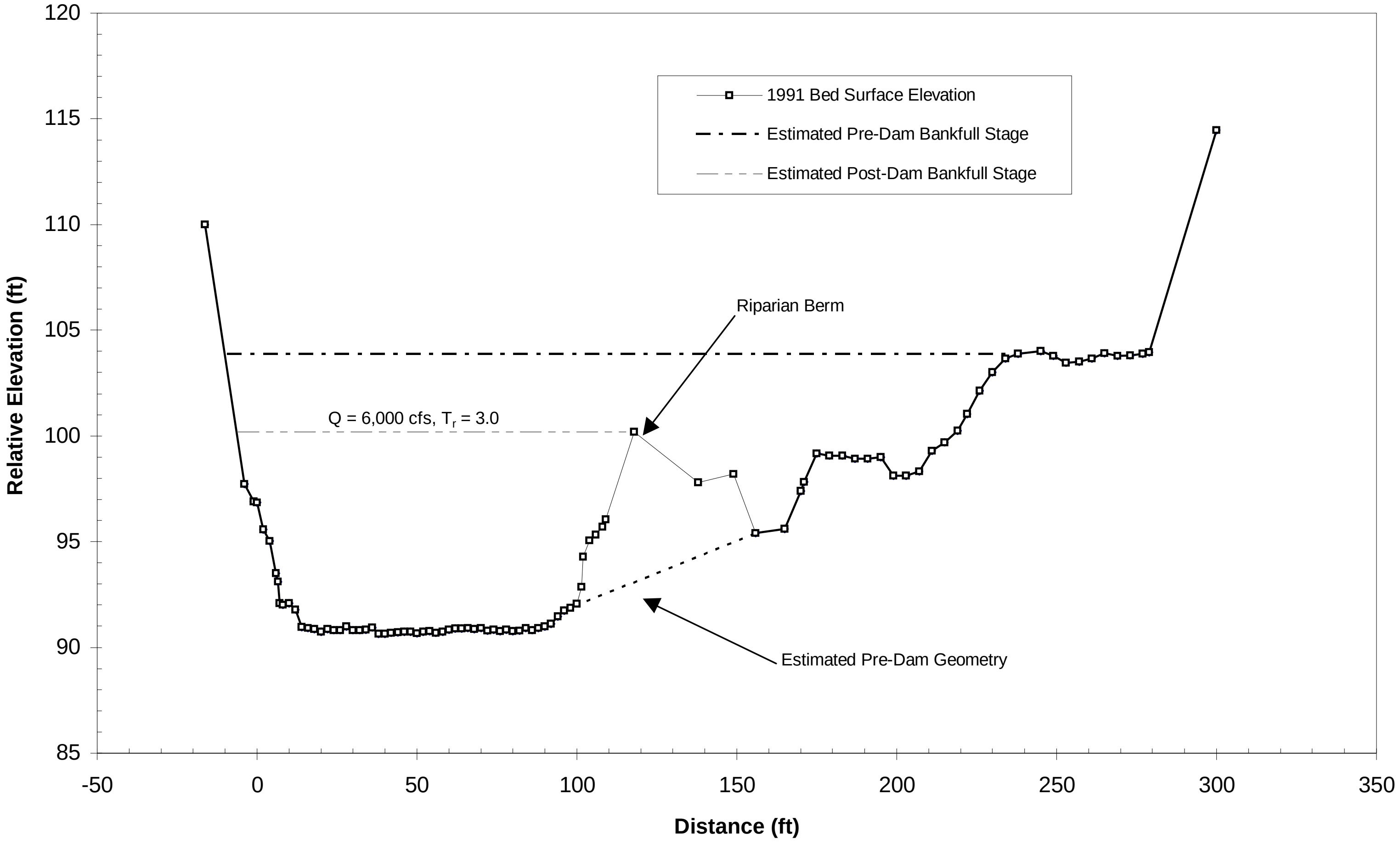

Figure 4.7. Change in Trinity River channel morphology and bankfull channel at Steiner Flat (RM 91.7), resulting from the TRD.

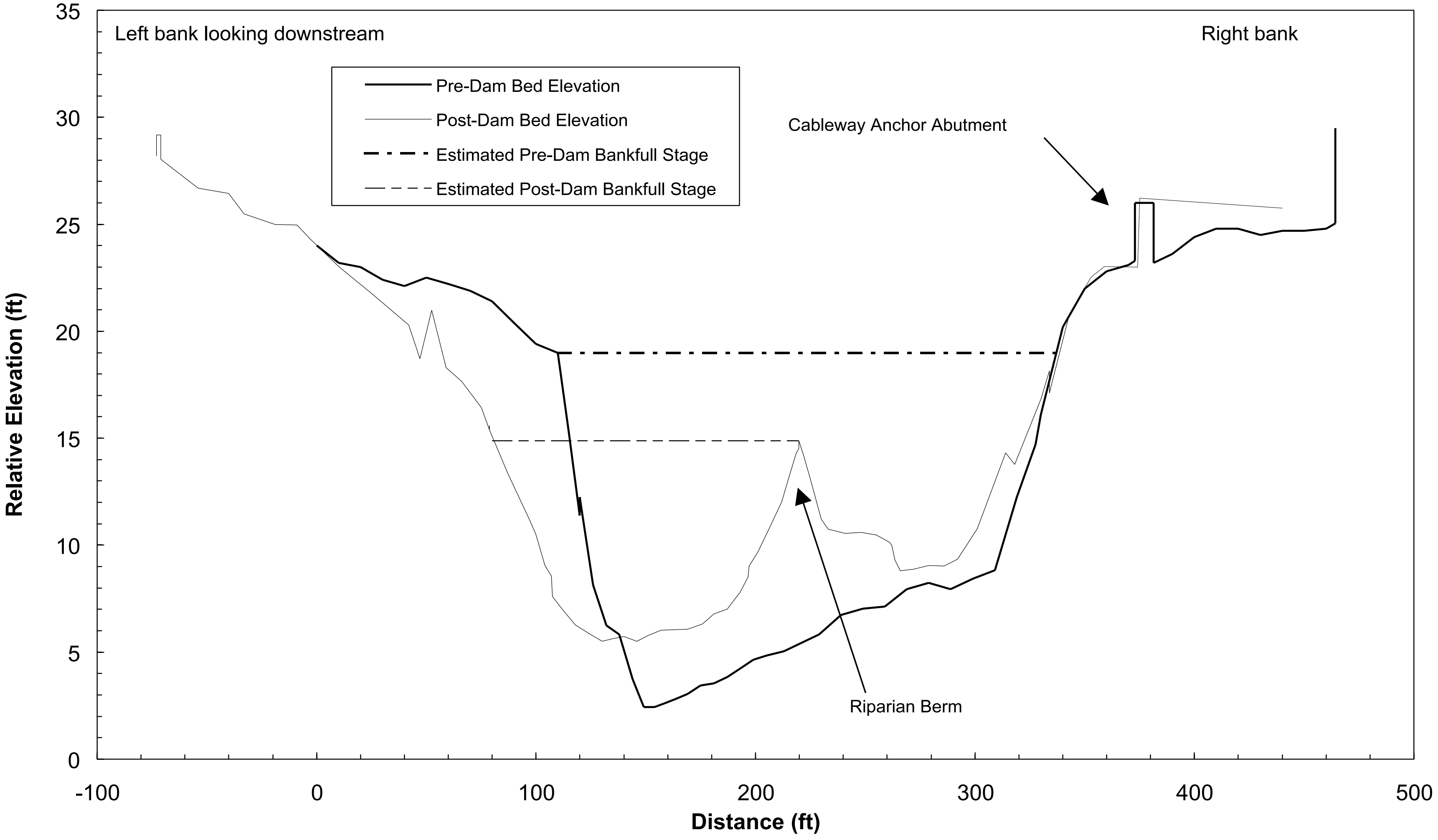

Figure 4.8. Change in Trinity River channel morphology and bankfull channel at the USGS gaging station at Lewiston (RM 110.2), resulting from the TRD.

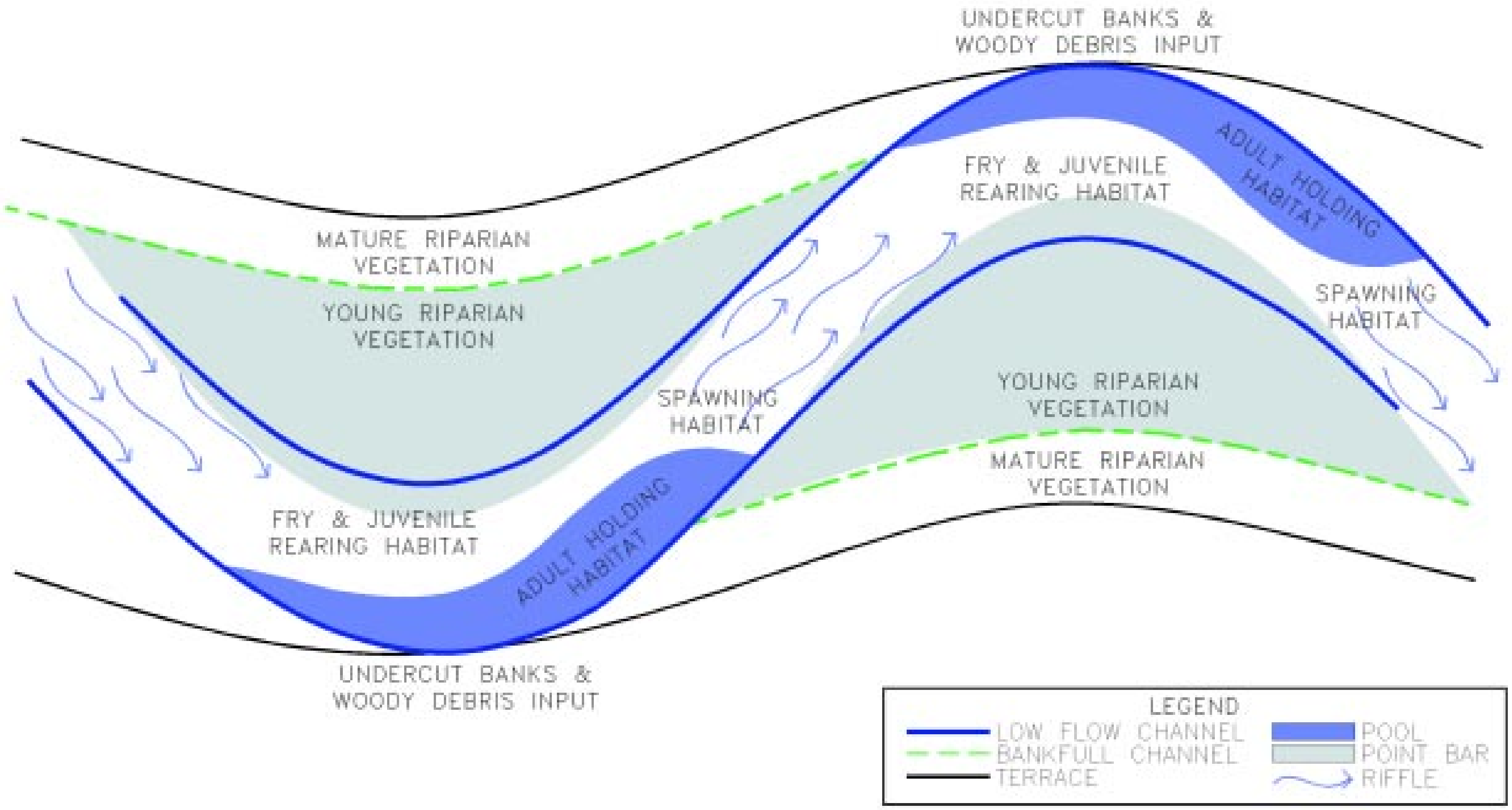

Figure 4.9. Salmonid habitats provided in an idealized alternate bar unit.

Alternate bar sequences provide additional ecological functions besides supporting anadromous salmonid habitat. A side channel commonly forms on the landward margin of an alternate bar and flows only during floods. The lower end of a side channel (the alcove) is usually deeper (having been scoured during large floods), and it provides amphibians refuge from high velocities during flooding, and thermal refuge during lower flows. Adult western pond turtles (*Clemmys marmorata*) forage and thermoregulate in and along pool and glide habitats of the main channel; smaller hatchlings and juveniles prefer backwater pools, shallow river margins, and side channels with vegetation (Reese, 1996). These habitats are typically created by alternate bar sequences. On the upstream end of alternate bars, a broad shallow area provides slightly warmer, slowly flowing water that attracts amphibians in the winter. The gently sloping, exposed flanks of alternate bars provide habitat for foothill yellow-legged frogs (*Rana boylii*) that deposit eggs in shallow, low-water-velocity areas on cobble bars with sparse vegetation (Lind et al., 1992). Early-successional riparian vegetation on mid- to upper surfaces of alternate bars provides habitat for many resident and migratory birds, including the willow flycatcher (*Empidonax trail*).

> The variable flow regime was responsible for maintaining the integrity of alternate bar sequences and high quality salmonid habitat.

4.1.3 Annually Variable Flows Within Common Hydrograph Components

Annual flow variability is a key attribute of contemporary alluvial and mixed-alluvial rivers. Without flow variation, diverse physical processes cannot be sustained. Annual flows in the pre-TRD Trinity River mainstem varied considerably. During rain-on-snow storm events, instantaneous peak flows at Lewiston could exceed 70,000 cfs, peaking as high as 100,000 cfs. At the other extreme, late summer flows during droughts could drop below 100 cfs. Flows had predictable general trends, such as higher peak flows in wet years, lowest flows in late summer, and snowmelt runoff peaks during late spring and early summer, but other flow characteristics, such as the magnitude of peak flows and droughts, were extremely variable.

Seasonal patterns for daily average flow are identifiable as "hydrograph components" for Pacific Northwest rivers. Hydrograph components were identified for pre-TRD annual hydrographs (Figure 4.10) using the USGS Lewiston gaging data, other USGS gaging stations (Table 4.2), and Reclamation Trinity Lake inflow data (refer to McBain and Trush, 1997, for detail). Annual hydrograph components included summer baseflows, winter flood peaks, winter baseflows, snowmelt peak runoff, and snowmelt recession. Each varied in its duration, magnitude, frequency, and seasonal timing. Peak snowmelt runoff and high summer baseflows dominated annual hydrographs for high-elevation sub-basins, whereas lower sub-basins (downstream from Lewiston) generated more winter rainfall runoff and relatively low summer baseflows. Therefore, distinct differences in flow magnitude, duration, frequency, and timing in each hydrograph component occurred inter-annually and by basin location. Each hydrograph component (Figure 4.10) uniquely influenced the morphology and function of the mainstem channel, as well as the biological community.

4.1.3.1 Winter Floods

Large magnitude, short duration events typically occurred from mid-November to late January, with moderate magnitude events extending through late March. Peak flows exceeding 70,000 cfs have occurred three times since WY1912. Alternate bar mobilization, transport of the coarsest bed material through alternate bar sequences, tributary delta scour, floodplain/terrace deposition, potential meander changes (including channel avulsions), side channel creation, and significant channel migration

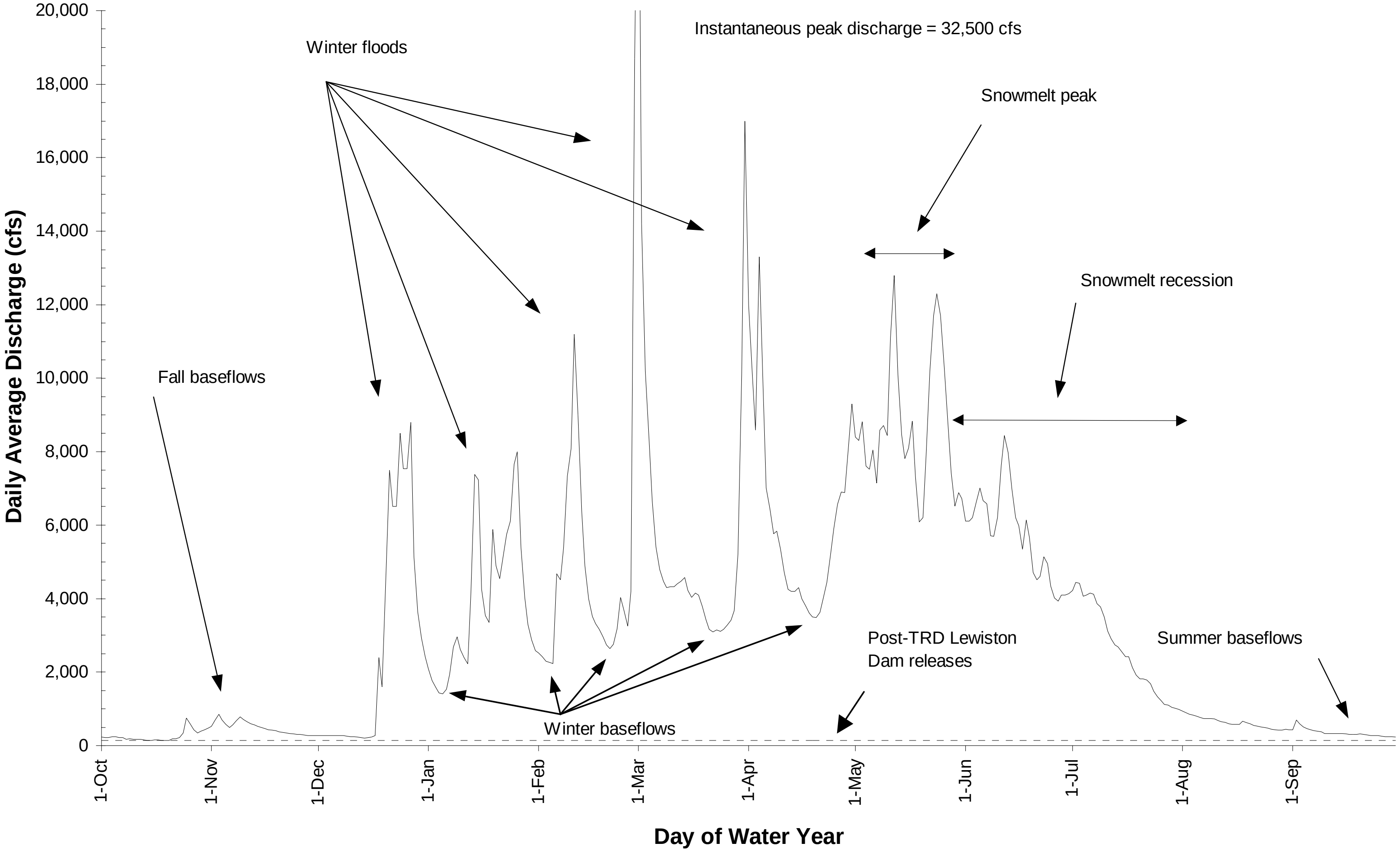

Figure 4.10. Trinity River at Lewiston streamflow hydrograph illustrating hydrograph components typical of a watershed dominated by rainfall and snowmelt runoff (Extremely Wet water year 1941).

Table 4.2. USGS streamflow gaging stations on the mainstem Trinity River and tributaries near the TRD.

Station Name	Drainage Area (mi^2)	USGS Station #	Period of Record Used	Number of Years
Trinity Lake near Lewiston	692	11525400	1961-1995	35
Trinity River @ Lewiston	719[b]	11525500	1912-60[a], 1961-95[b]	49, 35
Grass Valley Creek @ Fawn Lodge	30.8	11525600	1976-1995	20
Trinity River below Limekiln Gulch	812[c]	11525655	1981-1991[c]	11
Weaver Creek near Douglas City	48.4	11525800	1959-1969	11
Trinity River near Douglas City	933	11526000	1945-1951	7
Browns Creek near Douglas City	71.6	11525900	1957-1967	11
N.F. Trinity River @ Helena	151	11526500	1912,1913,1957-80	26
Trinity River near Burnt Ranch	1,438[d]	11527000	1932-40[a],1957-60[a],1961-95[d]	13,35
Trinity River at Hoopa	2,865[e]	11530000	1912,13,17,18,1932-60[a];1961-95[e]	33,35

[a] Pre-dam

[b] Post-dam, unregulated drainage area = 0.3 mi^2

[c] Post-dam, unregulated drainage area = 93.3 mi^2

[d] Post-dam, unregulated drainage area = 719 mi^2

[e] Post-dam, unregulated drainage area = 2,146 mi^2

were products of major winter floods. Moderate winter floods transported sand and intermediate volumes of coarse bed material, occasionally mobilized alternate bar surfaces, scoured the surfaces of spawning gravel deposits, and encouraged minimal channel migration.

4.1.3.2 Snowmelt Peak Runoff

The magnitude and timing of snowmelt peaks were largely a function of snow accumulation in the preceding winter. Extreme snowmelt peaks (generally rain-on-snow runoff) reached 26,000 cfs during wet years but typically ranged from 8,200 cfs to less than 2,000 cfs. The timing of the snowmelt peaks extended from late March to late June, with flows peaking later in wet years than dry. Snowmelt discharges produced flows that were generally smaller than winter floods, but of considerably longer duration. Moderate volumes of coarse bed material and large volumes of fine bed material were transported. Spawning-gravel deposits were rejuvenated, while scour and subsequent replacement of the channelbed surface only slightly reshaped alternate bars.

4.1.3.3 Snowmelt Recession

Snowmelt runoff could begin in late March and recede into late July in very wet years. In contrast, snowmelt runoff during dry years typically ended by mid-May. This component had only a minor direct influence on channel morphology by controlling areas of successful germination and seedling establishment. Off-channel wetlands also were influenced by the magnitude and timing of snowmelt recession into the summer.

4.1.3.4 Summer Baseflows

Generally, summer baseflows were established between mid- and late July. Summer baseflows typically ranged from 300 cfs during wetter years to less than 100 cfs during very dry years, although summer baseflows could drop to as low as 25 to 50 cfs. These baseflows indirectly influenced channel morphology by constraining woody riparian germination and seedling establishment to a narrow band above the baseflow stage height.

4.1.3.5 Winter Baseflows

The receding limbs of storm hydrographs and groundwater discharge supported relatively stable baseflows between winter storm events. Winter baseflows ranged from 3,000 cfs during wetter years to less than 500 cfs during drier years. Minor sand transport occurred.

Collectively, annual hydrograph components were responsible for alternate bars, riparian communities, and salmon populations. Big, infrequent floods were better at accomplishing some tasks such as mobilizing alternate bars, whereas smaller, more frequent floods produced smaller-scale benefits such as the scouring of seedlings. These variable flows created the spatial complexity underpinning salmon habitat and the riparian community in the pre-TRD mainstem.

4.1.4 Spatial and Temporal Diversity Sustained Salmon Populations

Salmon and steelhead populations persisted despite pervasive mining impacts because diverse habitat was available throughout many parts of the Trinity River Basin. Moffett and Smith (1950) describe habitat upstream from Lewiston (RM 110.9):

> *The 12 miles of river from Ramshorn Creek (RM 153) to Trinity Center (RM 141) traverse a broad valley into which many small tributary streams enter. The stream has a gradient of 58 ft. per mile [approximately one percent] and meanders through wooded and pasture lands wherever gold dredges have left the original terrain. Its channel is broad and gravelly with extensive riffles alternating with deep pools.*

This river reach must have been prime salmonid habitat for spawning and rearing. Lower-gradient reaches (relative to this mean gradient) would have provided high-quality spawning and rearing habitat for chinook and coho salmon, while the structural complexity of higher-gradient, upstream reaches would have sustained prime rearing habitat for multiple age classes of coho and steelhead. Moffett and Smith (1950) concluded that most chinook salmon spawning grounds were within 69 miles of the mainstem channel from Trinity Center (RM 141.0) downstream to the North Fork Trinity River confluence

(RM 72.5; Figure 2.2). This mainstem segment has a low average gradient of 15 feet per mile (or approximately 0.3 percent).

Many adult salmon and steelhead migrated above Lewiston to hold over in summer and (or) to spawn in fall and winter. Spring-run chinook salmon would migrate from March through June, holding in deep, thermally stratified pools below Lewiston during the daytime. Moving upward at night, they would eventually reach the river above Lewiston, where the melting snowpack lowered water temperatures. There they would remain in pools for several months until the onset of spawning. Adult summer-run steelhead entered the Trinity River in June and early July. They held in the deep pools below Lewiston and were "common in the deep holes along the river below North Fork" (Moffett and Smith, 1950). These behavioral patterns spatially segregated the summer-run steelhead and spring-run chinook salmon. Later in the year, when the fall-run chinook salmon entered the river and remained primarily below Lewiston, the steelhead would enter the tributaries to spawn. Coho salmon entered the river after chinook salmon; winter-run steelhead followed and spawned in reaches farther upstream than those used by salmon. Adult Pacific lamprey migrated sporadically through the summer, gaining momentum into the winter months, then spawned during the snowmelt runoff period (Moffett and Smith, 1950). Therefore, during any month one or more anadromous fish species was migrating up the Trinity River mainstem, while redds were distributed throughout the mainstem and tributaries.

Spatial segregation and temporally variable life histories enhanced productivity and decreased intra- and inter-species competition. All salmonid fry utilize similar low-velocity habitat, but because the fry of each species emerged from redds at different times, this habitat was occupied at different times. For example, because habitat preferences change as fish grow, most chinook salmon fry would have emerged and grown to sizes that preferred deeper, higher velocity habitats by the time coho salmon fry emerged.

4.1.5 Unregulated Riverflow and Salmon at Lewiston

Anadromous salmonids used the upper basin differently because it looked and functioned differently than the mainstem below Lewiston. Moffett and Smith (1950) identified a key hydrologic dichotomy along the mainstem, roughly located near Lewiston:

> *The general runoff pattern over the entire Trinity drainage varies somewhat from that recorded at Lewiston. The spring runoff peak at Burnt Ranch (RM 49) occurs a month earlier than the peak at Lewiston. Inflow from many small tributaries which drain an area with little snow accumulation contributes most of the earlier runoff at that point. River flow at Hoopa, including the inflow from New River and the extensive South Fork drainage, reaches a spring runoff peak in March, two months earlier than the peak at Lewiston.*

By virtue of its position in the watershed (at a transition point between high-elevation and low-elevation sub-basins), the mainstem near Lewiston possessed a dual hydrologic nature. The upper basin, including the Coffee Creek sub-basin, was heavily influenced by snowmelt runoff, although winter flows would peak briefly several times. From Coffee Creek (RM 145.5) downstream to Lewiston (RM 111.9), the basin was influenced significantly by winter storms and late-spring snowmelt runoff. The lower drainage basin, from Lewiston to Burnt Ranch, was dominated by winter storm runoff with relatively minor snowmelt runoff from a few tributaries (Rush Creek, Canyon Creek, and North Fork Trinity River). The future dam site at Lewiston would be located approximately at the Basin's transition from a snowmelt-dominated

The flood hydrology downstream of Lewiston is dominated by rainfall runoff events, whereas upstream of Lewiston is equally dominated by rainfall and snowmelt runoff events. Unimpaired peak floods at Lewiston sometimes exceed 70,000 cfs to 100,000 cfs.

watershed to a winter-storm-dominated watershed. A sub-category of rainstorm events, the rain-on-snow event, was responsible for the largest floods throughout the basin.

This dual hydrologic nature had important consequences for salmonid life histories basinwide. Snowmelt runoff in late spring to early summer above Lewiston sustained mainstem flows below Lewiston; thus adult and juvenile fish in the mainstem below Lewiston depended on the timing and duration of flows originating above Lewiston. However, the rapid decline in snowmelt runoff typically decreased discharges to well below 1,000 cfs (or even 500 cfs) by mid-July at Lewiston (Appendix F). Even snowmelt flows could not keep the mainstem below Lewiston hospitable to salmonids throughout the summer.

From 1942 to 1946, Moffett and Smith (1950) frequently monitored water temperatures and sampled the mainstem near the future dam site at Lewiston for anadromous salmonids (Figure 4.11 — thermographs reproduced from Moffett and Smith, 1950). These temperature findings are best summarized by the authors (p. 9):

> *Trinity River [at Lewiston] is warmest during July and August when spring and summer salmon are holding over in the main river. The maximum water temperatures and dates of occurrence for years of record are as follows: 78°F on August 13, 1943; 81°F on July 24 and 27, 1944; and 83°F on July 27, 1945. Temperature records were not complete enough in 1946 to show the highest temperature with certainty, but a high of 80.5°F was reached on July 22, 1946. The maximum temperature recorded for 1943 may not be the true peak temperature for that year, as it was taken from partial records made during August and September. A temperature of 80°F or higher was recorded on 9 days during the summer of 1944 and 27 days during the summer of 1945. As a result of experience gained at Deer Creek Station on the Sacramento River . . . , 80°F is considered lethal or near lethal for king salmon. The same species is able to survive when surface temperatures are above 80°F in the Trinity River by remaining in the cooler waters of deep holes along the river. In August 1944, water at depths over 8 feet in one of these large holes was 7°F cooler than surface water.*

Moffett and Smith documented water temperatures at Junction City that exceeded 80°F for 32 days in 1945 beginning in late July. The mainstem downstream from Lewiston was a stressful environment for juvenile salmonids or holding adults after mid-July. Salmonids incubated and reared above Lewiston in cooler waters (Moffett and Smith did not report monitoring temperature upstream from Lewiston) had to cope with and (or) avoid these near-lethal (if not lethal) mid-summer water temperatures during their seaward migration. Most species chose avoidance. Older age classes of juvenile steelhead outmigrated well before water temperatures rapidly increased, as observed by Moffett and Smith (1950) near Lewiston:

> *During extended winter dry periods when the river is low and clear, groups of several hundred steelhead trout 6 to 8 inches in length can be seen slowly drifting downstream. The size of these fish would indicate that they were in their second year or third year of life. These schools migrate down the center of the river hovering close to the bottom....*

Outmigration was timed to coincide with the periods when the pre-TRD river temperatures were lowered by snowmelt from the upper watershed. Juvenile chinook salmon outmigrated from Lewiston in late spring and early summer, prior to rapid temperature increases and low summer flows (Moffett and Smith, 1950; Figure 4.12). Most chinook salmon (approximately 90 percent) passed Lewiston by late June. Melting snow provided suitably cool temperatures and relatively large flows that aided downstream migration of smolts by reducing their travel time to the ocean. Combined, the large flows and suitable water temperatures would have given most fish sufficient time to reach the Klamath estuary before mainstem temperatures became unsuitable

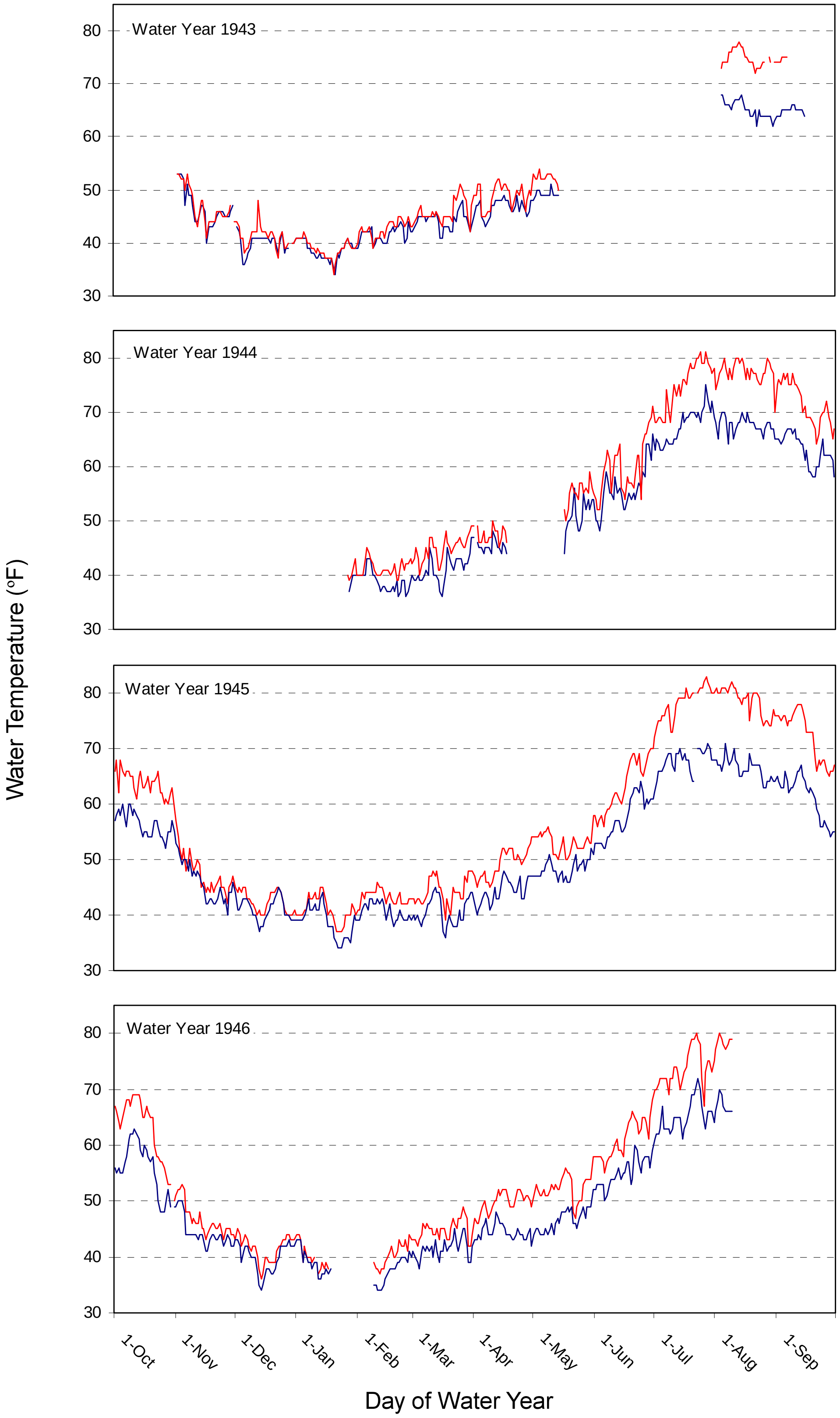

Figure 4.11. Maximum and minimum Trinity River water temperatures at Lewiston for water years 1941-1946. Data collected by Moffett and Smith (1950).

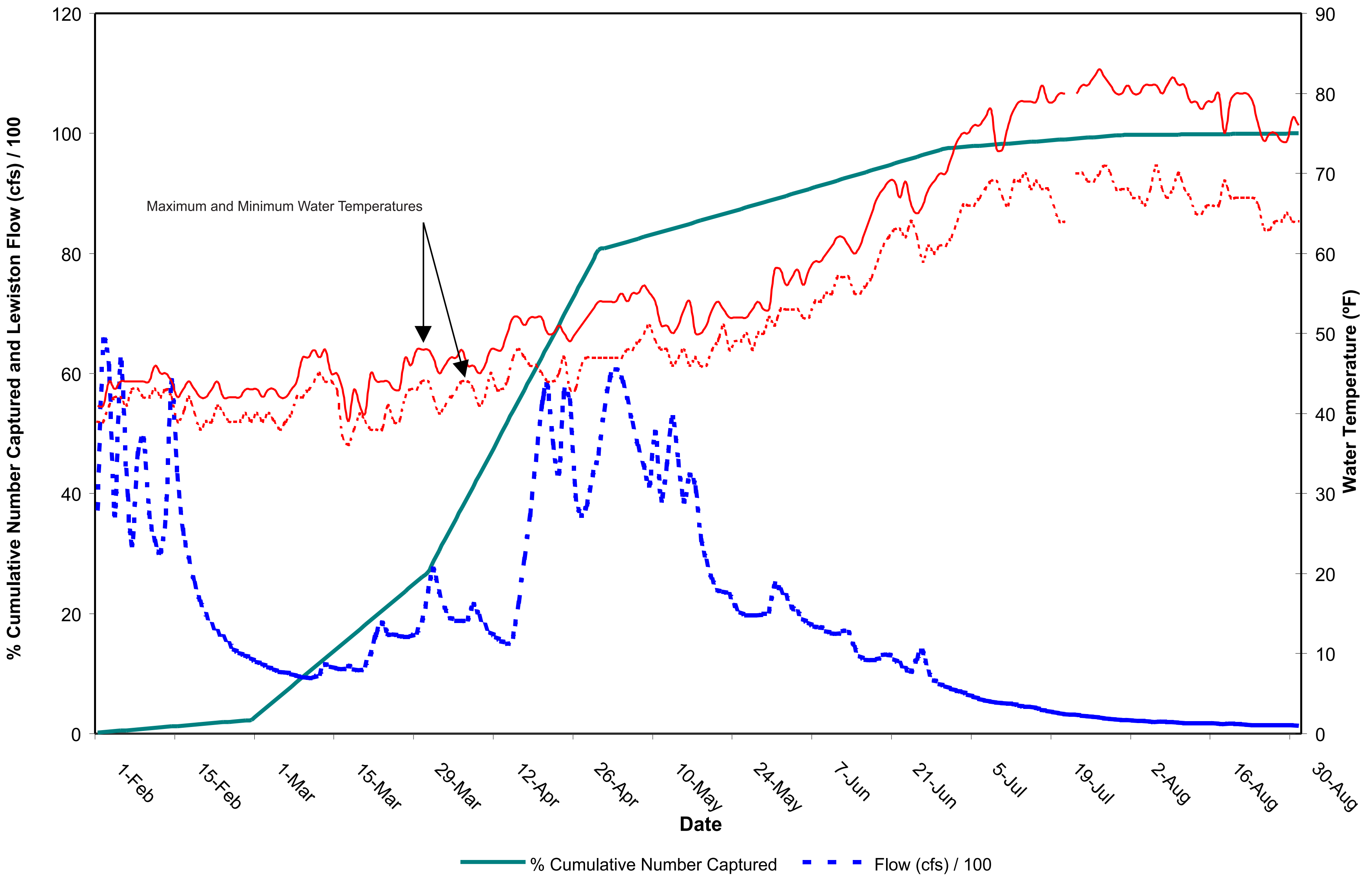

Figure 4.12. Water temperatures, flows, and chinook presmolt outmigration on the Trinity River near Lewiston, during the spring and summer of 1945. Data collected by Moffett and Smith (1950).

(>68°F for chinook salmon smolts). Those migrating later could have survived inhospitable water temperatures by migrating between thermal refugia, such as deep pools, seeps, springs, and some tributary deltas, or remaining in the cooler upper watershed until fall, when temperatures were cooler in the lower watershed.

4.1.6 Woody Riparian Plant Characteristics

With the exception of early aerial photographs, there are no descriptions of historical riparian communities; therefore, pre-TRD conditions were inferred by combining an interpretation of aerial photographs with observations of regional unregulated streams (e.g., South Fork Trinity River). Air photographs taken in 1960 and 1961 show sparsely vegetated point bars (Figures 4.2, 4.3, 4.4, and 4.6). Willow patches were interspersed on upper portions of the bars and along margins of dredger tailings. Plants on alternate bar surfaces were annual herbs, grasses, and pioneer woody species such as willows (*Salix spp.)* (Table 4.3). Other riparian trees, including white alder (*Alnus rhombifolia*), black cottonwood (*Populus balsamifera ssp. trichocarpa*), and Fremont cottonwood (*Populus fremontii*), were well established on developing floodplains, low terraces, and oxbows (abandoned channel bends).

> Frequent pre-TRD floods discouraged riparian vegetation from colonizing bars near the low flow channel, forcing vegetation to establish on floodplains, backwater channels, sloughs, and protected rocky slopes.

Woody riparian plant species are sensitive to intra- and inter-annual variation in flow. Viable seeds are released by most woody riparian species during the snowmelt runoff period (Figure 4.13). Two notable exceptions are white alder, releasing seeds in the fall, and shiny willow (*S. exigua*), releasing seeds from late spring through August. Floodplain and alternate bar surfaces, freshly deposited and scoured by snowmelt floods, were ideal germination sites, but long-term survival on mobile alternate bar surfaces was unusual.

Woody riparian vegetation did not completely colonize alternate bars for several reasons. In most wet years, flows during the snowmelt recession limb continued into July, inundating most alternate bar surfaces throughout much of the seed-release period. Seedlings can not germinate if the substrate is inundated. Exposed bar surfaces that could support successful germination were present primarily during drier years.

Newly germinated seedlings were vulnerable to scour by the following winter's high flows. Mobilization of the channelbed surface layer should have scoured out and (or) winnowed young seedlings rooted as deep, or slightly deeper, than the channelbed's surface layer. However, the entire channelbed surface was not uniformly susceptible to mobilization. Surfaces higher on alternate bars and on the floodplains required greater magnitude floods for bed surface mobilization. A range of threshold flow magnitudes would have been necessary to prevent seedling survival throughout alternate bar sequences. Mainstem flows capable of mobilizing at least a portion of the channelbed surface layer were commonly generated by winter floods and larger snowmelt runoff peaks.

If two or three consecutive drier years occurred, germination was favored. A small percentage of young seedlings often escaped scour for 2 years or longer, at which time they became securely rooted deeper than the surface layer. Occasionally, seedling establishment was widespread. Larger but less frequent floods would scour deeply rooted seedlings. Flood peaks occurring every 3 to 5 years could scour alternate bar sequences significantly deeper than their surface layers.

Table 4.3. Common woody riparian plant species along the Trinity River mainstem from Lewiston Dam (RM 111.9) downstream to the North Fork Trinity River confluence (RM 72.4).

Species	Common Name
Salix lucida ssp. lasiandra	Shining willow
Salix lasiolepis	Arroyo willow
Salix laevigata	Red willow
Salix melanopsis	Dusky willow
Salix exigua	Narrow-leaf willow
Alnus rhombifolia	White alder
Fraxinus latifolia	Oregon ash
Populus balsamifera ssp. trichocarpa	Black cottonwood
Populus fremontii	Fremont cottonwood

Maturing trees tended to establish in stands. As a stand matured, the hydraulic forces of flood flows were modified. Often hydraulic modification was so complete that the channel's surface beneath a stand experienced aggradation rather than scour. However, a stand could be undercut by lateral bank migration or isolated from the active mainstem channel by bank avulsion. Only large, relatively rare floods with recurrences of 10 to 30 years were capable of large-scale bank erosion or avulsion. These floods would have been generated by the more intense winter flows, or possibly rain-on-snow events.

4.2 Immediate Effects of Dam Construction on Basinwide Salmonid Habitat and the River Ecosystem

Completion of Trinity and Lewiston Dams in 1964 had three immediate effects on the river ecosystem. First, Lewiston Dam blocked all anadromous salmonid migration, eliminating all rearing and spawning habitat upstream. Second, bedload transport from 719 square miles of the Trinity River Basin above the dams was eliminated. A third immediate effect was major flow diversion from the Trinity River Basin to the Sacramento River Basin. All three effects would have severe consequences.

4.2.1 Loss of Habitat and Its Consequences

More than 100 miles of anadromous salmonid habitat above Lewiston were lost (USFWS, 1994). For chinook salmon, Moffett and Smith (1950, p.4) described this lost habitat:

> *Almost without exception, Trinity River salmon migrating above the South Fork spawn in the 72 miles of river between the North Fork and Ramshorn Creek. In addition to the main river, three tributaries are used by spawning salmon. A dam at the Lewiston site would cut off 35 miles of the main river and all of Stuart Fork [Figure 2.2], the most important spawning tributary. The salmon would be blocked from approximately 50 percent of their natural spawning grounds in the upper Trinity.*

Salmonid populations were now abruptly forced to rely on the mainstem below Lewiston Dam in new ways. Dam construction compressed the distribution and

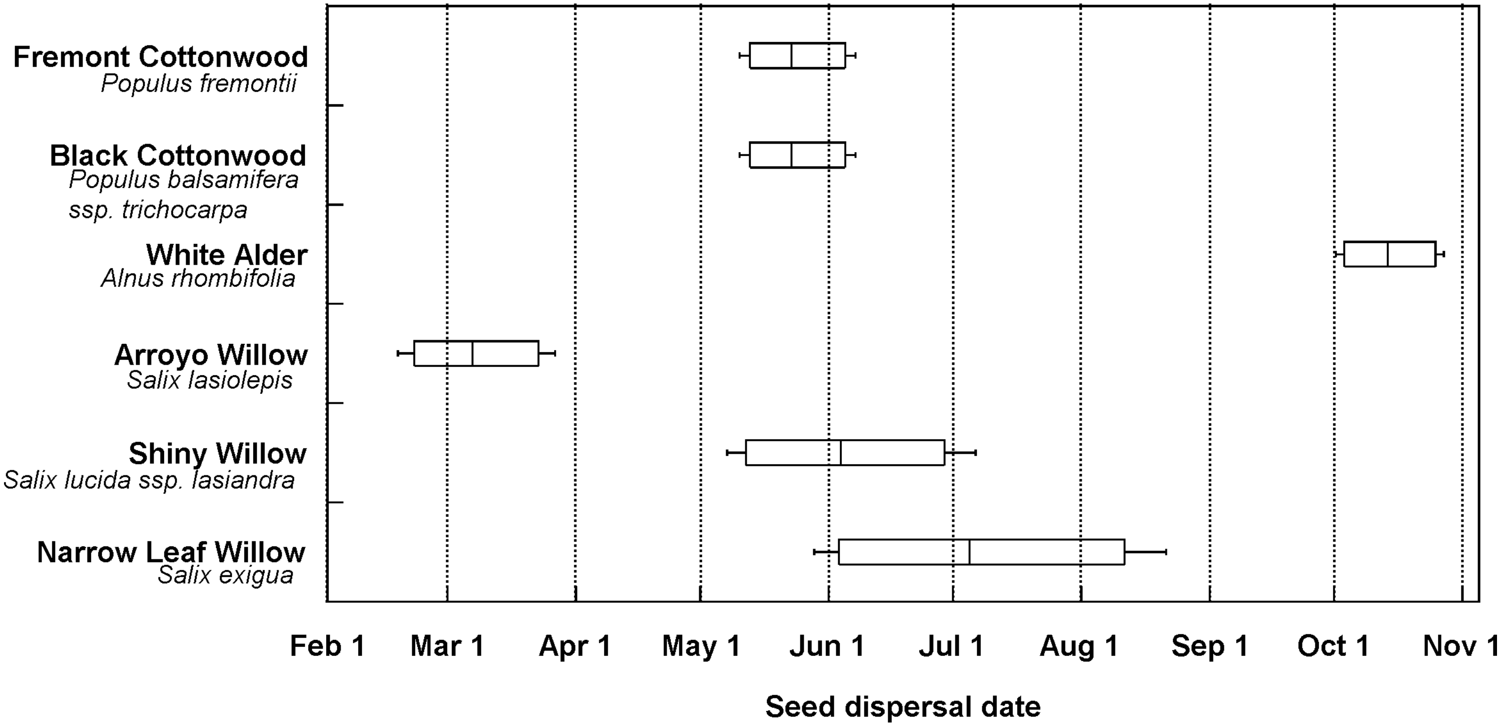

Figure 4.13. Woody riparian seed dispersal timing for six common species. Each box displays the length of time by which 90 percent of all seeds are dispersed. Median dispersal dates are represented by a vertical line through the box. Whiskers at either end of the box indicate the earliest and latest 5 percent of seed dispersal. White alder continues to drop seeds retained in the woody cone throughout winter and early spring, although more than 80 percent of the seeds are dropped during the initial seed dispersal period when female cones open.

seasonal timing of habitat use among species that were once segregated temporally and spatially. Spring-run chinook salmon that formerly held and spawned primarily above Lewiston (Moffett and Smith, 1950) were now forced to hold and spawn below Lewiston Dam. Summer-run steelhead historically held in these lower pools and now had to compete with spring-run chinook salmon.

Completion of the TRD: blocked salmonid access to the upper watershed, blocked all coarse sediment supply from the upper watershed, and greatly reduced the volume and magnitude of flows to the lower Trinity River.

Comparison of pre- and post-TRD descriptions of adult chinook salmon migration and spawning patterns indicates a compaction of spawning timing. Moffett and Smith (1950) describe three distinct spawning runs of chinook salmon that passed Lewiston on the Trinity River in 1944 and 1945, but Leidy and Leidy (1984) describe only two distinct chinook salmon runs: spring and fall. Direct comparison of these two reports is problematic, however, because Moffett and Smith (1950) describe spawning runs that passed Lewiston whereas Leidy and Leidy (1984) describe timing below Lewiston. Although Trinity River salmonids continue to have long spawning periods, there is less segregation between species and between races of the same species than prior to dam construction.

The mainstem below Lewiston had been an inhospitable environment in late summer. If the Trinity River had maintained its pre-TRD annual temperature regime downstream, fry emerging from areas below the dams would have had no choice but to leave the mainstem by mid- to late-July or seek very limited thermal refuge. As Moffett and Smith (1950) note, many returning adult steelhead had spent 2 or more years in freshwater prior to smolting; large smolts have a considerably improved prospect of surviving to adulthood in the ocean. Before the TRD, these older juveniles could rear in the cooler upper watershed and tributaries, then avoid the warm mainstem below Lewiston by outmigrating during the winter baseflows, snowmelt peak, and (or) snowmelt recession hydrograph components. Therefore, prior to the TRD, steelhead that spawned in the mainstem below Lewiston may have been poor contributors to the basin's next cohort. Coho salmon juveniles would have been similarly affected because of their overwintering requirement. The original claim that approximately half the basin's anadromous salmonid habitat was eliminated by the TRD is probably a significant underestimate.

The upper Trinity River watershed provided important rearing habitat and adequate summer water temperatures. Blocking the upper Trinity River watershed from salmonid access forced the remaining anadromous reaches to assume the habitat role historically provided by the upper watershed.

4.2.2 Loss of Suitable Coarse Bed Material

An alluvial river can function appropriately only if continuously supplied with bed material. Construction of Trinity Dam stopped all bedload supply to the lower reaches. Balancing the sediment budget, as one prerequisite for sustaining a dynamic river channel morphology and salmonid habitat, was ignored amid the early-1960's promises that salmon populations would thrive and possibly improve under TRD operating policies (Trinity Journal, 1952).

As occasional high-flow releases scoured the channelbed and mobilized bed material downstream without replacement from upstream, the net effect was channel degradation. In coarser river channels, as is the Trinity River mainstem, occasional high- flow releases transport only the finer fraction of the channelbed, leaving the coarser particles behind. Eventually, the channelbed coarsens until it virtually immobilizes. The extent of channel degradation will depend on channelbed particle-size composition and the relationship between the magnitude, duration, and frequency of flow releases.

In the mainstem below Lewiston, the already coarse channelbed coarsened even more without significant channel downcutting. Prominent alluvial features, such as alternating bars, disappeared or were immobilized. The post-TRD flow reductions also caused spatial changes in sediment-transport processes. The absence of high mainstem flows permitted tributary-derived sediments to accumulate and form aggrading deltas at the tributary confluences. Additionally, larger particles that were commonly transported during pre-TRD floods were no longer mobilized by the post-TRD flow regime, such that only the finer gravels and sands were transported downstream. In many reaches, a veneer of these finer particles is evident on top of the coarser, pre-TRD bed surface.

Coarse bed material forms the channel and habitat within the channel. Loss of coarse bed material from the upper watershed, combined with riparian encroachment of alluvial deposits downstream of Lewiston, greatly decreased the quantity and quality of remaining habitat.

Salmon-spawning habitat is as dynamic as the river and watershed that creates and maintains it. Gravel deposits in the tails of pools and runs, often preferred spawning habitat, are subject to frequent scour. As hatchery operators are aware, salmon eggs are extremely sensitive to handling during early development and can be killed simply by vibration. For salmon to have chosen to spawn in gravel subject to the forces of channelbed scour must mean that the risk is offset by the benefits of frequent gravel mobilization and sorting. Frequent cleansing of fine sediments from sorted gravels is advantageous to egg vitality and emergence success. High-quality spawning habitat requires frequent mobilization and gravel replenishment.

Moffett and Smith (1950) failed to link their spawning-flow recommendations for the future TRD, (which were based on observed depth and velocity preferences of spawning salmon), to the higher sediment transport flows required to shape and maintain the spawning habitat. The habitat they quantified in the 1940's would not have existed unless the flow-related physical processes that shaped the alluvial deposits and supplied the gravel also existed. Their recommended daily average flow release of 150 cfs could not accommodate these processes nor supply the necessary gravel. Spawning-habitat degradation began the first year of the TRD's bedload blockage.

4.2.3 Loss of Flow

Trinity River hydrology dramatically changed when the TRD regulated instream flows. The USGS has collected annual river discharge at Lewiston (USGS Sta. No. 11-525500), just downstream from Lewiston Dam (Figure 4.1), beginning in WY1912 (Table 4.2). Since WY1964, this gage has monitored flows regulated by the TRD. By monitoring stage height in Trinity Lake, Reclamation has been able to estimate annual unregulated flow since TRD operations began. Therefore, by combining gaging records for the USGS Lewiston gage before TRD operations (WY1961) with Reclamation stage height monitoring, an 84-year record of unregulated annual flows was reconstructed. Mean annual (October 1 through September 30) unregulated water yield from the Trinity River Basin (WY1912 to WY1995) above Lewiston is 1,249 TAF, ranging from a low of 234 TAF in WY1977 to a high of 2,893 TAF in WY1983 (Table 4.4).

Since TRD operations began, annual instream releases to the Trinity River downstream from Lewiston Dam, including flood control releases above the 120.5 TAF fishery flows, ranged from 119 TAF in WY1977 to 1,291 TAF in WY1983 with an overall mean of 325 TAF. Post-TRD instream releases to the Trinity River ranged from 8 percent of the unregulated annual yield in WY1965 to 63 percent in WY1994. From WY1961 to WY1995,

Table 4.4. Trinity River watershed pre- and post-TRD annual water yield (af) and percent instream release. (Yield = volume flowing past Lewiston (pre-TRD) or post-TRD water inflow to Trinity Lake, Release = annual volume released to the Trinity River (post-TRD), % Instream = percentage of inflow released to Trinity River (post-TRD)). Full TRD operations began in 1964.

WY	Yield (AF)	WY	Yield (AF)	WY	Release (AF)	Yield (AF)	% Instream
1912	1,029,000	1946	1,415,000	1961	223,000	995,000	18
1913	1,074,000	1947	732,300	1962	157,200	885,800	15
1914	2,028,000	1948	1,205,000	1963	862,500	734,500	54
1915	1,506,000	1949	1,090,000	1964	158,800	617,200	20
1916	2,154,000	1950	853,700	1965	129,100	1,666,700	8
1917	652,500	1951	1,610,000	1966	150,900	1,320,800	11
1918	602,400	1952	1,817,000	1967	238,500	1,638,000	15
1919	1,151,000	1953	1,612,000	1968	129,300	1,060,900	12
1920	408,400	1954	1,595,000	1969	155,800	1,765,600	9
1921	1,795,000	1955	734,800	1970	213,700	1,585,600	13
1922	783,400	1956	2,027,000	1971	179,900	1,695,200	11
1923	686,000	1957	1,083,000	1972	123,000	1,193,600	10
1924	266,300	1958	2,694,000	1973	132,800	1,413,000	9
1925	1,499,000	1959	1,042,000	1974	705,600	2,675,800	26
1926	808,900	1960	1,025,000	1975	275,400	1,415,000	19
1927	1,826,000	1961	TRD	1976	126,600	704,800	18
1928	1,058,000		construction	1977	119,400	233,800	51
1929	528,600		began;	1978	178,100	2,038,800	9
1930	814,400			1979	225,100	867,800	26
1931	402,200			1980	322,600	1,476,800	22
1932	720,800			1981	282,400	884,700	32
1933	803,600			1982	468,100	2,002,000	23
1934	683,000			1983	1,291,300	2,893,300	45
1935	965,600			1984	569,700	1,535,700	37
1936	1,025,000			1985	250,700	861,200	29
1937	999,300			1986	495,200	1,596,700	31
1938	2,105,000			1987	309,200	898,900	34
1939	573,300			1988	255,700	977,500	26
1940	1,613,000			1989	329,900	1,074,000	31
1941	2,547,000			1990	233,100	732,100	32
1942	1,804,000			1991	270,800	503,800	54
1943	1,108,000			1992	354,900	936,400	38
1944	654,100			1993	367,600	1,766,200	21
1945	1,048,000			1994	355,400	568,200	63

annual instream releases represented 28 percent of the unregulated annual water yield of the Trinity River above Lewiston. Prior to the 1981 Secretarial Decision (Chapter 2), this annual percentage averaged 20 percent. After 1981, an annual average of 35 percent of the unregulated yield was released below Lewiston (Table 4.4). The current annual instream flow volume of 340 TAF is equal to the third driest year at Lewiston in the 84-year period of record, which indicates the Trinity River has largely experienced severe drought conditions since TRD operations began.

For the first 20 years of operation, the TRD exported 80% to 90% of the water yield at Lewiston to the Sacramento River Basin.

4.3 Cumulative Downstream Effects of the Trinity River Division

Direct effects of the TRD triggered rapid, cumulative downstream effects. By the mid-1970's, resource agencies and the public sensed that "something" needed to be done (Sill, 1973; Hubbel, 1973).

4.3.1 Post-TRD Hydrologic Changes in the Mainstem

To identify gross changes, annual maximum flood frequencies and daily average flow duration were compared for the unregulated (pre-TRD) and the regulated (post-TRD) mainstem (McBain and Trush, 1997). Hydrologic data for comparing pre-TRD conditions to post-TRD conditions included (1) instantaneous peak discharges (for annual maximum flood frequency analysis) and (2) daily average discharge (for plotting annual hydrographs) obtained from various USGS gaging stations (Table 4.2).

4.3.1.1 Annual Maximum Peak Discharges

Pre-TRD maximum flood flows at Lewiston were highly variable, ranging from a low of 3,060 cfs in WY1920 to a high of 71,600 cfs in WY1956 (Figure 4.14). Flood magnitude increased rapidly downstream as larger unregulated tributaries (e.g., North and South Fork Trinity River, New River) contributed to flood flows at Burnt Ranch and Hoopa (Figures 4.14 to 4.16, Table 4.5).

The TRD substantially altered flood magnitudes at the Lewiston and Burnt Ranch gages, with the post-TRD 1.5 year flood having 10 percent of the pre-TRD flood magnitude at Lewiston and 50 percent at Burnt Ranch (Table 4.5). The TRD has minimal influence on the annual maximum flood magnitude at Hoopa because of flood contributions of the South Fork Trinity River and the New River, both entering the mainstem below Burnt Ranch (Figure 2.1). The Lewiston gage provides post-TRD flood-frequency estimates only immediately below Lewiston Dam, but not farther downstream because of tributary floods. Large floods still occur downstream from Browns Creek (RM 87.8), but flow magnitudes were nearly always less than 50 percent of the pre-TRD magnitude and were less frequent (refer to McBain and Trush, 1997, for details).

4.3.1.2 Mainstem Flow-Duration Curves

For both the pre-TRD record (pre-WY1960) and post-TRD record (WY1961 to WY1993), flow-duration curves were generated for Lewiston (RM 110.9), Burnt Ranch (RM 48.6), and Hoopa (RM 12.4) (Figures 4.17 to 4.19). Operation of the TRD reduced flow durations at Lewiston by nearly an order of magnitude at the 10 to 30 percent exceedence probabilities (pre-TRD 4,000 cfs to 1,900 cfs; post-TRD 550 cfs to 310 cfs) (Figure 4.17).

The 1.5 year flood, largely responsible for channel formation, channel sizing, and mobilizing coarse bed material, was reduced from 10,700 cfs to 1,070 cfs. The latter value is incapable of mobilizing particles greater than sand, such that coarse sediment transport nearly ceased to occur.

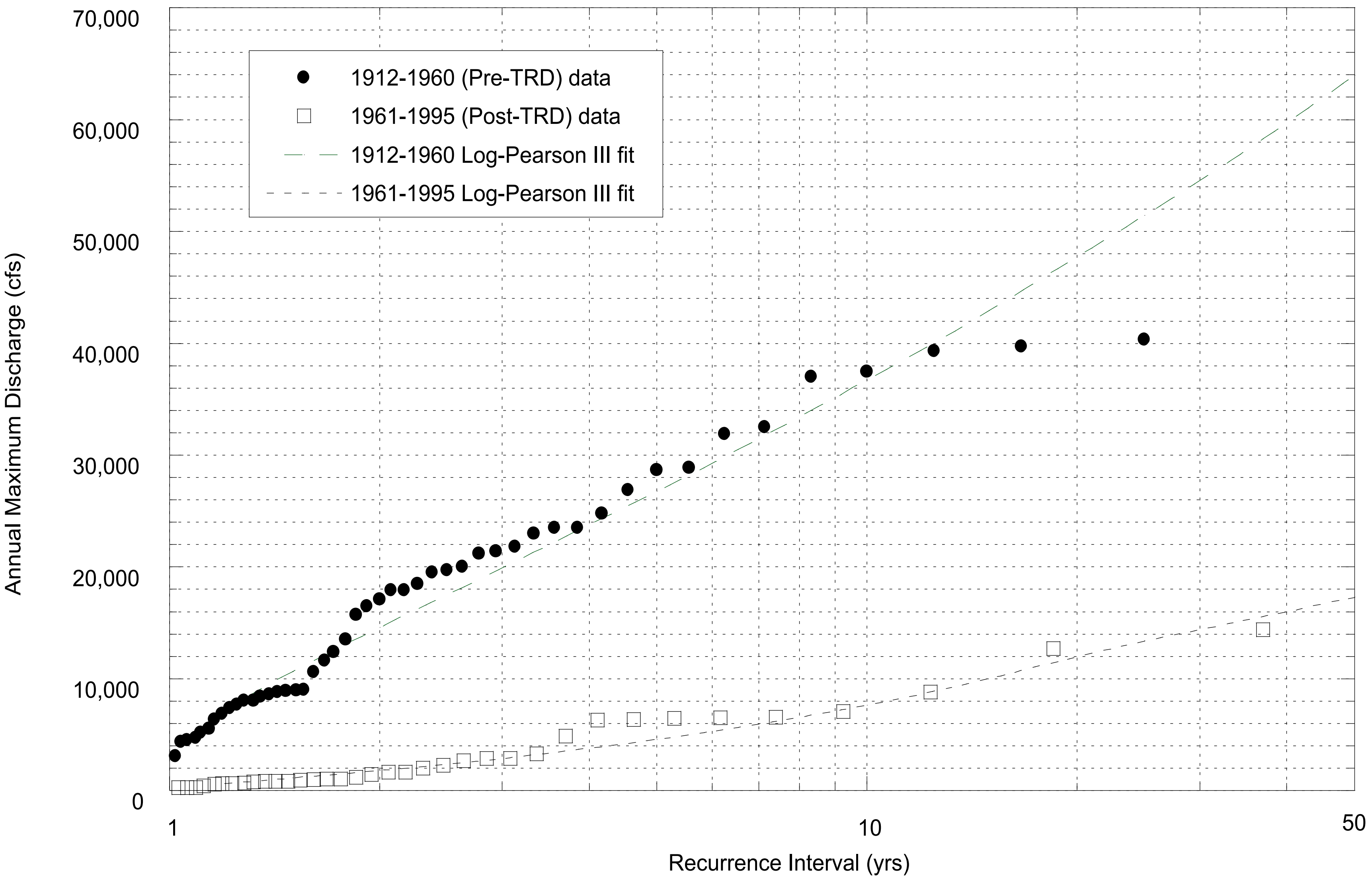

Figure 4.14. Trinity River flood-frequency curves at Lewiston (RM 110.9) before (1912-1960) and after (1961-1995) construction of TRD.

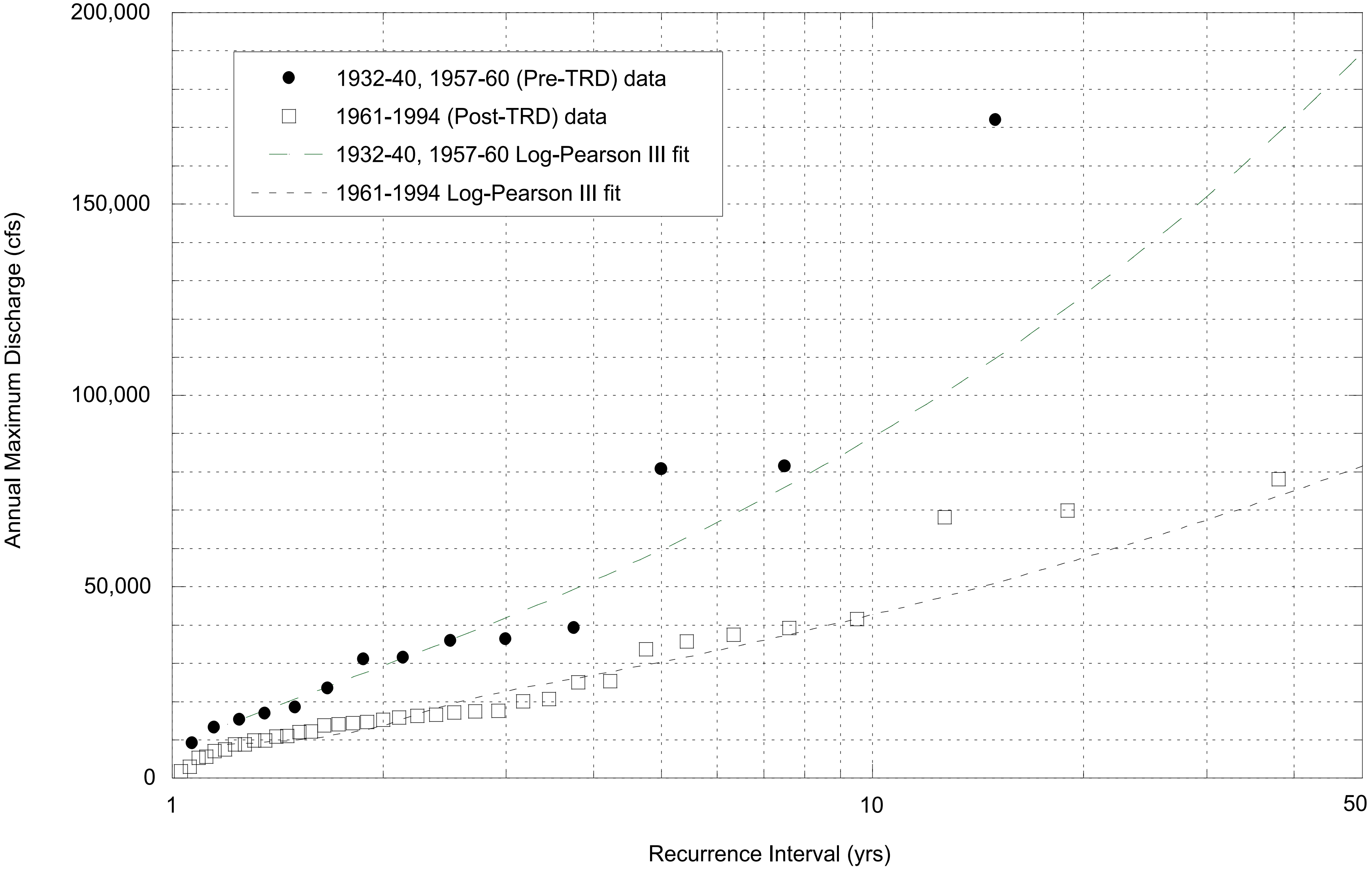

Figure 4.15. Trinity River flood-frequency curves at Burnt Ranch (RM 48.6) before (1912-1960) and after (1961-1995) construction of TRD.

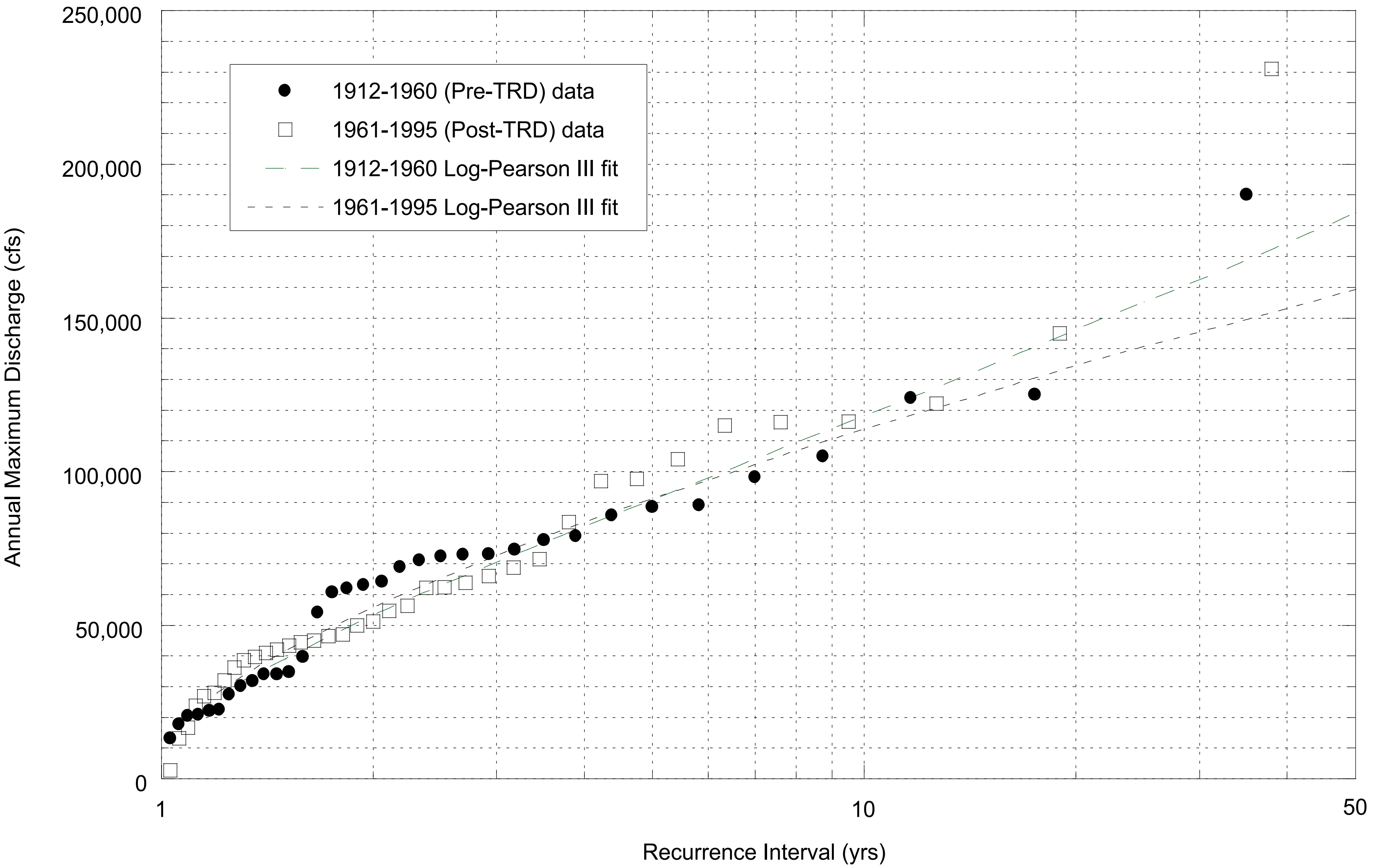

Figure 4.16. Trinity River flood-frequency curves at Hoopa (RM 12.4) before (1912-1960) and after (1961-1995) construction of TRD.

Table 4.5. Comparison of pre- and post-TRD flood magnitudes at USGS Trinity River gaging stations.

	Lewiston (RM 110.9)	Burnt Ranch (RM 48.6)	Hoopa (RM 12.4)
Pre-TRD 1.5-yr flood (cfs)	10,700	21,200	39,000
Post-TRD 1.5-yr flood (cfs)	1,070	10,700	42,000
Percent of pre-TRD	10%	50%	108%
Pre-TRD 10-yr flood (cfs)	36,700	88,400	118,000
Post-TRD 10-yr flood (cfs)	7,500	40,500	114,000
Percent of pre-TRD	20%	46%	97%

Downstream from Lewiston, a reduction in the 10 to 30 percent exceedence probabilities is still present, but the effect is moderated by tributary flows.

A consistent trend emerges from the flow-duration curves at all three locations: (1) the magnitude of higher flows, particularly those exceeded less than 50 percent of the time, decreased as a result of the TRD; and (2) extremely low flows, exceeded more than 85 percent of the time, increased as a result of the TRD (Figures 4.17 to 4.19). The reduced higher flows were due to lake storage of winter baseflows and snowmelt runoff, and to a lesser degree, elimination of winter storm contributions from the upper Basin. The low-flow magnitude increase for the 85 to 100 percent exceedence was due to artificially high summer baseflows, particularly after 1978 when summer flows were increased to 300 cfs. Finally, the flattening of the post-TRD flow-duration curves also indicates a reduction in flow variability, which is best illustrated by comparing the dramatic differences in pre- and post-TRD hydrographs (Appendix F).

4.3.1.3 Changing Influence of Tributary Runoff on Post-TRD Mainstem Hydrology

Present-day mainstem floods increase in magnitude downstream as tributaries cumulatively augment flood flows and baseflows (Table 4.6, McBain and Trush, 1997). Post-TRD mainstem hydrology has two flood populations: (1) frequent tributary floods generated by winter storm events, and (2) infrequent mainstem reservoir releases caused by unusually large snowpack runoff, a major upstream winter flood, or a full reservoir that triggers a dam safety release. These releases occur days or weeks after the actual runoff event(s) and generally are not synchronized with natural tributary flood peaks. As tributary contributions increase downstream, there is a transition near Douglas City where the magnitude and frequency of tributary-induced floods exceed the magnitude and frequency of peak dam releases (see McBain and Trush, 1997 for details). The influence of tributary flows to mainstem Trinity River flows between Lewiston Dam and the North Fork Trinity River was evaluated by Fredericksen, Kamine, and Associates (1980) by examining three exceedence curves for the mainstem Trinity River: below Canyon Creek (RM 79.1), below Indian Creek (RM 95.2), and below Deadwood Creek (RM 110.8) (Figure 4.20). The small difference between the three

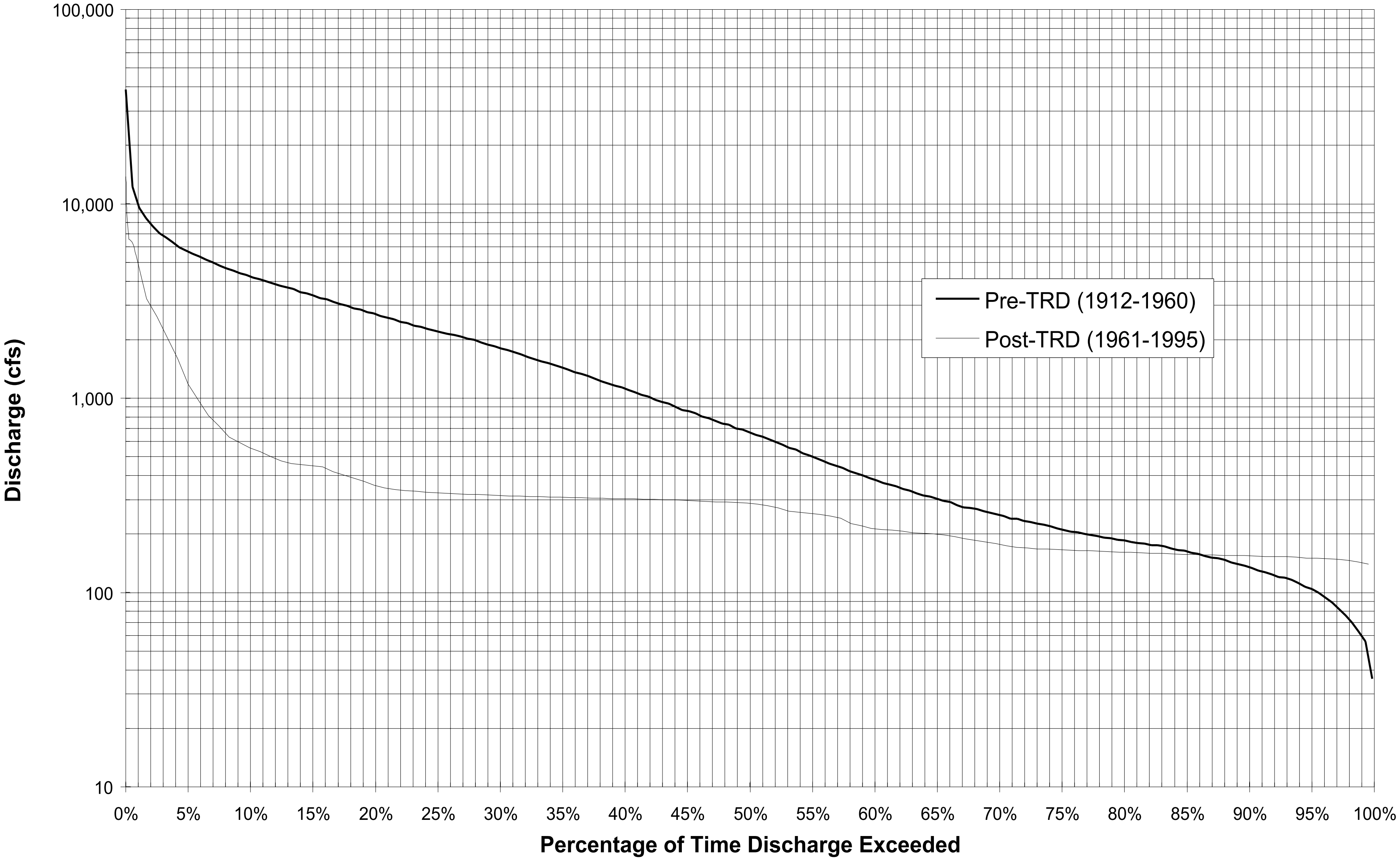

Figure 4.17. Trinity River flow-duration curves at Lewiston (RM 110.9) before (1912-1960) and after (1961-1995) construction of TRD.

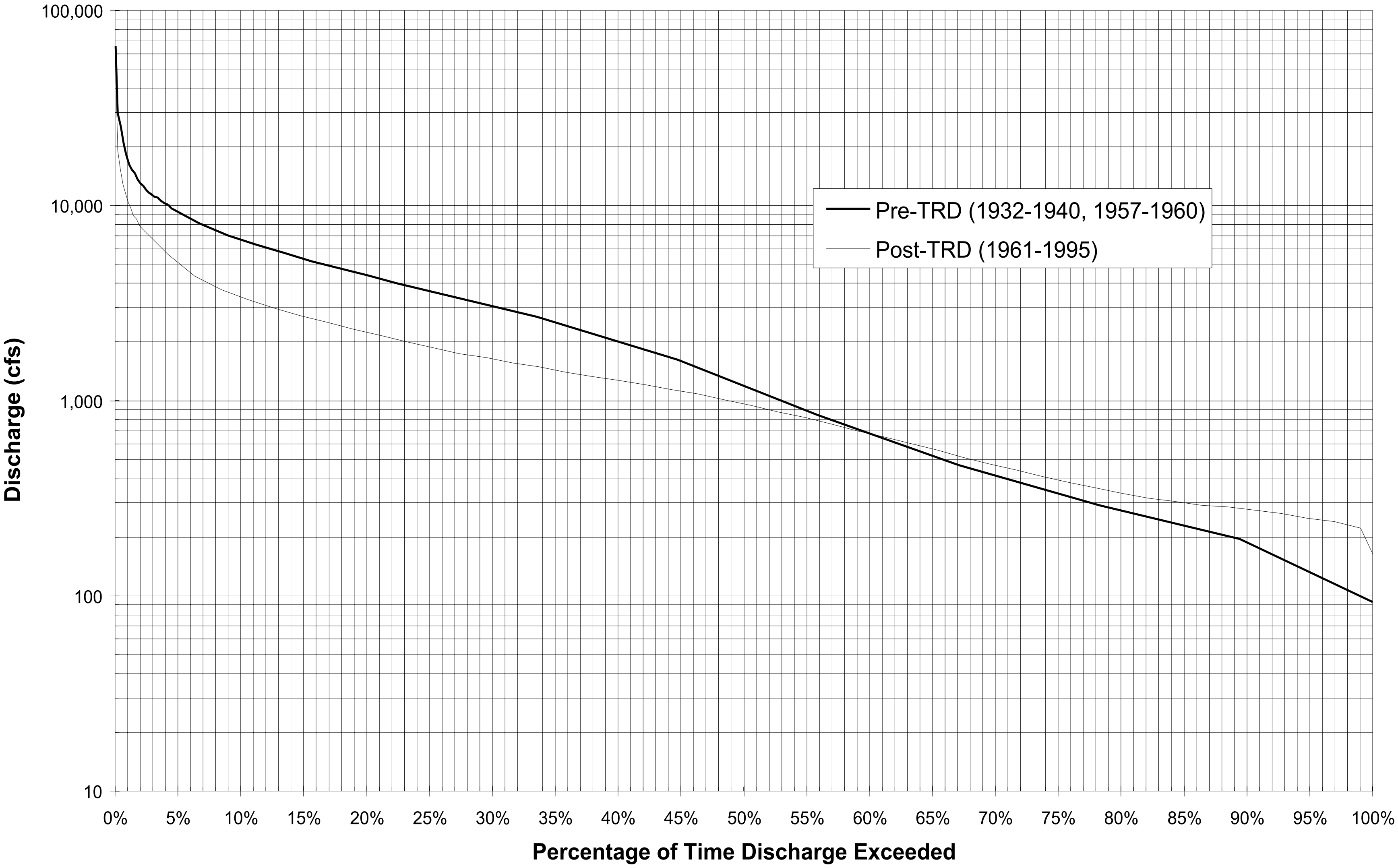

Figure 4.18. Trinity River flow-duration curves at Burnt Ranch (RM 48.6) before (1912-1960) and after (1961-1995) construction of TRD.

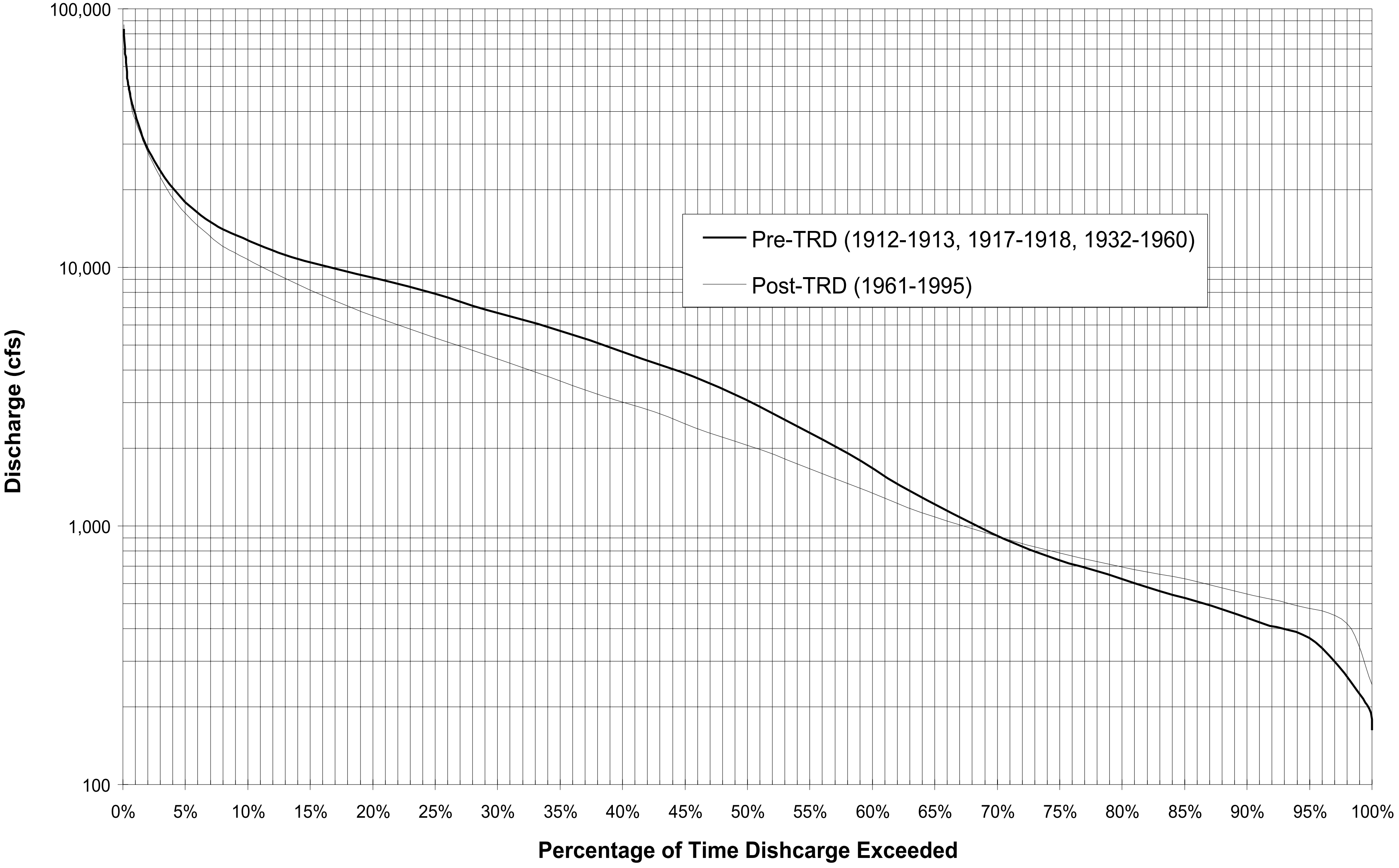

Figure 4.19. Trinity River flow-duration curves at Hoopa (RM 12.4) before (1912-1960) and after (1961-1995) construction of TRD.

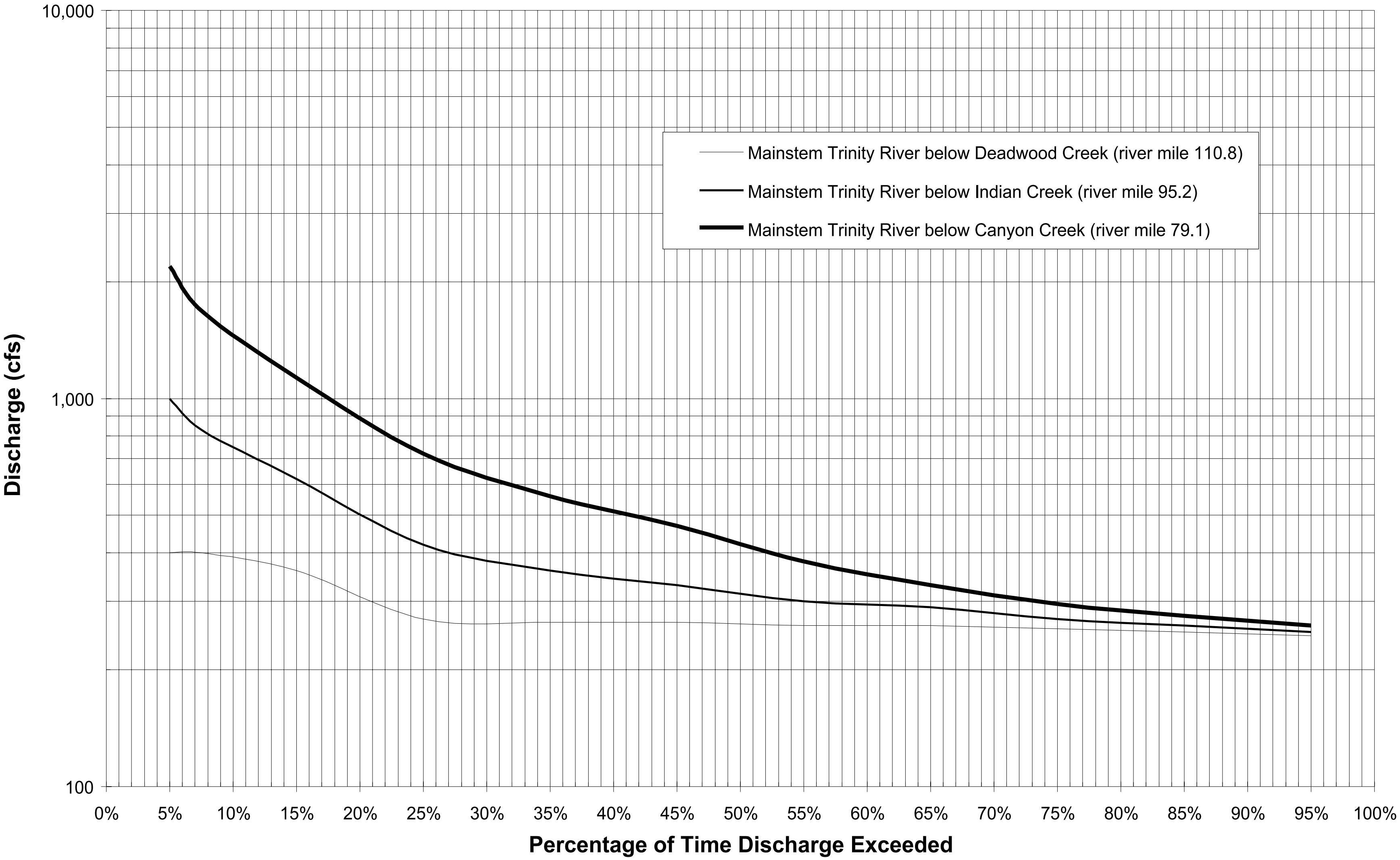

Figure 4.20. Trinity River modeled flow-duration curves at three locations between Lewiston and North Fork Trinity River.

curves for low flows (>65 percent exceedence) was primarily due to the minor summer baseflow contribution of the small tributaries to mainstem Trinity River flows. However, the divergence of the three curves for larger flows was due to the significant tributary contribution during winter storms, winter baseflows, and snowmelt period. Figure 4.20 and Table 4.6 were developed using simple additive models of tributary flows due to the lack of longitudinal streamflow gaging on the mainstem Trinity River. Flows of a given exceedence (recurrence) are usually not additive due to regional runoff differences. However, these analyses, while not precise, illustrate that tributaries contribute a significant volume of flow during winter and spring baseflow periods, as well as during winter storm events. For example, a 300-cfs release can be at least tripled within 30 miles downstream from Lewiston Dam.

> Tributaries downstream of Lewiston increase flood magnitudes down-river, but provide minor contribution to snowmelt runoff or summer baseflows.

4.3.2 Missing Hydrograph Components

Most ecological consequences of the TRD were not as obvious or direct as the lost habitat above Lewiston. The snowmelt hydrograph (including both snowmelt peak and recession hydrograph components) was almost eliminated downstream; today, only a few downstream tributaries contribute significant snowmelt. No mention is made of this in early project evaluations, not even by Moffett and Smith (1950). Big winter floods, often associated with rain-on-snow runoff, also were eliminated, but this was generally considered a benefit to humans and salmon alike. The TRD mostly eliminated all winter storm flows at Lewiston (excluding downstream tributary contribution), with the exception of dam safety releases in wetter years (e.g., in WY1974). Dam safety releases are generally much less (<14,500 cfs) than unregulated inflow into Trinity Lake. Finally, the year-round flow release of 150 to 250 cfs blurred any previous distinction between summer and winter baseflows and eliminated baseflow variability. To illustrate the change in flows since TRD operations began, each unregulated annual hydrograph (the unregulated daily average flow entering Trinity Lake) has been overlaid onto its regulated annual hydrograph (the USGS gaging station at Lewiston) in Appendix F. Refer to McBain and Trush (1997) and Section 5.4 for greater detail on pre-TRD and post-TRD hydrograph components. Given the importance of the annual hydrograph components in transporting sediment, creating and maintaining alternate bar sequences, and influencing riparian life-history, their loss signaled the eventual habitat loss and ecosystem impairment that was to follow.

4.3.3 Riparian Vegetation

4.3.3.1 Riparian Encroachment and Bar Fossilization

Riparian vegetation downstream from Lewiston Dam encountered more than 30 years of man-made droughts since the TRD began diverting up to 92 percent of the annual inflow. With only 150 cfs to 250 cfs released year-round through the 1970's (except occasional, higher dam safety releases), seedlings and saplings escaped desiccation and (or) scour. These significantly reduced, and virtually constant instream flows impacted channel morphology and the river ecosystem by allowing woody riparian vegetation to rapidly encroach across the former active channel and down to the edge of the low-water channel (Figure 4.21 and 4.22).

At Gold Bar (RM 106.3) willow and white alder rapidly encroached by 1975 (Figures 4.23 to 4.26). The downstream end of the median bar shows mature trees approximately 50 feet tall and over a foot in diameter toppled by the 1974 flood (peaking at 14,500 cfs),

Table 4.6. Summary of pre- and post-dam flood frequency estimates as a function of distance downstream from Lewiston Dam, demonstrating the influence of tributary floods on mainstem flood flows.

	1.2 Year Flood			1.5 Year Flood			2.33 Year Flood			5 Year Flood		
River Mile	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam
112	7,171	630 *	9% *	11,813	1,110 *	9% *	14,599	2,160 *	15% *	26,745	4,500 *	17% **
112	7,171	400 **	6% **	11,813	400 **	3% **	14,599	400 **	3% **	26,745	400 **	1% **
107.5	7,478	681 **	9% **	12,376	816 **	7% **	15,315	1,189 **	8% **	28,393	1,826 **	6% **
104	7,616	807 **	11% **	12,752	1,060 **	8% **	15,834	1,760 **	11% **	29,987	3,204 **	11% **
95.4	8,338	1,469 **	18% **	13,951	1,981 **	14% **	17,319	3,398 **	20% **	33,209	5,991 **	18% **
93.8	9,260	2,314 **	25% **	15,309	3,076 **	20% **	18,939	5,182 **	27% **	36,397	8,749 **	24% **
92.8	9,918	2,917 **	29% **	16,402	3,914 **	24% **	20,292	6,673 **	33% **	39,336	11,291 **	29% **
87.8	10,652	3,590 **	34% **	17,520	4,803 **	27% **	21,641	8,159 **	38% **	42,121	13,700 **	33% **
79.2	11,569	4,430 **	38% **	19,073	5,986 **	31% **	23,575	10,290 **	44% **	46,348	17,356 **	37% **
72.5	14,120	6,769 **	48% **	23,648	9,397 **	40% **	29,365	16,670 **	57% **	59,573	28,795 **	48% **

	10 Year Flood			25 Year Flood			50 Year Flood		
River Mile	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam
112	36,700	7,600 *	21% *	51,431	13,400 *	26% *	63,958	17,300 *	27% *
112	36,700	400 **	1% **	51,431	400 **	1% **	63,958	400 **	1% **
107.5	39,392	2,538 **	6% **	55,624	3,385 **	6% **	69,985	4,365 **	6% **
104	42,501	5,008 **	12% **	62,328	8,156 **	13% **	80,882	11,533 **	14% **
95.4	47,602	9,059 **	19% **	70,352	13,867 **	20% **	92,227	18,997 **	21% **
93.8	52,220	12,727 **	24% **	77,580	19,012 **	25% **	101,768	25,273 **	25% **
92.8	56,870	16,421 **	29% **	84,941	24,251 **	29% **	112,160	32,110 **	29% **
87.8	61,067	19,755 **	32% **	91,842	29,163 **	32% **	121,599	38,319 **	32% **
79.2	67,798	25,101 **	37% **	102,908	37,039 **	36% **	137,538	48,805 **	35% **
72.5	88,949	41,901 **	47% **	139,728	63,246 **	45% **	189,598	83,053 **	44% **

Note: Tributary floods and high flow releases from the dam do not usually have similar timing, thus the distribution of dam releases are considered different and non-additive to tributary floods. Therfore, it is assumed that dam releases during tributary floods were 400 cfs.

Boxed values illustrate where tributary derived flood frequency regime exceeds dam release flood frequency regime.

* flood frequency estimates are from actual post-dam releases.

** flood frequency estimates assume a 400 cfs release from dam (tributary floods not timed with dam releases, thus not additive).

Figure 4.21. Typical fossilization of a point bar surface (circa 1995) near Douglas City (RM 91.8) by encroachment of riparian vegetation that has occurred since TRD construction.

although most trees on the bar appear unaffected (Figure 4.25). Upstream, approximately 200 feet from the riffle crest, other mature trees along the right bank also were toppled as the flood spilled onto the floodway and then returned across the newly formed riparian berm. Large woody debris on the right bank in the pre-TRD photograph (faintly visible as scattered lines in Figure 4.23) is conspicuously absent in later photographs.

As these established plants grew, elevated hydraulic roughness generated by the stems and dense understory along the low water channel encouraged fine sediment deposition during tributary-derived high flows, providing seedbeds for additional plants. Their foothold on previously dynamic alluvial bars soon became permanent, such that by 1970 Lewiston releases were incapable of scouring the bars or the trees. A WY1997 flow of approximately 12,000 cfs at Gold Bar, similar to that of the WY1974 flood, dislodged only a few trees (Figure 4.25). The extensive root system of riparian vegetation along the length of the mainstem low-water channel immobilized, or "fossilized," the bars' alluvium (Figure 4.21). In this fossilized state, alluvium can no longer be transported downstream, thus eliminating another gravel/cobble source for sustaining an alternate bar morphology.

The continual low flow releases from the TRD allowed riparian vegetation to initiate, establish, and mature along the low flow channel, eventually fossilizing the channel and inducing sand deposition to form a confining berm.

Riparian encroachment was fastest upstream from Weaver Creek. Ritter (1968) had already observed extensive willow colonization along the low-water channel (150 to 200 cfs water surface) by 1965, and significant deposition of fine sediment

Figure 4.22. Development of riparian berm on the mainstem Trinity River at the confluence with the North Fork Trinity River (RM 72.4) looking upstream. The top photograph was taken pre-1960, the bottom photograph was taken in 1996.

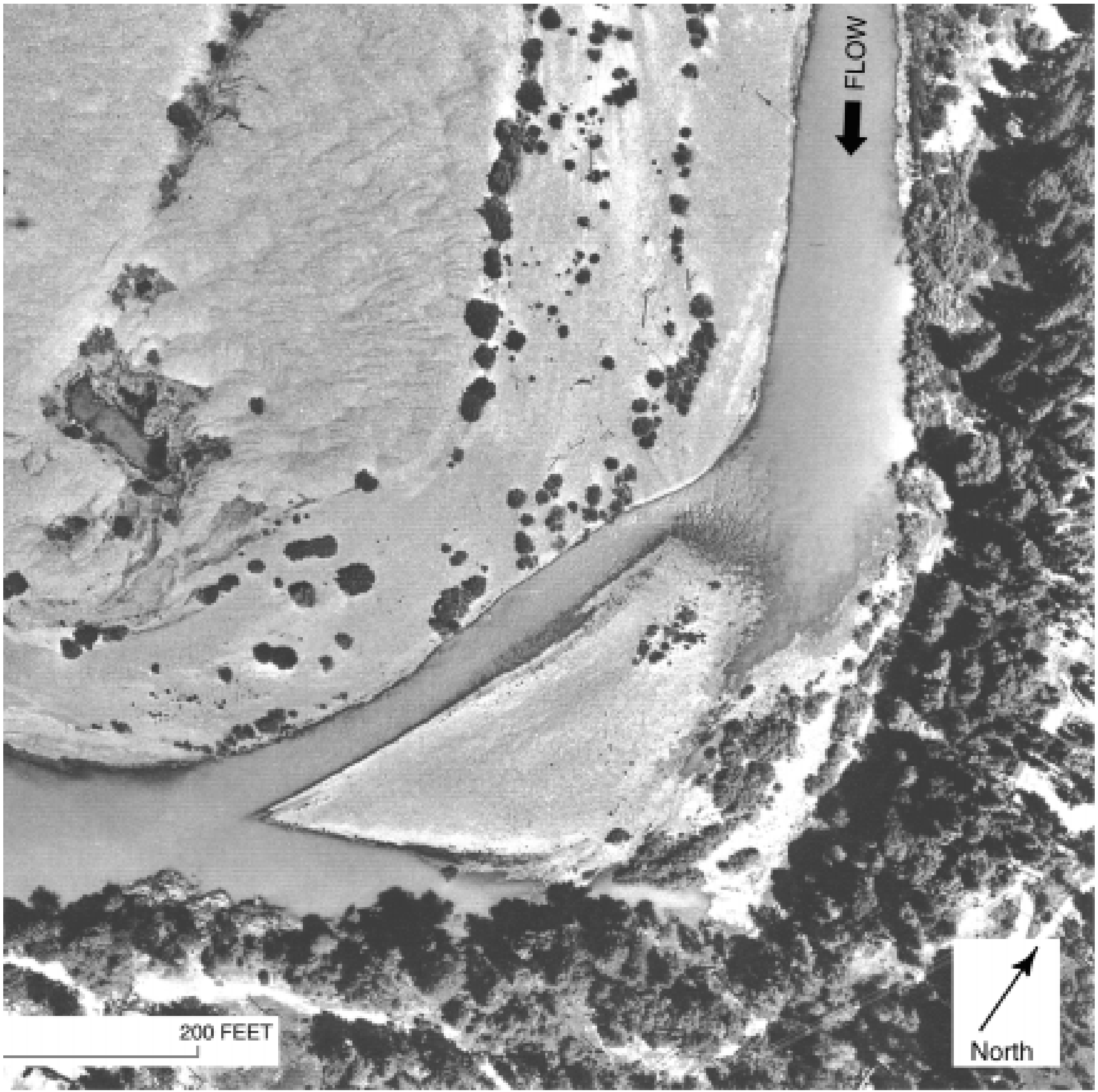

Figure 4.23. Gold Bar (RM 106.3) in 1961, showing exposed cobble/gravel surfaces and patches of riparian vegetation typical of pre-project conditions. Note woody debris on right bank (looking downstream) floodplain.

within this emerging riparian band. This sediment deposition occurred primarily during the December 1964 flood; deposition ranged from almost none near the dam to more than 3 feet near the Weaver Creek confluence. Ritter (1968) also observed at Rush Creek, a few years following dam closure:

> *The downstream cross-section, which had no earthmoving activity, showed a small amount of aggradation, but the most evident change was the great profusion of young willows which grew along the right bank since the first survey [in 1960].*

Four years of optimal growing conditions easily produced conspicuous 6-foot-high willows, suggesting that seedling survival in WY1964 and WY1965 was abnormally high.

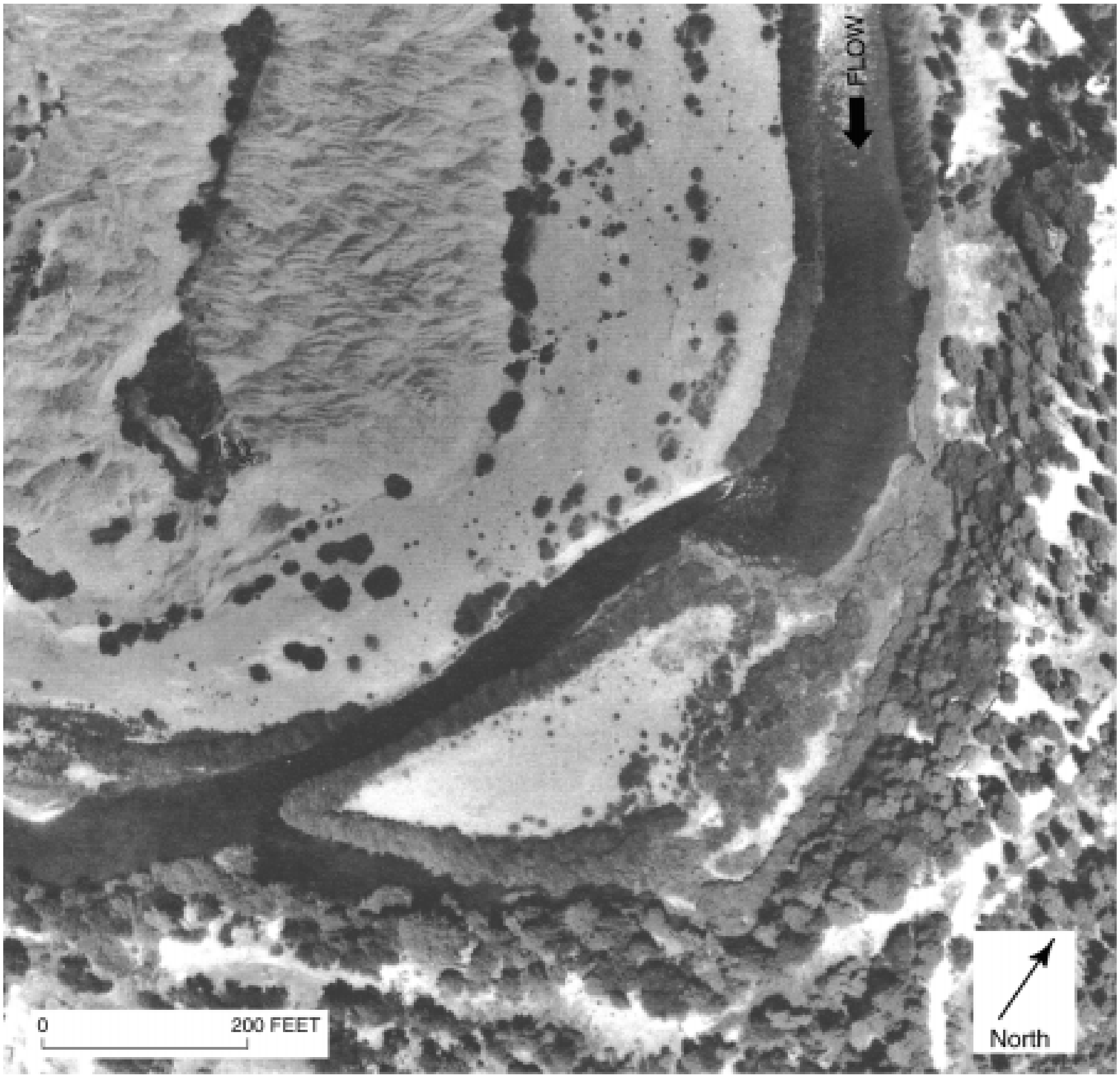

Figure 4.24. Gold Bar (RM 106.3) in 1970, showing effects of seven years of riparian encroachment on alluvial deposits. Note thick riparian band developing along low-water surface.

Pelzman (1973) concludes that riparian encroachment was prevented prior to the TRD primarily by rapid flow reduction during the summer when seedlings were initiating. He states that receding flows and associated declines in groundwater tables caused many seedlings to desiccate. The construction and operation of the dams eliminated this mortality agent and greatly increased seedling survival. Pelzman (1973) also notes, "Reduced spring flows, followed by stabilized flow, exposed considerable areas of the stream channel with moist soil during the period most favorable for germination." Seedling survival close to the Lewiston Dam was almost guaranteed. Even with downstream tributary flow augmentation and occasional floods capable of mobilizing the mainstem's channelbed surface (especially below Dutch Creek at RM 86.3), rapid plant establishment reached the North Fork Trinity River confluence.

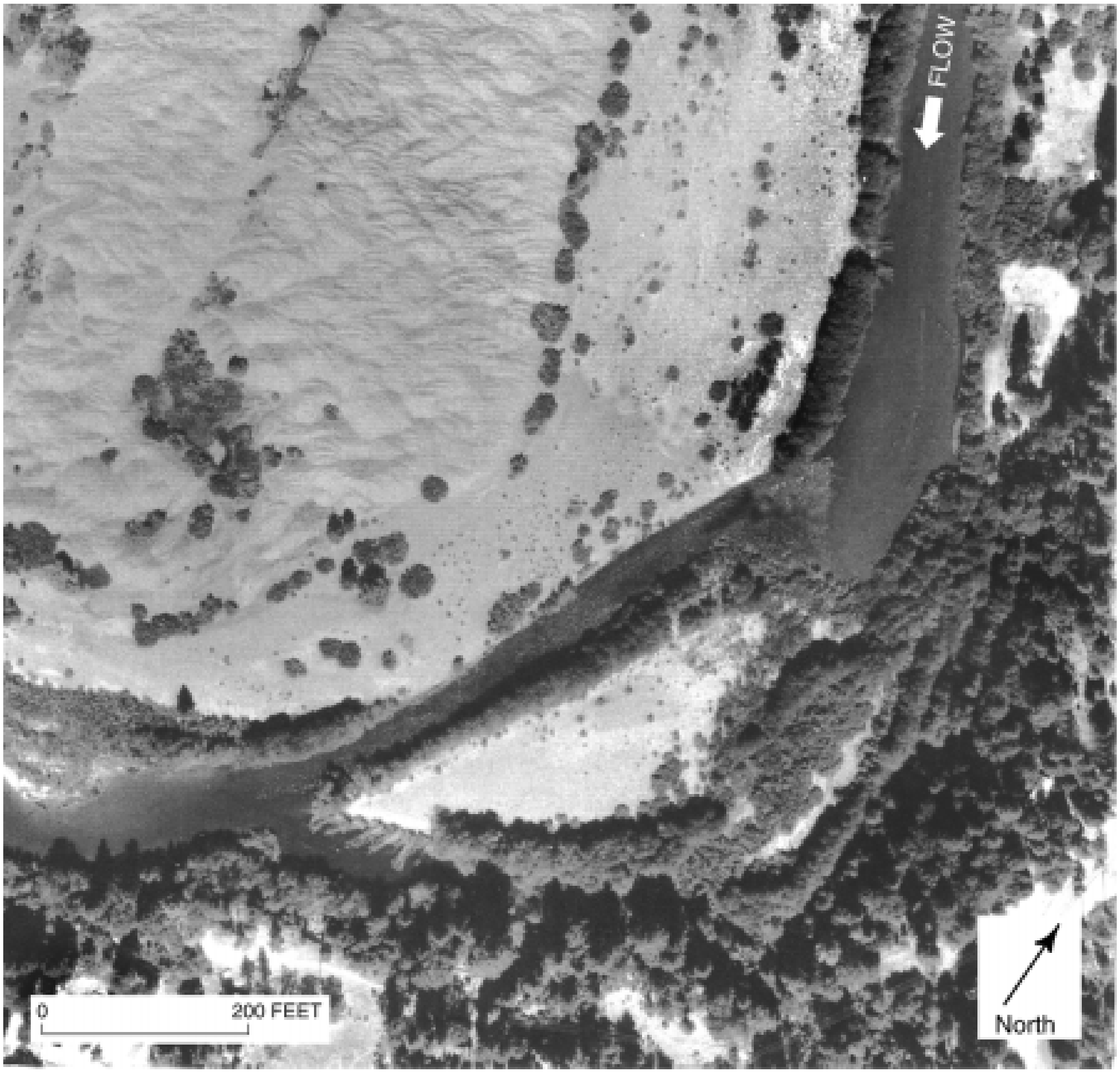

Figure 4.25. Gold Bar (RM 106.3) in 1975, showing twelve years of riparian encroachment. Note minimal effect of January 1974 14,000 cfs flood on riparian berm.

Later, Evans (1980) documented the total change in the areal extent of riparian vegetation between 1960 and 1977. He reported that riparian stands of willow and alder increased from 187 acres to 853 acres between Lewiston and the North Fork Trinity River. Early on, these communities were dominated by willow overstories. As these communities matured, alders replaced willows in the overstory. He also predicted that broad-leaf riparian plants on the riparian berm would be shaded out and ultimately replaced by upland conifer species in approximately 35 years. Wilson (1993) repeated Evan's (1980) areal census, extending the temporal analysis to include 1989 riparian conditions. Wilson's results were comparable, finding 313 acres in 1960 and 881 acres in 1989 for the same length of mainstem. Impact to the mainstem riparian community was more serious than a shift in riparian acreage accounting. Community structure was simplified by a reduction in diversity, with an understory

Figure 4.26. Gold Bar (RM 106.3) in 1997, showing the current status of morphology downstream to North Fork Trinity River. Note that willow patches on old right bank (looking downstream) floodplain are same trees as shown in 1961 photo.

now dominated by dense blackberry. Cottonwood forests, which require overbank deposits and channel migration for initiation and establishment, have disappeared.

4.3.3.2 Riparian Berm Formation

Deposition of fine sediment within newly encroached riparian plant stands created levee-like features along the low-water's edge, referred to as "riparian berms" (compare

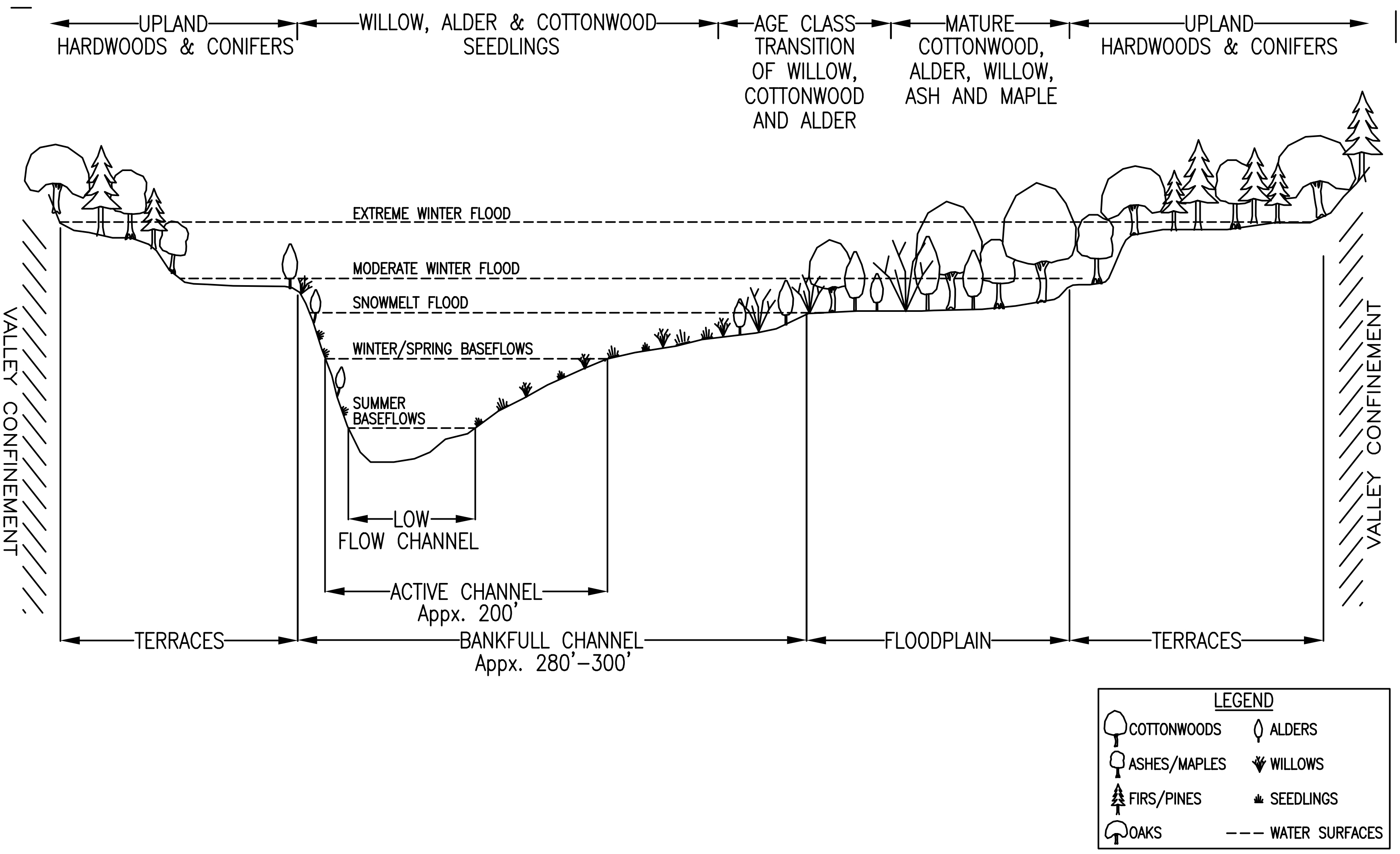

Figure 4.27. Present idealized channel cross section and woody riparian communities near Steiner Flat (RM 91.7).

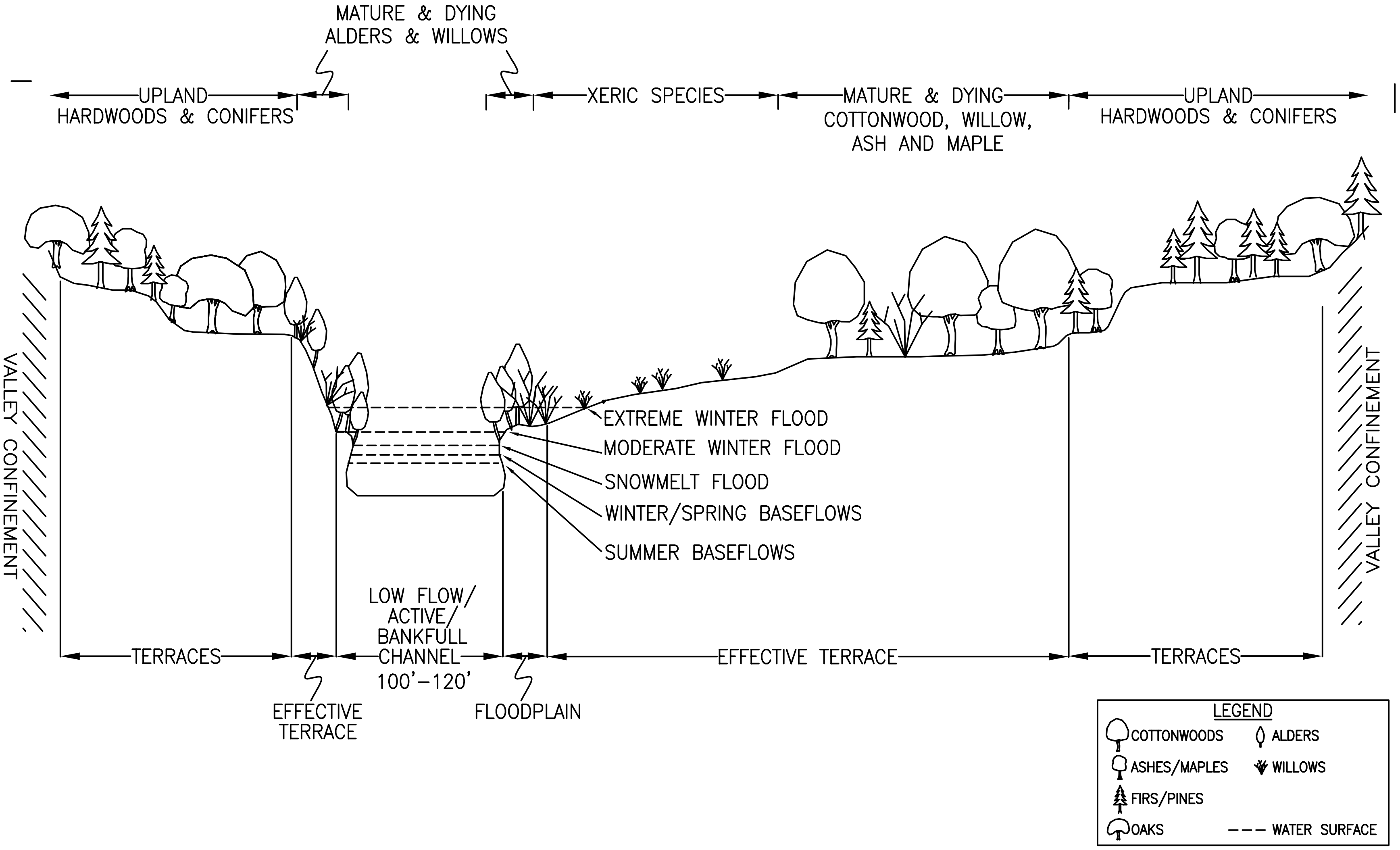

Figure 4.28. Conceptual evolution of the Trinity River channel cross section following the operation of the TRD.

Figure 4.27 and 4.28). They are now ubiquitous depositional features throughout the mainstem, signaling a change in alluvial behavior riverwide. Riparian berms formed within the historical active channel margin. Low flows released in the late 1960's and early 1970's were well below the flows required to inundate the pre-TRD active channel margin. Willow growth flourished near this low flow waterline, then colonized upslope to the first sharp slope break (Figure 4.28). This break was at the active channel margin, corresponding to the elevation of pre-TRD high winter baseflows. The varying width of the present-day riparian encroachment band probably reflects, in most locations, pre-TRD active channel dimensions. The progression of riparian colonization onto the Gold Bar median bar (Figures 4.23 to 4.26) illustrates this widening of the riparian zone at the riffle crest where the pre-TRD active channel gently sloped up the median bar. Along the steep flank of this active channel, upstream from the riffle crest, riparian encroachment has been restricted to a relatively narrow band.

The riparian berm fossilized alluvial deposits, simplified the channel, reduced habitat diversity, removed floodplain access, and reduced riparian species and age class diversity.

During riparian berm removal at the Sheridan (RM 82.0) and Steiner Flat (RM 91.8) bank rehabilitation sites by bulldozers, mature willow trunks that appeared rooted on the riparian berm tops were actually buried in the riparian berm and rooted on the original pre-TRD channelbed surface (McBain and Trush, 1997). A sharp interface between the original cobblebed surface and recently aggraded coarse sand of the riparian berm revealed the abrupt depositional environment created by maturing saplings along the channel edge. Mature willows had several sets of adventitious roots along their buried trunks, each set presumably correlated to a discrete depositional event. The lack of large gravels and cobbles in the riparian berms' stratigraphy also indicated the pronounced role of small to intermediate floods in facilitating riparian berm formation. Only one coarse layer was excavated, presumably corresponding to the WY1974 flood. White alders approximately 20 years old were rooted on this layer. Although cobbles were deposited onto the riparian berms during this event, the willows had become sufficiently established to resist removal.

Today, riparian berms exceeding 7 feet in height are extensive below Junction City (RM 80.0). Some riparian berms are still aggrading but at highly variable rates. The 20-year-old alders in the Sheridan bank-rehabilitation site (RM 82.0) were buried by only 0.8 foot of fine sediment though they were rooted 5 feet high on the riparian berm. In contrast to this slow accretion (at least since the mid-1970's), recent blackberry understories along the left bank of the Gravel Plant monitoring site (RM 105.5) trapped several feet of coarse sand in one 6,000 cfs dam release in WY1992 (Trinity Restoration Associates, 1993). Riparian berms can continue aggrading if higher flood elevations are experienced, if the riparian berm vegetation becomes even denser, or if fine sediment supply increases.

4.3.4 Changing Channel Morphology

TRD releases created a Trinity River that abandoned its former floodplain and therefore narrowed the river corridor. Channel width also narrowed. For example, the cross-section at the Lewiston USGS cableway narrowed (from 187 to 137 feet) and became shallower (from 3.9 to 2.5 feet), but it almost doubled in mean velocity (from 1.2 to 2.5 feet/sec) at a discharge of approximately 840 cfs (Figure 4.8). Cross sectional-shape changed quickly, with alluvial channel reaches affected most. Asymmetrical cross sections, typical of alluvial channels with alternate bars, were transformed into uniform trapezoidal configurations (Figures 4.27 to 4.28).

The present mainstem channel location is almost a snapshot of its location in 1960; meanders have been immobilized by flow regulation and subsequent encroachment of riparian berms. Some immobilized reaches, however, developed subtle meander patterns between the riparian berms such that their thalwegs were only slightly deeper (0.5 foot) than the mean channel depth. One or more present-day meanders can be placed into half a meander of the pre-TRD channel (Figure 4.29). Today, the presence of a more defined meandering thalweg in an erodible channel, especially downstream from the Dutch Creek confluence (RM 86.3), indicates a trend back to a dynamic alternate bar morphology although with a shorter wavelength and amplitude than pre-TRD conditions.

4.3.5 Lost Alluvial Features, Lost Habitat Complexity

Flow regulation triggered a chain of geomorphic and riparian events that by the mid-1970's had rapidly simplified habitat complexity in the mainstem. One salient reason for habitat degradation was the loss of alternate bars and their associated sequences of pool-riffle-runs (Figure 4.30). From Lewiston Dam to Indian Creek, fossilized alternate bars and point bars dominate the channel morphology (McBain and Trush, 1997). Accretion of flow and sediment from tributaries has allowed some bar formation, particularly downstream from the Indian Creek confluence (RM 95.2). However, these bars do not have the size, shape, mobility, or riparian vegetation expected of unregulated alternate bars. Recovery of an alternating bar morphology is never fully realized until downstream from the confluence with the North Fork Trinity River (RM 72.4).

Lost alluvial features compromised salmonid habitat by producing monotypic habitat characterized by extensive runs with high velocities (Figure 4.30). Habitat diversity is critical, not only because species utilize different habitats, but because individual fish use different habitats during their daily activities (e.g., feeding, holding, evading predators). Monotypic environments meet all needs of very few species and generally lack adequate microenvironments for the specific activities of most species (i.e., feeding or providing cover, etc.). Such inadequacies force fish into sub-optimal habitat.

Another consequence of lost alternate bar morphology was the transformation of asymmetrical channel cross sections into uniform, trapezoidal cross sections. Today's salmonid rearing habitat, especially fry habitat, is constrained to narrow ranges of slower flows located immediately adjacent to the channel banks (Figure 4.30) (Section 5.2). Low-velocity areas are used by salmonid fry, as well as fry of suckers and dace, and lamprey ammocoetes. The shallow slackwater habitat preferred by recently emerged fry nearly disappears in the present channel at intermediate discharges (between 400 cfs and 2,000 cfs), only to reappear at flows greater than 2,000 cfs once riparian berms have been overtopped (USFWS, 1997). Flows greater than 1,500 cfs begin to inundate the area behind riparian berms and create slow-water areas suitable to salmonid fry. As flows decrease, some fry do not return to the mainstem and become stranded in isolated pools formed behind riparian berms.

Loss of flow volume, flood magnitudes, and flow variability virtually eliminated the fluvial processes responsible for creating and maintaining high quality salmonid habitats. Subsequent riparian encroachment, fine sediment accumulation in the mainstem, and loss of coarse sediment supply and transport contributed to decreased salmonid habitat quantity and quality in the mainstem Trinity River.

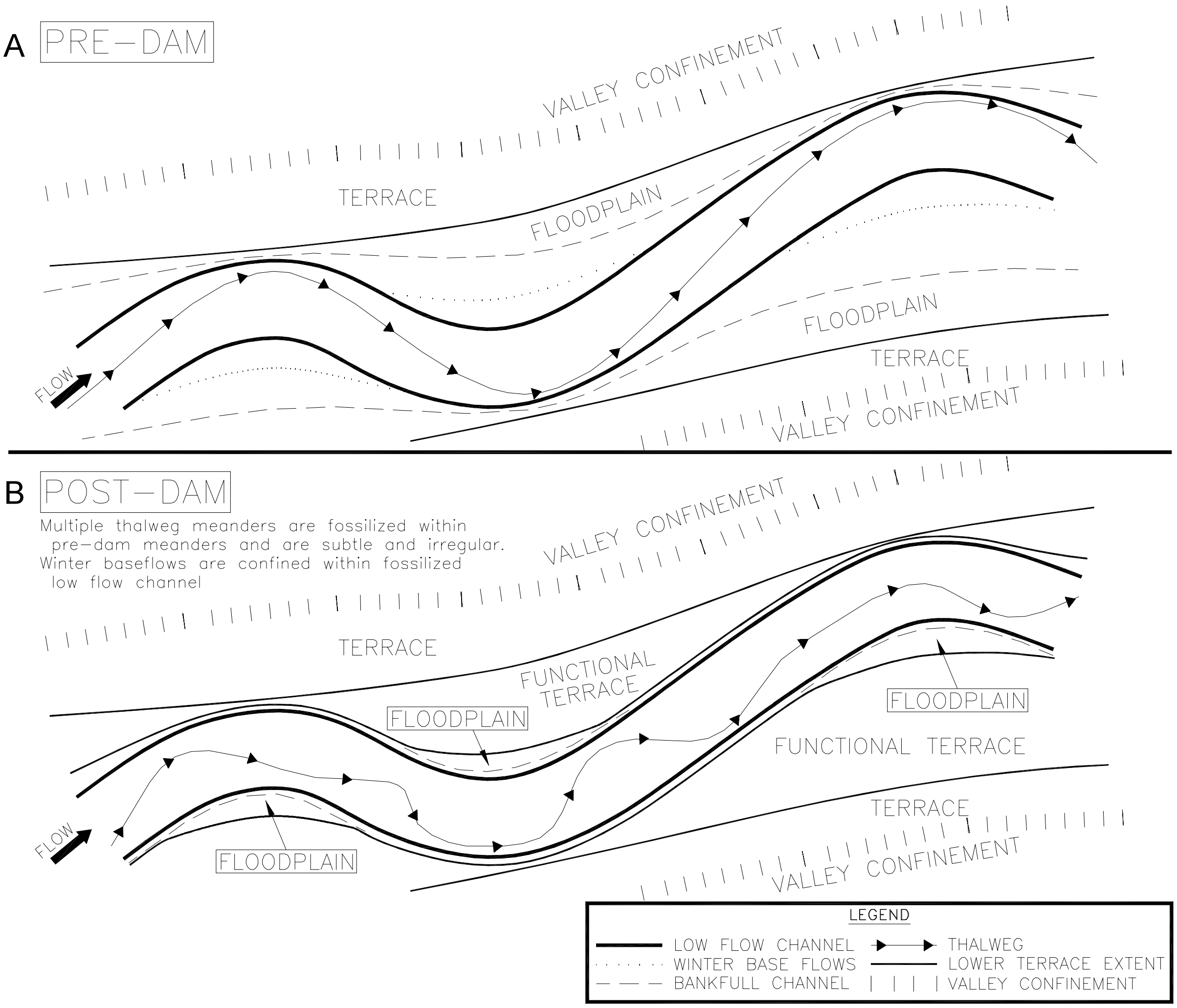

Figure 4.29. Conceptual evolution of the Trinity River planform geometry from Lewiston Dam to the North Fork Trinity River due to TRD operation. A) Pre-TRD meanders were fossilized by riparian vegetation, and remain so under post-TRD conditions. B) A few locations do exhibit some slight meandering of the thalweg within the fossilized banks.

4.3.6 Colder Summertime Water Temperatures

Prior to construction of the TRD, mean monthly water temperatures of the Trinity River at Lewiston were quite variable. During the winter months, temperatures were 39 to 41°F and were generally lowest during January. With the onset of spring and increasing day length, mean monthly water temperatures slowly increased to about 53.6°F in May and continuously increased until July and August when water temperatures were highest, usually exceeding 68°F. During these summer months, a difference as great as 12°F was recorded between daily maximum and minimum water temperatures, and maximum daily water temperatures exceeded 80°F on several occasions (Moffet and Smith, 1950). Because of low-flow conditions (100 cfs) during these warm periods,

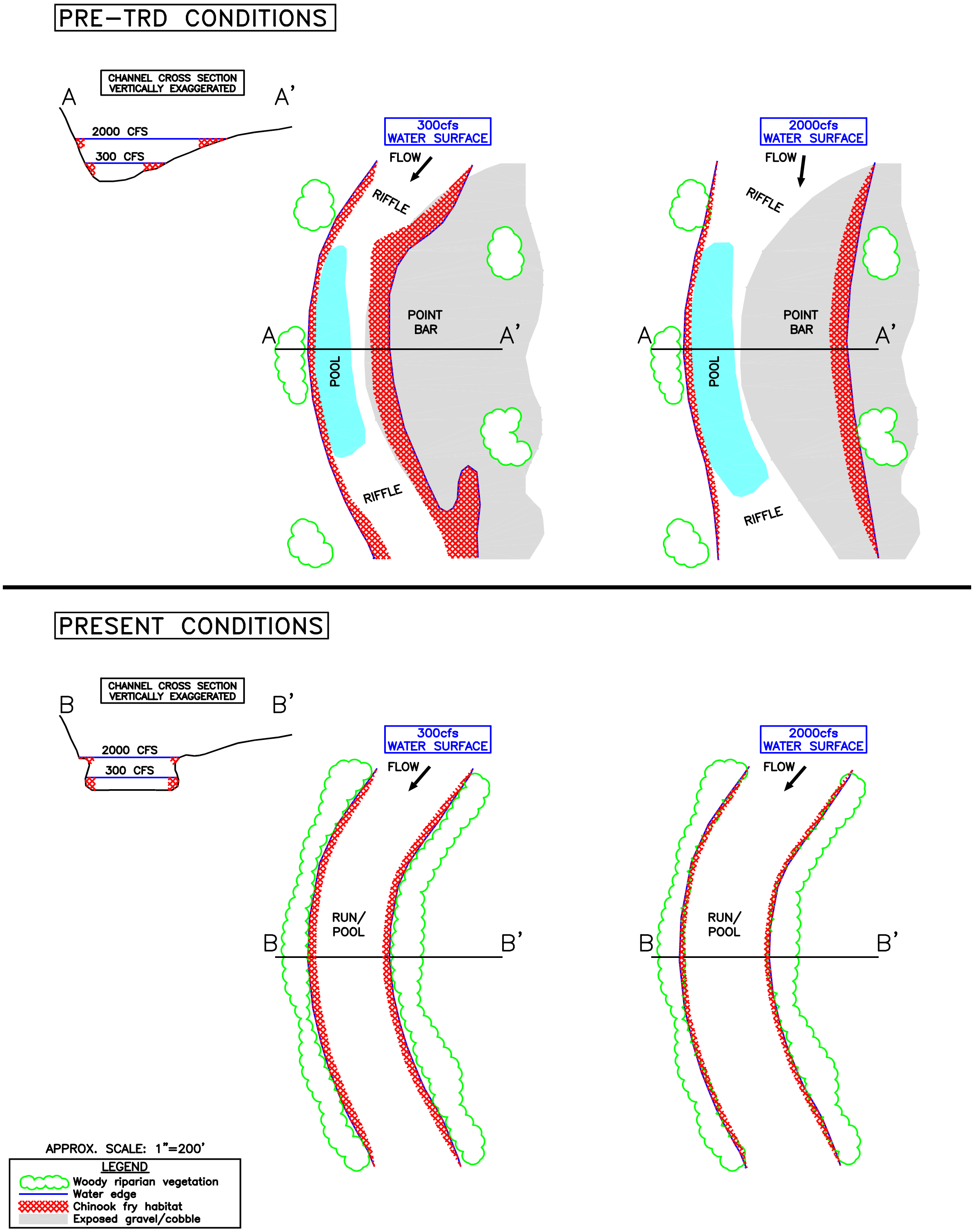

Figure 4.30. Idealized pre-TRD point bar showing relative surface area of fry chinook rearing habitat in comparison with present conditions of riparian encroachment and narrow channel.

pools stratified and surface water was as much as 7°F warmer than the bottom (Moffet and Smith, 1950). From September to December water temperatures continued to decrease as a result of cooler meteorological conditions and reduced day length.

Since construction of the TRD, water temperatures at Lewiston have become relatively stable and conditions are therefore much different from pre-dam conditions (Figure 4.31). From November to May, water temperatures have become as much as 4°F warmer, and conditions for the remaining months of the year have become as much as 20°F colder. It was generally believed that the TRD would increase salmonid production due to more stable flows and cooler summer water temperatures provided by dam releases. This increased production was never realized. Most salmonid smolts outmigrated before summer water temperatures were unsuitable. Rearing juvenile salmonids (pre-TRD) remained in the cooler habitats above Lewiston that were predominantly fed by snowmelt, or sought the cool refugia in stratified pools. Operation and construction of the TRD blocked these habitats and altered flows such that pools no longer stratify.

Although meteorological conditions can influence the temperature of water released from Lewiston Dam, the operation of diversions through the Clear Creek Tunnel to the Sacramento River can have a greater effect. In the summer, when diversions to Whiskeytown Reservoir are large (as great as 3,200 cfs), Lewiston Reservoir essentially becomes a slow-moving river and remains cold (Trinity County, 1992). Conversely, when diversions are low and residency time is high, Lewiston Reservoir temperatures begin to warm during the summer months.

The TRD changed pre-TRD water temperature patterns downstream of Lewiston: winter water temperatures are warmer than pre-TRD temperatures, and summer temperatures are colder.

During the summer, two types of operational scenarios have been used to reduce this residency time (Trinity County, 1992). During periods of low diversion and warm meteorologic conditions, "slugging" of Lewiston Reservoir is usually requested by the Trinity River Fish Hatchery to obtain cold water temperatures; "Slugging" is a short-term, high-volume diversion through the Clear Creek Tunnel followed by refilling of Lewiston Reservoir with cold Trinity Lake water. The other scenario is to divert large volumes of water at a continuous rate through Lewiston Reservoir by way of the Clear Creek Tunnel or down the Trinity River. The latter method is rarely used.

Reservoir storage also affects water temperatures in the Trinity River. Although uncommon, the storage in Trinity Lake can be relatively low, especially as a result of successive dry years. In August 1977, a warm water release (approximately 79°F) made below the TRD resulted in adult and juvenile mortalities in TRFH and in the river downstream. The release occurred when warmer surface waters were drawn through the main power outlet (2,100 feet) in Trinity Dam. The reservoir elevation at the time of the release was 2,145 feet. Cold water releases were resumed downstream when Reclamation operators bypassed the main outlet works and opened the auxiliary outlet (1,995.5 feet).

4.4 Managing the Mainstem for Salmon

Salmon have been the focus of flow management since TRD operations began. When salmon populations began to decline, all management prescriptions, including all flow-release recommendations, dredging operations, and hillslope protection measures, were intended to improve some aspect of salmon populations.

4.4.1 Dam Releases

Preliminary studies determined that TRD releases necessary to maintain the fishery resources of the Trinity River ranged from 150 to 250 cfs (Moffett and Smith,

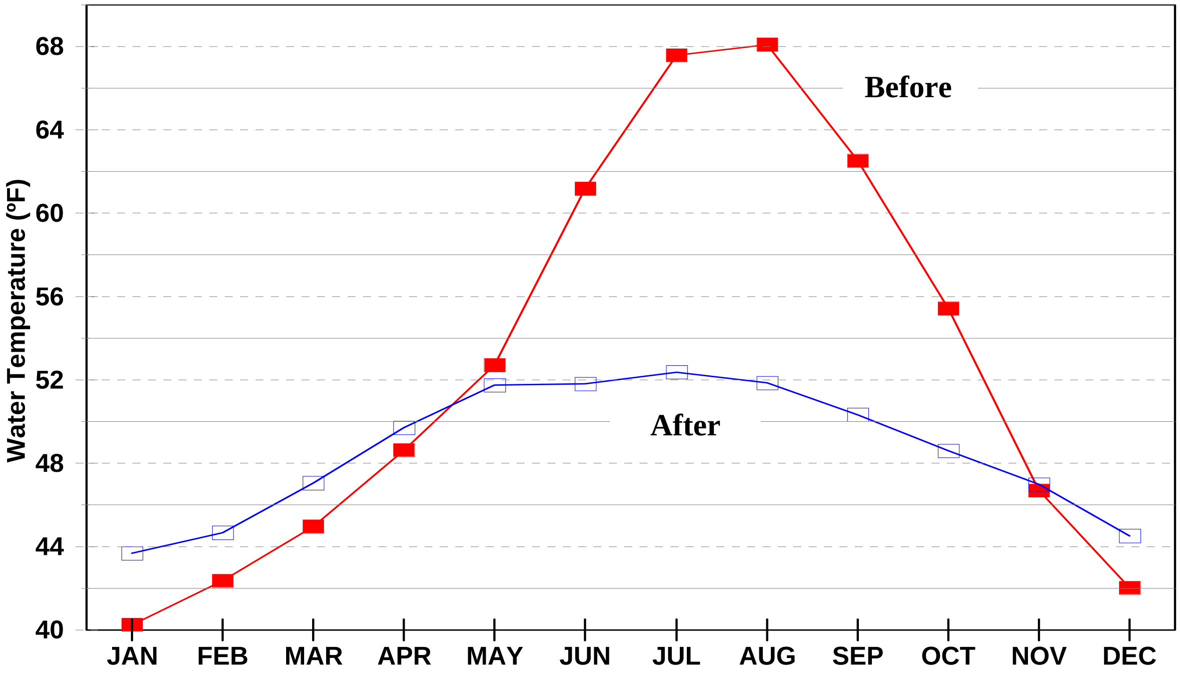

Figure 4.31. Mean monthly water temperatures of the Trinity River at Lewiston before and after construction of the TRD in 1963. Data years were 1942 to 1946, 1959 to 1961, 1964 to 1983, 1987 to 1992.

1950). These recommendations were primarily based on the depth and velocity requirements of spawning chinook salmon. However, after completion of the TRD, subsequent declines in anadromous fish populations were apparent (Hubbel, 1973). To reverse these declines, CDFG initiated a study in 1973, requesting increased releases ranging from 300 to 1,750 cfs during the spring to mimic natural snowmelt conditions. However, drought in 1976/1977 interrupted these experimental flows. In response to public concerns about the status of the fishery resources and to instream flow study needs, Reclamation voluntarily maintained minimum releases of 300 cfs year-round from 1978 through the early 1980's (USFWS, 1983).

During those years, an instream flow study conducted by the Service (USFWS, 1980a) found that increased flows were essential to restore and maintain the Trinity River fishery resources. This study provided the basis for the instream flow volumes put forth in the 1981 Secretarial Decision. Increased annual volumes allowed daily releases to increase to a minimum of 300 cfs in normal or wetter years. Daily releases for dry-year flow regimes (140 TAF) remained between 150 and 300 cfs. Unfortunately, 5 of the first 6 years of the TRFE were dry years, and releases remained low. The series of low releases contributed to the continued decline of the fishery resources, but also jeopardized the TRFE. In response, the Hoopa Valley Tribe filed a successful administrative appeal, which increased the annual flow regime in all years to 340 TAF beginning in 1992. This annual volume allowed for minimum flows of 300 cfs year-round plus additional water that has been used to provide appropriate temperatures for holding spring chinook during the summer that previously held in the cooler waters above Lewiston, as well as releases of higher flows for several studies.

4.4.2 The Trinity River Restoration Program

As described in Chapter 2, Congress established the Trinity River Fish and Wildlife Restoration Program (the Program) in 1984 to reverse salmonid habitat decline below Lewiston. Program objectives were to: (1) increase the quantity and quality of salmonid juvenile and adult habitat in the mainstem; (2) reduce fine sediment contributions to the mainstem from tributaries; and (3) remove fine sediment from critical spawning habitat within the mainstem channel. Over the initial 10-year authorization, the Program mostly focused on controlling fine sediment entering the mainstem from tributary basins.

4.4.2.1 Buckhorn Debris Dam and Hamilton Sediment Ponds

The Program's accomplishments included the construction of Buckhorn Debris Dam and Hamilton sediment catchment ponds, the purchase of the Grass Valley Creek Basin, and the implementation of numerous basin restoration projects (TCRCD/ NRCS, 1998). Construction of Buckhorn Debris Dam and the operation of the Hamilton sediment ponds have prevented a considerable amount of fine sediment from entering the mainstem via Grass Valley Creek. Other mechanical efforts to remove sediment and improve habitat conditions in the river have included cleansing of spawning riffles, dredging of sand from mainstem pools, side channel construction, and a pilot bank rehabilitation program to improve mainstem channel morphology.

Grass Valley Creek is a major source of granitic sand entering the upper river (BLM, 1995). Accumulation of this fine sediment in the mainstem has contributed substantially to the degradation of the river ecosystem and salmonid habitat. VTN Environmental Sciences (1979) and Fredericksen, Kamine, and Associates (1980) recommended periodic dredging of the Hamilton sediment ponds built at the mouth of Grass Valley Creek (Figure 4.1). In the ponds, coarse granitic sand and coarser bedload is settled out before it can enter the mainstem. Since their construction in 1984, the Hamilton sediment ponds, which have a storage capacity of 42,000 yd^3, have been dredged as needed (TCRCD/ NRCS, 1998). The efficiency of bedload retention was estimated to be 70 to 80 percent, and have greatly reduced the volume of fine sediment entering the mainstem Trinity River. Unfortunately, the storage capacity of these ponds has been exceeded during a single storm event (e.g., in January 1995), which allows substantial coarse sand to enter the mainstem before the ponds can be dredged. Dredging is expected to continue in the Hamilton sediment ponds to maintain their effectiveness as sediment traps.

4.4.2.2 Riffle Cleaning

Several riffle sites in the Trinity River were mechanically manipulated by “gravel ripping” to reduce the volume of fine sediment in spawning gravels. In summer 1986, a crawler tractor equipped with rip bars was used to break up cemented gravels and dislodge fine sand from the substrate. The riffle cleaning was not completely successful. The lowered flow releases that allowed the tractor to operate within the channel were incapable of transporting large volumes of sand from the study reach. Gravel ripping did bring larger gravel and cobbles to the surface, thus reducing the percentage of surficial sand. However, the dislodged fine sediment was only redistributed a short distance downstream; the total volume of fine sediment in the targeted channel reach remained unchanged (USFWS, 1987). If larger releases had followed the gravel ripping procedures, the fine sediment may have been transported from the study reach and habitat improvement may have been greater.

4.4.2.3 Mainstem Pool Dredging

Thirteen mainstem pools (Table 4.7) have been periodically dredged to reduce fine sediment storage. The primary advantage of pool dredging has been the removal of fine sediment without additional flow releases. However, this technique has limitations. Mainstem pool dredging removes all sediment, including gravels and cobbles. Dredged pools also inhibit the recruitment of upstream bedload to downstream reaches. Although dredging does reduce the total amount of fine sediments, these benefits have not been achieved riverwide because of accessibility problems. Another drawback is that pool dredging increases water turbidity and can disrupt spring chinook salmon holding in the Trinity River in the summer.

4.4.2.4 Side Channel Construction

Natural and artificially constructed side channels have provided valuable low-velocity spawning, rearing, and wintering habitat for juvenile salmon and steelhead (USFWS, 1986, 1987, 1988; Krakker, 1991; Macedo, 1992; Glase, 1994b), as well as appropriate habitat for yellow-legged frogs and juvenile western pond turtles (Lind et al., 1996). From 1988 to 1994, 18 side channels (7 downstream from Douglas City (RM 91.0)) (Appendix G, Plate 2) were constructed pursuant to the Trinity River Restoration Program’s goals to improve rearing and spawning habitat. Side channels were constructed on pre-TRD gravel bars on the inside bends of river meanders and in straight reaches.

Once constructed, these side channels were expected to be maintained by periodic scour from high flows. However, the seven side channels downstream from Douglas City required significant maintenance because their inlets often aggraded (Hampton, 1992). Because of much lower sediment loading, only 1 of the 11 side channels above Douglas City (the site just downstream from the Rush Creek confluence) has required substantial maintenance.

4.4.2.5 Pilot Bank-Rehabilitation Projects

Monitoring suggested that the gently sloping channel margins of the pre-TRD channel, a contemporary morphological feature almost missing upstream from the North Fork Trinity River confluence, were important habitat for salmonid fry (USFWS, 1994). To provide fry habitat, a pilot project to mechanically rehabilitate portions of the mainstem channel was conducted. Nine bank rehabilitation projects, spanning WY1991 to WY1993, were constructed by Reclamation and the Service (Appendix G).

Bank-rehabilitation projects were constructed along straight channel reaches and bends of river meanders (Appendix G, Plate 1). Project sites ranged from 395 to 1,200 feet long. Heavy equipment removed the riparian berm down to the historical cobble surface along one

Table 4.7. Location, name, and date last dredged of pools in the mainstem Trinity River.

Name	River Mile	Date	Name	River Mile	Date
New Bridge	111	1985	SP Pool	103.5	1987
Old Bridge	110	1985	Ponderosa	103.4	1987
Upper Cemetery	109.3	1989	Tom Lang	102.9	1991
Cemetery	109.2	1989	Reo Stott	102	1991
Rush Creek	107	1980	Society	101.5	1990
Bucktail	105	1989	Montana	101	1991
Wellock	104	1984			

bank. The opposite bank remained undisturbed. Since construction, these sites have been monitored and evaluated (Sections 5.2 and 5.4)

4.5 What Has a Historical Perspective Taught Us?

Despite an urgency to restore salmonid populations, single-species management in the Trinity River has not succeeded. The single-species management approach has ignored basic ecosystem functions and has valued river ecosystem integrity as a secondary benefit, rather than the primary contributor, to productive salmon populations.

4.6 The Mainstem Trinity River As It Is

Substantial environmental changes resulting from TRD construction and operation are significantly degrading anadromous salmonid habitat and the river ecosystem. This impact might have been reduced had it been possible to construct the dam without degrading the channel downstream. That was not the case, however. Recent declines in salmon populations may not exist entirely as a consequence of the degradation or loss of habitat, but if fish populations are to be restored and maintained, mainstem habitat quality and quantity must be improved. Rehabilitation will demand no easy and simple cure.

> To date, restoration efforts have focused on slight modifications to baseflows and mechanical restoration approaches, most of which have been ineffective in increasing natural salmon production in the Trinity River.

The mainstem rebounded from human-induced changes during the gold-rush era, but the TRD eliminated or too powerfully altered the two basic ingredients it needed to stay resilient: flow and sediment. Morphologic change was inevitable. The morphologic adjustment to the new, imposed flow and sediment regimes was most dramatic from Lewiston Dam downstream to Douglas City, particularly in the alluvial channel reaches. Fortunately, the mainstem is graced with many significant tributaries, especially the high concentration of tributaries near Douglas City - including Indian, Weaver, Reading, and Browns Creeks. The cumulative contribution of unregulated flows and sediment by these and other tributaries greatly mitigated, but could not prevent, dam-related impacts. A riparian berm is obvious downstream to the North Fork Trinity River confluence, and it might have extended farther if the mainstem did not enter a narrow canyon.

From Lewiston Dam downstream to the North Fork Trinity River confluence, the mainstem narrowed, ceased to migrate, lost its macro-alluvial features, abandoned floodplains, reduced its meander wavelength, had tributary deltas aggrade, and assumed a trapezoidal channel shape. Early successional woody riparian communities, with many of their mortality agents now missing, accelerated morphologic changes by encroaching into the former actively scoured channel. Dense colonization made the banks virtually non-erodible and quickly fossilized alternate bars. Alluvial reaches became rigid within 10 to 15 years.

All spawning and juvenile rearing that once occurred in the mainstem and its tributaries upstream from Lewiston were shifted downstream. The TRFH was built and operated to mitigate for lost habitat upstream from Lewiston. The mainstem channel below Lewiston, which pre-TRD salmon populations had avoided by late-summer, was now home. Hypolimnial dam releases may have cooled water temperatures to an acceptable range for juvenile salmonid rearing, but other native fauna may have been affected. As the mainstem lost its dynamic alluvial nature, this home became less hospitable.

Disruption of the annual pre-TRD flow regimes with their diverse hydrograph components and the loss of coarse sediment supply, both of which were responsible for creating and sustaining the Trinity River ecosystem, caused substantial habitat degradation. Downstream tributaries partially offset the TRD's effects by contributing flow and sediment to the mainstem, but downstream tributaries cannot mitigate the lost snowmelt hydrograph components once generated above Lewiston.

Construction of the TRD resulted in a new ecological role for the mainstem below Lewiston Dam. The mainstem from Lewiston to the North Fork Trinity River confluence must now support spawning and rearing, transport smolts to the ocean, and accommodate upstream migrating adults of several species and stocks. Before the TRD, this was accomplished over a much broader and more diverse geographic area. Can a management philosophy with an ecosystem perspective, rather than the past single-species management philosophy, make this imposed ecological role a reality?

4.7 Toward a Restoration Philosophy

Fluvial geomorphic processes underpin the structure and function of alluvial river ecosystems; this must have been the case for the Trinity River ecosystem. As interactions between a river's physical and biological components increase geometrically, even simple cause-and-effect relationships become obscured: teasing out isolated causes or effects becomes a study in contingencies. The most effective strategy for rehabilitating habitat and fully realizing the potential productivity of an anadromous salmonid fishery is a top-down approach: the restoration of river system integrity. Anadromous fish in the Trinity River evolved in a dynamic, mixed alluvial river system that has since become static. If naturally producing salmonid populations are to be restored, habitats on which these populations historically depended must be provided to the greatest extent possible, by rejuvenating the necessary geomorphic and ecological processes within contemporary sediment and flow constraints.

Restoring the Trinity River to pre-TRD conditions cannot occur barring significant reconfiguring or removal of the TRD. Likewise, continuing existing management will not significantly improve habitat and salmonid productivity. The optimal solution is to restore a Trinity River smaller in scale than the pre-TRD river,but that possesses the fluvial processes and channel morphology of the pre-TRD channel.

Total restoration of the pre-TRD channel morphology is not the goal: as long as the TRD operates, the historical channel dimensions cannot be recreated because not all physical processes can be restored to pre-TRD levels. The former huge winter floods will never happen again, and the dams will continue to trap all coarse bedload. Instead, a different mainstem will be targeted, an approximation of the pre-TRD mixed alluvial channel, although smaller in scale than the pre-TRD river. If an alluvial river system can be restored, the structural components of anadromous fish habitat will reappear.

Creating a dynamic alternate bar channel form and maintaining its habitat characteristics will be critical in this effort, but rehabilitating the physical habitat is only part of the challenge. Water quality needs, particularly summer water temperatures, also must be addressed. This will mean creating an environment that did not exist prior to the TRD.

4.8 Attributes of Alluvial River Ecosystems

To develop the goals and objectives for rehabilitating the Trinity River, attributes of an alluvial riverine system are identified, as well as the physical processes necessary to sustain each attribute (Appendix H). The attributes were derived from studies of the Trinity River (McBain and Trush, 1997) and published research on alluvial rivers. These attributes were used to assess mainstem river integrity and select/prioritize the appropriate restoration strategies presented in this report.

Pristine, unregulated rivers with morphologies comparable to the Trinity River no longer exist regionally, making within-basin comparisons between regulated and unregulated river systems impossible. Instead, it was necessary to associate general fluvial geomorphic processes with contemporary annual flow regimes in unregulated river systems outside the region. The mainstem Trinity River below Lewiston has no reasonable unregulated counterpart to serve as a model, so these attributes were developed from historical streamflow records, cross sections, aerial photographs, and local and scientific literature review. Development of these attributes largely circumvented the common shortcoming of having insufficient pre-regulation data regarding channel morphology, pre-TRD channel dynamics, and associated anadromous salmonid production.

The following attributes target specific distinguishing physical and biological processes in coarse gravel-bedded alluvial rivers such as the Trinity River mainstem:

ATTRIBUTE No. 1. Spatially complex channel morphology.

No single segment of channelbed provides habitat for all species, but the sum of channel segments provides high-quality habitat for native species. A wide range of structurally complex physical environments supports diverse and productive biological communities;

ATTRIBUTE No. 2. Flows and water quality are predictably variable.

Inter-annual and seasonal flow regimes are broadly predictable, but specific flow magnitudes, timing, durations, and frequencies are unpredictable because of runoff patterns produced by storms and droughts. Seasonal water-quality characteristics, especially water temperature, turbidity, and suspended-sediment concentration, are similar to those of regional unregulated rivers and fluctuate seasonally. This temporal "predictable unpredictability" is a foundation of river ecosystem integrity;

ATTRIBUTE No. 3. Frequently mobilized channelbed surface.

Channelbed framework particles of coarse alluvial surfaces are mobilized by the bankfull discharge, which on average occurs every 1 to 2 years;

ATTRIBUTE No. 4. Periodic channelbed scour and fill.

Alternate bars are scoured deeper than their coarse surface layers by floods exceeding 3- to 5-year annual maximum flood recurrences. This scour is typically accompanied by re-deposition, such that net change in channelbed topography following a scouring flood usually is minimal;

ATTRIBUTE No. 5. Balanced fine and coarse sediment budgets.

River reaches export fine and coarse sediment at rates approximately equal to sediment inputs. The amount and mode of sediment storage within a given river reach fluctuates, but sustains channel morphology in dynamic quasi-equilibrium when averaged over many years. A balanced coarse sediment budget implies bedload continuity: most particle sizes of the channelbed must be transported through the river reach;

ATTRIBUTE No. 6. Periodic channel migration or avulsion.

The channel migrates or avulses at variable rates and establishes meander wavelengths consistent with those of regional rivers with similar flow regimes, valley slopes, confinement, sediment supply, and sediment caliber;

ATTRIBUTE No. 7. A functional floodplain.

On average, floodplains are inundated once annually by high flows equaling or exceeding bankfull stage. Lower terraces are inundated by less frequent floods, with their expected inundation frequencies dependent on norms exhibited by similar, but unregulated river channels. These floods also deposit finer sediment onto the floodplain and low terraces;

ATTRIBUTE No. 8. Infrequent channel-resetting floods.

Single large floods (e.g., exceeding 10- to 20-year recurrences) cause channel avulsions, rejuvenation of mature riparian stands to early-successional stages, side channel formation and maintenance, and creation of off-channel wetlands (e.g., oxbows). Resetting floods are as critical for creating and maintaining channel complexity as are lesser magnitude floods;

ATTRIBUTE No. 9. Self-sustaining diverse riparian plant communities.

Natural woody riparian plant establishment and mortality, based on species life-history strategies, culminate in early- and late-successional stand structures and species diversities (canopy and understory) characteristic of self-sustaining riparian communities common to regional unregulated river corridors;

ATTRIBUTE No. 10. Naturally fluctuating groundwater table.

Inter-annual and seasonal groundwater fluctuations in floodplains, terraces, sloughs, and adjacent wetlands are similar to those of regional unregulated river corridors.

Attributes No. 1, 2, 5, and 10 can help diagnose river ecosystem integrity. Attribute No. 2, central to all physical and ecological processes, is repeatedly addressed in the other attributes. But the need to emphasize annual flow variation warranted a separate attribute. Excepting

Restoring the Trinity River requires quantitative objectives. Ten fundamental attributes of alluvial river integrity were developed to provide these quantitative objectives.

Attribute No. 2, these attributes are direct consequences of fluvial geomorphic processes comprising other attributes. Their usefulness is derived from regional and (or) historical expectations of runoff patterns, channel morphology, and riparian community structure in unregulated river ecosystems with minimally disturbed watersheds. All help define a desired condition and quantify channel rehabilitation goals.

Attributes No. 3, 4, 6, 7, 8, and 9 are process-oriented and can be departure points (in most cases, initial hypotheses) for investigating important physical and biological processes. These attributes also served as our restoration goals and lead to adaptive management monitoring objectives. Many attributes are interrelated. For example, maintaining an alternate bar morphology (No. 3 and No. 4) strongly affects channel migration and avulsion (No. 6), floodplain formation (No. 7), and woody riparian establishment (No. 9).

To maintain the channel processes that provide high-quality instream and riparian habitats described in these attributes, flow recommendations must link two flows: those that provide suitable seasonal habitat and those that create and maintain the structural framework and spatial complexity that is the foundation of the micro-habitats. No single flow can provide sufficient habitat for all life stages and species of salmonids that existed prior to construction of the TRD; rather, a varied regime of flows is required to restore and maintain the overall health and productivity of this alluvial river, and thus restore and maintain the fishery resources of the Trinity River.

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CHAPTER 5 Study Approaches and Results

Between 1984 and 1997, the Service conducted the TRFE to assess various flow regimes and other measures necessary to restore and maintain the Trinity River anadromous salmonid fishery resources. The TRFE involved studies that assessed the extent of habitat degradation resulting from hydrological and morphological changes caused by the construction and operation of the TRD, and that evaluated approaches that would reverse the decline of naturally produced anadromous salmonid populations of the Trinity River. These studies, among other things, addressed specific riverine components and included documentation of fisheries habitat within the existing post-TRD channel, evaluated how fluvial geomorphology and associated processes affected the pre- and post-TRD channel, and evaluated the effect of channel rehabilitation efforts on fish habitat. This chapter summarizes these flow-related studies and presents data and scientific interpretations that have contributed to the recommendations that are presented in Chapter 8.

5.1 Microhabitat Studies

The physical space required for an aquatic organism to develop, grow, or reproduce can be described as micro-habitat. For anadromous salmonids in the Trinity River, the amount of microhabitat available at a given streamflow was determined from area measurements, structural descriptions, and quantification of hydraulic conditions. A study of microhabitat, undertaken as part of the TRFE, included the development of site-specific habitat suitability criteria (curves) and the derivation of the relation between microhabitat and streamflow for riverine life stages of chinook salmon, coho salmon, and steelhead. The terms habitat or physical habitat as they appear in this section of this report should be interpreted as referring to micro-habitat.

5.1.1 Habitat Suitability Criteria

For each life stage of each species studied, habitat suitability criteria (HSC) are used to translate the use of hydraulic and structural elements of rivers into indices of relative suitability for these species. HSC are normalized values of suitability, with the poorest quality conditions receiving a suitability of 0.0 and the highest a suitability of 1.0. In order to quantify the amount of physical habitat available at different streamflows, these habitat suitability indices are used to weight discrete stream areas (cells) according to the quality of habitat conditions (e.g., water depth, water velocity, substrate composition) either directly measured or simulated (i.e., modeled) in each cell.

> Microhabitat can be described as the physical space, and the characteristics of that space, required for an aquatic organism to develop, grow, and reproduce. Understanding the microhabitat needs of anadromous salmonids of the Trinity River was necessary to derive relations between streamflows and the amount of habitat in the river.

One task identified during the initial design of TRFE studies was the development of site-specific habitat suitability criteria in the Trinity River. The original Plan of Study (Appendix I) describes the objective of the task as "to develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for chinook and coho salmon and steelhead spawning, incubation, rearing, holding, and migration."

Much of the following information (Sections 5.1.1 and 5.1.2) has been previously reported in Flow Evaluation Annual Reports (USFWS, 1985-91) and by Hampton (1988, 1997). These reports provide much greater detail than is presented here. Additional unreported data collected during the later years of the TRFE, and analyses that have affected initial results, are included in this report. The habitat suitability criteria contained herein are the final result of this task, incorporating both information acquired during the research and contemporary criteria curve developmental techniques that evolved during the course of the TRFE.

> Habitat suitability criteria are used to translate hydraulic and structural elements of rivers into indices of relative suitability for the organism being studied. Habitat suitability criteria are normalized values of suitability, with the poorest quality conditions receiving a suitability of 0.0 and the highest a suitability of 1.0.

5.1.1.1 Study Sites

Fourteen study sites where fish observations would be made and habitat-use data collected were selected within three major river segments between Lewiston Dam and the Klamath River confluence at Weitchpec, a distance of approximately 112 miles. The river segments separate the Trinity River hydrologically and by overall character from Lewiston Dam to the North Fork Trinity River, the North Fork to the South Fork Trinity River, and the South Fork to the Klamath River (USFWS, 1985). The study sites were chosen by professional judgment as being representative of each segment. Nine sites were located in the segment directly below the dam (thought to be most affected by TRD operations), two were in the middle segment, and three sites were located in the lower segment (Figure 5.1). Data were collected to describe the habitat conditions selected by overwintering steelhead juveniles at five additional study sites that contained microhabitat conditions available during the winter season (USFWS, 1985). Two of these study sites were located in side channels and three were in the main river channel.

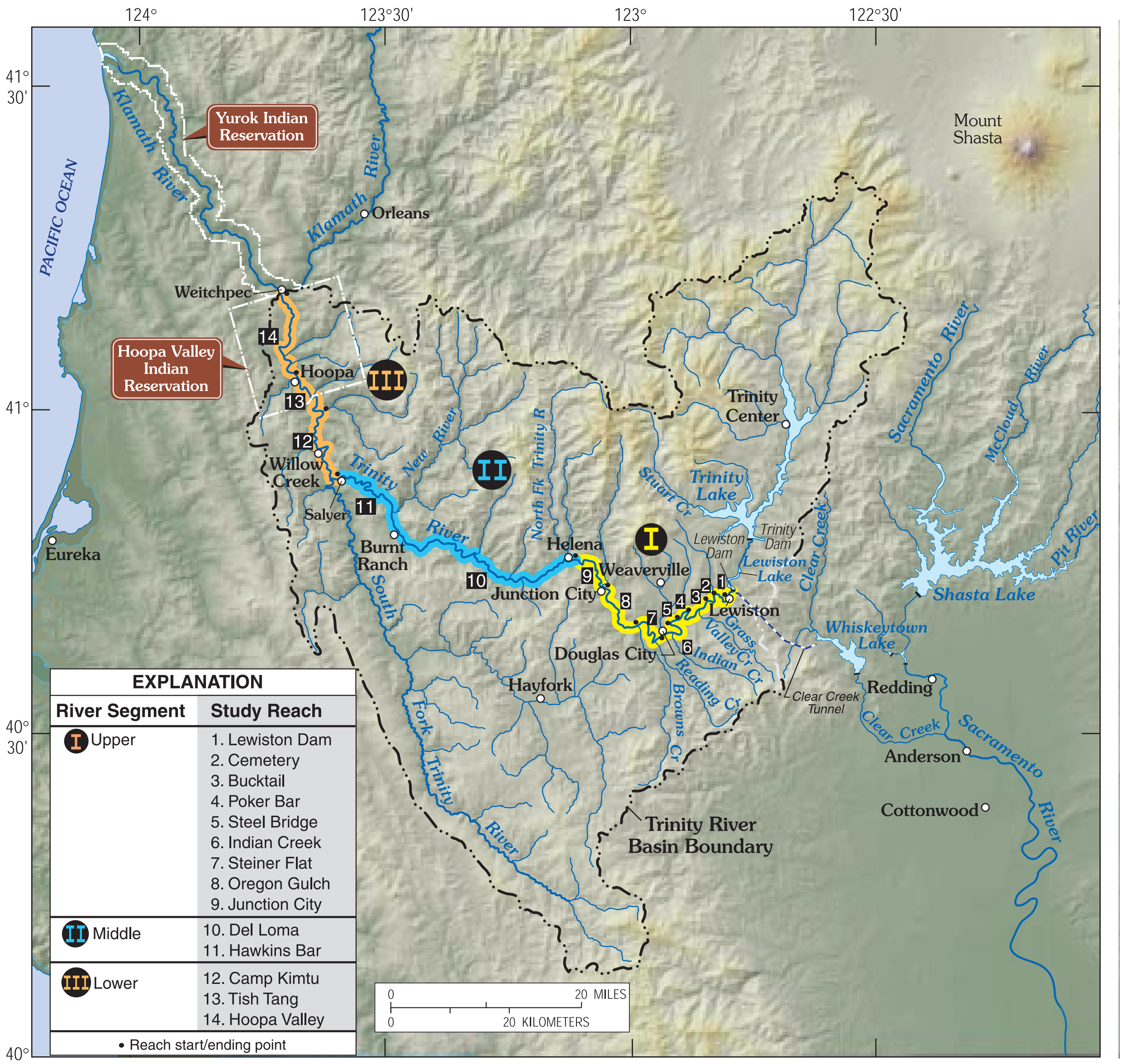


Figure 5.1. The Trinity River Flow Evaluation Study area.

5.1.1.2 Methods for Habitat Suitability Criteria

Habitat-use data were collected for all life stages of chinook salmon, coho salmon, and steelhead as fish were encountered within the study sites. Sampling methods included both direct and indirect observational techniques. Direct observations were made underwater by snorkelers and above water from the river banks or a raft. During extended periods of poor water clarity, indirect observations were made using a backpack electrofisher or a bag seine. Observations were made when Lewiston Dam releases were between 300 and 450 cfs, a moderate level of flow at which diverse depth and velocity habitat conditions were present in the river.

When a fish or group of fish was located, 14 parameters were measured (or described) and recorded (USFWS, 1986; Hampton, 1988). These included species, size (fork length), water depth (total), water velocity (mean water column), substrate (dominant particle size, subdominant particle size, and percent embedded), and cover type (dominant, subdominant, and quality). Rearing salmonids less than 2 inches (fork length) were considered fry, those larger than 2 inches were considered juveniles, and fish with a fork length greater than 7.9 inches were considered adults. Schools of fish were treated as single observations at the focal point of the school.

Observations of habitat availability were made in order to generate habitat preference criteria (curves), as was specified in the original Plan of Study (Appendix I). Preference criteria are derived from the ratio of habitat use over habitat availability (data, by physical variable). Availability data were collected initially by taking a minimum of 150 random microhabitat measurements at each study site for each discharge sampled. Sampling locations were determined from previously prepared tables of paired random values of a length–width grid of the sites. Availability data were collected for essentially the same parameters as for habitat use. This process was man-power intensive and time consuming, leading to an alternative that allowed field efforts to be allocated more toward collection of habitat-use data. Using this alternative, physical habitat availability data were obtained from hydraulic simulation models that were run on transects located within the fish-observation study sites. The method is described in detail in the 1986 Annual Report (USFWS, 1986) and includes a comparison of the two approaches showing the similarity in estimates of habitat availability between them. Results of the comparison are also reported by Aceituno and Hampton (1987) and Hampton (1988).

Chinook and coho salmon fry prefer shallow stream margins with very slow water velocities, while steelhead fry preferred edge habitats adjacent to riffles and swift runs.

Initial data frequencies (bar histograms) of habitat use by each species and life stage were constructed following the guidelines presented by Bovee and Cochnauer (1977). Frequency intervals for depth and velocity were calculated using the Sturges Rule, as cited by Cheslak and Garcia (1987). Resulting frequency bar histograms were subjected to two series of three-point running mean filters and normalized to a maximum value of 1. For cover, a simple frequency bar histogram was constructed using only the dominant cover type. Two frequency bar histograms were constructed for substrate, one a histogram of dominant substrate types and the other a histogram of percent embedded in fines. These were also normalized to a maximum value of 1, with each remaining interval given a value proportional to its relative occurrence.

Preference criteria development followed the early theories and procedures described in the documentation of the Instream Flow Incremental Methodology (Bovee, 1982). These criteria were computed by ratios of use intervals to corresponding availability intervals (forage ratios). Curve-smoothing techniques were applied to those criteria that still exhibited large deviations between adjacent intervals. Resulting preference criteria were then normalized to values between 0.0 and 1.0.

5.1.1.3 Results for Habitat Suitability Criteria

Criteria Data Collection

The first 2 years of data collection in all three segments produced 2,418 fish observations and associated microhabitat measurements for four salmonid species in four life stages (USFWS, 1986). This number was later pared to 1,809 observations for three salmonid species in three life stages (Hampton, 1988). This reduction occurred because data for brown trout and holding adult salmon were not included. Subsequently, this data set was further restricted to (1) observations made above the North Fork Trinity River where habitat availability data for preference criteria could be generated from hydraulic simulation modeling; and (2) data

Juvenile life stages of chinook salmon, coho salmon, and steelhead have divergent microhabitat preferences; with chinook preferring deeper areas with higher water velocities; coho preferred low-velocity conditions such as were present in backwaters, side channels, and pools; and steelhead preferred run, riffle, and riffle-pool transition habitats that provided diverse velocity conditions.

collected by direct observation only. Data collected in later years for steelhead fry, overwintering steelhead juveniles, and holding adult steelhead were added to the data set, resulting in a final total of 1,721 observations (Table 5.1).

Chinook salmon fry were most often found along the edge of the stream where very slow water velocities (Figure 5.2) and structural cover were present. Woody debris, undercut banks, and cobble substrates provided velocity shelters for chinook fry and possibly functioned as escape cover from surface-feeding predators. As chinook salmon grew larger, they became less dependent on edge habitats and began to use areas with higher water velocities in deeper water (Figure 5.3). Object cover continued to provide shelter from swift water velocities in run and riffle habitats. In deep-pool habitats, schools of juvenile chinook salmon positioned themselves in relation to eddies and shear velocity zones where food items could be easily taken in the drift. In these habitats, most juvenile salmon would feed near the water surface, retreating to deeper water between feeding forays. At night, chinook salmon fry and juveniles congregated in areas with slow water velocities, usually close to the river bed.

The majority of chinook salmon redds were located in water from 0.8 to 2.5 feet deep (Figure 5.4). The range of water velocities measured at established redds was relatively broad, but most redds had mean column velocities between 0.8 and 2.6 feet per second (fps). For redd construction, spawning chinook salmon used gravels and cobbles 2 to 6 inches in diameter that were less than 40 percent embedded in fines (Figure 5.5). Areas closer to the river banks were generally favored for redd excavation over areas in midstream.

Low-velocity areas with clean cobble substrates were preferred overwinter habitat for juvenile steelhead.

Coho salmon fry selected microhabitats similar to those of chinook salmon fry (Figure 5.6) and the two species were often found together. Agonistic behavior between the species was rarely observed. As coho salmon became larger they did not shift their habitat selection to areas of faster velocity as did chinook salmon (Figure 5.7). Juvenile coho were usually found in low-velocity conditions such as were present in backwaters, side channels, and along stream edges adjacent to slow runs and pools. These habitats often contained cover such as woody debris, aquatic vegetation, and overhanging vegetation. Spatial segregation between juvenile coho and chinook salmon was common owing to differences in microhabitat selection.

Coho salmon spawned in slightly shallower, slower water velocity areas in comparison with chinook salmon. Most coho salmon redds were constructed in water from 0.5 to 2.0 feet deep with water velocities between 0.5 and 2.2 fps (Figure 5.8). Gravels and cobbles 1 to 3 inches in diameter and less than 20 percent embedded in fines were favored for redd construction (Figure 5.9).

Steelhead fry preferred edge habitats adjacent to riffles and swift runs where they selected focal points close to the substrate or instream objects providing velocity shelters. Unlike the fry of chinook or coho salmon, steelhead were often observed in the turbulent conditions found in shallow riffles. Overall, the depths utilized by steelhead fry were shallower than

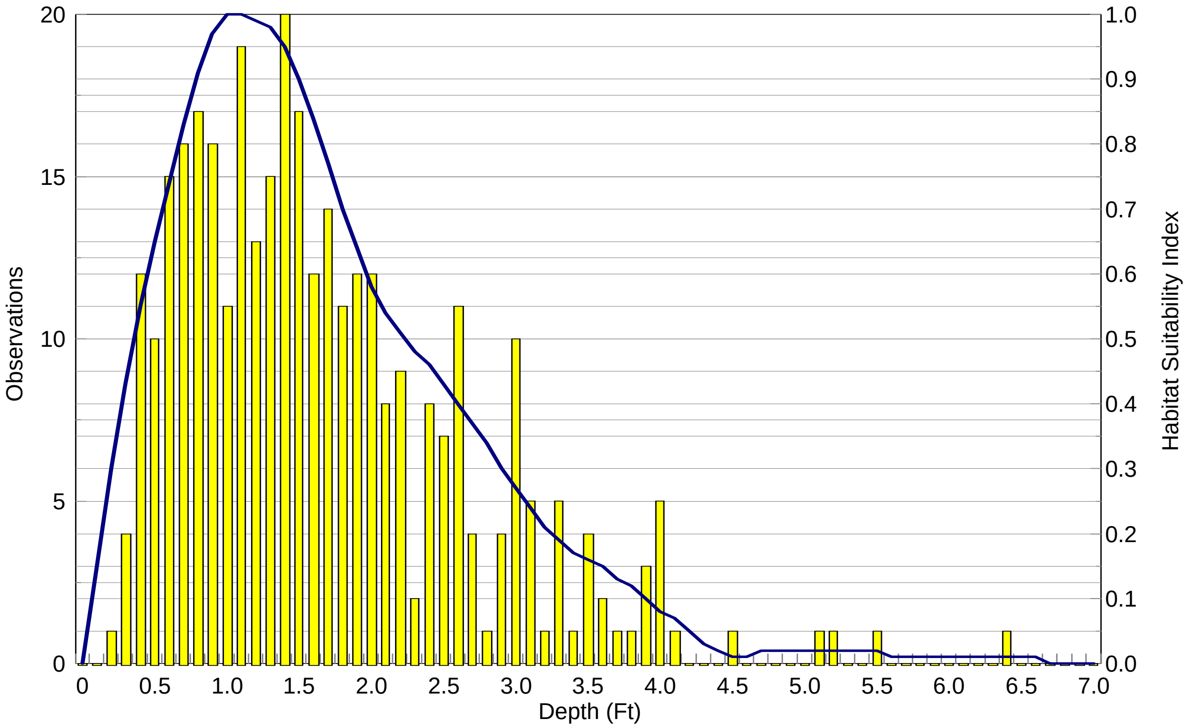
Table 5.1. Summary of the total fish numbers used for criteria curve development collected in the Trinity River above the North Fork Trinity River, 1985-1992.

Species	Life Stage	Number of Observations
Chinook Salmon	Fry	345
	Juvenile	251
	Spawning	311
Coho Salmon	Fry	131
	Juvenile	82
	Spawning	107
Steelhead/Rainbow Trout	Fry	80
	Juvenile	185
	Adult Holding	44
	Spawning	88
	Over-Wintering	97
Total		1,721

those used by salmon fry and the water velocities were significantly higher (Figure 5.10). Steelhead fry were rarely observed in monotypic mesohabitats such as long, slow runs or pools.

Juvenile steelhead preferred run, riffle, and riffle-pool transition habitats that provided diverse velocity conditions. They showed a distinct preference for higher water velocities than did juvenile salmon (Figure 5.11) and were efficient in their use of velocity shelters. In riffles and across the tail end of run habitats, steelhead used boulders and large cobbles to establish feeding stations that they actively defended. When found in riffle-pool transition habitats, juvenile steelhead were usually positioned below the ledge located at the upper boundary of the pool. Here the fish were sheltered from the swifter surface current, which conveyed invertebrate drift from the riffle upstream. Microhabitats selected by steelhead juveniles during the winter season had slower water velocities than those used in other seasons (Figure 5.12) and were characterized by clean cobble substrates. Overwintering steelhead juveniles were reclusive and most often found underneath cobbles or boulders (Figure 5.13).

Observations were made for both spawning and holding adult steelhead. The range of depths at which redds were constructed was relatively narrow and generally shallower than for the salmon species— although preferred velocities were much the same as for coho salmon (Figure 5.14). Spawning steelhead preferred gravel from 1 to 3 inches in diameter that was less than 20 percent embedded in fines (Figure 5.15). It is obvious from the depth distribution for the 44 holding steelhead adults observed that this life stage is very flexible in its depth requirements. Adult steelhead were found holding in water from 1.5 to 10 feet deep with preferred holding water velocities ranging from 1.0 to 2.5 fps (Figure 5.16).



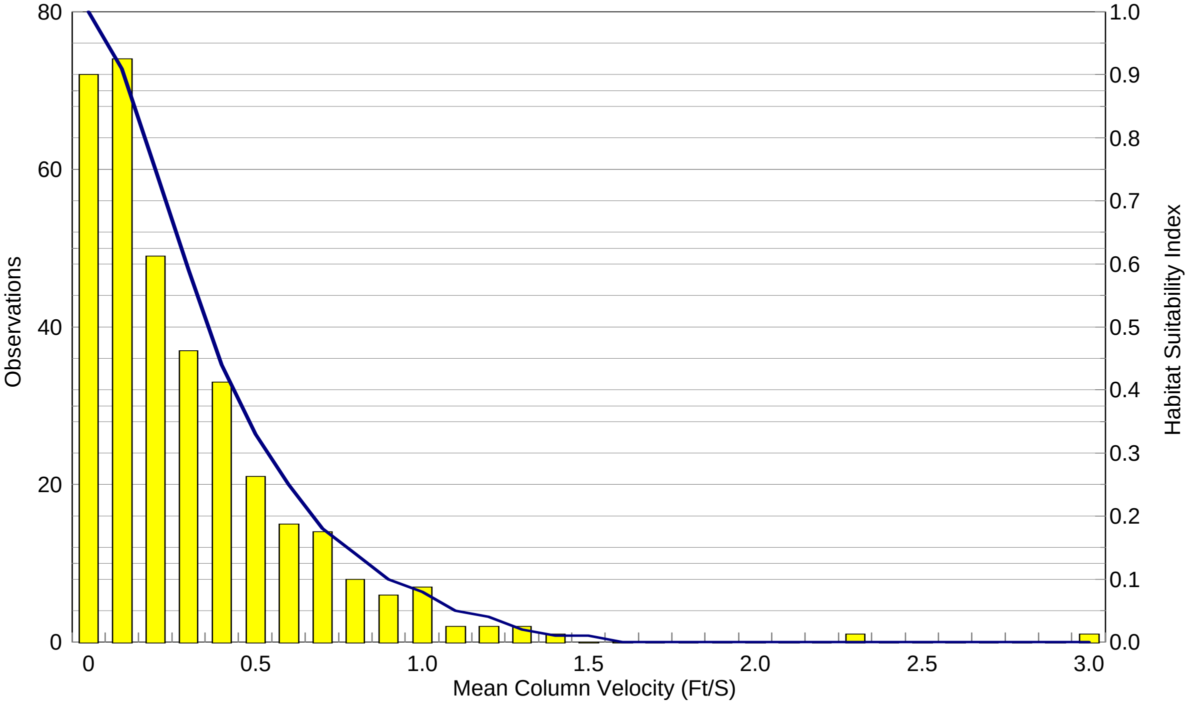
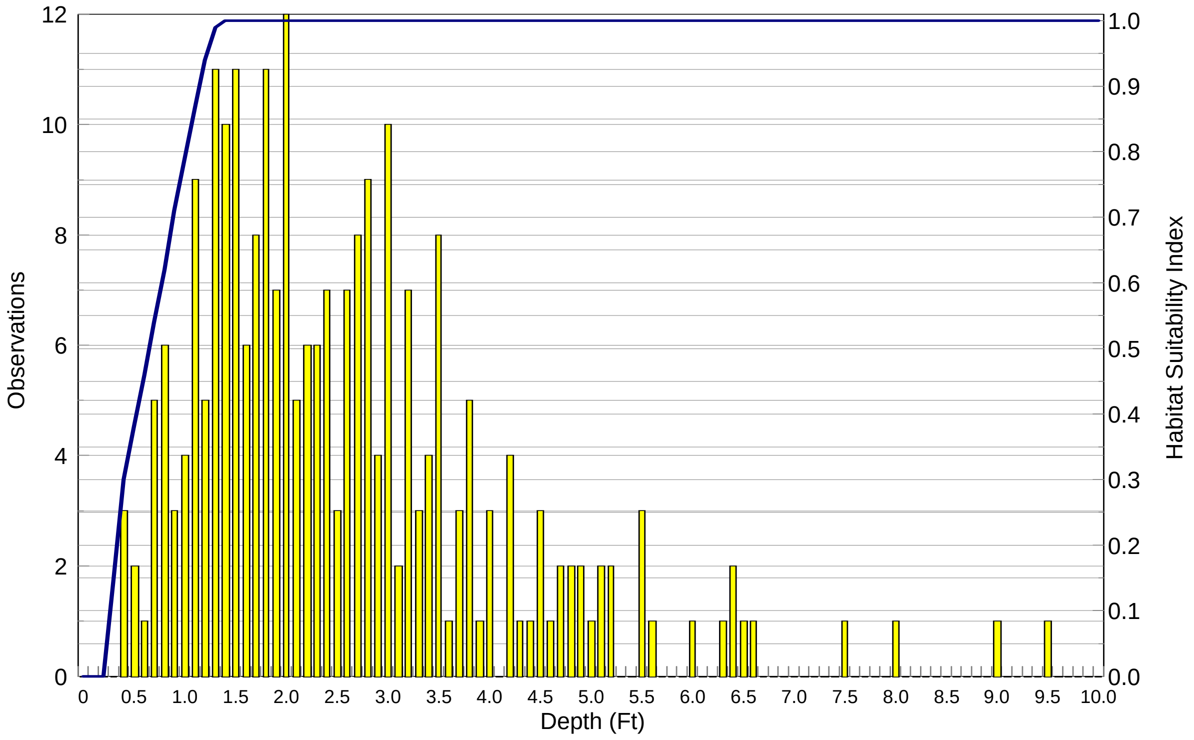


Figure 5.2. Chinook salmon fry observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=345).



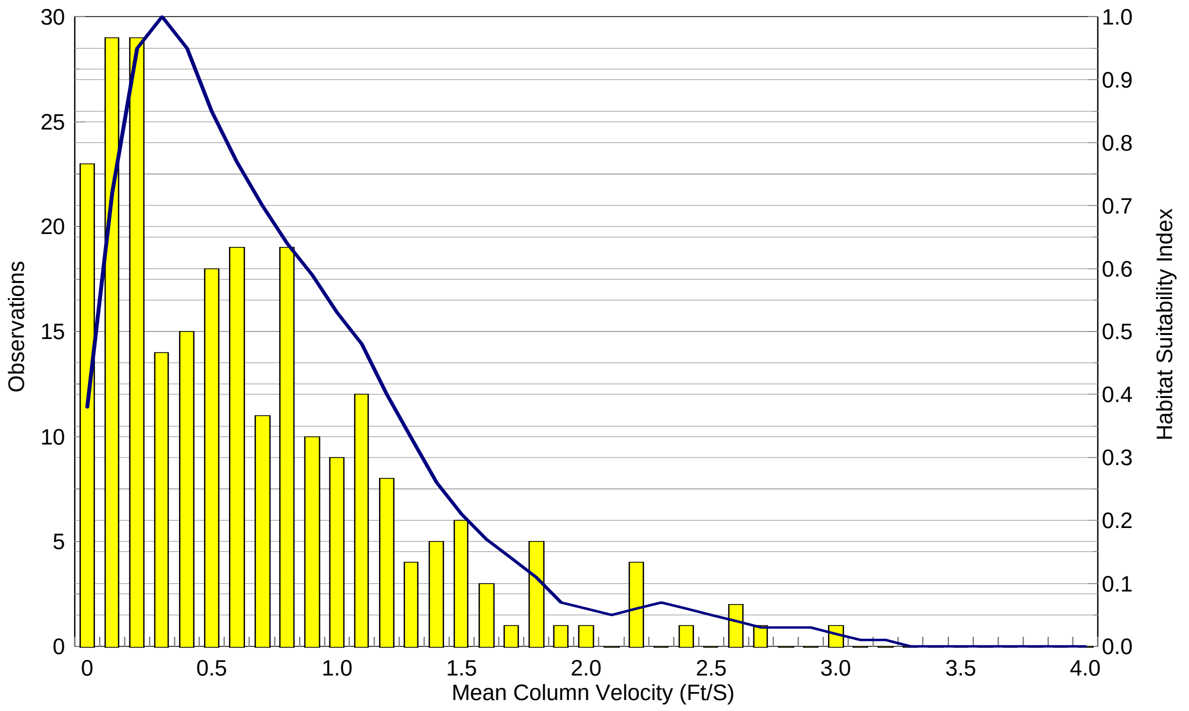
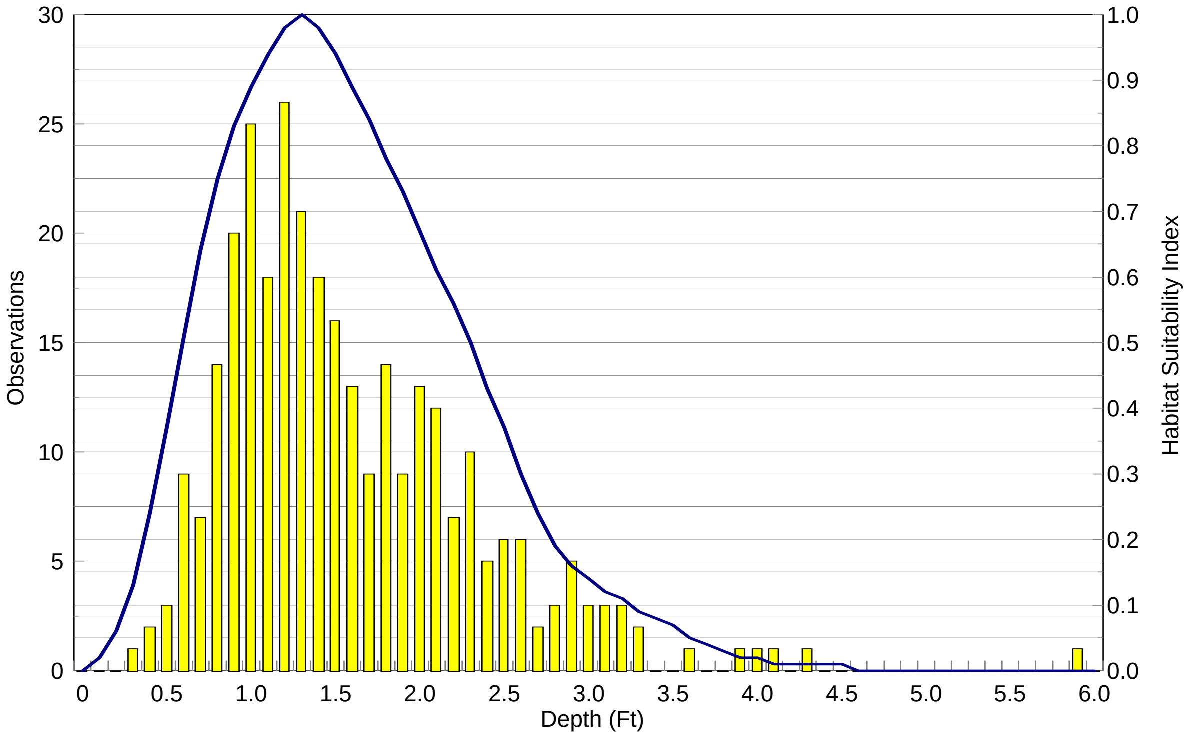


Figure 5.3. Chinook salmon juvenile observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=251).



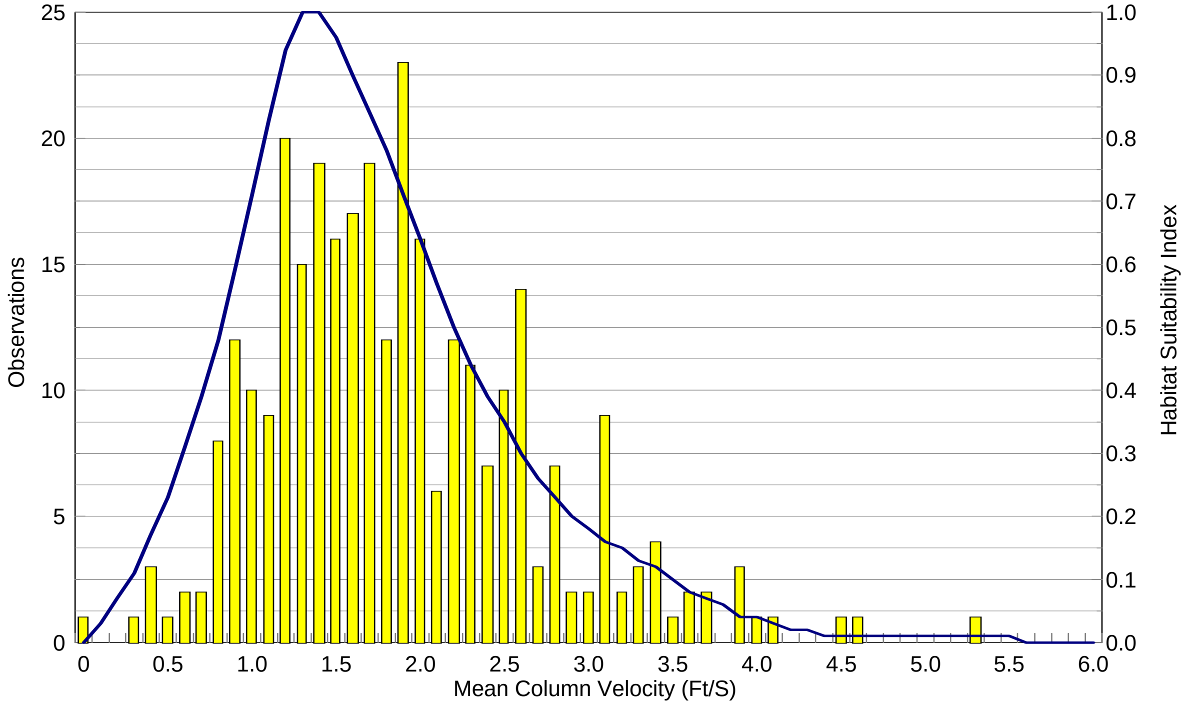


Figure 5.4. Chinook salmon spawning observations (yellow bars) and final water depth and velocity habitat suitability curves (lines), Trinity River, CA. (n=311).

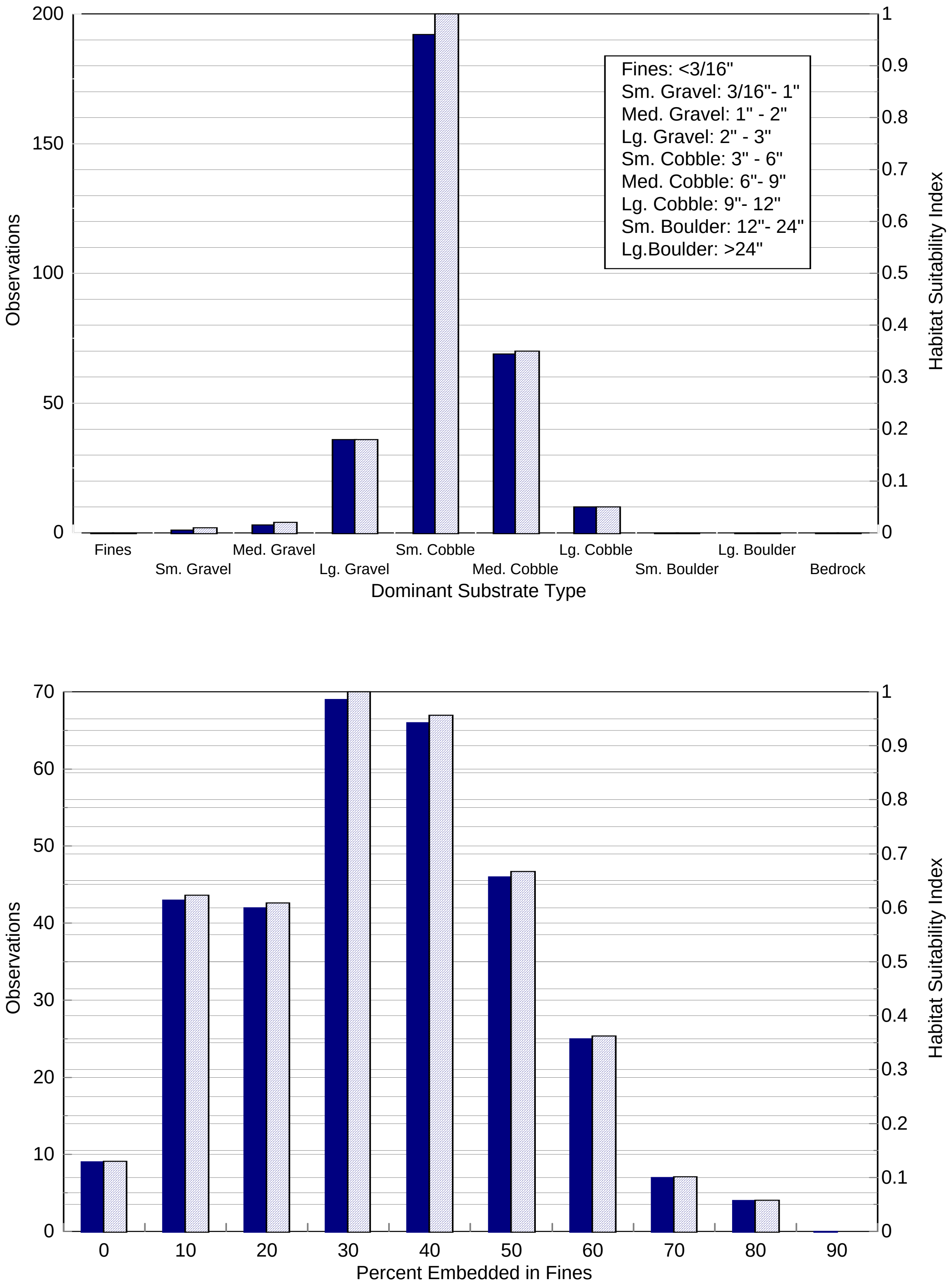


Figure 5.5. Chinook salmon dominant spawning substrate and percent embeddedness observations (blue bars) and final habitat suitability indexes (gray bars), Trinity River, CA.

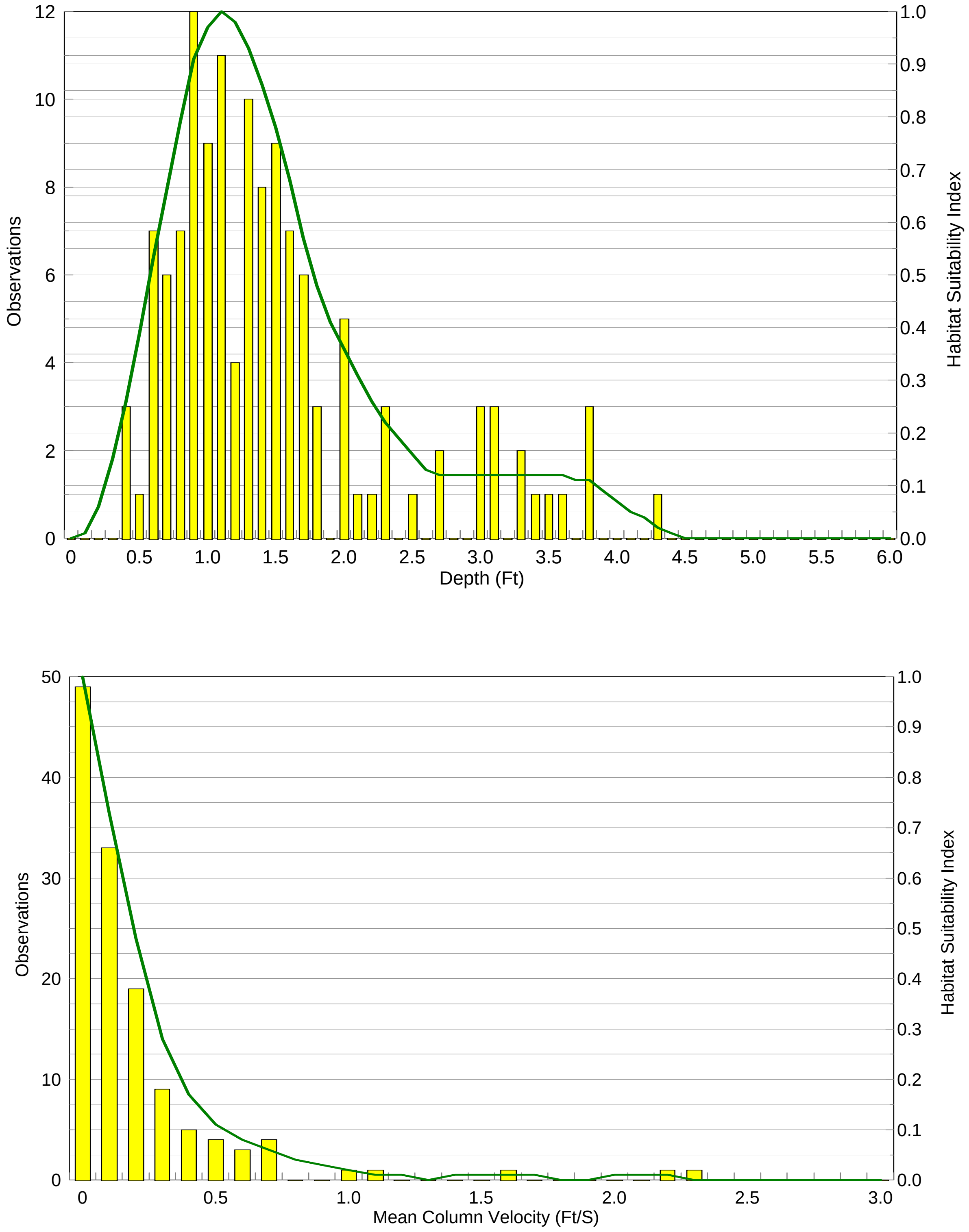
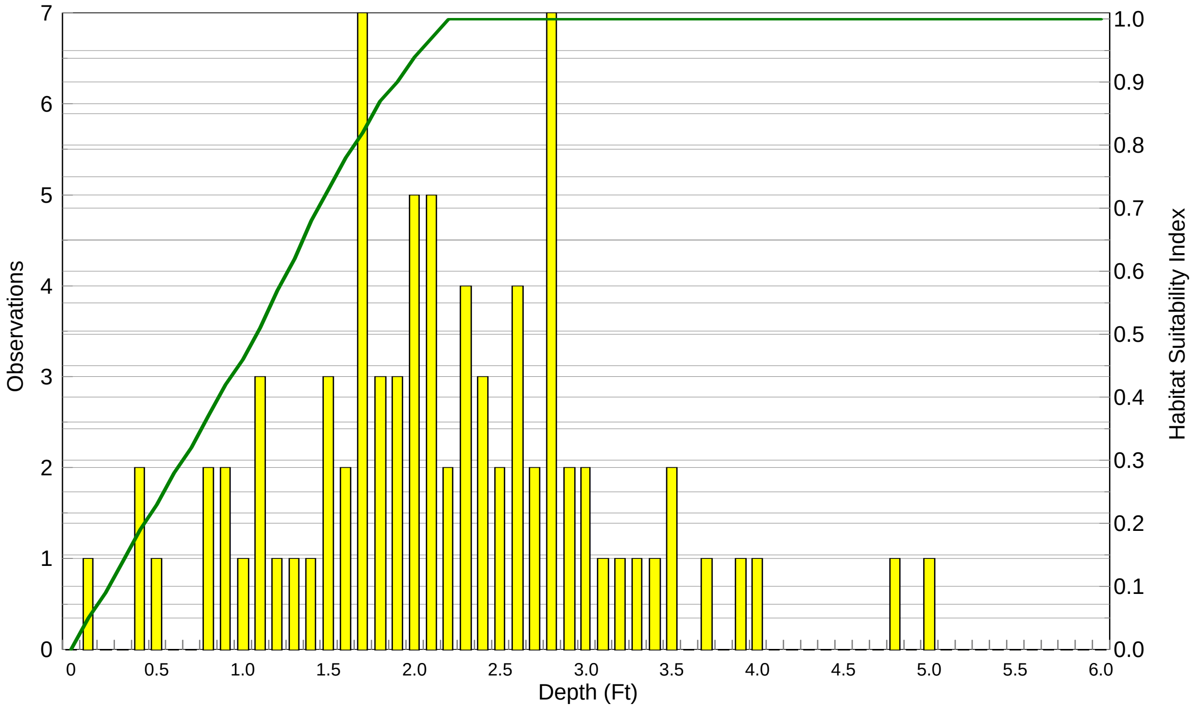


Figure 5.6. Coho salmon fry observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=131).



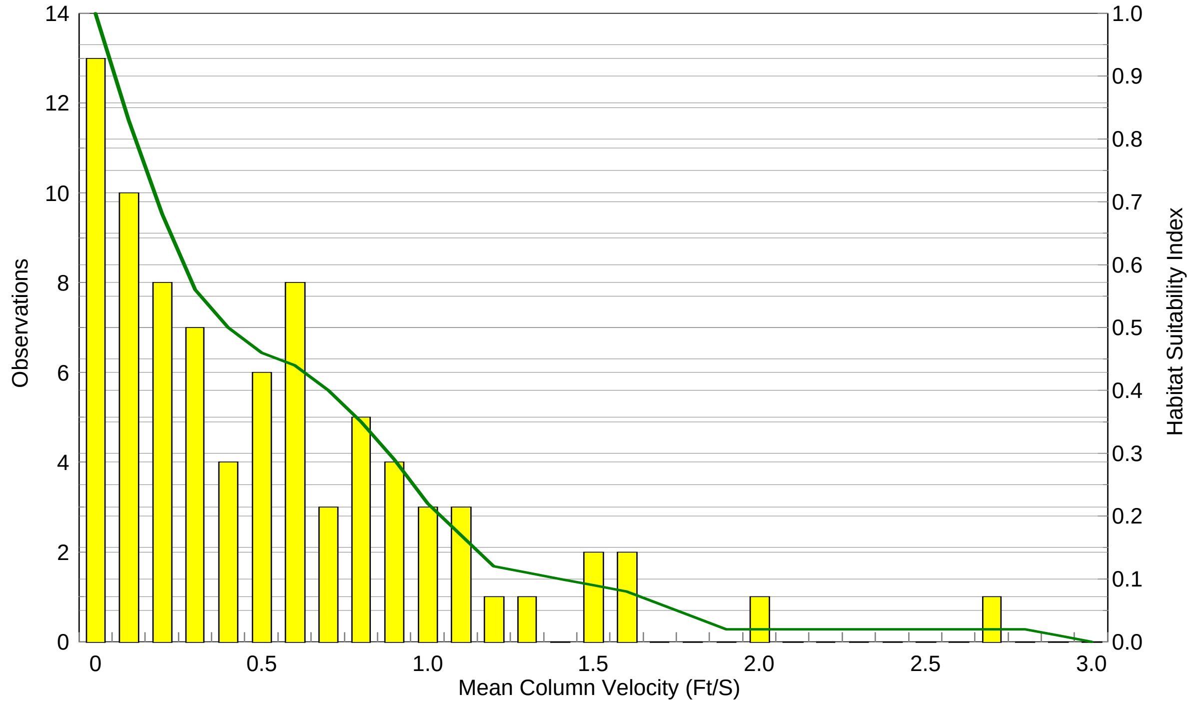
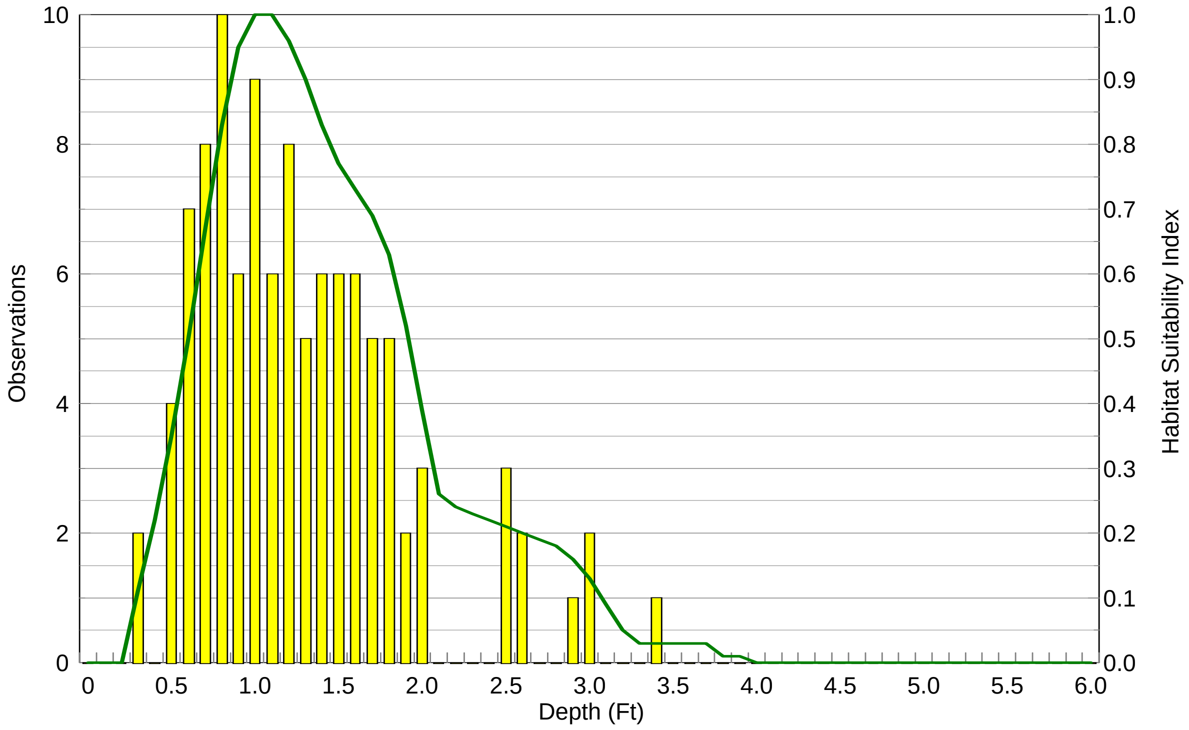


Figure 5.7. Coho salmon juvenile observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=82).



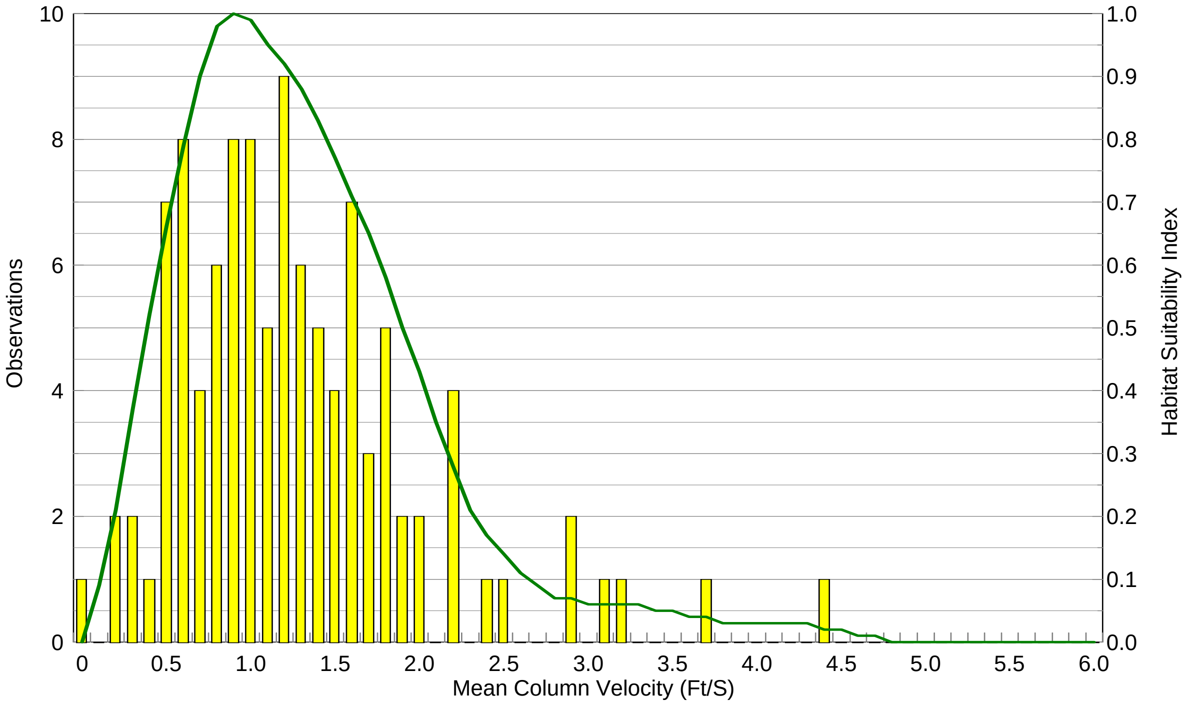
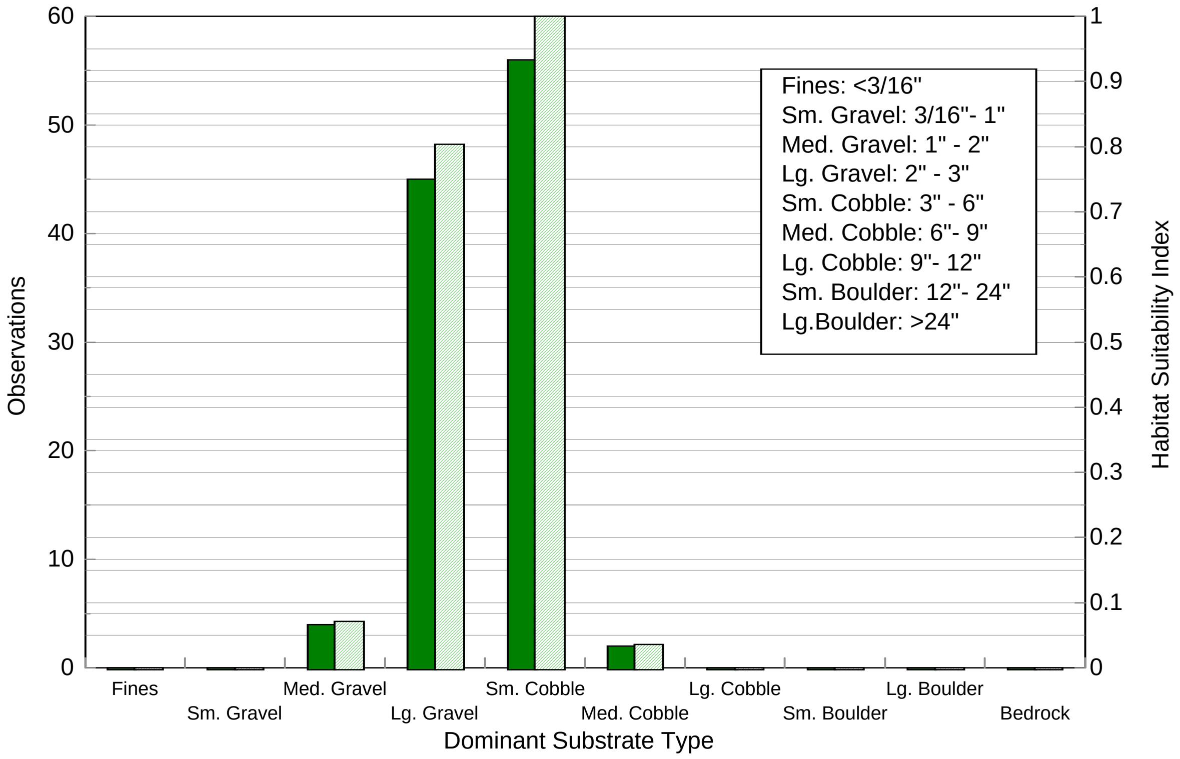


Figure 5.8. Coho salmon spawning observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=107).



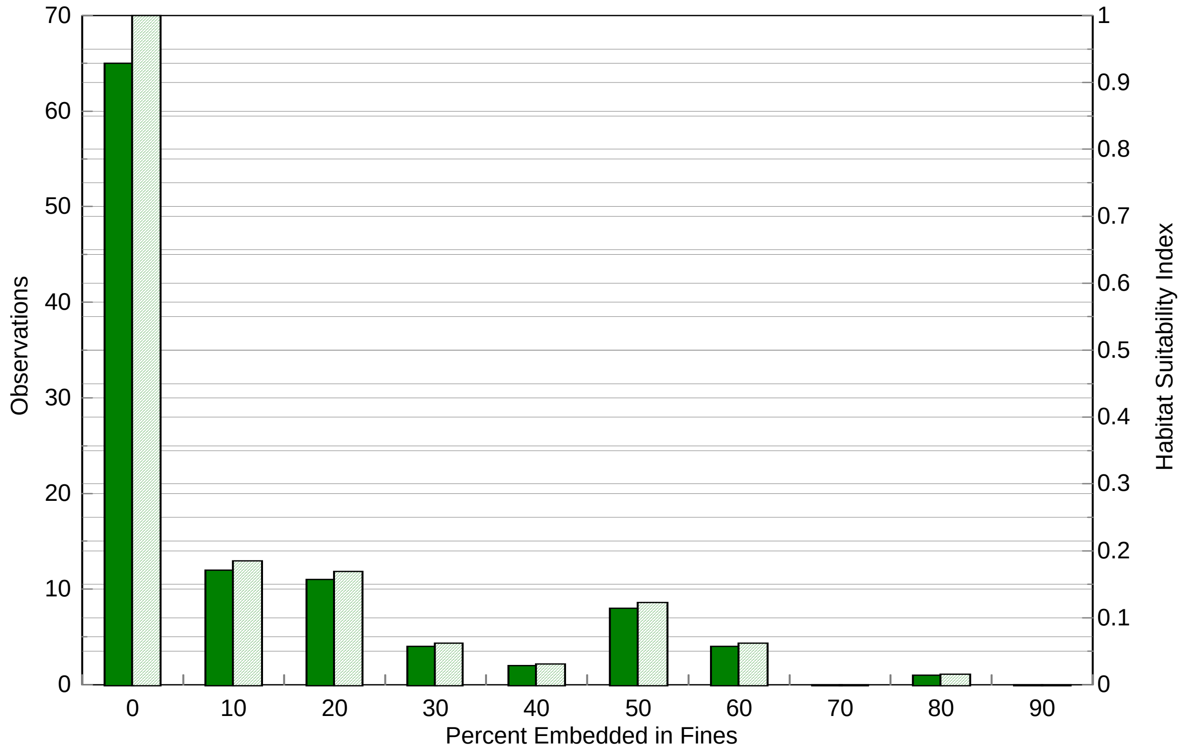
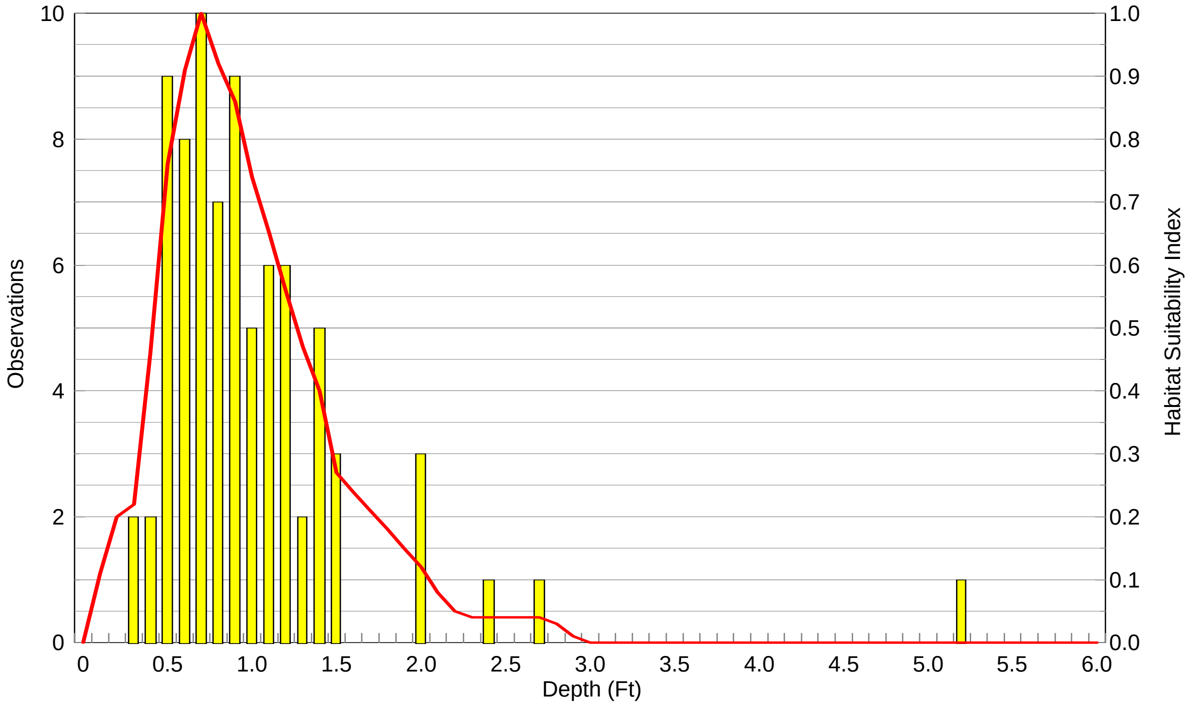


Figure 5.9. Coho salmon dominant spawning substrate and percent embeddedness observations (green bars) and final habitat suitability indexes (gray bars), Trinity River, CA. (n=107).



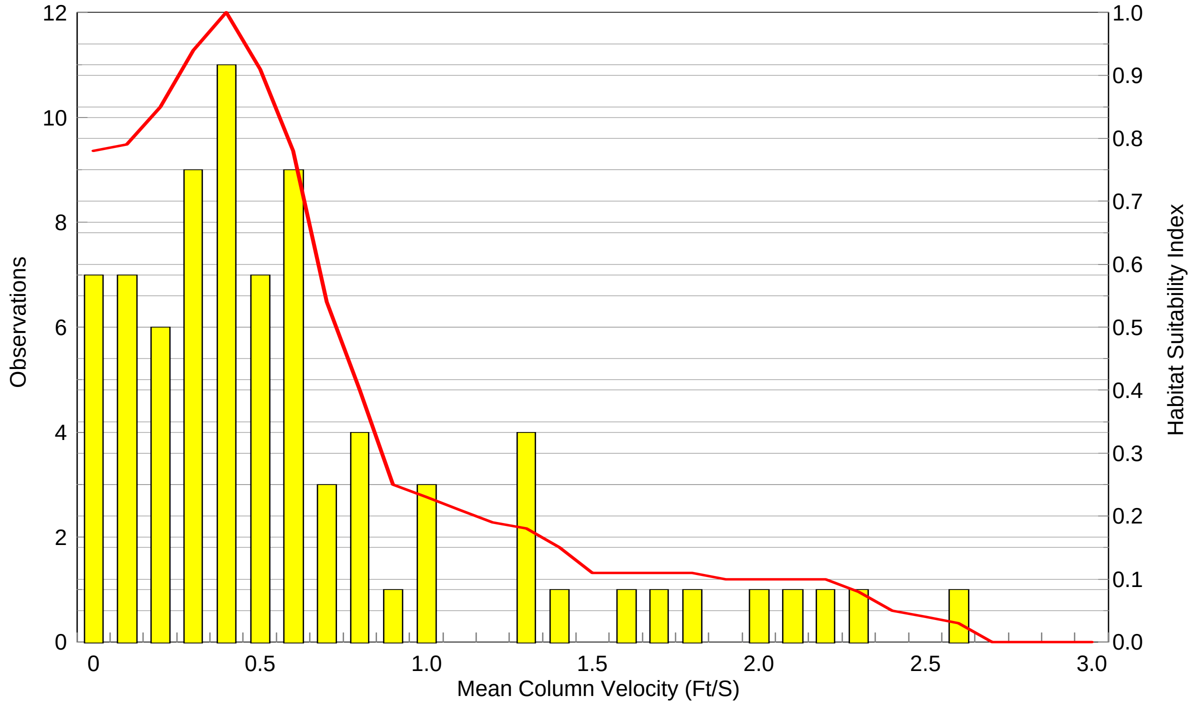
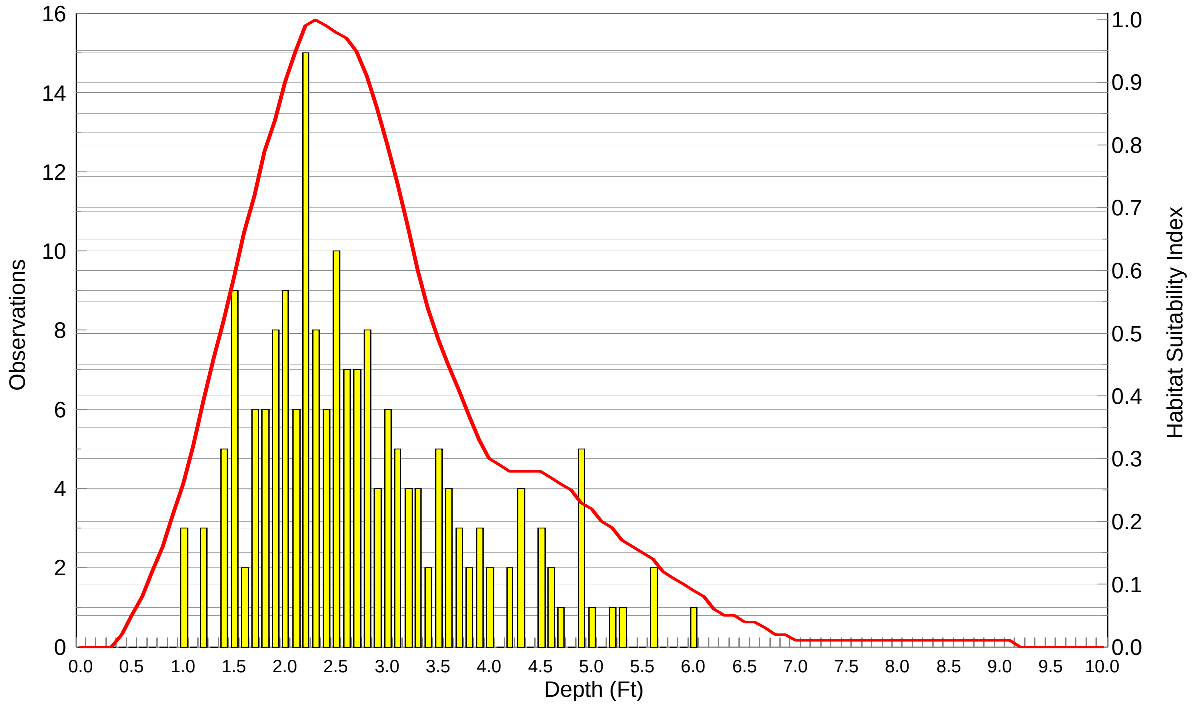


Figure 5.10. Steelhead fry observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=80).



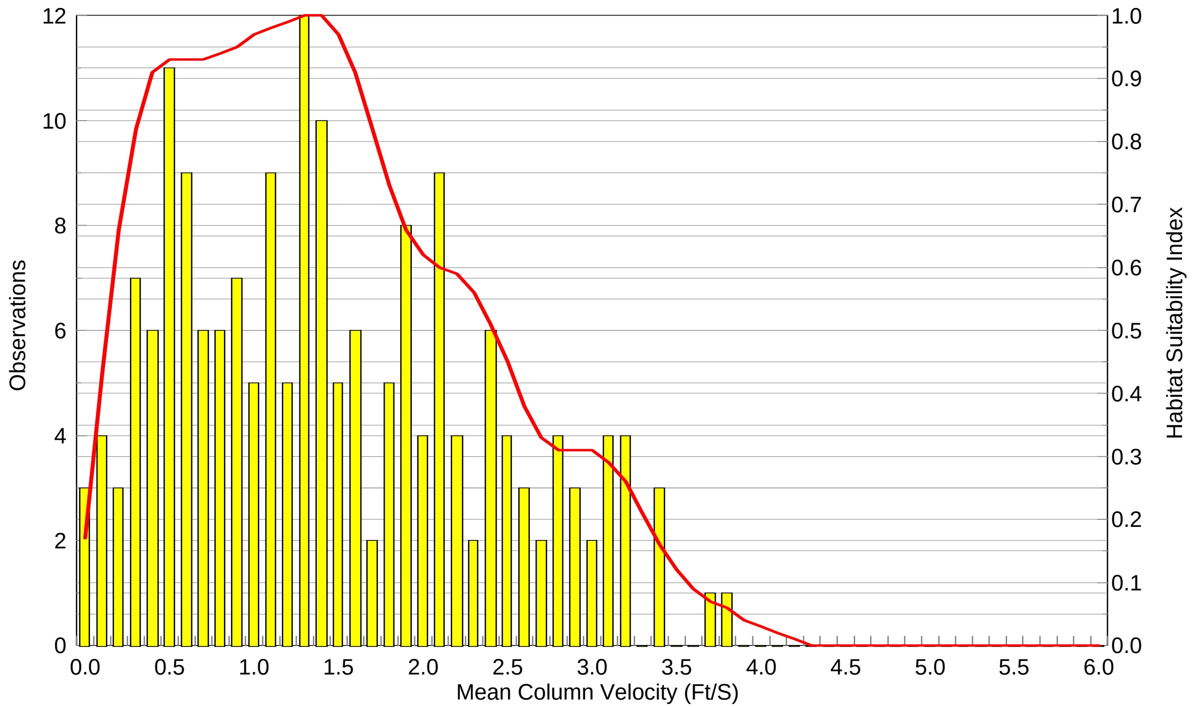
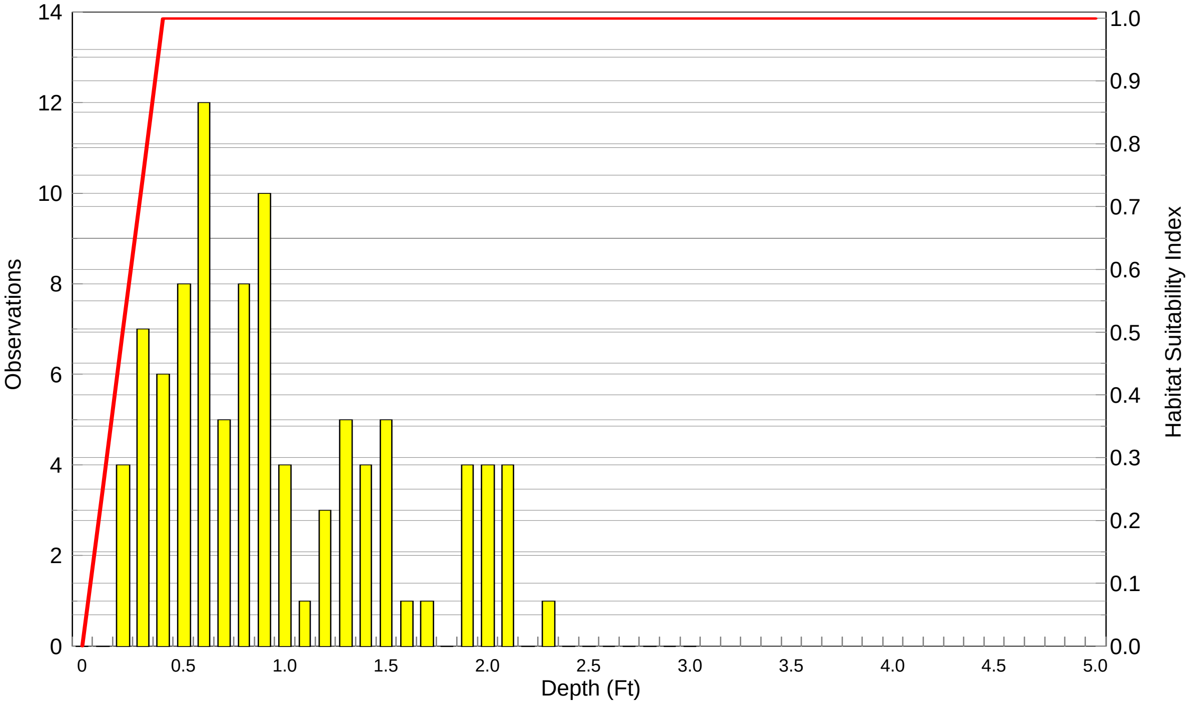


Figure 5.11. Steelhead juvenile observations (yellow bars) and final water depth and velocity habitat suitability curves (line), Trinity River, CA. (n=185).



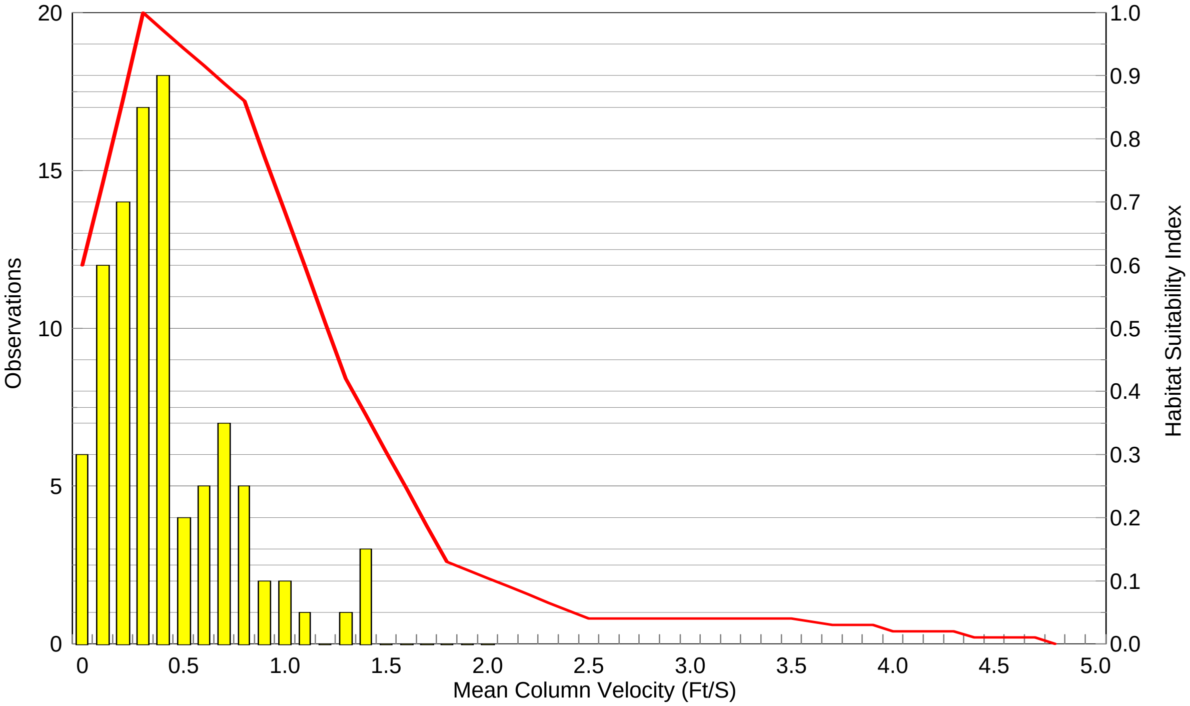


Figure 5.12. Juvenile steelhead overwintering observations (yellow bars) and final water depth and velocity habitat suitability curves (lines), Trinity River, CA. (n=97).

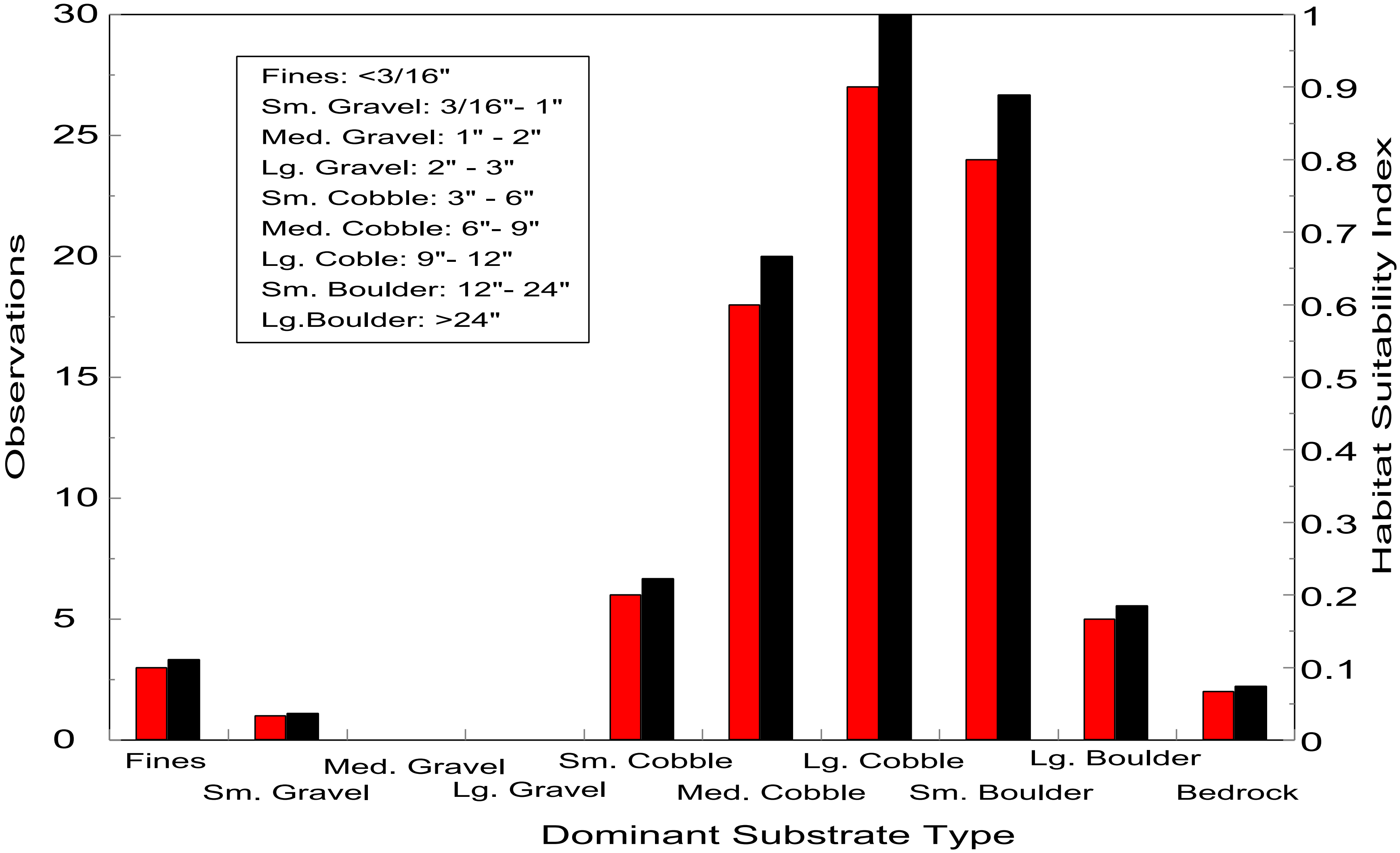
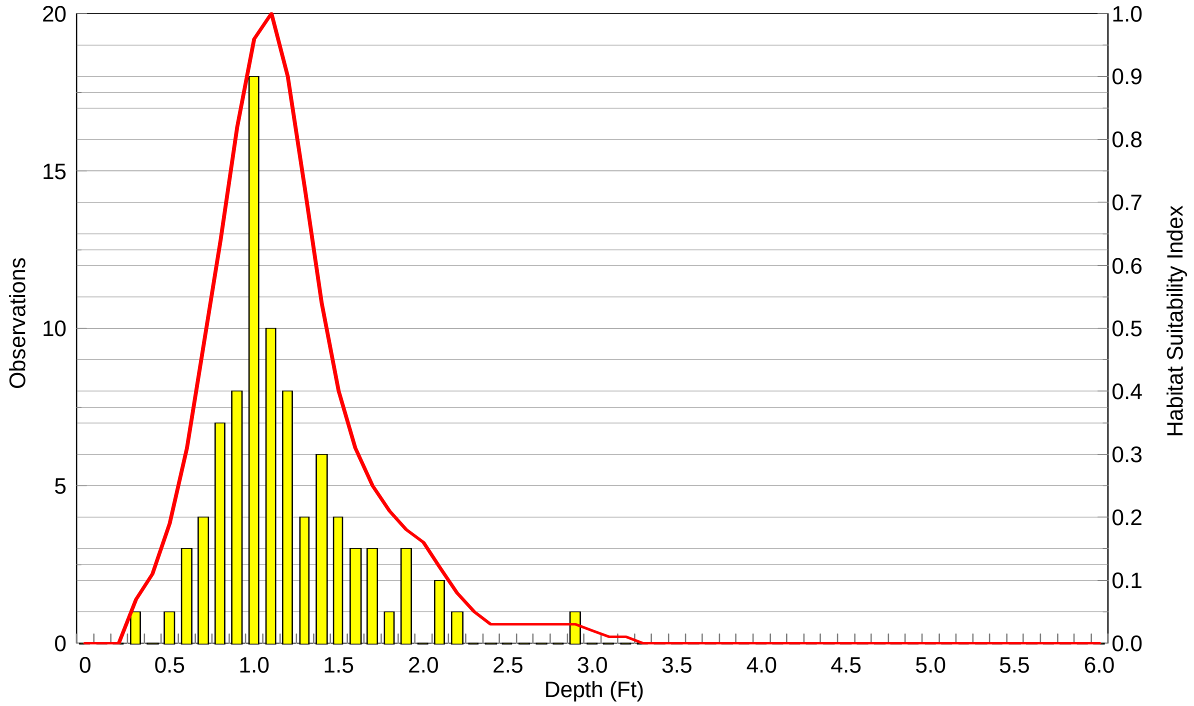


Figure 5.13. Juvenile steelhead overwinter dominant substrate type observation (red bars) and final habitat suitability indexes (black bars), Trinity River, CA. (n=97).



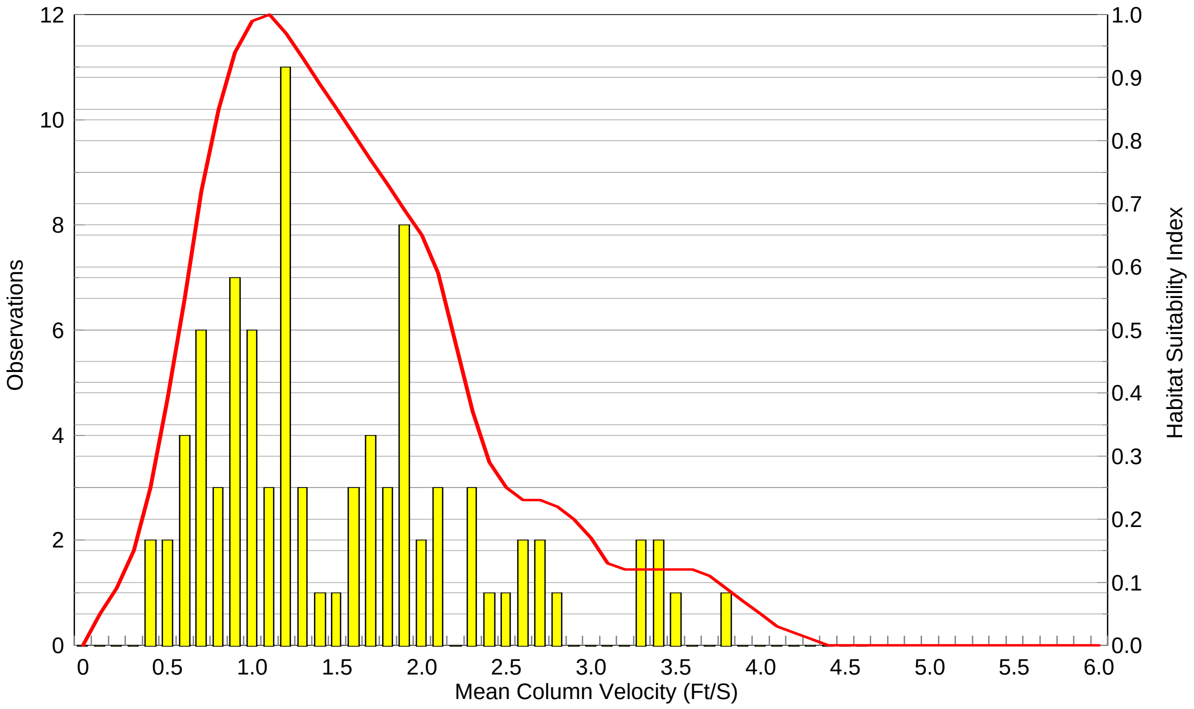
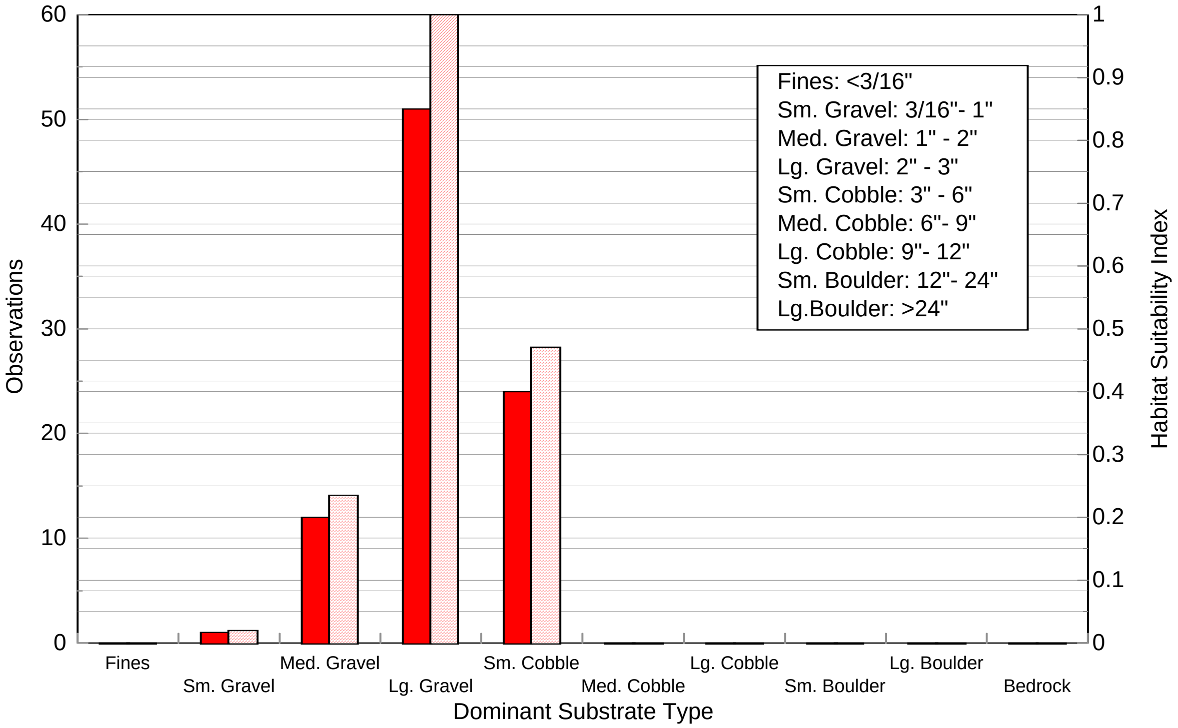


Figure 5.14. Steelhead spawning observations (yellow bars) and final water depth and velocity habitat suitability curves (lines), Trinity River, CA. (n=88).



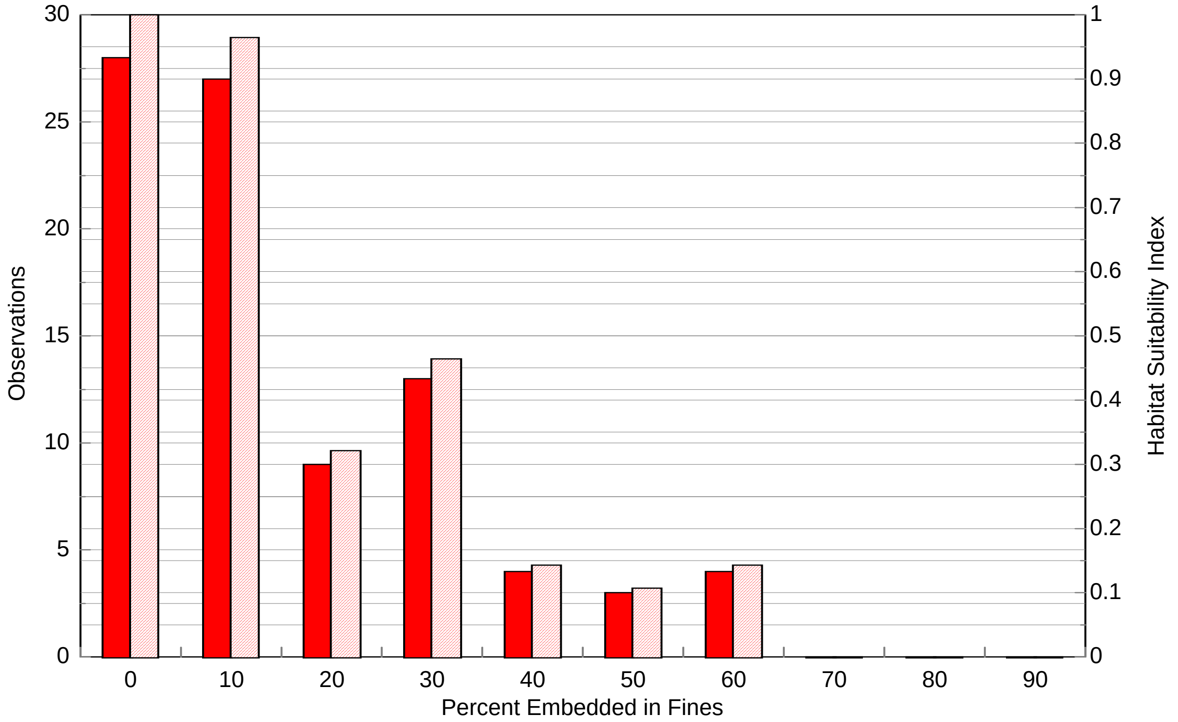
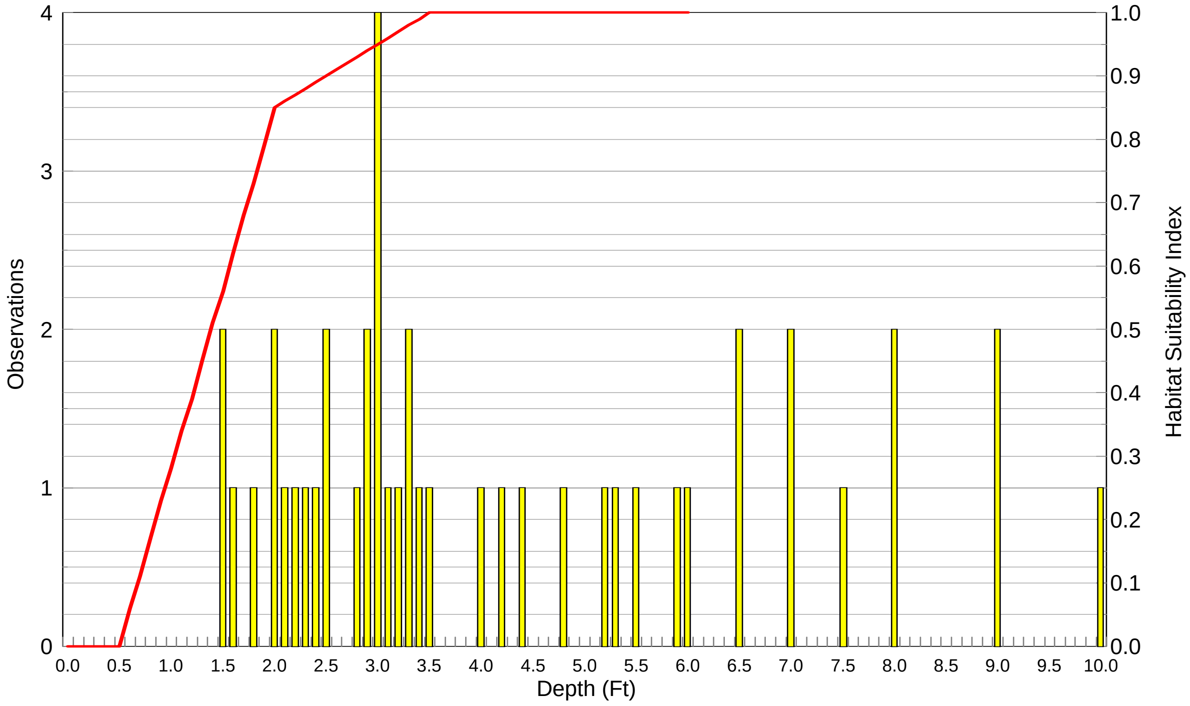


Figure 5.15. Steelhead dominant spawning substrate and percent embeddedness observations (red bars) and final habitat suitability indexes (gray bars), Trinity River, CA. (n=88).



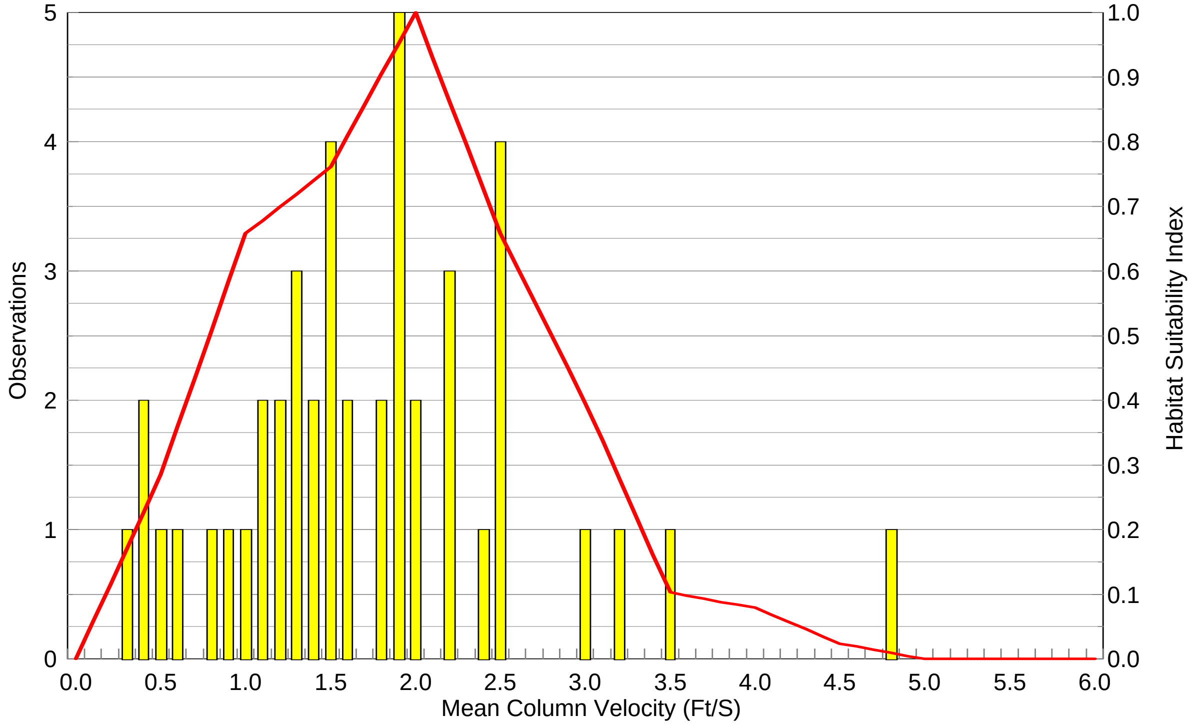


Figure 5.16. Observations of adult steelhead holding (yellow bars) and final water depth and velocity habitat suitability curves (lines), Trinity River, CA. (n=44).

Chinook salmon, coho salmon, and steelhead generally constructed redds in areas with depths ranging from 0.5 to 2.5 feet and velocities ranging from 0.5 to 2.5 feet per second, although each has slightly different preferred depths and velocities. Chinook salmon selected gravel substrates for constructing redds ranging from 2 to 6 inches that were less than 40% embedded in sand, while coho salmon and steelhead selected substrates ranging from 1 to 3 inches and less than 20% embedded in sand.

Criteria Development

The development of the habitat suitability curves went through several iterations during the course of the TRFE. Complications were encountered with the original plan to derive preference curves by the ratio of use to availability. Problems, mostly related to small sample sizes at the tails of the distributions, resulted in preference curves for some species and life stages that were unduly influenced by the habitat selection of only a few individuals within the sampled population. Many of these curves showed highly unusual suitability values that seriously contradicted most of the use observations.

The concern generated over the use of forage ratios to derive preference criteria was reflective of the debate on this issue that was occurring at the time within the instream flow modeling community (Morhardt and Hanson, 1988). A validation study was undertaken to determine if a relation existed between juvenile chinook salmon use of discrete river areas (cells) and cell suitability as defined by the preference criteria. The methods employed and the results of this study are reported in the 1989 Annual Report (USFWS, 1989). Findings indicated that there was poor correlation between juvenile salmon density and habitat suitability. These findings led to the decision to test criteria developed from only utilization data. A second validation study was undertaken in 1991 using the habitat utilization curves developed to determine cell suitability. This study, the methods and results of which are reported in the 1991 Annual Report (USFWS, 1991), found a positive correlation between juvenile chinook salmon density and habitat suitability.

On the basis of these findings, it was decided to use utilization criteria in the physical habitat analyses for the Trinity River. This decision is consistent with that reached by Bovee et al. (1998), who recommended, on the basis of results of curve transferability testing, that preference criteria developed using a forage ratio no longer be used in Physical Habitat Simulation (PHABSIM) applications. Utilization data alone, with the exceptions noted below, were used to develop the final habitat suitability criteria for evaluation of anadromous salmonid physical habitat availability.

The exceptions to stand-alone utilization as final criteria were for depth for juvenile chinook and coho salmon, overwintering juvenile steelhead, and holding adult steelhead. For these curves, depth was retained at a 1.0 suitability at all depths greater than that providing the initial 1.0 value, so that deep water pool habitats would not be eliminated as potential habitat areas. In contrast, the depth suitability for rearing juvenile steelhead was not altered because of the observed heavy use by this species/ life stage of shallow riffle and riffle-pool transition areas. Final depth and velocity criteria curves and the substrate criteria used for spawning salmon, steelhead, and overwintering juvenile steelhead are presented in Figures 5.2 to 5.16.

5.1.1.4 Conclusions

Habitat suitability criteria curves were developed for the Trinity River anadromous salmonids and were used in all analyses of physical habitat availability for the anadromous salmonids that spawn and rear in the Trinity River.

These HSC curves were considered acceptable and were used in all analyses of physical habitat availability for the anadromous salmonids that spawn and rear in the Trinity River. Although HSC curves were derived from data collected in the mainstem above the North Fork Trinity River confluence, these curves were considered acceptable for use in estimating habitat availability in all sections of the Trinity River. Some effects of the bias of habitat availability on the utilization data probably remain in the final criteria curves owing to the original study design, but retention of the use data in its unadjusted form (with the exceptions noted above) was believed to be better than accepting the unsatisfactory results obtained using the forage ratio method. The results of the 1989 and 1991 criteria validation studies support this conclusion.

5.1.2 Habitat Availability

Physical Habitat Simulation (PHABSIM) was used to estimate the amount of physical habitat available at varying flows for each anadromous salmonid species and life stage.

Identified in the initial TRFE study design was the need to conduct a habitat availability study to determine (1) the amount of salmon and steelhead habitat available in the Trinity River downstream from Lewiston Dam under various flow conditions, and (2) the various levels of habitat rehabilitation that may be achieved either through the Trinity River Basin Fish and Wildlife Management Program or through other resource management actions (Appendix I).

Basic theoretical concepts for the study followed those developed for the PHABSIM component of the Instream Flow Incremental Methodology (Bovee, 1982). PHABSIM is based on a linkage between hydraulic and habitat data obtained from stations (cells) measured across representative stream cross sections (transects), and HSC for hydraulic (depth and velocity) and habitat (substrate and cover) variables. Numerous computer models have been developed as part of PHABSIM, which is described by Milhous et al. (1984). Hydraulic simulations to predict unmeasured flow conditions from measured calibration flow data are optionally part of PHABSIM, as is empirical analysis that computes habitat availability only for the measured flows. Both hydraulic simulation and direct computational analysis were used in this assessment, depending on data availability and inherent limitations of the hydraulic models. A customized computer model was written to calculate habitat availability for all direct computation analyses (Hamilton, 1987). Output of either analysis is in the form of a physical habitat availability index called weighted usable area (WUA). WUA at a given streamflow is the sum of all cell areas in a grid of cells representing the stream, with each cell area weighted by a composite suitability (between 0 and 1.0) for depth, velocity, and substrate or cover at that flow. WUA is displayed graphically in this report for ease of interpretation.

Much of the following information has been previously reported in Annual Reports (USFWS, 1985-91) and in three additional reports prepared by the Service (Gard, 1996, 1997; Hampton, 1997). These reports provide much greater detail than is presented here. This section will summarize the methods employed and the analyses conducted to quantify the amount of physical habitat available for anadromous salmonids in the Trinity River downstream from Lewiston Dam under various flow conditions.

5.1.2.1 Study Sites

Fourteen study sites for physical habitat availability analyses were selected within three major river segments between Lewiston Dam and the confluence of the Trinity and Klamath Rivers at Weitchpec, a distance of approximately 112 river miles (Table 5.2, Figure 5.1). The segments separate the Trinity River by significant changes in hydrology and overall character from Lewiston Dam to the North Fork Trinity River (40 miles), the North Fork to the South Fork (40 miles), and the South Fork to the Klamath River confluence (30 miles). The sites were chosen as being representative of each segment. Nine study sites were placed in the upper segment (Segment I) where the majority of spawning activity for all three anadromous salmonid species occurs, and which, consequently, is also a critical reach for rearing fry; two sites were in the middle segment (Segment II); and three sites were placed in the lower segment (Segment III). Subsequently, two of these sites were eliminated. The Indian Creek site in Segment I had unstable channel conditions owing to copious gravel input from Indian Creek (the Steel Bridge site was used to represent habitat in this area), and the Camp Kimtu site was eliminated following a decision that the Tish-Tang site adequately represented the upper portion of Segment III. In the remaining 12 sites, 127 transects were placed (Table 5.2). Detailed study-site maps are presented in the 1987 Annual Report (USFWS, 1987).

5.1.2.2 Methods for Habitat Availability

The "representative reach" approach, the most common approach for conducting riverine habitat analyses using PHABSIM in the early 1980's, was initially chosen as the method by which physical habitat availability would be quantified on the Trinity River. Using this approach, study sites are considered to be representative of larger sections (reaches) of the river, and transects placed in those sites represent the variable physical conditions within the site and, thus, the reach. The habitat/streamflow functions (WUA) derived at each representative study site are considered valid for the entire reach. After extensive scoping and on-the-river reconnaissance of the Trinity River, study reaches were identified, study sites were selected, and transects were placed at these sites.

In the mid-1980's an alternative method for representing instream habitat known as habitat mapping was developed (Morhardt et al., 1983). Using this method, the major habitat types (e.g., riffle, run, deep pool) within a study reach are identified and the linear distance represented by each is determined. Transects are placed in each of these habitat types (usually with replicates) so as to fully represent the range of physical conditions present. Separate WUA functions are derived for each identified habitat type, and a total WUA function is calculated for the reach when the representative distances are considered. A comparison was run using both the representative reach and the habitat-mapping approach on the approximate 26-mile reach from Lewiston Dam to Dutch Creek. The results of this comparison showed little difference between the two methods in calculating total WUA (USFWS, 1989). The results using habitat mapping were used for this segment of the upper reach (hereafter referred to as "Segment IA"), and representative reach results were retained for the remainder of the river. The remainder of Segment I (hereafter referred to as "Segment IB") constituted the reach from Dutch Creek to the North Fork Trinity River.

Output from PHABSIM modeling is a physical habitat availability index called weighted usable area.

Field-data collection methods generally followed those prescribed by Trihey and Wegner (1981) and are described in detail in the 1986 Annual Report (USFWS, 1986). In the first year of the study (1985), the intent was to evaluate releases from Lewiston Dam of 300, 450, and 600 cfs. Measurements were made at 300 and 450 cfs to obtain hydraulic (depth and velocity) data at all transects and study sites. However, because of dry-year conditions (defined

Table 5.2. Representative study reaches, Trinity River Flow Evaluation Study, 1985.

	River Segment	Study Reach	Description	No. Transects
IA	Upper	Lewiston Dam	Lewiston Dam to Old Fish Weir	19
		Cemetery	Old Fish Weir to Rush Creek	13
		Bucktail	Rush Creek to Grass Valley Creek	11
		Poker Bar	Grass Valley Creek to Limekiln Gulch	10
		Steel Bridge	Limekiln Gulch to Indian Creek	12
		Indian Creek	Indian Creek to Douglas City	0
		Steiner Flat	Douglas City to Dutch Creek	10
IB	Upper	Oregon Gulch	Dutch Creek to Canyon Creek	9
		Junction City	Canyon Creek to North Fork Trinity	9
II	Middle	Del Loma	North Fork Trinity to Cedar Flat	11
		Hawkins Bar	Cedar Flat to South Fork Trinity	8
III	Lower	Camp Kimtu	South Fork Trinity to Horse Linto Creek	0
		Tish-Tang	Horse Linto Creek to Hoopa Valley	9
		Hoopa Valley	Hoopa Valley to Weitchpec	6

by water-supply criteria), water was unavailable for the 600-cfs release. A wetter year followed and measurements were taken at 800 cfs in 1986.

During the 1986 field season it was obvious that some significant morphological changes had occurred within the river channel at sites below Segment IA in Segments IB, II, and III. These changes were the result of some major flood events in February and March of that year. The most significant changes occurred downstream from Canyon Creek and the North Fork and South Fork Trinity Rivers. It was apparent that streamflows below the North Fork Trinity River were influenced to such an extent by unregulated tributary accretion that management objectives dependent on controlled releases from the TRD would be difficult to achieve. Therefore, after 1987, data collection was focused on the upper river (Segment IA) between Lewiston Dam and Dutch Creek. Enough additional data, however, were collected in the lower river segments to complete hydraulic and habitat modeling in these reaches.

Several successive dry years occurred after 1986, and releases from Lewiston Dam did not vary significantly from those at which data had already been gathered. It was not until 1989 that a release of sufficient magnitude (2,000 cfs) occurred at which data could be collected to expand the capability to estimate habitat availability at higher flows. Very low flows were measured in 1990, a critically dry year, at the 5 sites in Segment IA when 150 cfs was released from the dam. High-flow releases for concurrent, related Trinity River studies of sediment transport and geomorphological processes enabled additional data collection in the later years of the TRFE. Partial data sets were obtained on most transects in Segment IA at flows of 1,500 and 3,000 cfs in 1993, and 4,500 and 6,000 cfs in 1995.

Data were compiled and data decks were constructed as the study progressed. Hydraulic modeling was done for each study site in every segment utilizing, at one time or another, all of the models available within PHABSIM (Gard, 1996, 1997). These reports provide complete hydraulic calibration details. The HABTAE modeling program was used to calculate WUA, combining hydraulic model output with the HSC previously described and presented as digitized indices in Gard (1996, 1997). The suitabilities for the velocity, depth, and substrate variables were combined using standard multiplicative defaults and cell offset averaging.

Physical habitat availability was calculated for the spawning, fry, and juvenile life stages of chinook salmon, coho salmon, and steelhead. In addition, WUA was computed for overwintering juvenile steelhead and holding adult steelhead. Depth and velocity HSC were used in computing WUA for adult steelhead holding and for the fry and juvenile life stages, except for overwintering juvenile steelhead. Substrate criteria were included for them, as well as for spawning for all three anadromous salmonid species. Cover or substrate criteria were not incorporated into WUA computations for the remaining life stages because of lack of observed habitat selectivity for these variables (USFWS, 1987). WUA for Segment IA (Lewiston Dam to Dutch Creek) was derived empirically using directly measured data. Computations were performed using a computer program developed by the Service (Hamilton, 1987). All WUA results for the segments downstream from Segment IA were derived using output from hydraulic simulation models.

Spawning and rearing habitat varied with stream discharge and species throughout all study reaches.

5.1.2.3 <u>Results for Habitat Availability</u>

<u>Lewiston Dam to Dutch Creek (Segment IA)</u>

Total WUA for spawning salmon and steelhead varied with discharge and species (Figure 5.17A). More physical habitat area was available for spawning chinook salmon than for either coho salmon or steelhead. Maximum habitat was available for all three species at flows between 150 and 350 cfs and decreased steadily as streamflow increased. Adult steelhead holding WUA increased rapidly between 150 and 450 cfs and moderately up to 800 cfs.

The WUA functions for salmon and steelhead fry were very similar to each other over the entire flow range (Figure 5.17B). Chinook salmon and steelhead habitats were available in nearly equal amounts, and these WUA values were consistently greater than values for coho salmon. Fry habitat for all species decreased sharply between 150 and 800 cfs, remained relatively stable to 1,500 cfs, and sharply increased as higher flows inundated the heavily vegetated areas behind the riparian berms and created low-velocity habitat.

The habitat–flow relations for juvenile coho salmon and chinook salmon were similar to those of fry and to each other over the entire range of flows (Figure 5.17C). WUA peaked at 150 cfs, decreased sharply up to a flow of 1,500 cfs, and then increased steadily up to 3,000 cfs. Unlike salmon fry, juvenile WUA was greater at flow levels below about 500 cfs than at flows between 2,000 and 3,000 cfs. Juvenile steelhead WUA peaked at 450 cfs, decreased sharply to 1,500 cfs, and was stable from

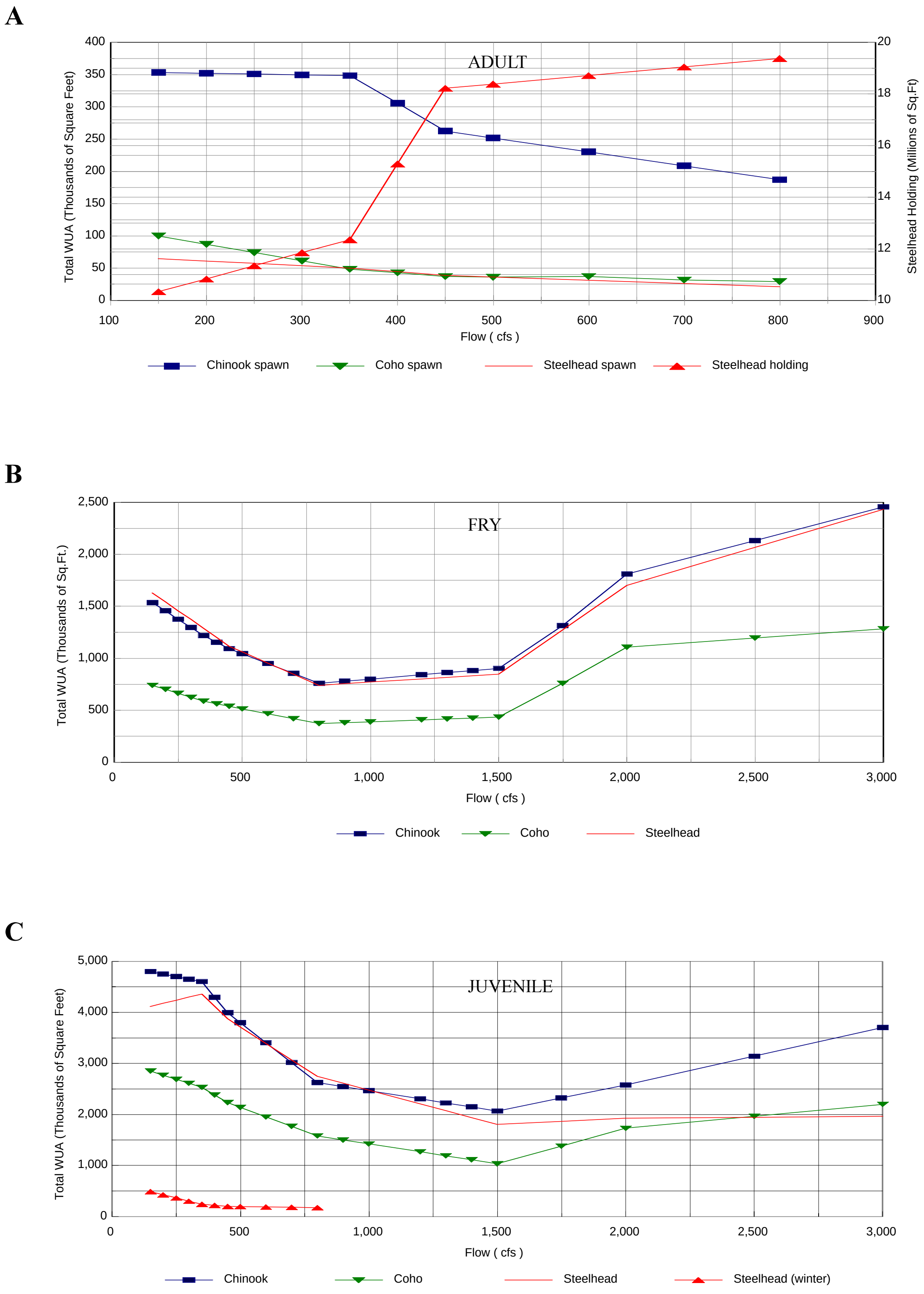


Figure 5.17. Physical habitat for adult (A), fry (B), and juvenile (C) chinook salmon, coho salmon, and steelhead as estimated through direct observation, in Segment IA. Values were derived through direct measurement at 150 cfs, 350 cfs, 450 cfs, 800 cfs, 1,500 cfs, 2,000 cfs, and 3,000 cfs. Habitat estimates between measured flows were interpolated.

1,500 to 3,000 cfs. Overwintering juvenile steelhead habitat values were greatest at the lowest flows measured (150 cfs).

Flow-habitat relations for the fry and juvenile life stages were greatly influenced by the existence of the riparian berms in the reach from Lewiston Dam to Dutch Creek.

A subset of 10 transects were measured at a flow of 4,500 cfs, allowing computation of WUA for salmonid fry and juveniles up to that flow. These transects, selected on the basis of accessibility, safety, and geographic distribution, represented 24 percent of the total habitat in the segment. Computed WUA was combined with that derived for the same 10 transects at lower flows (Figure 5.18). Results show increases in WUA between 3,000 and 4,500 cfs for fry and juveniles of all three species. The fry and juvenile WUA indices in Segment IA illustrate the pronounced effect of riparian berms on microhabitat. Suitable physical habitat is present in the main channel at low discharges, but it decreases with greater depths and faster velocities at higher flows. Only when the riparian berms are overtopped at increasing flows (1,500 to 2,000 cfs) and the wetted area can increase does suitable habitat area again begin to increase.

Dutch Creek to North Fork Trinity River
(Segment IB)

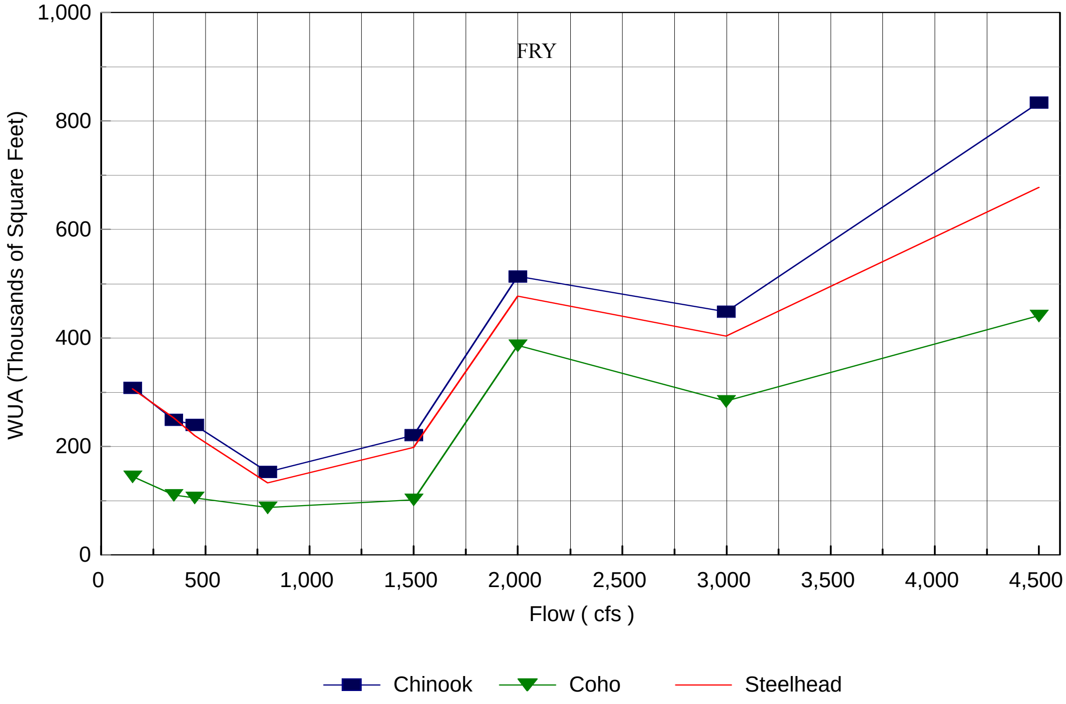
The spawning WUA functions in Segment IB were more complex than those observed in Segment IA. Chinook salmon and coho salmon have very similar habitat–flow relations: the habitat values are highest at 150 cfs, but a secondary peak at about 1,200 cfs nearly matches the first (Figure 5.19A). WUA declines after this peak but stabilizes between 1,700 and 2,500 cfs before gradually declining again. Steelhead spawning habitat is available in much lower quantities in this segment, displaying a sinusoidal function that gradually peaks and declines several times over the range of flows evaluated. Steelhead adult holding WUA rises sharply to 450 cfs and then declines sharply as flows increase.

The WUA curves for fry indicate that the effects of riparian berms on habitat characteristic of Segment IA are a lesser factor in Segment IB. Habitat values for all three species are greatest at 150 cfs and generally decline thereafter (Figure 5.19B). Coho salmon fry have the least amount of habitat and steelhead fry the most. The juvenile WUA curves also do not display the strong bimodality of the functions in the upper segment (Figure 5.19C). Chinook salmon and coho salmon habitats peak at 150 cfs and decline, but the decline is very slight over a wide range of flows (700 to 3,000 cfs). Steelhead juvenile WUA increases to 450 cfs and then steadily declines, whereas overwintering juvenile steelhead habitat is very stable over the entire range of simulated flows, peaking at 750 cfs. Overall, Segment IB rearing habitat favors steelhead over chinook salmon over coho salmon.

North Fork Trinity River to South Fork Trinity River
(Segment II)

The spawning functions in Segment II were bimodal for all three species (Figure 5.20A). Spawning WUA in the lower end of the flow range peaked at 450 cfs for chinook salmon and 300 cfs for coho salmon and steelhead; the second peak of the function for all three species occurred at a flow of about 2,500 cfs. For the salmon species, these functions represented significantly different habitat–flow relations than those observed in Segment IB, where both WUA peaks occurred at flows at least 50 percent lower than these (Figure 5.19A). The adult steelhead holding function is also very different from those in the previous segments. Holding habitat is very limited at 150 cfs, increasing sharply to a maximum level at about 700 cfs, which is maintained over a wide range of flows up to about 1,700 cfs before declining again gradually.

A



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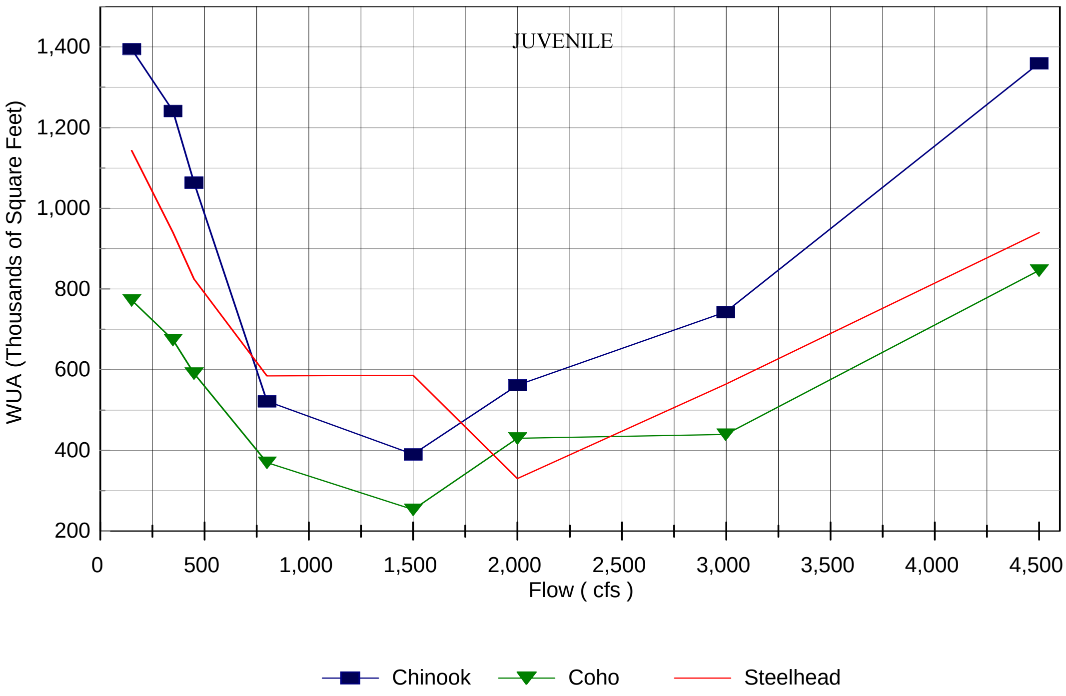


Figure 5.18. Physical habitat availability for fry (A) and juvenile (B) chinook salmon, coho salmon, and steelhead as estimated through direct measurement of a subset of 10 transects representing 24 percent of the total habitat at flows up to 4,500 cfs in Segment IA. Interpolation was used to estimate probable habitat-flow relationships between measured flows.

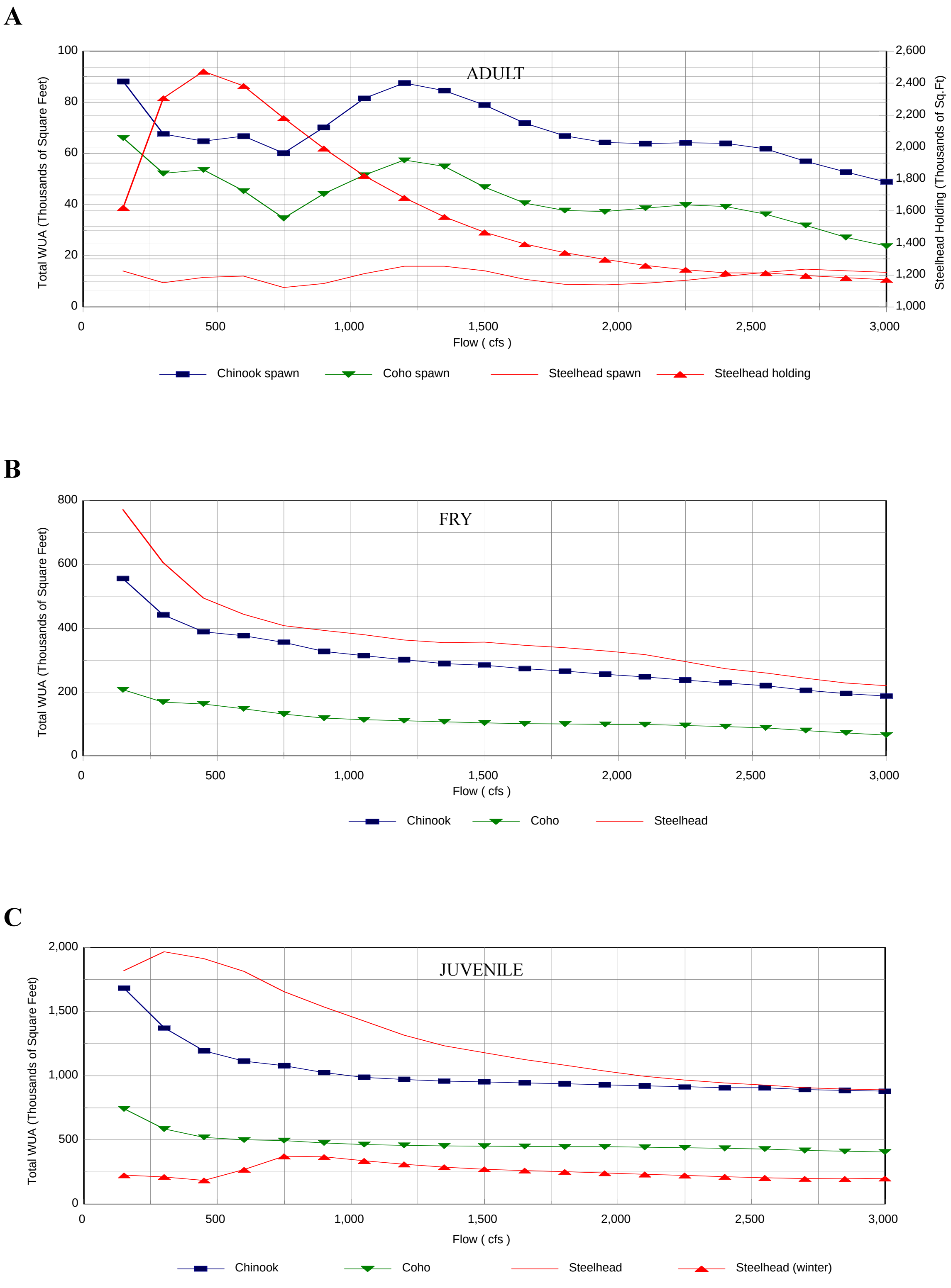


Figure 5.19. Physical habitat availability for adult (A), fry (B), and juvenile (C) salmon and steelhead in Segment IB. Estimates were derived through model simulation.

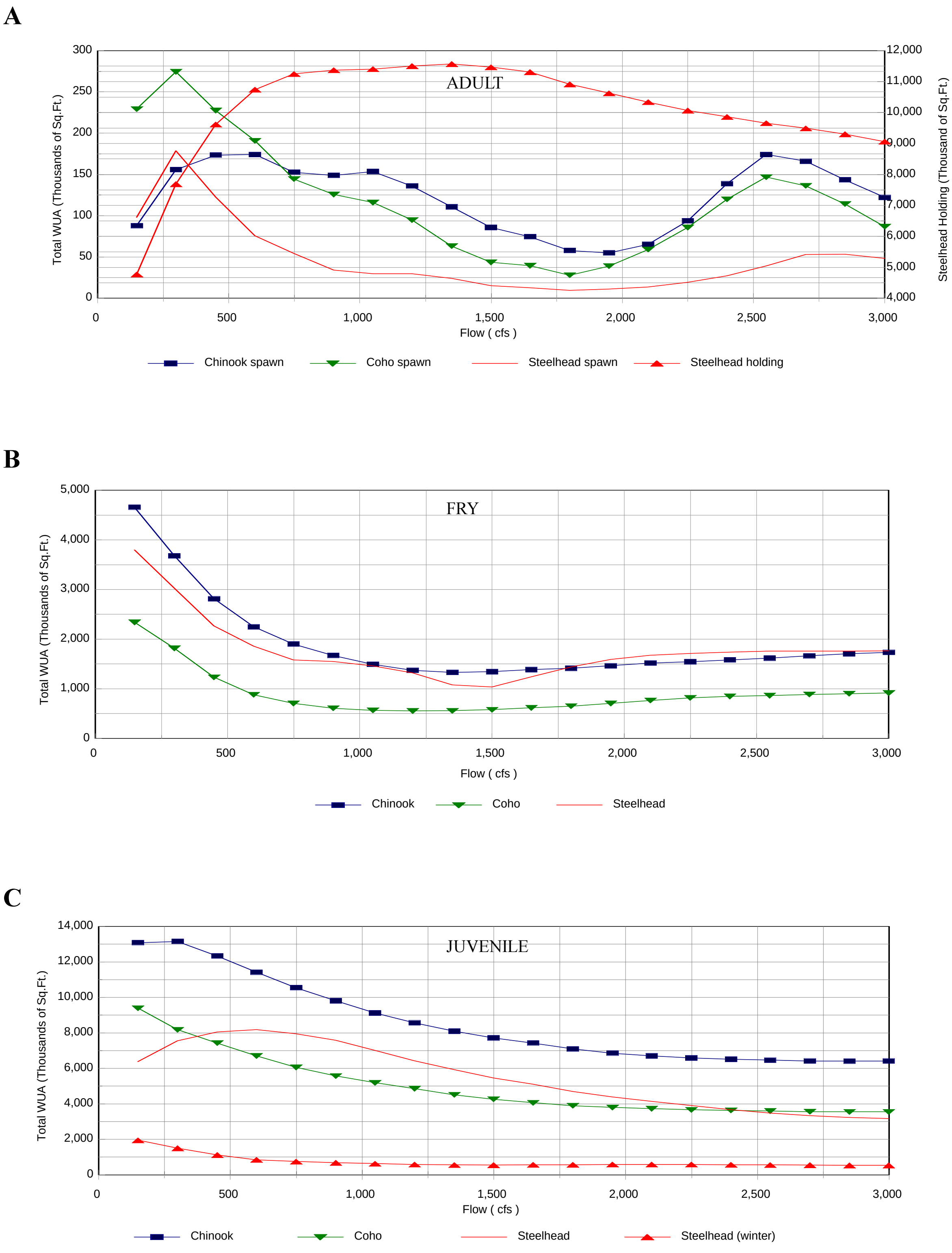


Figure 5.20. Physical habitat availability for adult (A), fry (B), and juvenile (C) salmon and steelhead in Segment II. Estimates were derived through model simulation.

The majority of the WUA curves in Segment II show a reduced influence of riparian berms on channel morphology. Fry WUA was highest at 150 cfs for all three species (Figure 5.20B). The amount of habitat decreased steadily before stabilizing at about 1,000 cfs (chinook salmon and coho salmon) or 1,500 cfs (steelhead); WUA gradually increased as flows increased to 3,000 cfs. Juvenile habitat for chinook salmon and coho salmon was highest at lower flows and decreased steadily (Figure 5.20C). WUA for juvenile steelhead peaked at about 600 cfs. The amount of overwintering steelhead habitat was greatest at 150 cfs and showed about a 50 percent reduction at 600 cfs and greater flows. Overall, the segment favors chinook salmon rearing over coho salmon and steelhead rearing.

<u>South Fork Trinity River to Weitchpec (Segment III)</u>

Spawning habitat availability in Segment III for chinook salmon and coho salmon was greatest at low flows, whereas spawning WUA for steelhead was bimodal, increasing from 150 to 500 cfs and then decreasing to 1,200 cfs before increasing gradually again with flow (Figure 5.21A). Adult steelhead holding WUA was lowest at 150 cfs, climbing sharply to a peak at about 600 cfs and slowly decreasing thereafter to 3,000 cfs.

The WUA curves for Segment III continue to show a reduced influence of riparian berms on channel morphology. The amount of habitat for chinook salmon and coho salmon fry was virtually stable, particularly that for coho salmon (Figure 5.21B). The steelhead fry WUA function had numerous peaks and valleys; flows between 2,000 and 2,500 cfs provided the greatest WUA. For all

Instream flow recommendations for the Trinity River can be made using the results of physical habitat availability modeling in conjunction with information on fish life-history patterns and habitat needs, streamflow patterns (both existing and historical), water-quality variables (such as water temperature), and changing channel morphology.

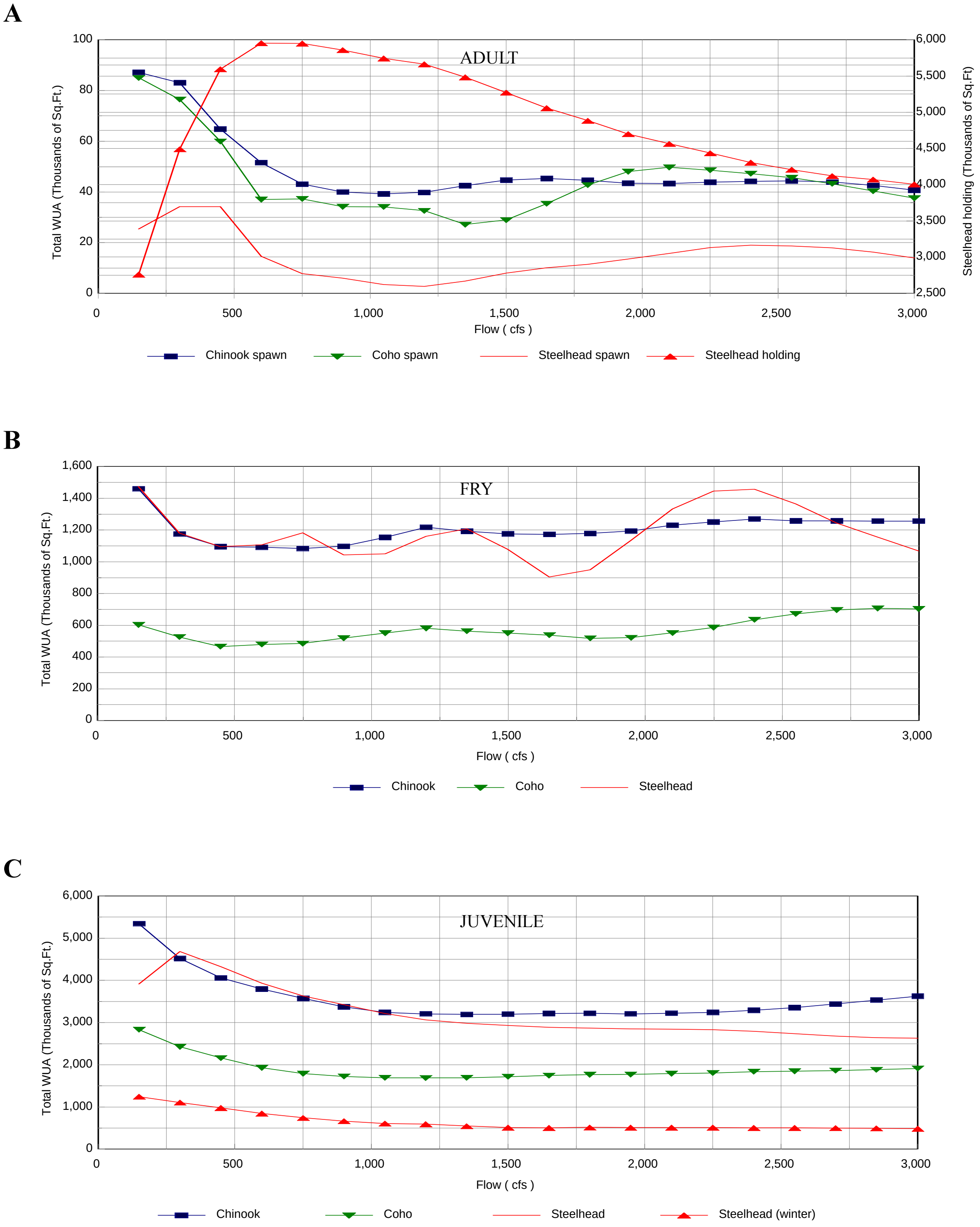


Figure 5.21. Physical habitat availability for adult (A), fry (B), and juvenile (C) salmon and steelhead in Segment III. Estimates were derived through model simulation.

juveniles, WUA curves were almost identical in shape to those in Segment IB (Figure 5.21C). Chinook salmon and coho salmon WUA was greatest at 150 cfs, decreased to about 1,000 cfs, and remained stable thereafter. The juvenile steelhead WUA function peaks at 350 cfs and then declines. Overwintering juvenile steelhead habitat characteristics were identical to those in Segment II.

5.1.2.4 Conclusions

Results of physical habitat availability modeling on the Trinity River are some of the criteria for providing instream flow recommendations and evaluating potential management alternatives. As with any use of PHABSIM habitat modeling, the weighted usable area indices need to be interpreted in the context of fish life-history patterns and habitat needs, streamflow patterns (both existing and historical), water-quality variables (such as water temperature), and changing channel morphology, according to the procedures of the Instream Flow Incremental Methodology.

5.2 Physical Habitat of Bank-Rehabilitation Projects on the Trinity River

5.2.1 Introduction

Monitoring during the initial phases of the TRFE (USFWS, 1988) indicated that the gently sloping point bars of the pre-dam alluvial channel were critical habitat for salmonid fry, which often utilize open, shallow, low-velocity gravel bar habitats (Everest and Chapman, 1972; Hampton, 1988). To rehabilitate the Trinity River, the Service identified as necessary the restoration of the river's historical alternate point bar morphology and the maintenance of this morphology with increased streamflows (USFWS, 1988).

In 1991, the Trinity River Restoration Program initiated a pilot "feathered edge", or bank-rehabilitation program by mechanically removing the riparian berms to reshape portions of the river channel to its historical configuration. From 1991 to 1993, nine pilot bank-rehabilitation projects were constructed by Reclamation and the Service (Table 5.3; Appendix G, Plate 1). Selection of project sites was based on survey data collected by Reclamation and on pre- and post-dam aerial photographs. Additional consideration was given to site access, required excavation volumes, available disposal areas for excavated materials, and land ownership. Projects were constructed along the inside bends of river meanders along historical gravel bar habitats, typically where the post-dam channel confinement had created monotypic run habitats. Heavy equipment was used to remove the riparian berm down to the historical cobble surface, typically 2 to 3 feet below the water-surface elevation associated with a 300-cfs dam release (Gilroy, 1997, pers. comm.), and to reshape the bank. The opposite bank of each site was left undisturbed. Project sites ranged from 395 to 1,200 feet in length.

To evaluate the effectiveness of the bank-rehabilitation projects in providing increased salmonid fry rearing habitat, the Service initiated microhabitat assessments of the pilot bank-rehabilitation projects.

> Construction and operation of the TRD resulted in a change in channel morphology from one of gently sloping point bars to a narrow trapezoidal channel contained within steep riparian berms. This change in channel morphology eliminated most of the gently sloping point bars of the pre-dam alluvial channel that provided open, shallow, low-velocity gravel bar habitats for rearing salmonid fry. Restoration and maintenance of the fishery resources of the Trinity River requires, in part, rehabilitation of the channel morphology in the mainstem below Lewiston Dam similar to that of the pre-TRD channel morphology.

Table 5.3. Channel-rehabilitation project sites on the mainstem Trinity River.

Site	River Mile	Construction Date
Bucktail	105.6	1993
Limekiln	100.2	1993
Steel Bridge	98.8	1993
Steiner Flat	91.8	1991-1993
Bell Gulch	84.0	1993
Deep Gulch	82.2	1993
Sheridan Creek	82.0	1993
Jim Smith	78.5	1993
Pear Tree Gulch	73.1	1992

5.2.2 Methods

Two salmonid rearing habitat assessments of the bank-rehabilitation projects were conducted using PHABSIM (Bovee, 1982). PHABSIM was used to relate changes in stream discharge to changes in WUA. The first habitat assessment was a site-specific comparison of pre- and post-rehabilitation habitat for chinook salmon fry. Pre-rehabilitation WUA indices were available for two bank-rehabilitation sites: Steel Bridge (RM 98.8) and Steiner Flat (RM 91.8). Post-construction WUA indices for these same sites were computed using PHABSIM data collected in 1995 (USFWS, 1996).

The second habitat assessment evaluated the effect of bank-rehabilitation on the chinook salmon fry flow–habitat relations for a generalized bank-rehabilitation project. Three of the nine sites, Bucktail (RM 105.6), Steiner Flat (RM 91.8), and Sheridan Creek (RM 82.0), created shallow, low-velocity salmonid habitat (Appendix G, Plates 3 and 4). These sites contained characteristics similar to those of natural gravel bars, mid-channel bars, backwaters, and other features typical of unregulated riverine systems (McBain and Trush, 1997). WUA indices were computed for a combination of 15 transects (3 from the Bucktail site, 7 from the Steiner Flat site, and 5 from the Sheridan Creek site) (USFWS, 1997). WUA indices were computed for the non-rehabilitated channel from data collected at 11 transects (equally weighted) representing run habitats from the Bucktail (4 transects) and Steiner Flat (7 transects) study sites in 1985, 1986, 1989, and 1990 (USFWS, 1997). Run-habitat transects at the Bucktail and Steiner Flat sites were

Proper design and construction of channel-rehabilitation projects increases salmonid rearing habitat. Rehabilitation of the Steel Bridge site had little effect on chinook salmon fry rearing habitat at low flows and it decreased chinook salmon fry rearing habitat at moderate to high flows. At the rehabilitated Steiner Flat site, chinook salmon fry rearing habitat was increased at all flows.

selected to represent the non-rehabilitated channel because the bank-rehabilitation sites were run habitats prior to construction (Gallagher, 1995) and because these sites were in close proximity to the representative bank-rehabilitation sites.

The absolute reliability of the WUA indices was limited by the relatively small number of appropriate transects, the narrow flow range for hydraulic modeling, and the uncertainty regarding the ultimate configuration of the rehabilitated sites and the adjacent reaches of the river. WUA indices for fry and juvenile chinook salmon, coho salmon, and steelhead were computed for a rehabilitated channel and the non-rehabilitated channel. For this report, data for only chinook salmon are presented: data for coho salmon and steelhead indicated similar trends in flow–habitat relations in the rehabilitated and non-rehabilitated channel (USFWS, 1997). Because of the differences in locations of transects representing the rehabilitated and non-rehabilitated channel, direct comparisons of the magnitude of the flow–habitat relations were not possible. The data were used to assess the changes in the WUA flow–habitat relation as a result of bank rehabilitation.

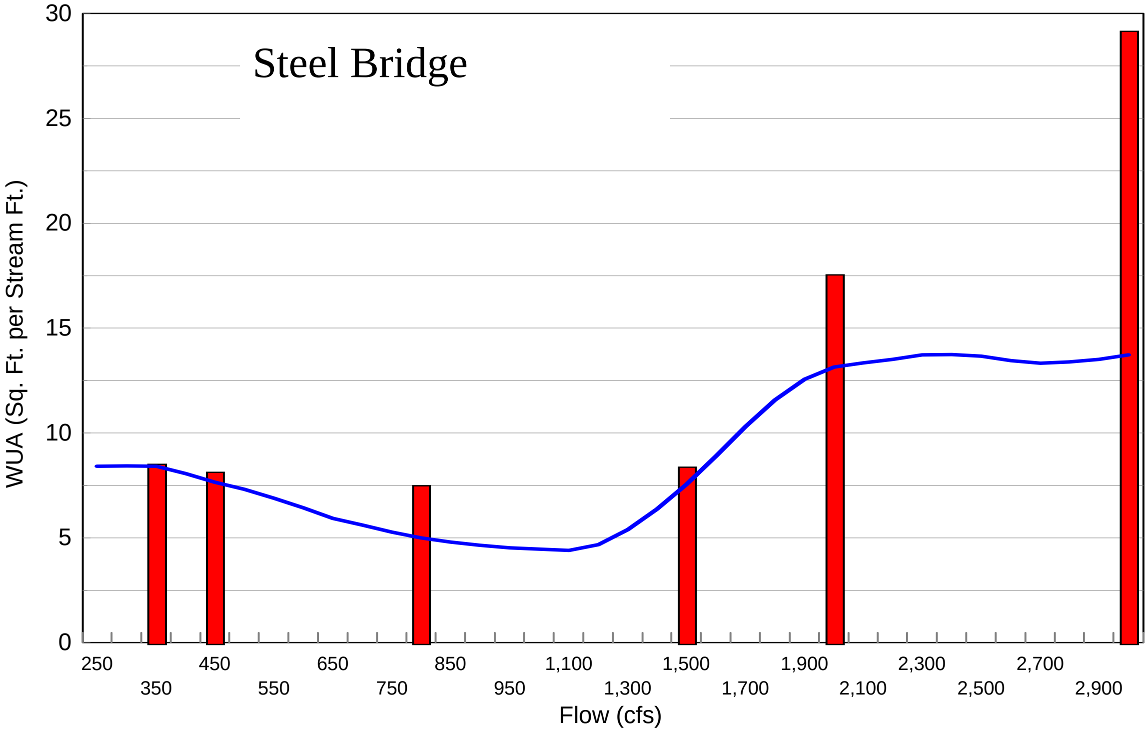
5.2.3 Results

Site-specific comparisons of the chinook salmon fry WUA before and after construction of the Steel Bridge and Steiner Flat sites showed variable results. Rehabilitation of the Steel Bridge site had little effect on chinook salmon fry WUA at low flows (≤450 cfs), and it decreased chinook salmon fry rearing habitat at higher flows (>450 cfs) (Figure 5.22). At the rehabilitated Steiner Flat site, chinook salmon fry WUA was increased throughout the range of flows studied (Figure 5.22).

In the non-rehabilitated channel, the largest WUA values for fry and juvenile chinook salmon occurred at the lowest and highest flows (Figures 5.23A, 5.23C). As flows increased to approximately 1,500 cfs, water velocities and depths increased to levels that were less suitable for rearing salmonids. However, as flows increased above approximately 1,500 cfs, the areas behind the riparian berms became inundated and suitable depths and velocities were again available. The high WUA values at the lowest flows (150 cfs) were derived primarily from large areas of poor habitat (Composite Suitability Value <0.20) over a broad area. The greatest variability in WUA in the non-rehabilitated channel occurred for the fry life stage.

As flows change, the amount of salmonid fry rearing habitat in the existing channel varies greatly, whereas in the rehabilitated channel the amount of rearing habitat was relatively stable.

In contrast, WUA values for the rehabilitated channel were relatively stable throughout the range of flows modeled (Figures 5.23B, 5.23D). Chinook salmon fry WUA varied little throughout the range of flows modeled. Juvenile WUA initially decreased as flow increased from 150 cfs to approximately 750 cfs, and then gradually increased to levels equal to those at the lowest flows.



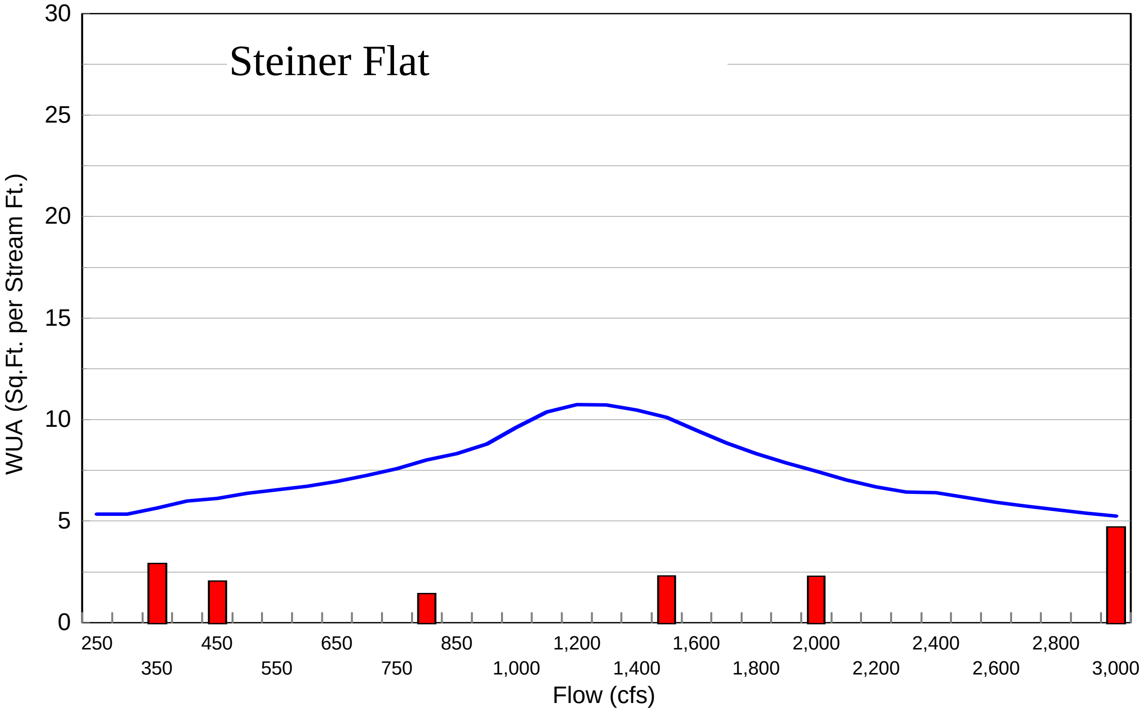


Figure 5.22. Comparison of chinook fry habitat before (bars) and after (line) construction of Steel Bridge (RM 98.8) and Steiner Flat (RM 91.8) bank-rehabilitation projects. Habitat estimates for "before" conditions were derived from direct measurement. Habitat estimates for "after" conditions were derived through modeling.

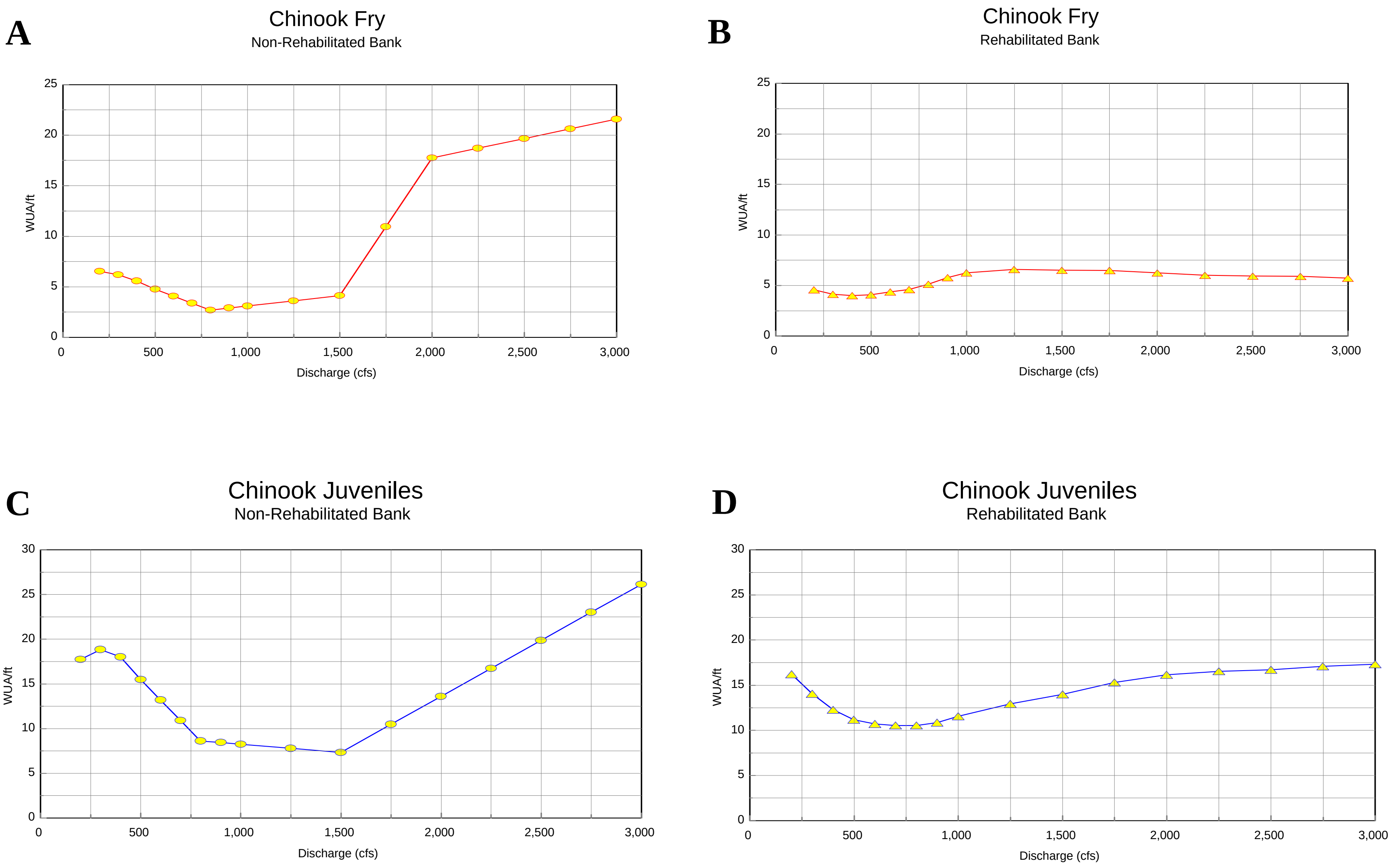


Figure 5.23. Flow-habitat relations for fry and juvenile chinook salmon with non-rehabilitated and rehabilitated banks, Trinity River.

5.2.4 Conclusions

Implementing channel-rehabilitation projects allows for a broadening and gradual sloping of the narrow trapezoidal channel, which allows the river flows to spread out and water velocities to decrease. This provides suitable depths and velocities for rearing salmonids regardless of flow magnitude, and because the river often experiences substantial changes in flow during winter storms, providing suitable habitat throughout a wide range of flows is necessary to prevent habitat bottlenecks.

Assessments of salmonid rearing habitat before and after bank rehabilitation indicate that, when properly designed and constructed, these projects can increase salmonid fry rearing habitat (Figure 5.22). The importance of project design and construction was exemplified by the Steel Bridge site, where the project failed to increase salmonid rearing habitat (Figure 5.22). The lack of a beneficial response was attributed to the morphological characteristics of the site. The rehabilitation of the bank resulted in a steep bank that did not provide shallow, low-velocity habitat when flow increased. In contrast to the Steel Bridge site, removal of the riparian berms and recreation of gently sloping point bars at the Steiner Flat site increased rearing habitat throughout the range of flows studied. Prior to construction of the Steiner Flat bank-rehabilitation project, the river at this site was a long, channelized run that provided little rearing habitat.

Comparison of the flow-habitat relations of the existing channel and a generalized bank-rehabilitation project indicated that bank rehabilitation had a positive effect on the flow–habitat relation. The restoration of gently sloping gravel bars changed the flow–habitat relation, from one in which there was great variability in habitat availability between low and high flows to one in which habitat availability was relatively stable throughout the range of flows studied (Figures 5.23B, 5.23D). In the non-rehabilitated channel, the large variability in habitat availability throughout the range of flows was due to the trapezoidal configuration of the channel (Figures 5.23A, 5.23C).

The broadening and gradual sloping of the narrow trapezoidal channel allowed the river flows to spread out and water velocities to decrease, providing suitable depths and velocities for rearing salmonids regardless of flow magnitude (Figures 5.23B, 5.23D). Bands of suitable habitat along the stream margin were relatively consistent at all flows and migrated up and down the gently sloping bank relative to changes in flow (Figure 5.24).

Because the river often experiences substantial changes in flow during winter storms, providing suitable habitat throughout a wide range of flows is necessary to prevent habitat bottlenecks.

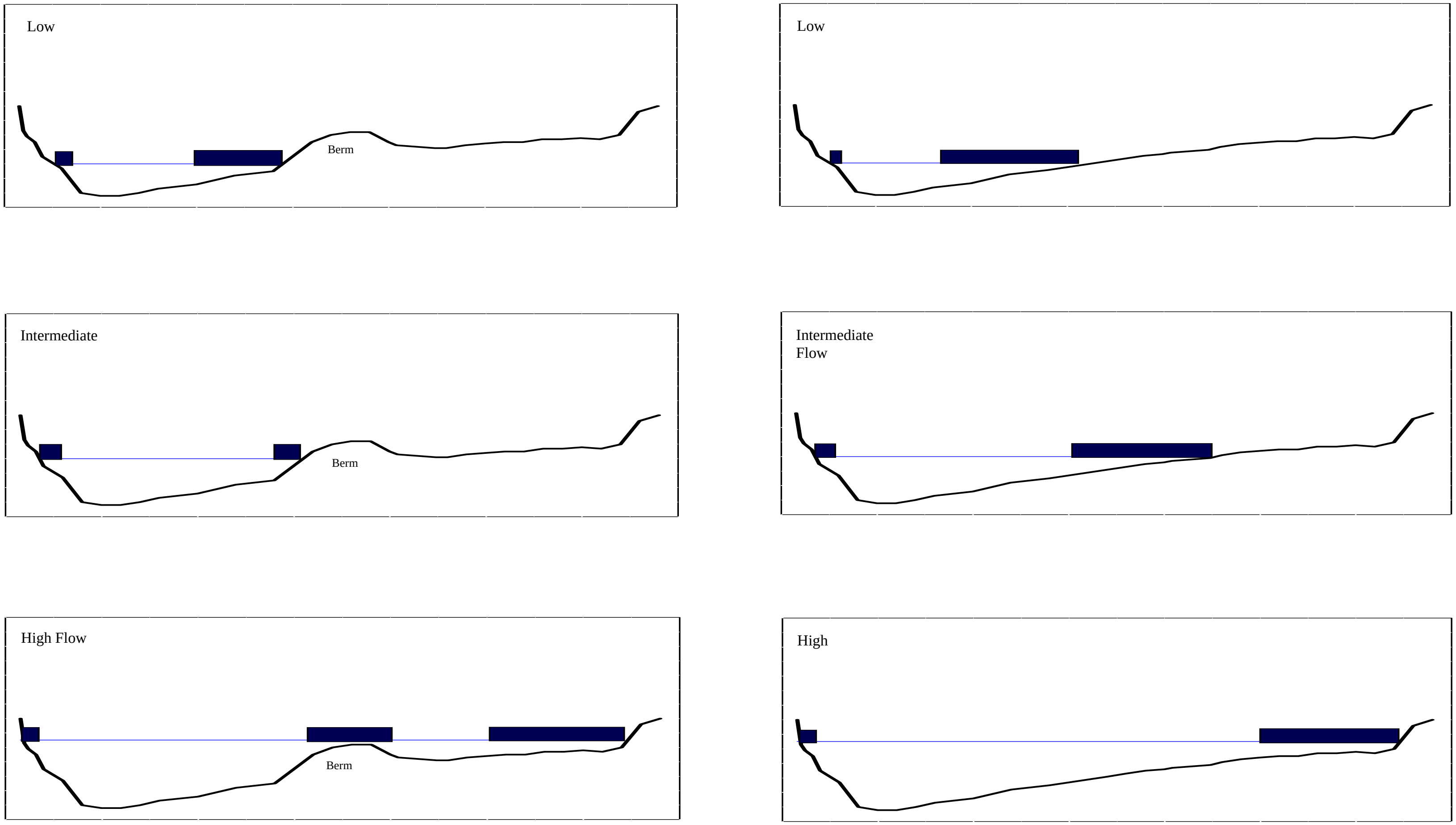


Figure 5.24. Representation of the existing channel with the riparian berm and the rehabilitated channel with salmonid fry rearing habitat (represented by the boxes) at low, intermediate, and high flows.

> Evaluation of the pilot bank-rehabilitation projects indicated that, when properly constructed, bank rehabilitation can effectively increase the amount of salmonid fry rearing habitat in the mainstem Trinity River.

Habitat stability throughout the rearing period is crucial to the survival of young salmonids, especially fry that are particularly vulnerable to rapid and significant habitat changes (Healey, 1991; Sandercock, 1991). In the rehabilitated channel, stable amounts of suitable rearing habitat are maintained as flows change, in distinct contrast to the pattern evident in the non-rehabilitated channel.

Channel-rehabilitation projects will have the additional benefit of reducing salmonid fry stranding that is exacerbated by the presence of riparian berms (Zedonis, pers. comm; Aguilar, 1997, pers. comm.). When safety of dam releases exceed ~1,500-2,000 cfs, which typically occur during the chinook fry lifestages, the areas behind the riparian berms are inundated, creating slow water areas. Salmonid fry, seeking refuge from high velocities, move into these slow water zones behind the riparian berms and become isolated from the mainstem as flows are reduced. Channel rehabilitation will lessen the effects of high flow on fry stranding by eliminating the riparian berms and providing consistent amounts of contiguous habitat over a wider range of flows.

5.2.5 Recommendations

Rehabilitation of degraded salmonid rearing habitat requires reforming the existing channel to one that resembles the pre-TRD channel. Evaluation of the pilot bank-rehabilitation projects indicated that, when properly constructed, bank rehabilitation can effectively increase the amount of salmonid fry rearing habitat in the mainstem Trinity River. In addition to providing shallow, low-velocity habitat for rearing salmonid fry, these projects provide habitat stability over a wide range of flows.

5.3 Fine Sediment Transport and Spawning-Gravel Flushing

5.3.1 Introduction

Wilcock et al. (1995) investigated a fine sediment flushing flow that could (1) maximize the removal of fine-grained sediment (particles finer than $^{5}/_{16}$ inch) stored in the mainstem Trinity River from the Grass Valley Creek confluence (RM 104.0) downstream to the BLM Steel Bridge Campground (RM 99.0); (2) minimize water needed for fine bedload transport; (3) minimize downstream gravel loss; and (4) provide gravel entrainment sufficient to permit fine sediment removal from the channelbed to a depth typically excavated in redd construction. Wilcock et al. (1995) hypothesized that if planned dam releases could just mobilize the spawning-gravel substrate, fine sediment in gravel interstices would be exposed to fluid forces and transported downstream whereas gravel loss would be minimal. Once fine sediment in the channelbed was mobilized, this fine sediment would be deposited on floodplains, removed by dredging (assuming a maximum total annual instream volume of 340 TAF), or eventually transported from the study reach.

5.3.2 Methods

Two mainstem sites with abundant spawning-gravel deposits, simple hydraulic characteristics at high flows, and convenient access were investigated (Figure 5.25): Poker Bar (RM 102.4), 1.6 miles downstream from Grass Valley Creek; and Steel Bridge (RM 99.0), 5.0 miles downstream from Grass Valley Creek. The Steel Bridge site consisted of two mainstem channels separated by a densely wooded island that likely was once a mobile medial bar before TRD operations. In addition to these

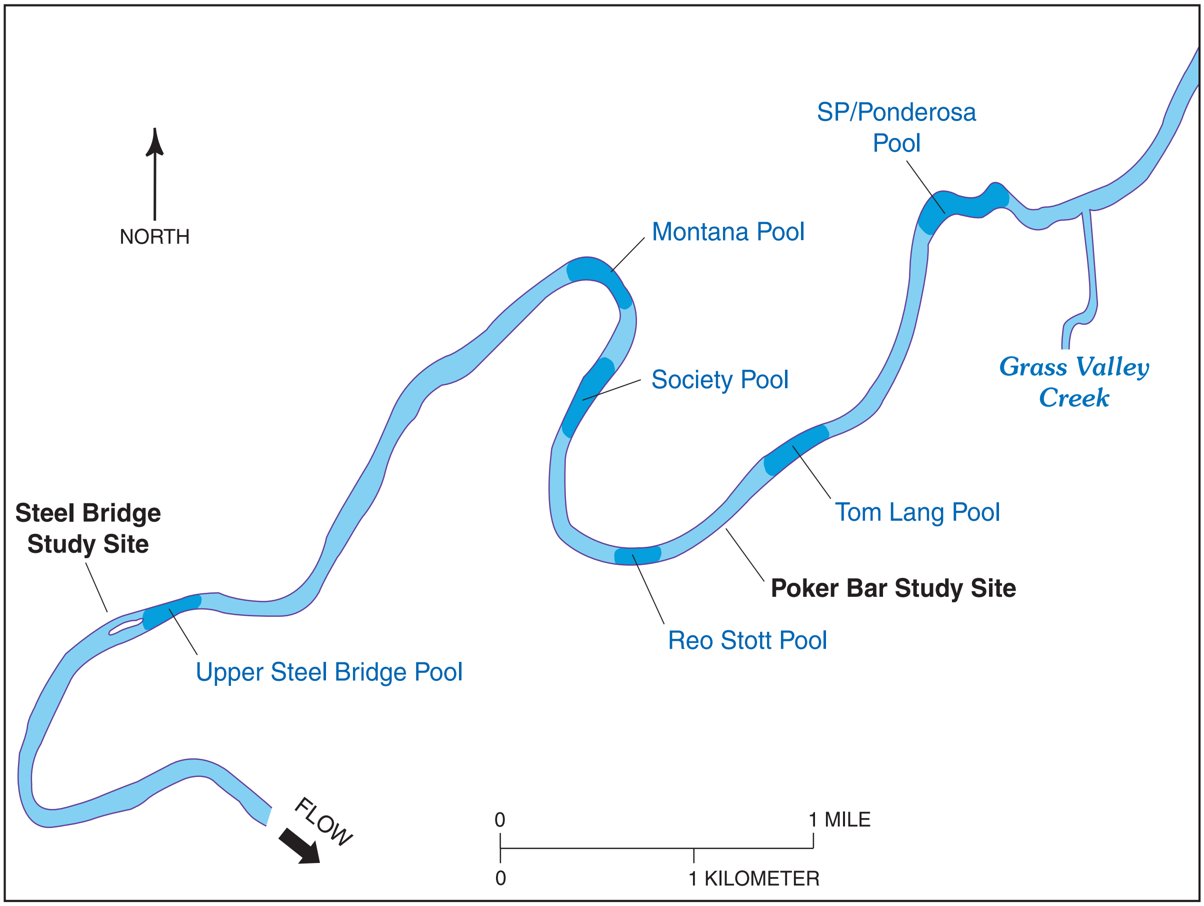


Figure 5.25. Study area showing study sites and pool locations.

sites, five pools were chosen to quantify anticipated changes in fine sediment storage following experimental flow releases.

Three dam releases were investigated. The WY1991 flow release extended 6 days, from May 28 to June 2, with a daily maximum release between 2,600 cfs and 2,800 cfs from May 29 to June 1. From May 30 to June 1 the discharge measured at the study site was a relatively constant 2,670 cfs. In WY1992 the flow release extended 10 days from June 10 to June 19. A relatively constant discharge of 5,800 cfs was observed at the study sites from June 13 to June 16. The WY1993 flow release, lasting 22 days from April 13 to May 4, narrowly fluctuated around 3,000 cfs from April 14 to April 30.

Excavated pits filled with marked tracer gravels documented gravel entrainment by dam releases at both study sites. Following a dam release, the number and size of tracers remaining in the pit were recorded, as well as the distance mobilized tracers were displaced. Net scour or fill at each tracer pit was measured by comparing channelbed elevation before and after a release. Comparison of the pre- and post-release elevations of the marked tracers yielded a measurement of scour depth and subsequent fill in the tracer pit.

To estimate the flow threshold for gravel entrainment, the exchange depth, d_{ex} (defined as the total depth of tracer gravels multiplied by the proportion of gravels entrained) was compared with the surface D_{90} (the 90th percentile rock diameter) for each dam release. The surface D_{90} diameter defined the thickness of the channelbed's

Fine sediment reduces salmonid production by infiltrating spawning gravels and increasing egg and alevin mortality, depositing on exposed cobble bar surfaces and reducing salmonid fry and over-wintering rearing habitat, and in extreme cases, filling pools and reducing adult holding habitat. Reducing fine sediments in the mainstem Trinity River, particularly decomposed granitic sands, will greatly improve salmon habitat and salmon production.

coarse surface layer. Peak flows resulting in values of d_{ex}/D_{90} close to 1 represented a minimum flow threshold for gravel entrainment. Pebble counts (Wolman, 1954) were conducted to characterize surficial particle-size distributions before and after experimental releases. Subsurface bulk samples, collected before and after dam releases, characterized changes in particle-size distribution of the bed material to measure potential reductions in fine sediment (less than $^{5}/_{16}$ inch) accumulation attributable to the experimental releases.

Bedload transport rates were measured two ways: by Helley-Smith sampling from a cataraft and by means of bedload boxes placed in the streambed to catch mobilized bedload (refer to Wilcock et al., 1995, for sampling details). Samples collected with the Helley-Smith sampler were weighed and analyzed for particle-size distribution and bedload transport rate (tons/day). Bedload boxes were periodically cleaned by a diver during the dam release to prevent overfilling. The amount of trapped bed material and the time interval between box cleanings were converted to a bedload transport rate. Sediment rating curves were developed for sand and gravel.

From a cataraft, fine sediment storage in the upper 0.5 foot of the entire channelbed was mapped onto aerial photographs for the reach of the mainstem from the Grass Valley Creek confluence to the Steel Bridge Campground. The top 0.5 foot was assumed to be the depth at which flushing flows could scour and redeposit the bed surface. For the top 0.25 foot of the channelbed surface, a percentage of fine surficial sediment was visually estimated. For the underlying 0.25 foot, a constant percentage of 25 percent (based on bulk sampling at the Poker Bar site) was used. In the five study pools, bathymetric surveys quantified net changes in fine sediment storage between dam releases and were used to estimate pool trapping efficiency (refer to Wilcock et al., 1995, for details).

Sixty-five hundred cfs mobilized the bed surface particles, but did not scour the bed surface greater than a D_{90} depth; 3,000 cfs neither mobilized the bed surface particles nor cause bed scour.

The methodologies adopted by Wilcock et al. (1995) were based on three primary assumptions: (1) that the two study sites chosen for quantifying surface bed mobility, bed scour, and bedload transport rates represented most of the degraded reaches of the Trinity River; (2) that Grass Valley Creek would continue to supply fine sediment to the Trinity River mainstem; and (3) that a fixed annual volume of water (340 TAF) would be available for flushing flows and meeting fishery flow needs. An unstated assumption was that pool dredging was the most practicable means to reduce the volume of fine sediment in the reach because the necessary annual peak flow duration needed to remove all fine sediment required too much water.

5.3.3 Results

WY1991 (2,600 cfs) and WY1993 (3,000 cfs) peak releases did not significantly entrain underlying finer sediment in spawning-gravel deposits at either the Poker Bar study site or Steel Bridge study site (i.e., d_{ex}/D_{90} was less than 1). Sand was removed only from interstitial spaces at the channelbed surface. The WY1992 dam release (6,500 cfs), “was just sufficient to mobilize the surface gravel layer and entrain underlying finer sediment” (Wilcock et al., 1995, p. 87). For example, scour depths for three tracer gravel cores at cross section Poker Bar #2 were 3 $^{15}/_{16}$ to 5 $^{1}/_{8}$ inches, which was greater than the surface D_{90} depth.

High flow releases between 2,700 cfs and 6,500 cfs reduced surficial in-channel fine sediment storage, but not subsurface sand storage.

At the Poker Bar site, the median particle size of the subsurface bed material was $^{7}/_{8}$ inch, with 30 percent of particles finer than $^{5}/_{16}$ inch. Because the WY1991 experimental release did not mobilize the bed surface layer, the release did not significantly modify the subsurface composition. Scour depth was less than 1 $^{9}/_{16}$ inches for all five scour cores at Poker Bar, and less than 2 inches for all Steel Bridge scour cores. As previously stated, channelbed scour was substantially deeper at the Poker Bar site during the WY1992 release; surface grains from all gravel size classes were transported. Scour depths for three tracer gravel cores at Poker Bar were 3 $^{15}/_{16}$ to 5 $^{1}/_{8}$ inches, which exceeded the D_{90}. Pebble counts and bulk samples indicated no significant changes in the proportion of fine sediment resulting from the WY1992 release. The WY1993 release produced results similar to those of the WY1991 release, although flow duration was considerably longer. Similar results were recorded at the Steel Bridge Campground site for the three releases.

Fine sediment transport and spawning gravel flushing recommendations:

- 5-day release of 6,000 cfs to mobilize gravel-bed surface and maximize fine sediment transport;
- maximize fine sediment trapping efficiency in upper Trinity River by increasing pool volume in six pools immediately downstream of Grass Valley Creek;
- periodically dredge these six pools to reduce in-channel fine sediment storage.

Bedload boxes placed at Poker Bar during the WY1993 flow sampled a bedload transport rate of 0.023 tons/day for sediment coarser than $^{5}/_{16}$ inch. Sand bedload (finer than $^{5}/_{16}$ inch) transport rates, in tons per day, were 112,400; 223,600; and 34,400 for WY1991, WY1992, and WY1993 peak releases, respectively. Refer to Wilcock et al. (1995) for details of gravel transport model and sediment rating curves.

Prior to the WY1992 flow, weighted reach values of percent coverage by fine sediment (< $^{5}/_{16}$ inch) varied from 13.6 to 43.5 percent. Following the WY1993 flow, weighted reach values of percent coverage by fine sediment varied from 13.4 to 27.6 percent, which represented a substantial reduction of in-channel sand storage. However, the WY1992 release, “did not produce a substantial reduction in the proportion of fine materials in the bed. To achieve successful flushing at depth, the total volume of sand in the reach must be reduced.” (Wilcock et al., 1995).

The repeat bathymetric pool surveys detected net volume changes in each monitored pool for WY1991, WY1992, and WY1993 experimental releases, respectively, as follows: Reo Stott pool, –129 yd^3, +487 yd^3, and –414 yd^3; Society pool, +160 yd^3, +1,874 yd^3, and –77 yd^3. For WY1992 and WY1993 only, net volume changes for other monitored pools were: Tom Lang pool, +885 yd^3, -1,038 yd^3; Upper Steel Bridge pool, -167 yd^3, -551 yd^3; SP/Ponderosa, -516 yd^3, -1,095 yd^3.

5.3.4 Conclusions

The WY1992 release of 5,800 cfs for 5 days was just sufficient to mobilize the surface layer of gravel and scour the underlying sediment, although no significant decrease

> Fluvial geomorphic processes underpin the structure and function of complex river ecosystems. Restoring salmonid habitat (and populations) must be underpinned by restoring fundamental fluvial geomorphic processes.

in fine sediment was observed. On the basis of this finding, Wilcock et al. (1995) recommended a flushing release of 6,000 cfs for 5 days. Their flushing release schedule and recommendation for continued dredging were tailored around the assumption that only 340 TAF was available for instream releases (Wilcock, pers. comm., 1997). Given more water, sand transport could be improved by holding a given release level longer or increasing the magnitude within the given duration. For example, Wilcock et al. (1995) stated, "A sediment maintenance release need not use a constant discharge. One alternative is to use a short, large discharge to efficiently accomplish full bed surface mobilization, followed by a longer release at a low discharge to accomplish additional sand removal with little additional gravel loss."

The process of removing fine sediment from the reach is different from that of flushing fine sediment from gravels: flushing flows expose and transport fine sediment but do not necessarily remove it all from the river system. Wilcock et al. (1995) used flushing flows to transport fine sediment to local pools, where it would be trapped and periodically dredged. Four pools between Grass Valley Creek and Steel Bridge have been dredged; the authors recommended that two additional pools be added between Society Pool (RM 101.3) and Steel Bridge Campground (RM 99.0) because this reach is the longest without pools and has the greatest instream sand storage.

Trap efficiency is a function of local hydraulics through a pool, which in turn is related to the dimensions (width, length, and depth) of the pool. The recommended flushing flow, based on Wilcock's calculations, that maximizes pool trapping efficiency is from 5,000 to 6,000 cfs. Wilcock et al. (1995) found that at discharges between 5,000 and 6,000 cfs, pool trap efficiency can be optimized by dredging the pool 2 feet below the stable pool depth. Because this 5,000 to 6,000-cfs flow just begins to mobilize the gravel bed surface, bedload transport is minimized and sand transport is large. Dredging deeper could trap a greater volume of fine sediment transported by higher and (or) longer discharges.

5.4 Fluvial Geomorphology

The decline in the Trinity River salmonid fishery is directly correlated with the dramatic change in the geomorphologic character of the basin since construction of TRD. Chapter 3 describes the general habitat requirements and abundance trends for the fishery resources of the Trinity River and concludes that diverse habitats are needed to support the various life stages of the fish. Post-TRD changes in flows and sediment budgets have caused the habitats to become less diverse, leading to the decline in fish populations.

Fluvial geomorphologic processes underpin the structure and function of complex river ecosystems. To restore habitat diversity will require restoring natural geomorphologic processes within contemporary sediment supply and flow limitations. The alluvial attributes described in Section 4.8 provide a framework upon which initial hypotheses can be formulated relating unregulated (natural) flow regimes with important physical and ecological processes. Understanding these processes, and how they have changed because of TRD, provides insight into how they might be used to restore key components of the river ecosystem.

This section integrates geomorphologic studies into those physical and ecological processes. Examining historical flow data provides insight into needed flow variability (Section 4.8, Attribute No. 2). Measuring contemporary channelbed hydraulics provides data

Salmonids and other native riverine organisms evolved under a variable streamflow regime; water year classification describes inter-annual streamflow variability, and annual hydrograph components provide intra-annual streamflow variability.

regarding the flows needed to cause both incipient channelbed mobility and significant scour and fill (Section 4.8, Attributes No. 3 and No. 4). Understanding fine and coarse sediment budgets provides information needed to manage sediment inputs to provide the desired geomorphologic response (Section 4.8, Attribute No. 5). Studying processes leading to riparian encroachment provides insights into how encroachment can be managed (Section 4.8, Attribute No. 9).

5.4.1 Flow Variability

Flow variability within the Trinity River basin was assessed by examining historical data collected at three USGS gaging stations, and more recent data collected at five gages established and operated by the Hoopa Valley Tribe. Gage locations and periods of record are provided in Table 4.2.

5.4.1.1 Water-Year Classification

A water-year classification system for the Trinity River basin was developed by evaluating annual basin water yield for the watershed upstream from the Lewiston gage. For water years prior to TRD construction (WY1912 to WY1960), flow records from the USGS Trinity River at Lewiston gaging station were used to quantify annual basin water yield. For water years after TRD construction (WY1961 to WY1995), estimates of flows into Trinity Lake prepared by Reclamation were used. Individual annual basin water yields were ranked and the exceedence probability (*p*) calculated. A plot of the data is shown in Figure 5.26. Five water-year classes were delineated. Extremely Wet years have $p \leq 0.12$ and produce annual basin water yields greater than 2,000 TAF. Wet water years have $0.12 < p \leq 0.40$ and produce annual basin water yields between 2,000 and 1,350 TAF. Normal water years have $0.40 < p \leq 0.60$ and produce annual basin water yields between 1,350 and 1,025 TAF. Dry water years have $0.60 < p \leq 0.88$ and produce annual basin water yields between 1,025 and 650 TAF. Finally, Critically Dry water years have $p > 0.88$ and produce annual water yields less than 650 TAF.

5.4.1.2 Annual Hydrograph Components

Seasonal patterns of average daily flow for rivers in the Pacific Northwest consist of winter floods, winter baseflows, snowmelt peak runoff, snowmelt recession, and summer baseflows. These components are illustrated in Figure 4.10. Hydrograph components for various locations in the basin were characterized by duration, magnitude, frequency, seasonal timing, and inter-annual variability. Peak snowmelt runoff and high summer baseflows dominate annual hydrographs for sub-basins upstream from Lewiston, whereas for sub-basins downstream from Lewiston winter rainfall runoff and relatively low summer baseflows dominate. These differences have significant geomorphologic and ecological consequences.

Winter floods are either rainfall or rain-on-snow events that typically occur between mid-November and late March. Peak flows exceeding 70,000 cfs have occurred three times since WY1912. The magnitude of peak flows is generally correlated with water-year classification, with Extremely Wet water years producing bigger floods. An exception is the December 1964 flood that peaked above 100,000 cfs but occurred during a Wet water year. Floods at Lewiston have been greatly reduced since TRD because releases from Trinity Dam have always been less than 14,500 cfs.

Pre-TRD winter baseflows ranged from 3,000 cfs during Wet and Extremely Wet water years, to less than 500 cfs during Critically Dry water years. Winter baseflows were typically established by the first major storm in October or November. Post-TRD winter baseflows have been much lower, ranging from 150 cfs prior to WY1979 to

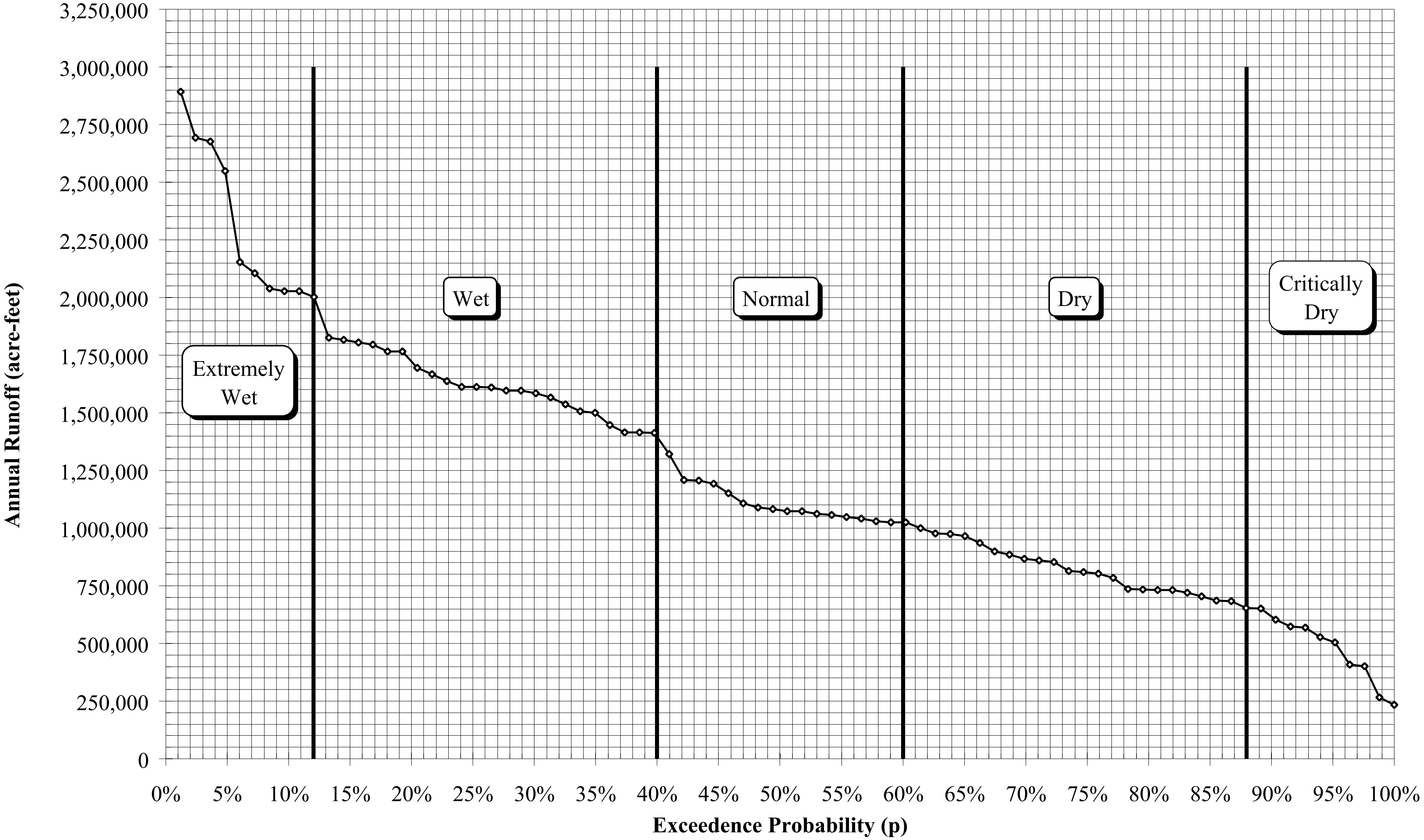


Figure 5.26. Cumulative plot of ranked annual water yields from the Trinity River upstream of Lewiston for 1912-1995.

300 cfs since WY1979. During Wet and Extremely Wet years, extended dam safety releases sometimes function as winter baseflows.

Trinity River streamflows varied widely, with unimpaired flood events periodically exceeding 70,000 cfs and summer streamflows as low as 100 cfs.

Magnitude of snowmelt peak runoff also is correlated with water-year classification. Extremely Wet water years produced snowmelt peak runoff as great as 26,000 cfs, while Critically Dry water years produced less that 2,000 cfs. Timing of snowmelt peak runoff ranged from late March to late May and generally peaked later in wetter years (Figure 5.27). Duration ranged from a few weeks (WY1976) to 1.5 months (WY1974). This hydrograph component has been all but eliminated by TRD, with the exception of a few experimental or dam safety releases.

Once most of the winter snowpack has melted, the annual hydrograph steadily decreases with occasional brief spikes. This snowmelt recession typically ends by late May during Critically Dry water years, but can extend into late July during Extremely Wet water years. The descending limb has a steep early segment and is followed by a less-steep recession limb. The descending limb receded at an average rate of 650 cfs/day. The recession limb typically begins at flows less than 4,500 cfs and recedes at an average rate of 100 cfs/day, spanning approximately 24 days.

Pre-TRD summer baseflows typically ranged from 100 cfs during Critically Dry water years to about 300 cfs during Wet and Extremely Wet water years (Figure 5.28). During Critically Dry water years, summer baseflows could be as low as 25 cfs. Post-TRD summer baseflows ranged from 150 to 200 cfs prior to WY1979, were held to 300 cfs from WY1979 to WY1990, and have been 450 cfs from WY1991 to present.

Tributary accretion below Lewiston has hydrologic and geomorphological significance. Four major tributaries join the Trinity River within the short mainstem segment from Indian Creek to Browns Creek. Tributary-derived floods exceed dam-release floods downstream from the Indian Creek confluence (RM 95.3). This hydrological transition area coincides with an alluvial transition zone (Trush et al., 1995) where tributary flow and sediment contributions begin to restore alluvial attributes. Downstream tributaries cannot replace lost snowmelt and recession hydrograph components originating upstream from Lewiston, but they do contribute significant winter and summer baseflow. The magnitude of releases from Lewiston Dam can triple (or more) within 30 miles downstream due to tributary accretion.

5.4.2 Channelbed Hydraulics

Channelbed particle size ranges from sand to boulder. Complex flow hydraulics caused by channel meandering and geologic controls sort these particles into a variety of fluvial features such as riffles (cobbles) and pools (gravels and sands). Healthy alluvial ecosystems require frequent mobilization of the channelbed and alternate bars to facilitate bedload transport and routing, to discourage riparian vegetation from colonizing and fossilizing alluvial features, to periodically cleanse fine-grained particles from spawning gravel deposits, and to otherwise rejuvenate a wide range of alluvial features (Section 4.8, Attribute No. 3).

5.4.2.1 Channelbed Mobility

Channelbed mobility was monitored at all WY1991 and WY1992 monitoring sites (Table 5.4). These sites, with established riparian berms, represent post-TRD channel morphology. Channelbed mobility was monitored at 3 bank-rehabilitation sites: Steiner Flat (RM 91.8), Bucktail

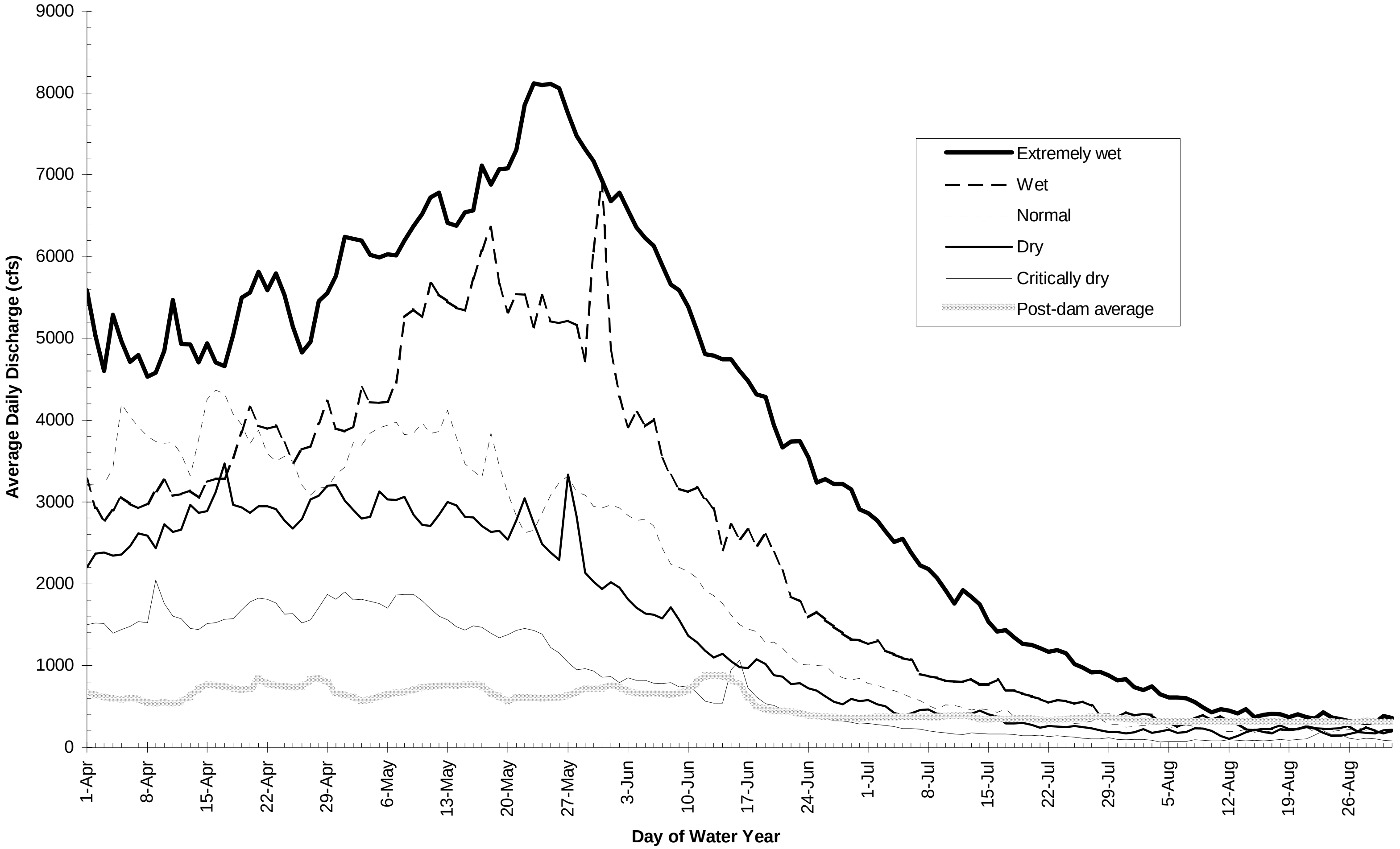


Figure 5.27. Average annual hydrographs of five water-year classes during snowmelt runoff period for all water years at the USGS gaging station at Lewiston (RM 110.9).

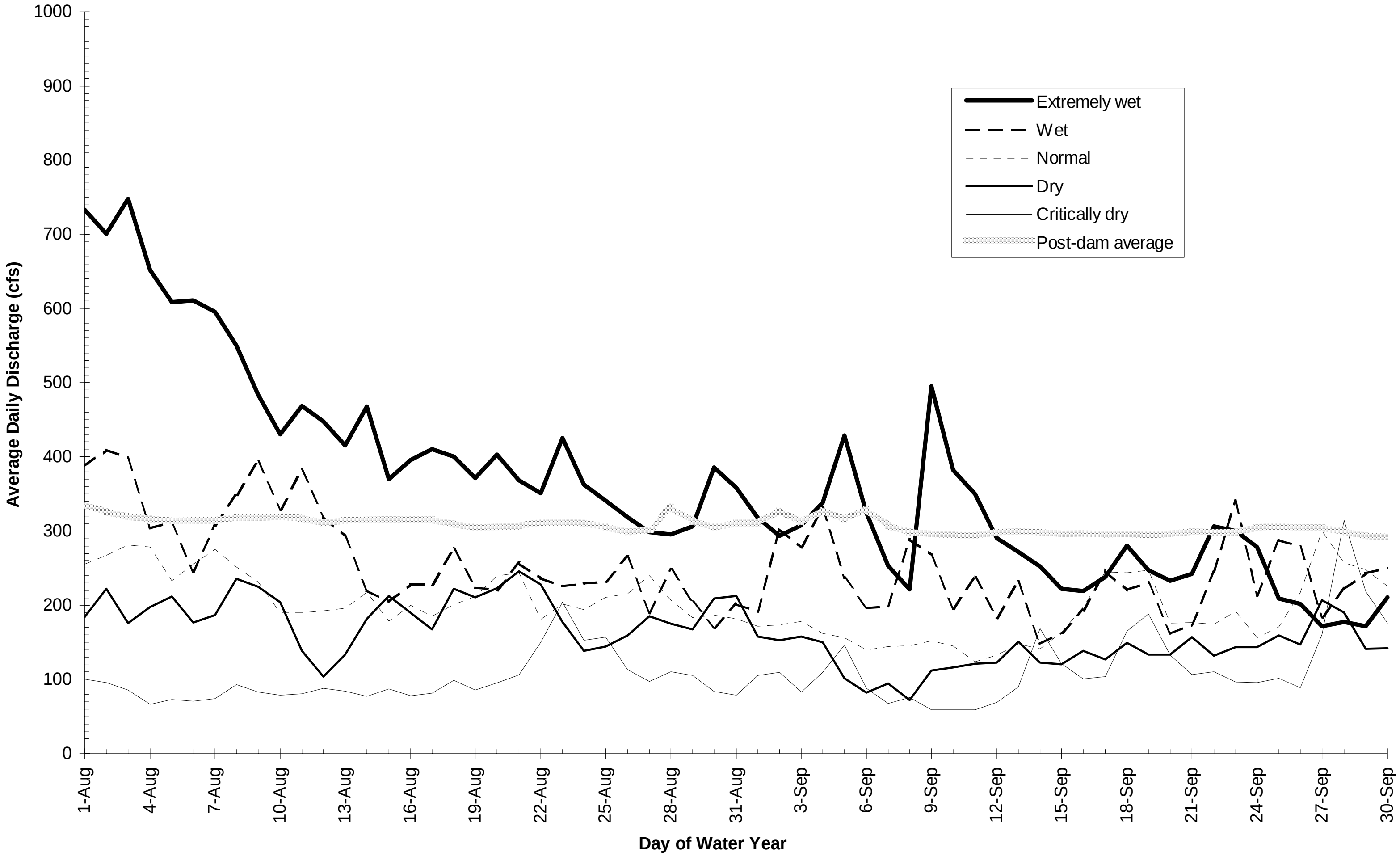


Figure 5.28. Average annual hydrographs of five water-year classes during summer baseflow period (August and September), for all water years at the USGS gaging station at Lewiston (RM 110.9).

Table 5.4. D_{50} and D_{84} tracer gravel mobility comparison between 2,700 cfs release (1991) and 6,500 cfs release (1992) at five consistent monitoring sites and cross section stations.

Gravel Plant Study Site RM 105.5

	Percentage of Particles Mobilized	
Cross Section/Particle Size	2,700 cfs (1991)	6,500 cfs (1992)
10+00/D50	28	80
10+00/D84	8	96

Steel Bridge Study Site RM 99.2

	Percentage of Particles Mobilized	
Cross Section/Particle Size	2,700 cfs (1991)	6,500 cfs (1992)
11+75/D50	20	94
11+75/D84	20	100
10+41/D50	43	100
10+41/D84	25	94
07+18/D50	30	100
07+18/D84	34	100

Indian Creek Study Site RM 95.2

	Percentage of Particles Mobilized	
Cross Section/Particle Size	2,700 cfs (1991)	6,500 cfs (1992)
11+55/D50	100	100
11+55/D84	97	100
10+00/D50	98	100
10+00/D84	82	100

Steiner Flat Study Site RM 91.7

	Percentage of Particles Mobilized	
Cross Section/Particle Size	2,700 cfs (1991)	6,500 cfs (1992)
10+56/D50	100	100
10+56/D84	97	100
00+45/D50	84	100
00+45/D84	76	93

Upper Sky Ranch Study Site RM 81.6

	Percentage of Particles Mobilized	
Cross Section/Particle Size	2,700 cfs (1991)	6,500 cfs (1992)
10+00/D50	75	100
10+00/D84	55	80

(RM 105.6), and Sheridan Creek (RM 82.0) during WY1996 and WY1997. These sites represent what channelbed hydraulics might be like (anticipated future channel morphology) in a rehabilitated channel. Detailed site descriptions and methods are provided in Trinity Restoration Associates (1993) and McBain and Trush (1997).

Periodic mobilization of gravel deposits creates and maintains high quality salmonid spawning and rearing habitat, and discourages riparian encroachment on gravel bars. Gravels and cobbles in undisturbed low-gradient alluvial rivers are typically mobilized every one to two years.

Incipient mobility studies had two objectives: (1) providing data to calibrate an incipient bed mobility model for the Trinity River mainstem; and (2) using the model to forecast flow magnitudes necessary to induce incipient mobility at other locations with other hydraulic characteristics, e.g., the upper channelbed surfaces of alternating bars (Trush et al., 1995; McBain and Trush, 1997). Cross sections were established at each study site. Particle-size distributions (represented by D_{16}, D_{31}, D_{50}, D_{69}, and D_{84}, the size particle whose diameter is larger than the subscripted percentile of all particles in the distribution) were determined for each cross section using pebble counts. Three size classes of tracer rocks were placed along each cross section to document channelbed mobility at quantified peak discharges: D_{84} tracers on the cross section, D_{50} tracers 2 feet upstream, and D_{16} tracers 3 feet upstream. Occasionally, D_{31} and D_{69} tracers were placed with the other tracers. Tracers were painted bright colors and numbered, then placed into the channelbed by removing a natural rock of similar size and placing the tracer rock in its location. Locations of the tracer rocks were precisely surveyed. After high-flow releases, the tracers rocks were resurveyed to measure movement.

Streamflows in the 5,000 cfs to 6,000 cfs range begin to mobilize larger cobbles and gravels on newly formed gravel bars.

Trinity Restoration Associates (1993) documented bed mobility for a 2,700-cfs release in WY1991 and a 6,500-cfs release in WY1992. The 2,700-cfs release mobilized finer grained particles and coarser particles on the steepest flanks of alternate bars. This flow also mobilized sand and gravel deposits overlying coarser channelbed surfaces in pool tails. The D_{50} rocks were mobilized on straight reaches and along the low-water margins of point bars. The 6,500-cfs release mobilized most particle sizes in straight reaches and larger particle sizes on the alternate bar surfaces. Rocks up to D_{84} were mobilized at these higher flows, although bar morphology remained relatively unchanged after both releases.

Mobility of tracer rocks on newly formed point bars at the Bucktail and Steiner Flat bank-rehabilitation sites was studied during flows of 5,400 cfs (WY1996), and at all 3 sites during WY1997 floods. The 5,400-cfs flow just began to mobilize D_{84} rocks near the lower bar surfaces (at approximately the 450-cfs water surface where riparian initiation is common (Figures 5.29 to 5.32)). Smaller rocks were mobilized over larger areas of the bars. These results indicate that 5,400-cfs flows begin to mobilize lower alternate bar surfaces and straight reaches, but higher flows are needed to mobilize entire bar surfaces. The WY1997 floods caused significant surface mobilization across the entire bars at all three bank-rehabilitation sites. WY1997 peak flows at the Bucktail, Steiner Flat, and Sheridan Creek sites were 11,400 cfs, 24,000 cfs, and 30,000 cfs, respectively.

5.4.2.2 Channelbed Scour and Fill

Channelbed scour was documented by Trinity Restoration Associates (1993) using scour chains installed in a variety of alluvial deposits in 1991 and 1992, and later by Wilcock et al. (1995) and McBain and Trush (1997) in the

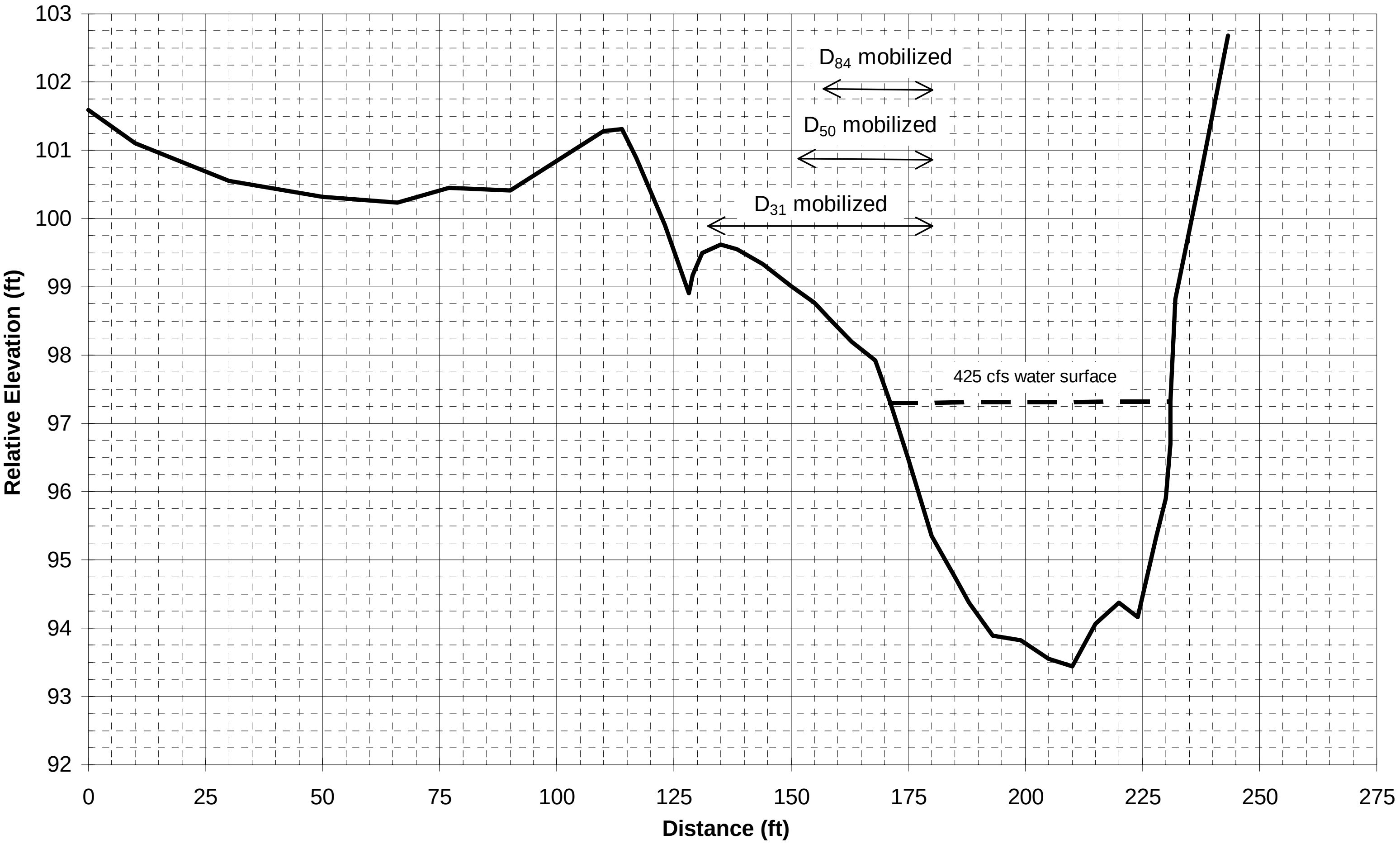


Figure 5.29. Bed mobility pattern at Bucktail bank-rehabilitation site (RM 105.6), cross section 11+00 during 5,400 cfs release. Rocks placed from station 131-179.

Figure 5.30. Bed mobility pattern at Bucktail bank-rehabilitation site (RM 105.6), cross section 12+00 during 5,400 cfs release. Rocks placed from station 96-156.

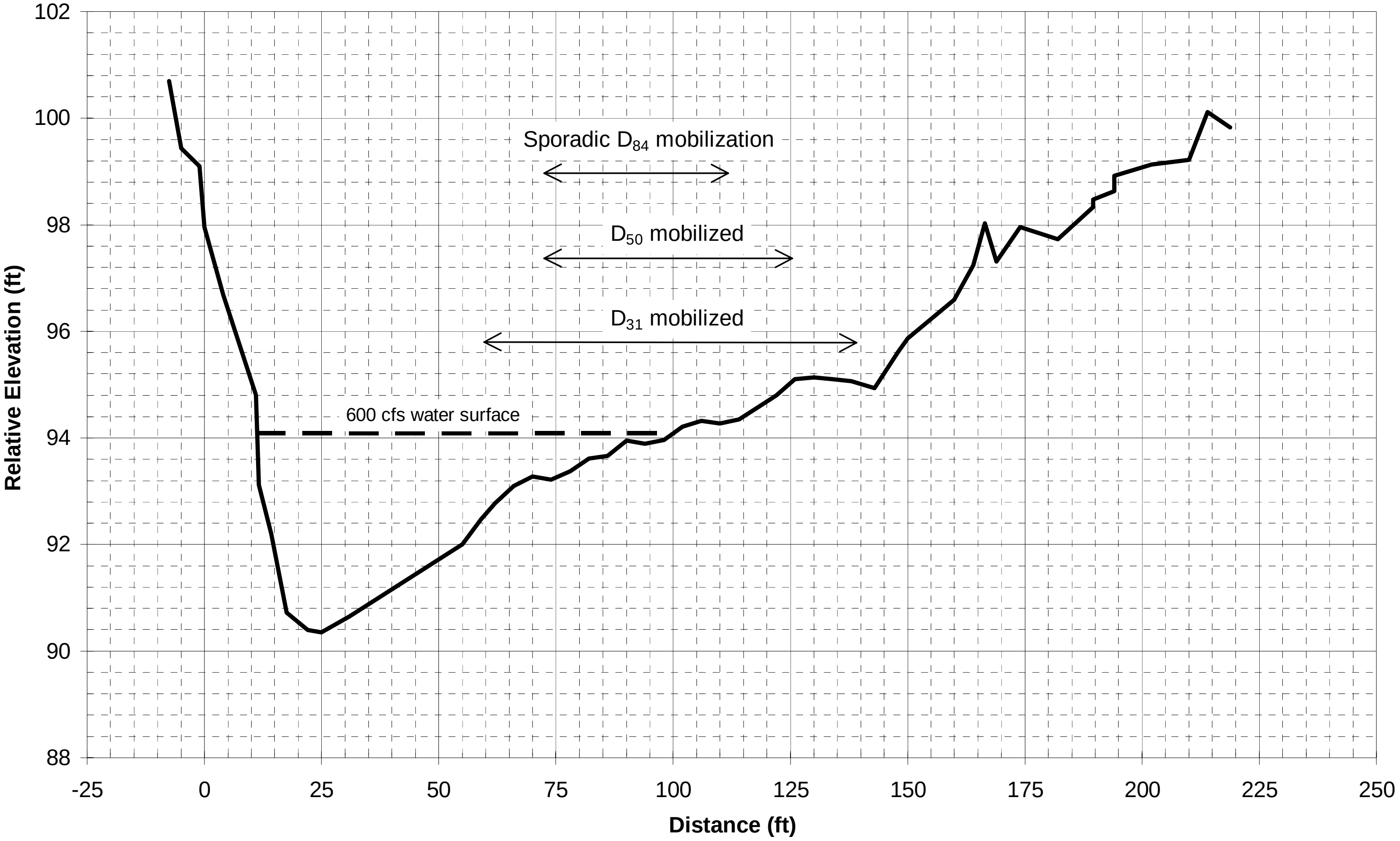


Figure 5.31. Bed mobility pattern at Steiner Flat bank-rehabilitation site (RM 91.8), cross section 5+02 during 5,400 cfs release. Rocks placed from station 62-138.

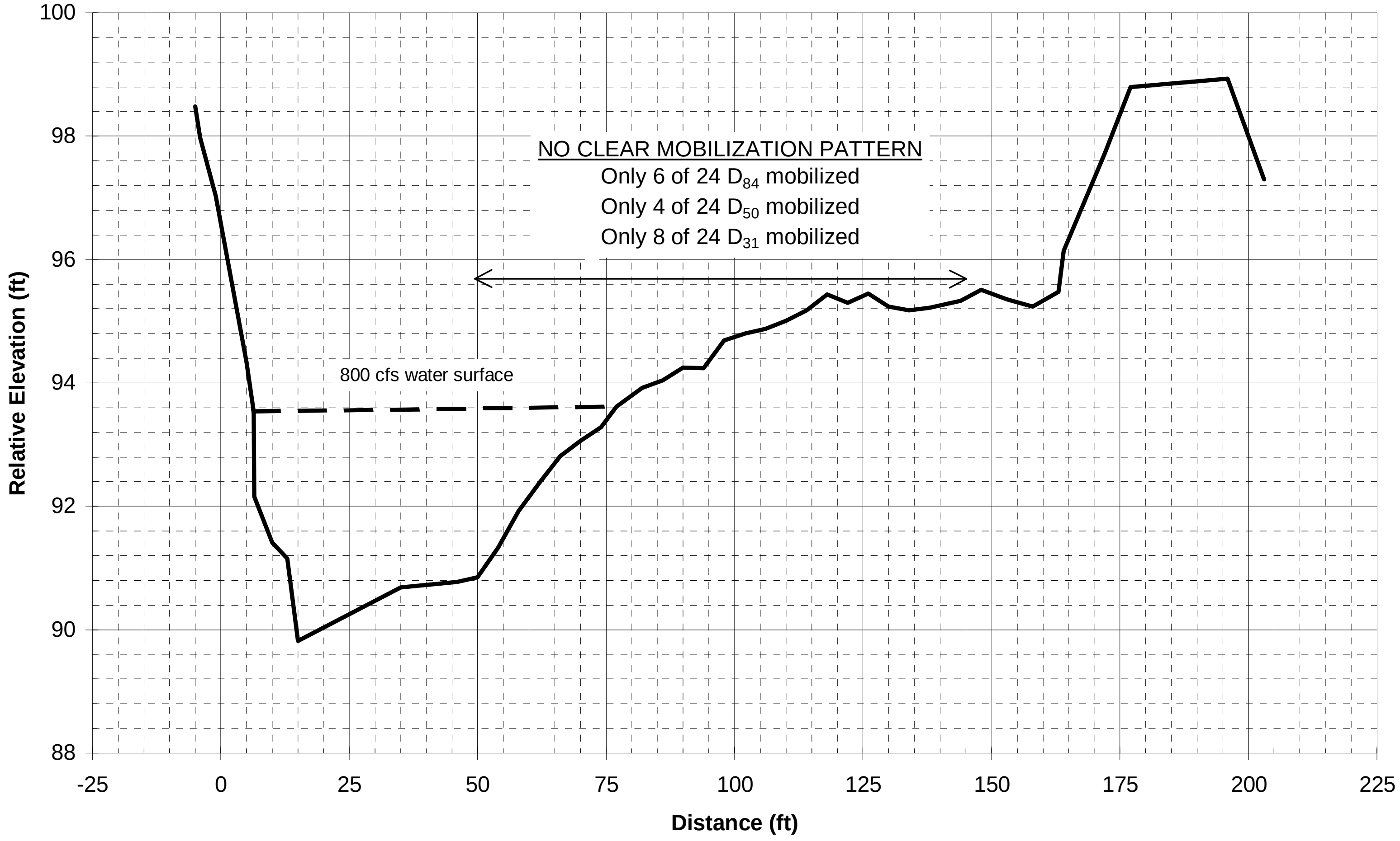


Figure 5.32. Bed mobility pattern at Steiner Flat bank-rehabilitation site (RM 91.8), cross section 5+98 during 5,400 cfs release. Rocks placed from station 52-144.

bank rehabilitation sites. These studies show that a 2,700-cfs flow did not cause significant scour, but scour from a 6,000-cfs flow began to exceed the 2 D_{84} depth in the straight-channel reaches. Significant scour did not occur along the alternate bar flanks, however.

McBain and Trush (1997) installed scour cores (Figure 5.33) on developing point bars at the Bucktail, Steiner Flat, and Sheridan Creek bank-rehabilitation sites (WY1996 and WY1997). Scour cores were placed on the face of point bars between the 300-cfs water surface elevation and the top of the bar. Peak flow releases during WY1996 ranged from 5,180 cfs (Bucktail, RM 105.6) to 5,600 cfs (Sheridan Creek, RM 82.0), indicating minor flow accretion. Scour depths, less than one D_{84} thickness, were approximately the same as subsequent redeposition during the receding limb of the same peak flow. There was no net change in cross section. The WY1997 peak flows ranged from 11,400 cfs at Bucktail to 30,000 cfs at Sheridan Creek, indicating a nearly three-fold flow increase owing to tributary accretion. All scour cores were scoured greater than 2 D_{84} except the highest core at the Bucktail site. A linear plot of discharge versus relative scour depth (Figure 5.34) showed that discharges between 8,000 and 12,000 cfs were necessary to scour greater than 2 D_{84} deep.

Modeling bed scour was attempted, but the difficulty in predicting local shear stress during peak flows precluded results comparable to tracer rock and scour core data results. Developing a better understanding of bed-scour mechanics and increasing the precision of bed-scour predictions should be addressed using an adaptive environmental assessment and management approach.

Coarse sediment supplied to the Trinity River by tributaries create the structure of high quality salmonid habitat. Achieving a balancing between coarse sediment supplied to the mainstem Trinity River with gravel transport during TRD streamflow releases ensures that gravel deposits and salmonid habitat are maintained from year-to-year.

Streamflows exceeding 6,000 cfs begin to scour the channelbed surface, while streamflows between 8,000 cfs and 12,000 cfs begin to scour and redeposit gravel bars greater than two particle sizes deep.

5.4.3 Bedload Budgets

Alluvial channel morphology is maintained in dynamic quasi-equilibrium where sediment is exported from the channel reach at a rate roughly equal to the sediment supplied. Coarse and fine sediment are transported through the reach or stored within the channel (dynamic), whereas the channel morphology fluctuates over a narrow range over time (quasi-equilibrium). The sediment budget,

$$I - O = \Delta S \qquad \text{(Equation 5.1)}$$

states that difference between the mass (or volume) of sediment moving into the reach (I), and the mass of sediment leaving the reach (O) is the change in sediment storage in the reach (ΔS) for channels in dynamic quasi-equilibrium (i.e., $\Delta S = 0$). In the post-TRD mainstem, sediment input from the watershed upstream from Lewiston Dam has been eliminated (I=0). Sediment output has been greatly reduced, but not eliminated, by flow regulation. In order to satisfy Equation 5.1, sediment storage in the reach below Lewiston Dam has decreased ($\Delta S < 0$). Therefore, this reach is not in dynamic quasi-equilibrium. Alluvial channels not in dynamic quasi-equilibrium tend to undergo changes in channel morphology (Williams and Wolman, 1984; Kondolf and Matthews, 1993).

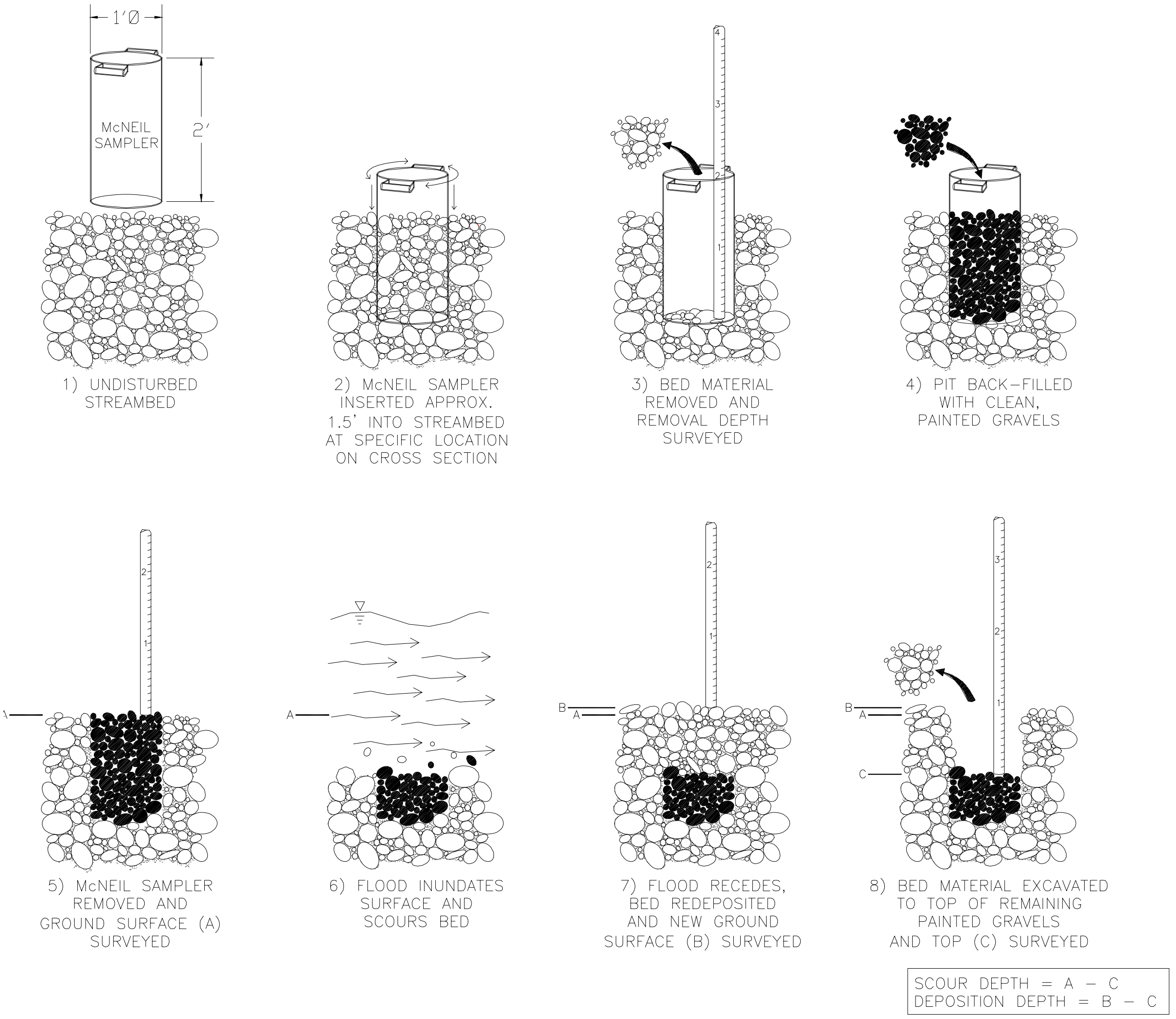


Figure 5.33. Methods for installing scour rock cores, and formulas for computing scour and deposition depth.

In cases where coarse sediment is in deficit, such as downstream from Lewiston Dam, desirable instream alluvial features such as alternate bars and spawning gravel deposits are gradually lost during periods of sediment transport. Most remaining mainstem coarse sediment stored in the reach below Lewiston has either been fossilized by riparian encroachment, abandoned in non-active parts of the former floodplain, or paved. Tributaries now provide the only significant coarse sediment supply.

Fine sediment supply to the mainstem has increased as a result of intensive land use in many tributary watersheds (BLM, 1995). Grass Valley Creek has the dubious distinction as the primary source of fine sediment oversupply to the Trinity River mainstem. The impact of increased fine sediment supply from tributaries is amplified by reduced transport capacity of the mainstem owing to decreased flows imposed by TRD. The increased fine sediment supply in combination with decreased carrying capacity, has allowed fine sediment to accumulate in pools and on riparian berms and to infiltrate gravel deposits.

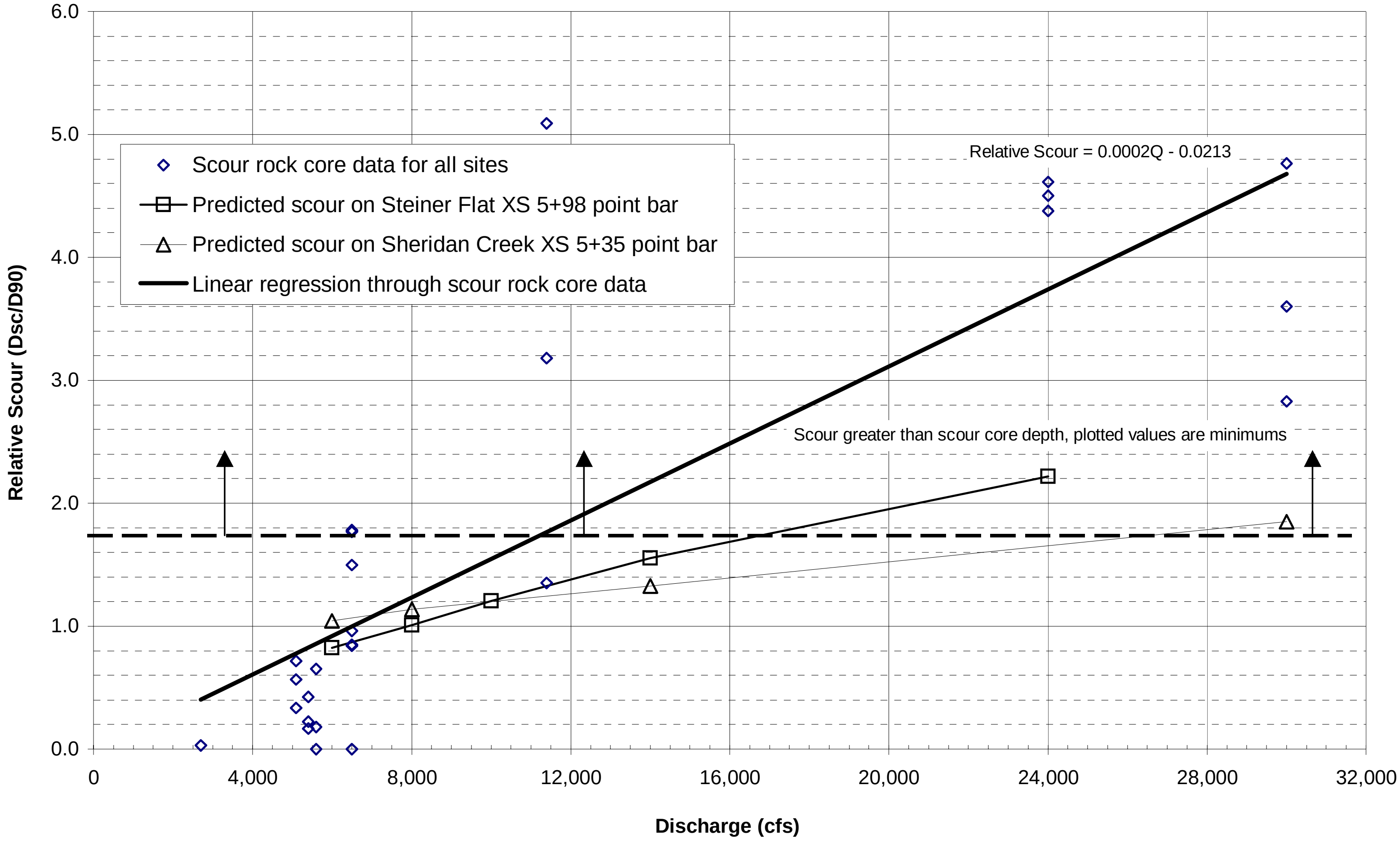


Figure 5.34. Relative scour depth (D_{sc}/D_{90}) as a function of discharge on newly formed point bars at bank-rehabilitation sites, including Wilcock et al., (1995) data.

Objectives for the studies described in this section were to (1) identify Trinity River mainstem reaches where coarse bed material supply is less than current and future transport capacities; (2) predict flows necessary to distribute tributary-supplied coarse bed material; (3) identify candidate reaches where coarse bed material should be augmented to balance the coarse sediment budget; and (4) predict volumes of coarse bed material needed to be introduced in these candidate reaches. Coarse bed material was quantified as that portion of the bedload transport greater than $^{5}/_{16}$ inch (Figure 5.35). This size delineation was chosen for data continuity with other researcher's work (Wilcock et al., 1995); it is a size class that is virtually never transported in suspension, which eases modeling assumptions, and is not harmful to salmonid habitat.

5.4.3.1 Coarse Bed Material Sampling Methods

The Trinity River reach from Lewiston Dam (RM 111.9) to the Weaver Creek confluence (RM 93.8) has been most affected by inadequate coarse sediment supply and oversupply of fine sediment (Ritter, 1968). For these reasons, this reach was selected for detailed study. The reach was divided into five subreaches where coarse sediment budget computations (Equation 5.1) could be made to describe specific balances or imbalances (Figure 5.35). A combination of historical and new sediment sampling stations were used: Deadwood Creek (RM 110.8), Rush Creek (RM 107.5), Grass Valley Creek (RM 104.0), Indian Creek (RM 95.3), Lewiston Cableway (RM 110.2), and Trinity River near Limekiln Gulch (RM 98.3). The USGS has measured bedload and suspended sediment transport at the Grass Valley Creek near Fawn Lodge gaging station (11-525600) from 1975 to 1997, and at the Trinity River near Limekiln Gulch gaging station (11-525655) from 1981 to 1991. The USGS sampling effort was supplemented in 1997 with the other tributary and mainstem stations, topographic monitoring of tributary deltas, and topographic monitoring of the Hamilton Ponds at the mouth of Grass Valley Creek.

Bedload transport was estimated at tributary and mainstem stations using either a hand-held 3-inch or cable-deployed 6-inch Helley-Smith pressure-difference samplers (Helley and Smith, 1971). Suspended sediment was sampled using depth-integrating samplers and USGS protocols (Guy and Norman, 1970; Edwards and Glysson, 1988). Refer to McBain and Trush (1997) for specifics on deployment, sample time intervals, and grain-size analyses. USGS bedload and suspended-sediment transport data were used for computing sediment transport rates in Grass Valley Creek and Trinity River near Limekiln Gulch. After lab analysis of the sediment samples, rating curves for bedload and suspended-sediment transport rates (tons/day) were computed using standard procedures (Edwards and Glysson, 1988). Separate bedload rating curves were developed for sediment coarser and finer than $^{5}/_{16}$ inch.

Significant coarse bedload transport occurs at flows that cannot readily be sampled owing to excessive flow velocities and debris. Because of

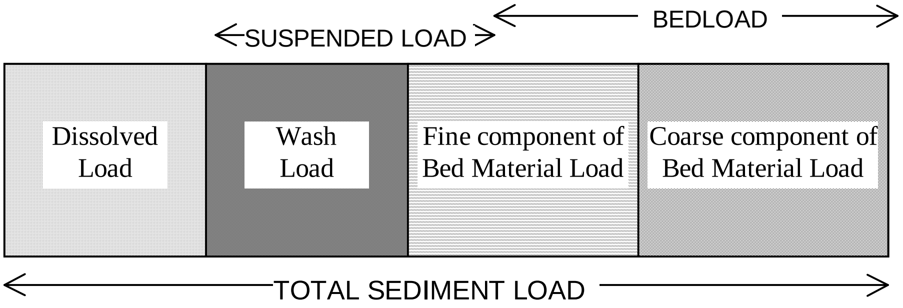


Figure 5.35. Delineation of total sediment load generated from a watershed. The coarse component of bed material load is typically beneficial to salmonid habitat (e.g., spawning gravel, point bars), while the fine component of bed material load is typically harmful to salmonid habitat (e.g., clogging of spawning gravels, embeddedness). Proportions of total sediment load in each box is unique to each watershed.

this, bedload sediment transport rating curves had to be extended. To improve extrapolation of the transport data to higher flows, bedload transport rating curves were fit to equations of the form (Wilcock et al., 1995):

$$Q_b = (w/a)*(Q-Q_c)^b \text{ (Equation 5.2)}$$

where:

Q_b is bedload transport (tons/day), either > $^5/_{16}$ or < $^5/_{16}$ inch,

w is the width of the active bed (feet) during transport,

a is a fitted coefficient (typically in the range of $1\text{x}10^5$ to $1\text{x}10^8$),

Q is the flow (cfs),

Q_c is the flow at which no bedload transport occurs, and

b is a fitted parameter typically between 2 and 3.

This rating curve form was used to estimate bedload transport at Deadwood Creek, Rush Creek, Indian Creek, Trinity River at Lewiston, and Trinity River near Limekiln Gulch sediment-measurement stations. Published USGS data were used for estimating bedload transport from Grass Valley Creek.

Topographic surveys of the Hamilton Ponds (on Grass Valley Creek 0.5 mile upstream from the Trinity River confluence; designed to reduce sediment entering the Trinity River from Grass Valley Creek) were used to obtain an independent estimate of coarse sediment transport in the Grass Valley Creek watershed. These ponds are periodically dredged to remove sediment that accumulated the previous winter. Repeat topographic surveys by NRCS (Roberts, 1996) and McBain and Trush (1997) provided coarse sediment deposition volume for discrete storm events as well as integrating sediment deposition over each water year.

Topographic surveys also were made on the tributary deltas of Deadwood Creek and Rush Creek. Tributary delta topography was surveyed from the tributary confluence downstream on the mainstem immediately before and after tributary flood events. When tributaries were flooding, mainstem releases often remained near 300 cfs, allowing tributary-derived coarse bed material to accumulate as deltas. These surveys allowed limited calibration to rating curve extensions (i.e., prediction of transport using flow and bedload rating curves should match delta accumulation).

5.4.3.2 Coarse Bed Material Sampling Results

Three mainstem bedload-transport measurements were made at the USGS cableway at Lewiston during the high-flow releases following the January 1, 1997 flood (Figure 5.36). Data collected suggest an estimated 25,000 tons of coarse bed material and 2,500 tons of fine bed material were transported past the site during WY1997. Deadwood Creek is the only tributary upstream from the Lewiston sampling station, and because Deadwood Creek does not produce a significant volume of fine bed material load, fine bed material supply and transport at the Lewiston gage sampling station is low. Fine-grained bed material load was no more than 10 percent of the total bed material load in any sample collected.

> The Trinity River from Lewiston Dam to Rush Creek will require yearly supplementation of coarse sediment due to the TRD blocking coarse sediment supply from the upper watershed, otherwise spawning gravels and gravel bars will be gradually depleted.

USGS has collected bedload transport data at its Limekiln Gulch gaging station from 1981 to 1992. As part of this study, two additional bedload transport measurements were made in WY1997. The WY1997 annual hydrograph was reconstructed from selected flow measurements, staff plate observations, and upstream gaging stations. The bedload transport rating curve (Figure 5.37) was used to estimate transport of 20,400 tons of coarse bed material and 12,600 tons of fine bed material past this site in WY1997. These WY1997 estimates closely agreed with the best-fit line for USGS bedload measurements from WY1989 to WY1991. USGS bedload data from WY1981 to WY1986 show much greater bedload transport rates at low flows than at similar flows during the WY1989 to WY1991 period, indicative of decreasing sand supply over time.

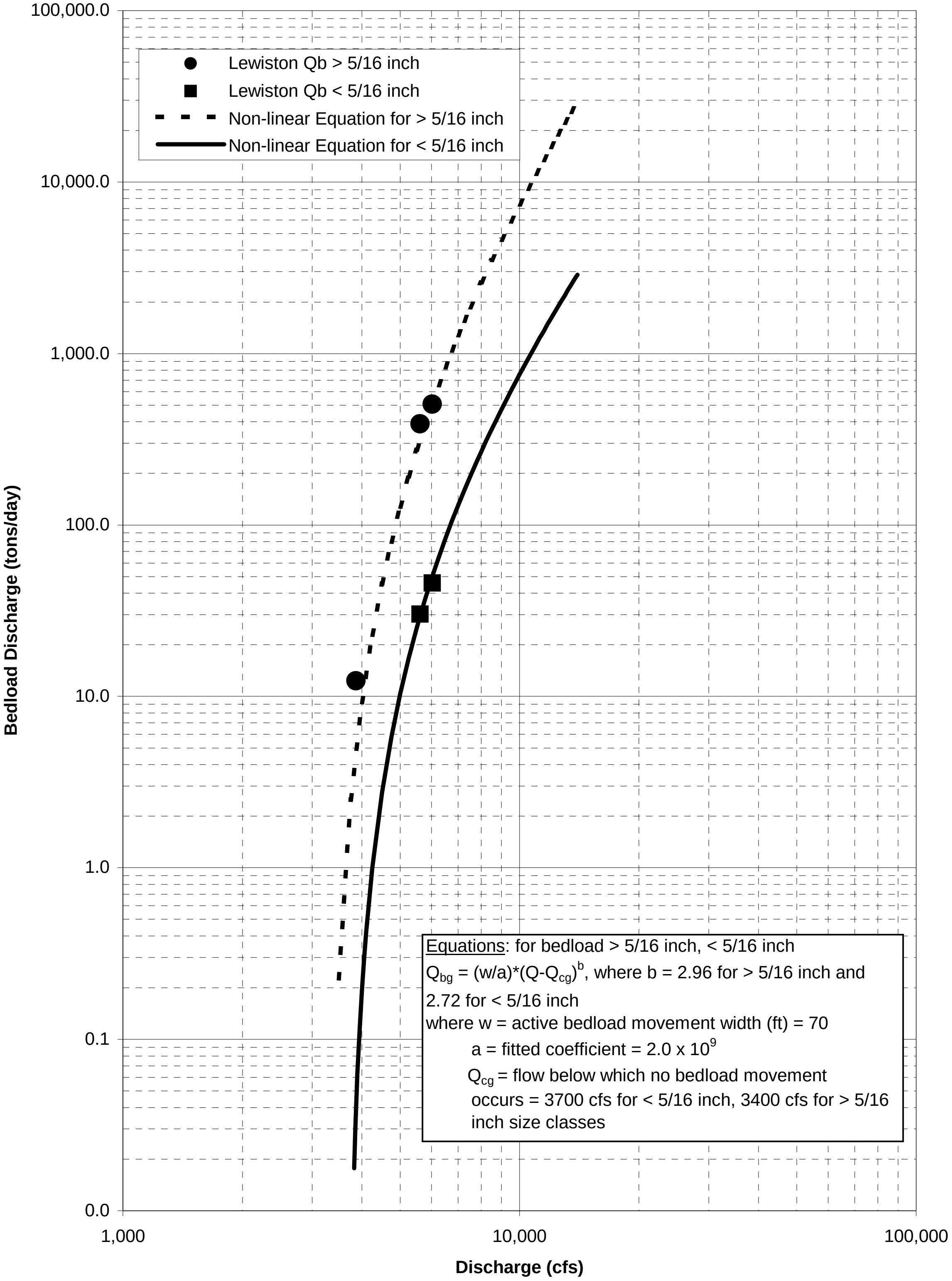
Rating curves for Deadwood Creek, Rush Creek, and Indian Creek were prepared using both simple power functions ($Q_s = aQ^b$, where "*a*" is a coefficient and "*b*" is the exponent describing the slope of the best-fit line) and Equation 5.2. Improved data fit was obtained by subdividing into pre- and post-January 1, 1997, flood periods and segregating rising/falling limb data sets to account for storm hysteresis. Predicted coarse tributary bed material yields for WY1997 are given in Table 5.5.

5.4.3.3 WY 1997 Coarse and Fine Bed Material Budget

Using the predicted mainstem Trinity River coarse sediment transport values of 25,000 tons and 20,400 tons at the Lewiston and Limekiln Gulch stations, respectively, a coarse bed material sediment budget was developed for WY1997. Comparing the 25,000 tons transported at Lewiston with the 140 tons contributed from Deadwood Creek and 16,100 tons contributed from Rush Creek indicated that the mainstem Trinity River was in a coarse bed material deficit at least downstream from Rush Creek (16,100 + 140 – 25,000 = 8,760 tons deficit) and possibly farther downstream. Therefore, significant coarse bed material augmentation would be required upstream from Rush Creek to balance the annual coarse bed material budget.

The corresponding fine bed material transport was 2,500 and 12,600 tons at the Lewiston and Limekiln Gulch stations, respectively. The fine bed material budget was in deficit downstream to Rush Creek (-2,460 tons), then in surplus downstream from Rush Creek (+16,100 tons using Lewiston data; +6,000 tons using Limekiln data).

The volume or mass of sediment transported in any given year for any given tributary is unique. Typically, the wetter the water year, the more sediment transported by tributaries. Ideally, predicting the volume of sediment delivered to the mainstem Trinity River by tributaries for each of the five water-year classes would be based on a long period of record for sediment yield. The only nearby tributary with a long-term sediment transport



Equations: for bedload > 5/16 inch, < 5/16 inch

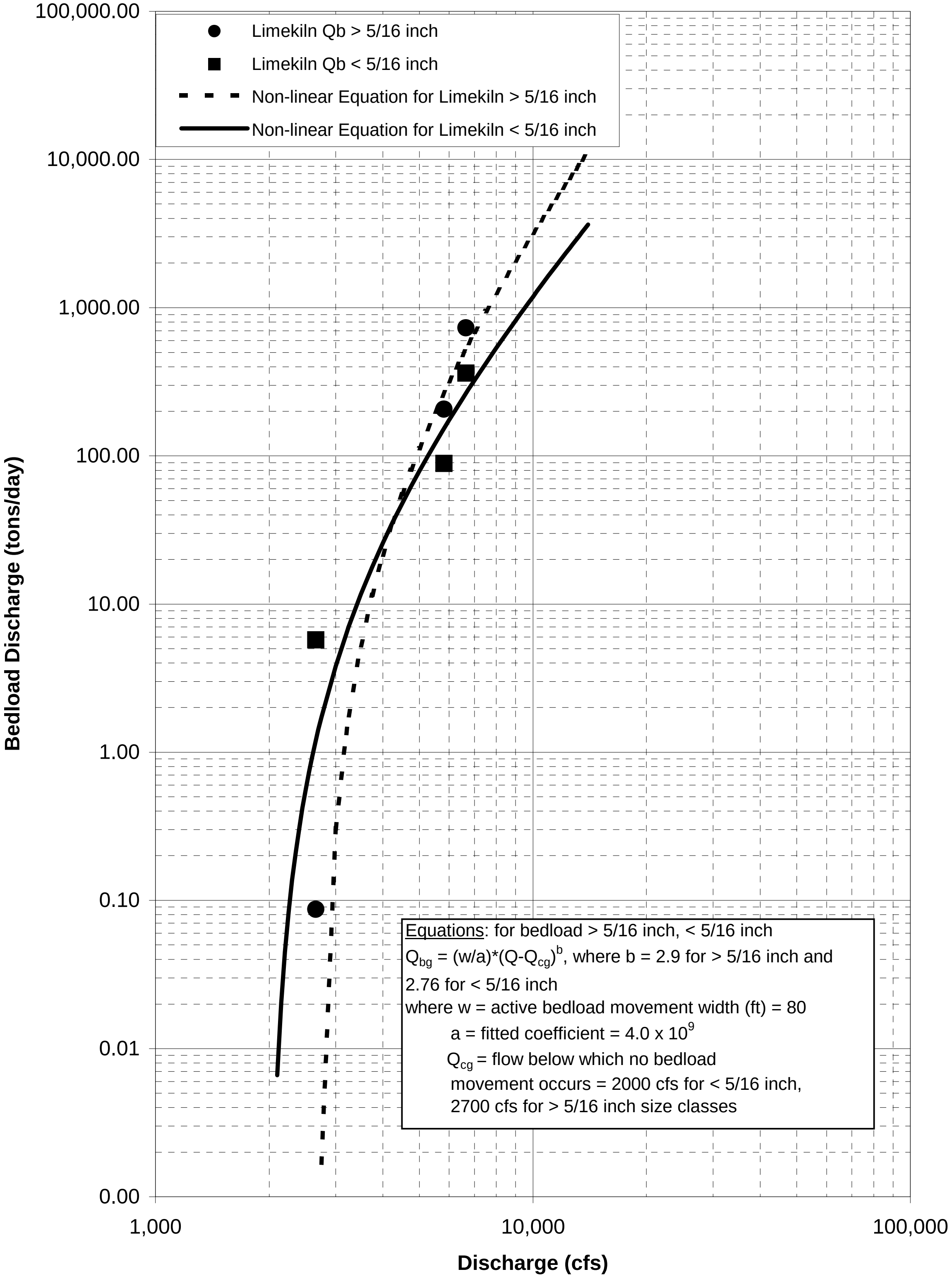
$Q_{bg} = (w/a)*(Q-Q_{cg})^b$, where b = 2.96 for > 5/16 inch and 2.72 for < 5/16 inch

where w = active bedload movement width (ft) = 70

a = fitted coefficient = 2.0×10^9

Q_{cg} = flow below which no bedload movement occurs = 3700 cfs for < 5/16 inch, 3400 cfs for > 5/16 inch size classes

Figure 5.36. Trinity River at Lewiston (RM 110.9) mainstem bedload transport for > $^5/_{16}$ inch and < $^5/_{16}$ inch size classes.



Equations: for bedload > 5/16 inch, < 5/16 inch

$Q_{bg} = (w/a)*(Q-Q_{cg})^b$, where b = 2.9 for > 5/16 inch and 2.76 for < 5/16 inch

where w = active bedload movement width (ft) = 80

a = fitted coefficient = 4.0×10^9

Q_{cg} = flow below which no bedload movement occurs = 2000 cfs for < 5/16 inch, 2700 cfs for > 5/16 inch size classes

Figure 5.37. Trinity River below Limekiln Gulch (RM 100.9) near Douglas City mainstem bedload transport for > $^5/_{16}$ inch and < $^5/_{16}$ inch size classes.

Table 5.5. Summary of WY 1997 tributary and mainstem bed material load transport.

Station	Total Bedload (tons)	Bedload > $^{5}/_{16}$ inch (tons)	Bedload < $^{5}/_{16}$ inch (tons)
Deadwood Creek	180	140	40
Rush Creek	34,700	16,100	18,600
Grass Valley Creek	14,100**	3,700*	>8,900*
Indian Creek	36,500	12,200	24,300
TOTAL:	85,480	32,140	>51,840
Trinity River at Lewiston	27,500	25,000	2,500
Trinity River near Limekiln Gulch	42,600	20,400	12,600
TOTAL:	70,100	45,400	15,100

* based on deposition in Hamilton Ponds (near mouth); portion of fine sediment routed through ponds to mainstem Trinity River.

** based on puiblished USGS data at Grass Valley Creek near Fawn Lodge gaging station, several miles upstream of mouth.

record is Grass Valley Creek. Therefore, Grass Valley Creek was used to extrapolate WY1997 sediment data measured in Deadwood Creek, Rush Creek, and Indian Creek to predict average annual sediment yield for each water-year class (Table 5.6). This prediction was then used to estimate peak flow duration for each water year required to transport that volume or mass of coarse bed material load downstream. For example, if tributaries delivered 10,000 tons of coarse bed material in a Wet water year, the 8,500-cfs peak would have to occur for 3 days for the mainstem to transport 10,000 tons based on the Lewiston bedload rating curve. A secondary objective was to determine whether the introduction of coarse bed material below Lewiston Dam would be needed, and if so, at what rates, for each water-year class.

Long-term annual coarse bed material input for each of the tributaries was predicted by correlating measured tributary coarse bed material yields with peak discharges from Grass Valley Creek. Extrapolating this tributary coarse bed material yield to Grass Valley Creek peak discharge to 1976 provided 21 years of synthetic coarse bed material yield from tributaries. Next, for each tributary, coarse bed material loads were grouped and averaged for each water-year class (Table 5.6).

The TRD is better able to manage mainstem coarse bed material transport nearer Lewiston Dam; therefore, Rush Creek was chosen as the initial point of balancing the coarse bed material budget. Next, a matrix of mainstem coarse bed material transport was developed for the Trinity River at Lewiston and Trinity River near Limekiln Gulch sediment-monitoring stations (Table 5.7). Using peak flow magnitudes determined from bed mobility and

Table 5.6. Estimated coarse bed material yields by water-year classification for major tributaries.

Water Year Classification	Deadwood Creek (tons)	Rush Creek (tons)	Grass Valley Creek at Mouth (tons)	Indian Creek (tons)
EXTREMELY WET average:	280	48,600	12,800	164,000
WET average:	50	9,000	3,050	14,300
NORMAL average:	4	800	1,300	340
DRY average:	2	290	1,150	85
CRITICALLY DRY average:	0	0	700	0

bed scour objectives (11,000 cfs for Extremely Wet years to 2,000 cfs for Critically Dry years), the following estimated flow durations are required to transport the coarse bed material load from Deadwood Creek and Rush Creek:

Extremely Wet	48,880 tons of supply: 5 days of 11,000 cfs and 5 days of 6,000 cfs transports 53,000 tons using Lewiston coarse bed material load data and 25,000 tons using Limekiln Gulch coarse bed material load data.
Wet	9,050 tons of supply: 5 days of 8,500 cfs and 5 days of 6,000 cfs transports 19,000 tons using Lewiston coarse bed material load data and 9,800 tons using Limekiln Gulch coarse bed material load data.
Normal	800 tons of supply: 5 days of 6,000 cfs transports 2,250 tons using Lewiston coarse bed material load data and 1,600 tons using Limekiln Gulch coarse bed material load data.
Dry	290 tons of supply: 5 days of 4,500 cfs transports 175 tons using Lewiston coarse bed material load data and 275 tons using Limekiln Gulch coarse bed material load data.
Critically Dry	Supply is functionally zero, and peak flow is below the threshold to transport coarse bed material load; therefore transport also is functionally zero.

This extrapolation based on a single year of sediment-transport measurement has considerable uncertainty, and these 5-day peak flow durations have corresponding uncertainty. Future flow releases should not strictly follow the above recommendations; rather, management should be adaptive to the conditions of each given year. For example, one Wet year may result in 10,000 tons of coarse bed material load delivered to the Trinity River downstream from Rush Creek, whereas another Wet water year may only contribute 6,000 tons. Therefore, the duration of peak flow release should be shorter for the latter Wet year. The intent of this evaluation is to estimate average duration needed to transport coarse bed material load — knowing that for any given year, the

Table 5.7. Total mainstem bedload transport ($> {}^{5}/_{16}$ in) in tons, at the Trinity River at Lewiston gaging station cableway (RM 110.2) and the Trinity River near Limekiln Gulch gaging station cableway (RM 98.3) as a function of release duration.

Discharge (cfs)	1 day	2 days	3 days	5 days	7 days	10 days
	Lewiston					
14,000[1]	29,000	57,500	86,000	144,000	200,000	287,000
11,000	11,000	21,000	32,000	53,000	75,000	107,000
8,500	3,300	6,600	9,900	16,500	23,000	33,000
6,000	450	900	1,350	2,250	3,150	4,500
4,500	35	70	105	175	250	350
2,000	0	0	0	0	0	0
	Limekiln					
14,000[1]	11,350	22,700	34,000	57,00	79,000	113,000
11,000	4,600	9,300	14,000	23,200	32,500	46,000
8,500	1,650	3,300	4,900	8,200	11,500	16,500
6,000	320	640	960	1,600	2,240	3,200
4,500	55	110	165	275	385	550
2,000	0	0	0	0	0	0

[1] 14,000 cfs was included for consideration in event 11,000 cfs does not provide adequate bed scour.

duration will be set by the adaptive environmental assessment and management program based on the coarse bed material yield for that year.

5.4.3.4 Coarse Bedload Routing

Alluvial and mixed-alluvial rivers must route (transport) coarse bed material downstream to maintain bedload transport continuity. Channel down-cutting ensues after high-flow events if there is not an upstream source of coarse bed material to replace bed material transported downstream. Lewiston and Trinity Dams have completely halted coarse bed material routing from sources upstream. The mainstem immediately below Lewiston Dam has responded with slight down-cutting and significant channelbed coarsening.

Bed material routing is also of concern farther downstream. Annual coarse sediment supply from downstream tributaries continues at rates equal to or slightly higher than before TRD, but lower instream flows reduce mainstem transport capacity. Many tributaries now have created deltas in the mainstem. Bed elevation at these deltas have aggraded as much as 8 feet. At Rush Creek, Grass Valley Creek, and Indian Creek, aggraded deltas have caused major backwaters during mainstem high flows. These backwaters decrease slope in the mainstem, prevent coarse sediment from routing past the tributary junctions, and cause coarse and fine sediment to deposit in these backwaters. Deep pools, such as those near Lewiston that exceed a depth of 20 feet, also may prevent or restrict coarse bed material routing. The purposes of this study were to: (1) determine if coarse bed material is being routed past significantly aggrading deltas and historically deep pools upstream from Weaver Creek (RM 93.8) under the contemporary annual flow regime; and (2) identify a peak flow threshold that would allow coarse bed material to be routed past these deltas and pools.

In WY1996, tracer rocks were placed in the mainstem upstream from the tributary deltas of Grass Valley Creek and Indian Creek following the same methodology applied in Section 5.4.2. Tracer rocks were not installed upstream from the Rush Creek delta because of excessive depths and exposed bedrock on the channelbed (routing was modeled instead). Hydraulic conditions (cross sections, water-surface elevation, and water-surface slope) were surveyed at Rush Creek, Grass Valley Creek, and Indian Creek deltas during a 5,100-cfs release. Tracer rocks placed upstream from Grass Valley Creek and Indian Creek had minimal mobilization. Only 17 percent of the D_{84} tracer rocks placed on the riffle crest of the Grass Valley Creek delta were mobilized. Mobility slightly upstream in the backwater was considerably less. For example, at Indian Creek, tracer rocks were placed on a deposition zone at the upstream end of the backwater, more than 500 feet upstream from the Indian Creek delta. None of the D_{84} and 16 percent of the D_{50} tracer rocks mobilized during the 5,100-cfs release. However, coarse bedload was moving into the cross section as evidenced by captured gravel in bedload traps placed on the cross section and by several tracer rocks that were partly buried by new gravel. This coarse bed material was deposited locally at the head of the backwater reach, causing the deposition zone to continue growing toward the Indian Creek delta. Therefore, coarse bed material is not routing past the Grass Valley Creek and Indian Creek deltas.

To determine whether coarse bed material was being routed through deep pools, movement of tracer rocks was monitored during the 5,100-cfs release. As a simple pilot experiment, 200 tracer rocks (D_{84}) were thrown-in immediately upstream from Sawmill Pool (RM 108.6) and Bucktail Pool (RM 104.6) during the rising limb of a dam release. A similar experiment also was performed in other pools in WY1992 (Trinity Restoration Associates, 1993). At both the Sawmill Pool and Bucktail Pool, no relocated tracer rocks were found downstream from the pools after 9 days at a flow of 5,100 cfs; most tracer rocks remained at or near the insertion point. Those that traveled into the pools were immediately deposited on subtle point bars on the inside bend. Tracer rocks deposited on these adjacent point bars may move to the next downstream riffle–pool sequence during future flows, but the experiment was not repeated in subsequent years.

The reduction in high flow regime by the TRD has allowed riparian vegetation to establish on and fossilize gravel bars that are important for salmonid habitat. This riparian encroachment has also formed a sandy berm within the vegetation. A future high flow regime that discourages riparian colonization of gravel bars and encourages riparian colonization of floodplains will reestablish a more natural and healthy riparian community.

In WY1992, several tracer rock sets were placed at the head of riffles to document routing. At the Steiner Flat site (RM 91.7), three tracer rocks (a D_{84}, a D_{69}, and a D_{50}) were transported through a 20-foot deep pool and onto the downstream median bar by the 6,500-cfs release (Trinity Restoration Associates, 1993). These two simple experiments suggested that 5,000 to 6,000 cfs was not only near the threshold for general bed mobilization, but also near the threshold for transporting coarse bedload through alternate bar sequences.

Channelbed surface mobility was modeled in the backwaters of all three deltas using the model described in Section 5.4.2. The Shields parameter for the local D_{84} was predicted at cross sections in the backwater of the Rush Creek, Grass Valley Creek, and Indian Creek deltas, and evaluated using the incipient Shields parameter observed at Steiner Flat. In all cases, predicted Shields parameters for flows up to 14,000 cfs were well below that needed to cause incipient mobility. The low predicted mobilities were caused by backwater-induced low slopes: Rush Creek = 0.00011, Grass Valley Creek = 0.00063, and Indian Creek = 0.0002. Water-surface slopes in most mainstem reaches ranged from 0.001 to 0.002. By increasing slope, best accomplished by partially excavating the deltas and thus lowering the hydraulic control, shear stress can be increased to restore coarse bed material routing.

5.4.4 Riparian Plant Communities

Woody riparian encroachment was instrumental in changing the mainstem's alluvial nature and consequently degrading salmonid habitat. Several important mortality agents that suppressed encroachment prior to TRD depended on the variable unregulated flow regime: bar inundation and desiccation (Section 4.8, Attribute No. 2); frequent mobilization of the channelbed surface that scours seedlings (Section 4.8, Attribute No. 3); less frequent channelbed scour that kills older seedlings (Section 4.8, Attribute No. 4); periodic channel migration that undercuts saplings and mature trees (Section 4.8, Attribute No. 6); scour of mature trees (Section 4.8, Attributes No. 7 and No. 8); and isolation of mature stands through channel avulsions (Section 4.8, Attributes No. 8 and No. 10).

Linking specific hydrograph components with river-channel dynamics and riparian mortality agents provides a framework for recommending how woody riparian encroachment, including riparian berm formation, can be discouraged in the future, and how natural regeneration on the floodplain surfaces can be encouraged. This linkage has been proposed before. Bradley and Smith (1986) showed that desiccation (killing seedlings high on a point bar) and scour (killing seedlings low on the bar) allowed only occasional cottonwood cohorts to survive. Scott et al. (1993), in relating specific components of the annual hydrograph to riparian life-history dynamics, concluded that aside from the rising limb, all aspects of the hydrograph play a vital role in the germination, establishment, and long-term survival of many riparian species. Returning these mortality agents to riparian vegetation near the post-dam low flow channel will encourage self-sustaining diverse riparian plant communities on geomorphic surfaces higher on the floodway (Section 4.8, Attribute No. 9).

5.4.4.1 Woody Riparian Encroachment Processes

Three key life-history characteristics of woody riparian plants can be used to discourage encroachment: a seed can only germinate on surfaces not underwater; a seedling can establish itself only on moist surfaces where water is readily available; and younger plants are easier to remove by scour than older plants. If an alternate bar is submerged during the period in which seeds are released, seedlings can not initiate on the bar surfaces. If seeds are released near the end of snowmelt recession or during summer baseflow, seedling initiation will be constricted to the moist lower bar surfaces (the exposed capillary zone). Seedlings established on these lower bar surfaces are more susceptible to being removed by scour during subsequent high flows (Section 5.4.4.4). In order to identify when inundation and effective channelbed scour would be most effective in minimizing riparian encroachment, it was necessary to: (1) establish seed viability windows for the dominant woody riparian species; (2) document flows that prevent germination by alternate bar inundation; (3) track surface and subsurface moisture in bars; and (4) quantify the depth of scour needed to remove a specific age class of woody riparian plant.

> Periodically scouring new seedlings on gravel bar surfaces near the low water surface will preserve the high quality salmonid habitat that these gravel bars provide.

Woody riparian life histories were monitored during WY1995 through WY1997 (Figure 4.13). Arroyo willow released seeds during or before the spring snowmelt peaks. Cottonwoods dispersed seeds later, during spring snowmelt recession, and for only a short period. Narrow-leaf and shiny willows released seeds beginning in late spring during the snowmelt recession and extending well into summer baseflow, making these species the most aggressive at encroaching onto exposed bar surfaces. White alder dispersed seeds during October low flows, and the catkins are distributed downstream by winter flows, delivering a fresh supply of alder seeds to newly deposited alluvial features. White alder and Oregon ash are the only woody riparian plant species on the Trinity River with seeds viable more than 2 weeks, typically 2 to 3 years.

5.4.4.2 Preventing Seedling Establishment

Encroachment can be discouraged by inundating bars during the seed-release period. Flows just inundating (0.5-foot deep) the tops of newly formed alternate bars at all pilot bank-rehabilitation sites were either documented in the field (with constructed rating curves) or estimated using the Manning's equation. Discharges inundating the bar tops varied by site and exhibited no longitudinal trend downstream (Table 5.8).

An exposed capillary zone extending a short distance above the water surface provides a narrow, but moist, germination surface. Above this capillary zone, the bar surface becomes increasingly dry and hot as summer progresses. This zone moves down the bar face as the water surface declines during the snowmelt recession and summer baseflows. Seedlings germinating high on the bar risk desiccation if their root systems cannot grow fast enough to stay in the moist zone. Species releasing seeds early in summer (e.g., both cottonwood species) are at greatest risk, even though many riparian species can develop extensive root systems quickly (Segelquist et al., 1993). From mid-June to mid-August, the capillary zone becomes the principal location for woody riparian seeds to successfully germinate.

Seedling initiation was monitored from late spring through summer on cross sections at the bank-rehabilitation sites. Water-surface elevations, daily average discharges, and highest elevations of the moist zone were plotted. Maximum elevation for the capillary zone, 2.5 feet above the low summer water surface, was recorded in a sand deposit at the Steiner Flat site. On gravel and cobble surfaces, capillary zones were

Table 5.8. Discharges required to inundate the tops of developed alternate bars (by 0.5 foot) at the bank-rehabilitation sites.

Site (RM)	Cross Section	Discharge to Inundate Bars (cfs)
Bucktail (105.6)	12+00	3,300[2]
Limekiln (100.2)	11+86	no bars
Steel Bridge (98.8)	12+10[1]	450[2]
Steiner Flat (91.8)	05+98	1,300[2]
Bell Gulch (84.0)	11+50	450[2]
Deep Gulch (82.2)	10+00[1]	no bars
Sheridan Creek (82.0)	05+35	1,900[2]
Jim Smith (78.5)	12+10	2,851[3]
Pear Tree (73.1)	15+00	1,300[3]

[1] cross section passes through pool. [3] estimated from Manning's equation.
[2] estimated from on-site rating curve.

considerably narrower. In summer 1995, the moist zone at the Bucktail site (cross section (XS) 12+00 on July 26) was 0.6 foot, at the Steiner Flat site (XS 04+31 on August 8) it was 0.5 foot, and at the Sheridan Creek site (XS 02+35 on August 15) the zone was 0.4 foot.

Initiating narrow-leaf willow and shining willow seedlings were present as much as 1.5 feet above the low summer flow stage at the Pear Tree site (RM 73.1) (Figure 5.38) and 1.8 feet at the Deep Gulch site (RM 82.2) (Figure 5.39). At the Limekiln site, narrow-leaf willow ranged up to 1.0 foot above the low summer flow surface (Figure 5.40). All three sites had coarse gravel and cobble bed surfaces.

Successful seedling initiation occurred over a wider elevation range on bar surfaces the greater the distance below Lewiston. Unregulated tributary flows augment Lewiston releases in late spring and summer, pushing the capillary zone higher on the bars. By mid- to late summer, tributary flows decrease and Lewiston releases experience minor augmentation down to the Pear Tree site. Therefore, the capillary zone migrates over a greater range on bars farther downstream and encourages potentially wider bands of seedlings. For example, at the Pear Tree site, declining tributary inflows from June 1, 1996, through July 1, 1996, significantly modified the influence of Lewiston Dam releases on bar inundation. Although dam releases declined from 800 cfs the first week to approximately 500 cfs the last 3 weeks, flows at Pear Tree XS 15+00 (Figure 5.38) gradually declined from 1,200 to 600 cfs. On XS 15+00, the bar top was just inundated the first week of June. As flow gradually declined, the slow migration of the capillary zone provided a favorable environment for germination at stations 99 through 128. Without tributary influence, a steady flow of 500 cfs with a 0.5 foot capillary zone would create the same favorable environment only from stations 99 to 106. Fixed low-flow releases and lesser tributary flow contributions will produce a narrower band of favorable germination conditions closer to Lewiston Dam.

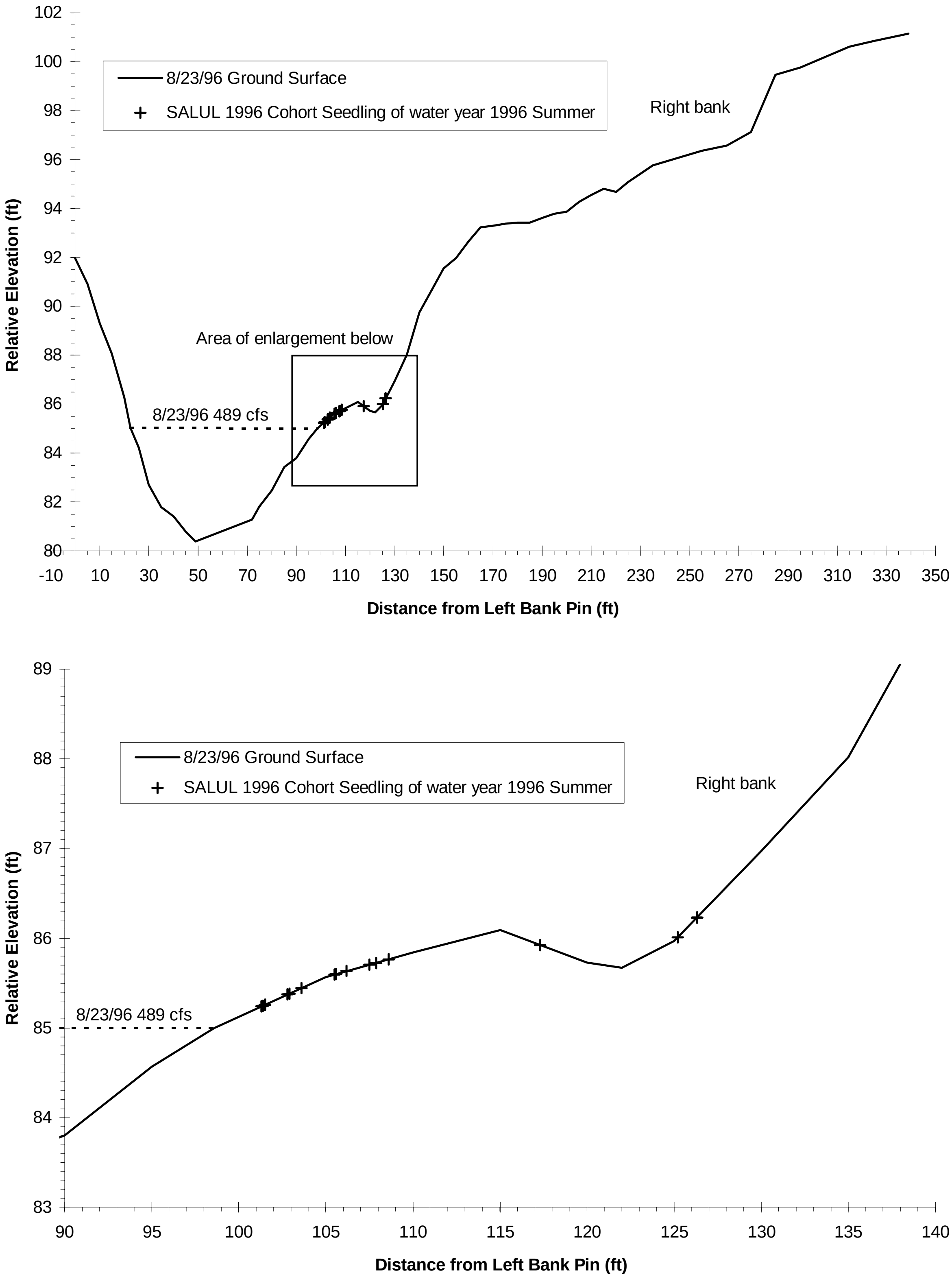


Figure 5.38. Pear Tree bank-rehabilitation site (RM 73.1) cross section 15+00, *Salix lucida ssp. lasiandra (*SALUL*)*, 1996 cohort, WY 1996 summer.

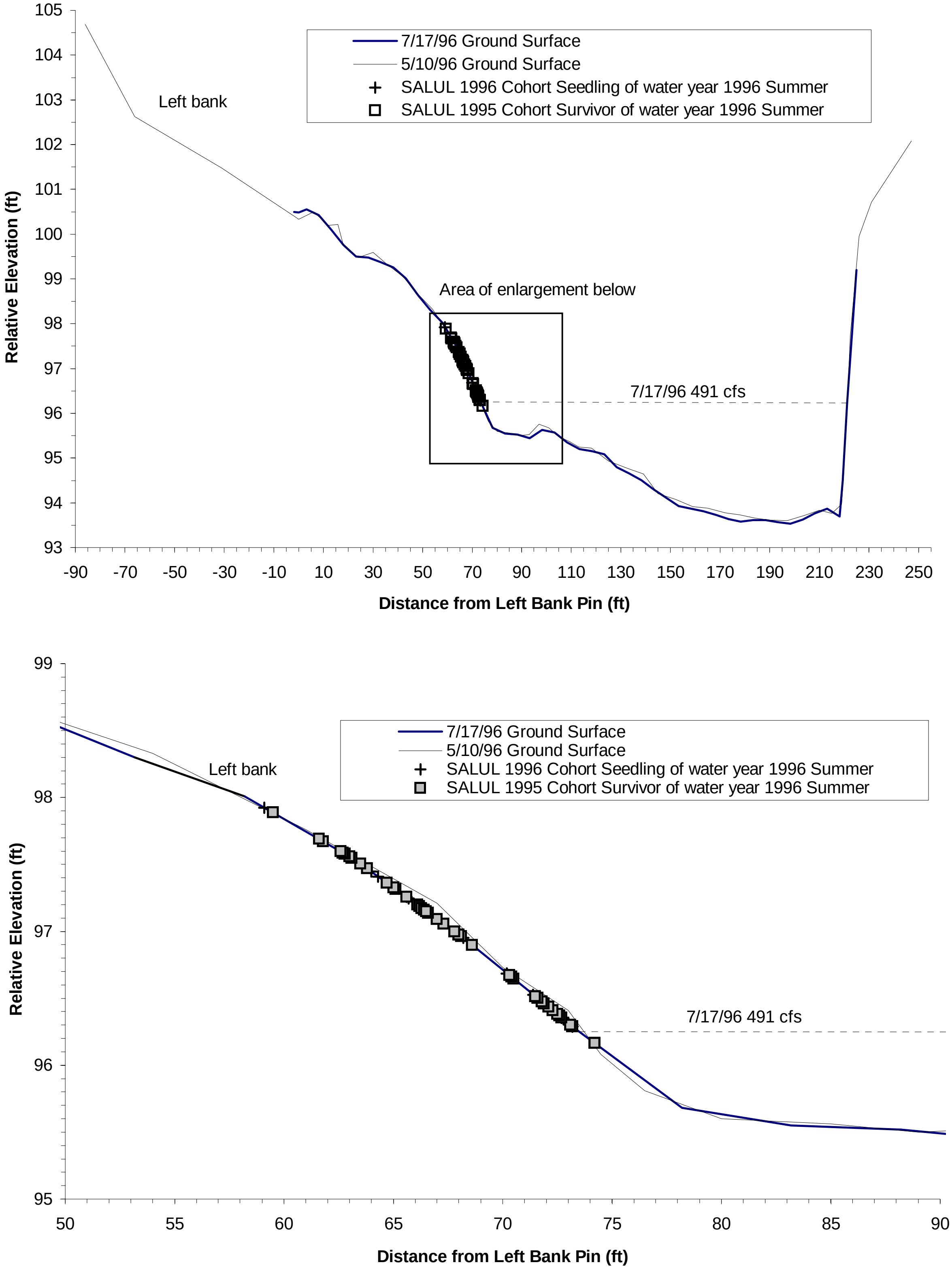


Figure 5.39. Deep Gulch bank-rehabilitation site (RM 82.2) cross section 13+90, *Salix lucida ssp. lasiandra* (SALUL), all cohorts, WY 1996 summer.

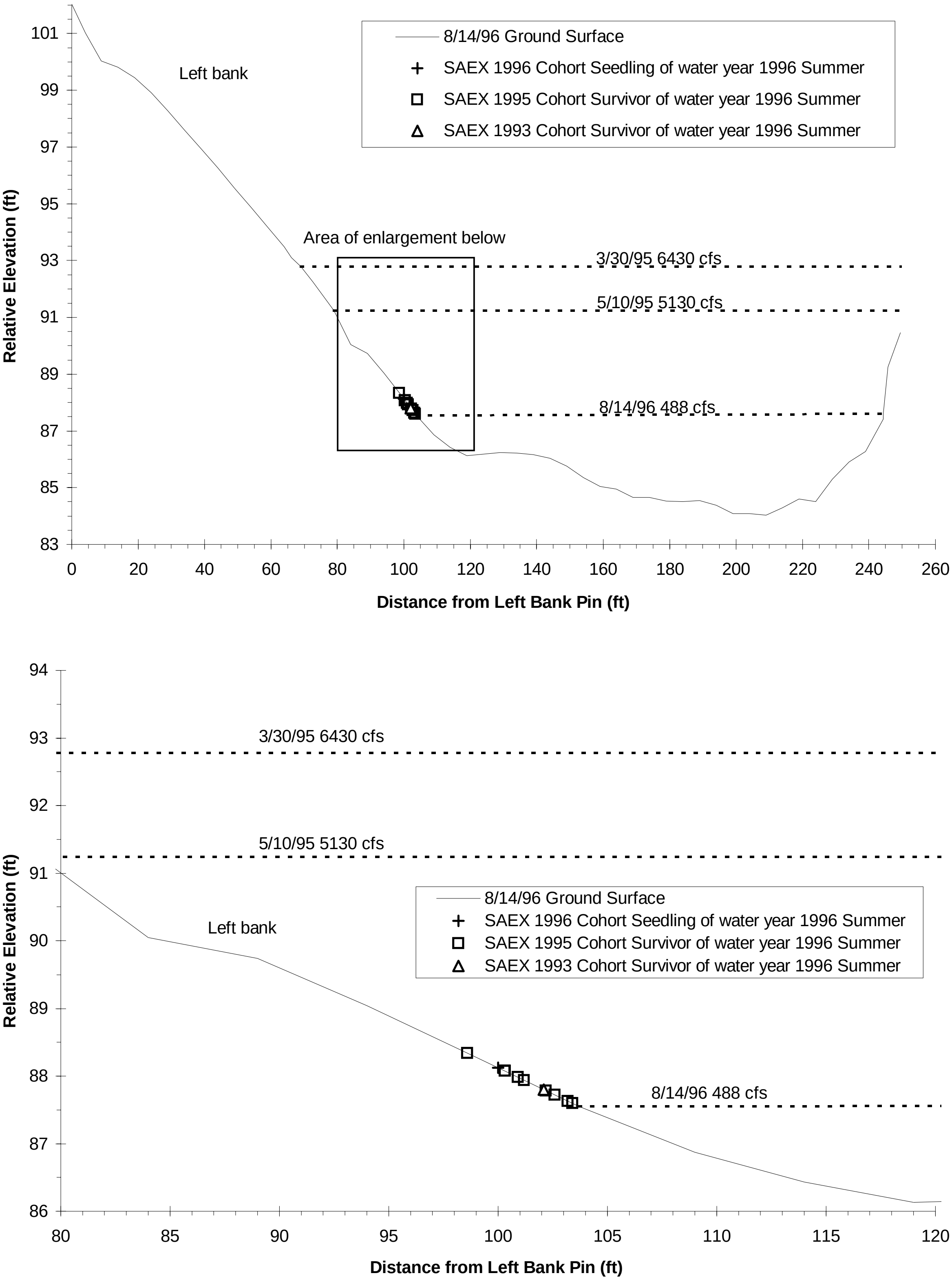


Figure 5.40. Limekiln bank-rehabilitation site (RM 100.2) cross section 11+86, *Salix exigua* (SAEX), 1996 cohort, WY 1996 summer.

5.4.4.3 Subsurface Moisture in Alternate Bars

Once germination at the surface occurs, seedlings can establish only if adequate subsurface moisture is available. Subsurface-moisture measurements were made throughout late spring and summer 1997. Three sets of gypsum-block soil-moisture sensors were placed at the Bucktail, Steiner Flat, and Sheridan Creek sites. Subsurface-moisture readings were converted to soil-moisture tension, and presented as a percentage of field capacity (the maximum amount of water that can be held without draining). Subsurface-moisture contents just below the bar surfaces approached field capacity. On the Bucktail site, subsurface soil moisture close to the bar surface remained high into August (Figure 5.41).

5.4.4.4 Critical Rooting Depth

Critical rooting depth is the root depth necessary to anchor the plant. If the bed scours beyond critical rooting depth, the plant is physically scoured from the channelbed surface. Critical rooting depth was estimated as follows: on alternate bars where high discharges had winnowed sand and pea gravels near the base of the plants, stems were gently pulled by hand until root strength failed. The plant height, root collar diameter, and critical root depth were measured and plant age was estimated. Local pebble counts were conducted to relate critical rooting depth to the particle-size distribution of the channelbed surface.

Critical rooting depth for 6-month old plants was the depth of the channelbed surface layer at both the Steiner Flat and Sheridan Creek bank rehabilitation sites (Figure 5.42). The surface layer is defined as the diameter of D_{84} particles. The relation of critical rooting depth to age appears asymptotic for 2-year to 5-year old plants. The asymptotic relation suggests that critical rooting depth may be more a function of local environmental factors (e.g., depth to water table) than seedling age or size after 2-years. If the surface D_{84} at the Sheridan Creek Site (RM 82.0) were mobilized, 6-month-old seedlings would probably be completely scoured out, but only half of the year old seedlings would be scoured out. While Figure 5.42 may imply that plants older than 3 years can be removed by scour exceeding 2 D_{84} deep, this usually does not occur because as plants grow older: (1) their lateral roots intermesh with roots of adjacent plants and stabilize the substrate from scour; and (2) the plant above ground continues to grow and shields the channelbed from scouring forces to the point where sediment deposition rather than scour occurs. Therefore, periodically mobilizing bar surfaces greater than 2 D_{84}'s deep are required to scour plants within the 2-3 year window of opportunity. Otherwise, another riparian berm will likely form along the low water edge.

5.4.4.5 Removal of Mature Trees

Maturing trees tend to become established in stands or in riparian berms. As a stand matures, flood-flow hydraulic forces are modified. Flood flows capable of scouring a single tree isolated on a bar commonly are incapable of scouring the same sized tree in a stand. Often, modification of the hydraulic forces is so complete that the surface beneath a stand experiences aggradation rather than scour. This occurred in many mainstem reaches during the January 1997 flood. A stand can be undercut by lateral bank migration (Section 4.8, Attribute No. 6) or isolated from mainstem low-flow channels by channel avulsion (Section 4.8, Attribute No. 8). Unregulated alluvial rivers typically migrate during bankfull and higher discharges. Bank avulsion can occur during infrequent large floods. Individual mature trees along the edge of stands may be especially susceptible to scour.

Although the magnitudes of flow required to remove a mature tree, a stand, or a riparian berm have been speculated, no quantitative flow estimates have been offered. Aerial photographs taken before, during, and after the 1974 flood (14,000 cfs released from Lewiston Dam) show local disturbance to the riparian berm (Figures 4.24 to 4.26). The WY1997 flood below Rush Creek (approximately 11,000 cfs) locally scoured and

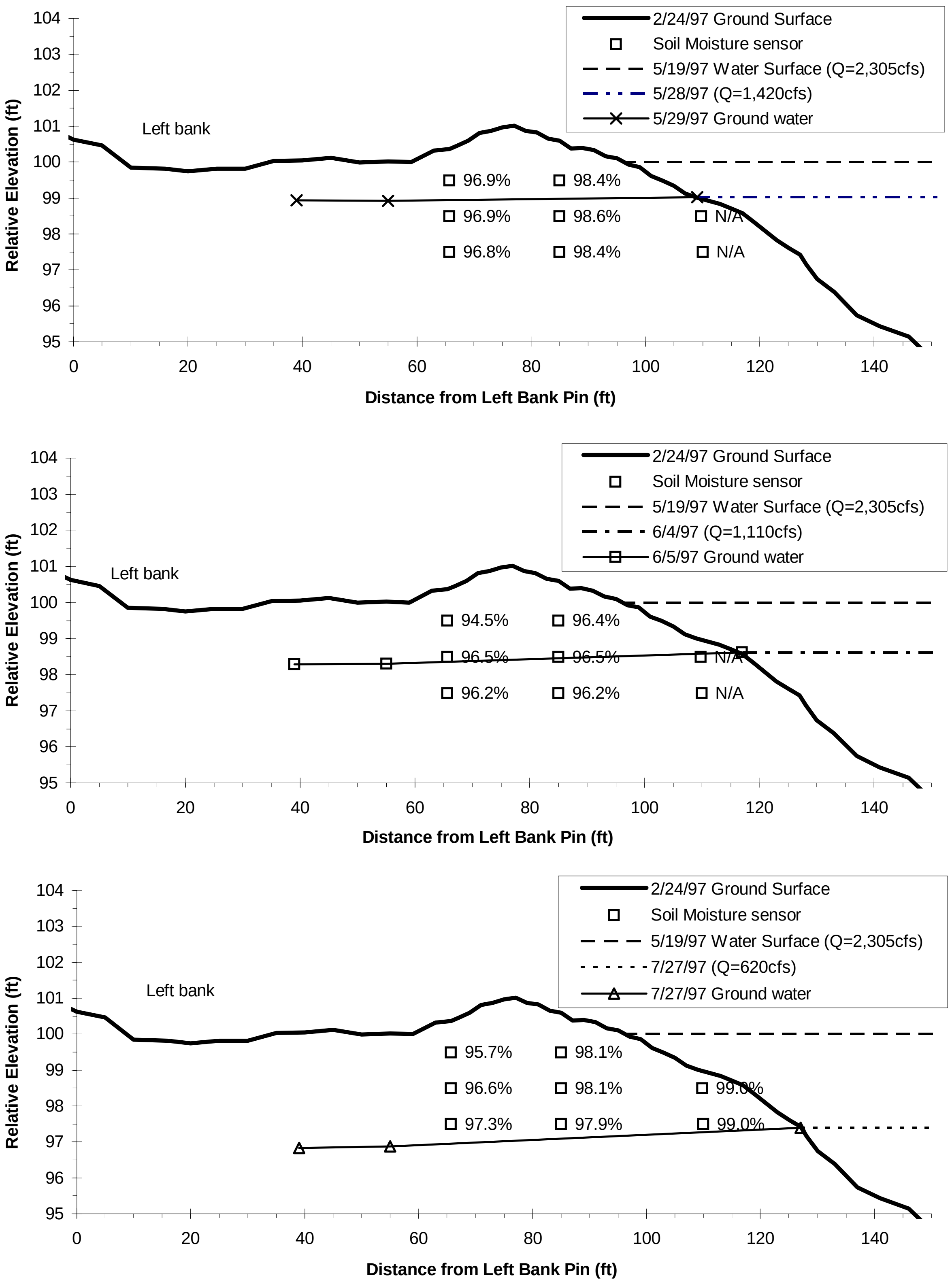


Figure 5.41. Bucktail bank-rehabilitation site (RM 105.6) ground water and soil moisture (as a percentage of field capacity) values, top: 5/28/97, middle: 6/5/97, bottom: 7/27/97.

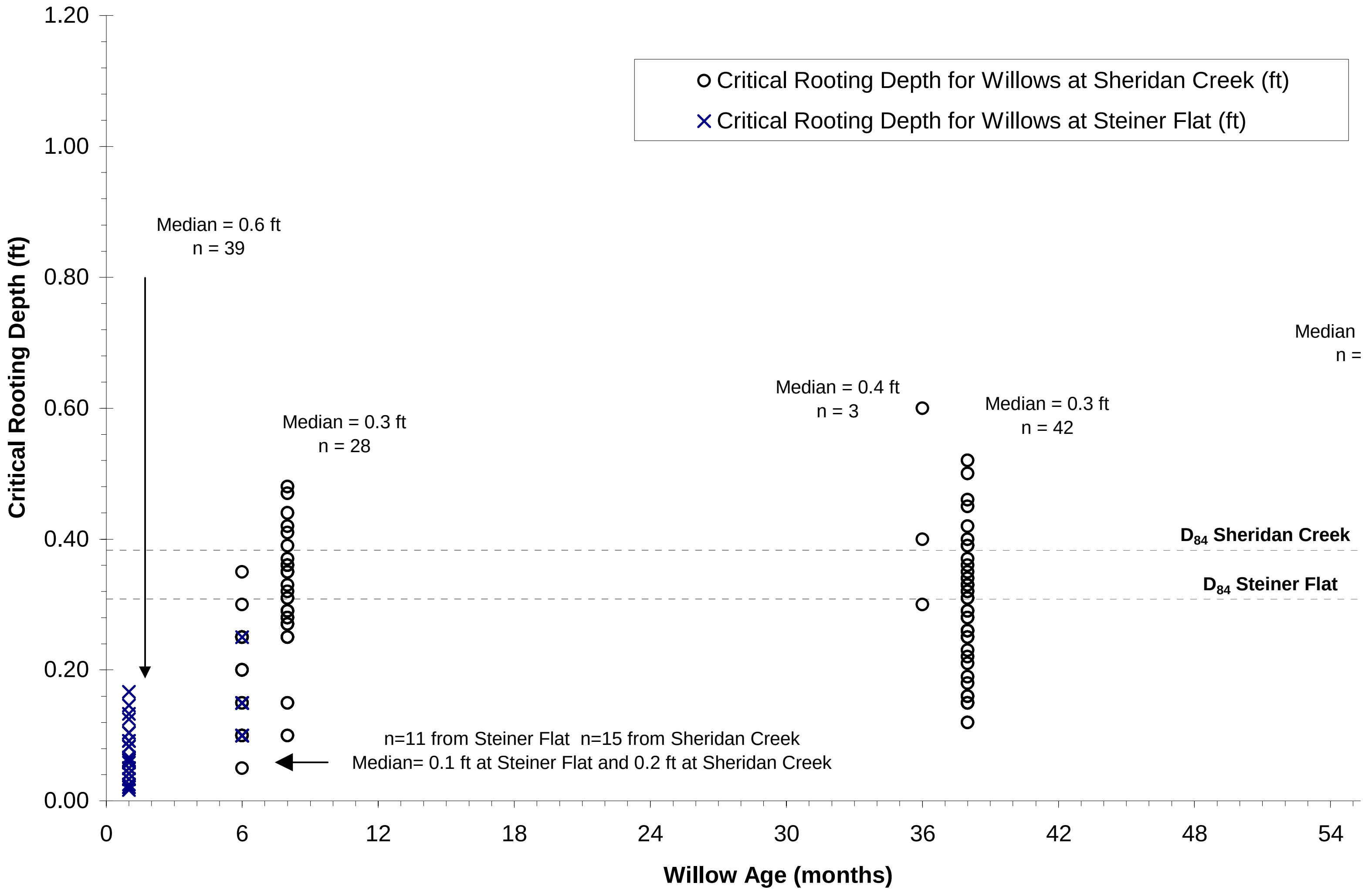


Figure 5.42. Critical rooting depth for willows of various ages, collected on exposed, active channel bed surfaces in the summer of 1995 and winter/spring 1996. Median values from each group sampled are given in millimeters. Two bank-rehabilitation sites were sampled: Steiner Flat (RM 91.8) and Sheridan Creek (RM 82.0). Sample size is indicated above each age by site. The D_{84} particle size represents summer 1998 conditions on point bar faces.

undercut a few mature trees in the riparian berm but it was not until the 1997 flows reached 30,000 cfs at Junction City when portions of the berm were removed completely. To estimate a flow threshold for scouring a mature tree, the critical moment required to topple a mature alder rooted in a riparian berm was estimated. The critical moment is synonymous to a critical torque, which is the product of a force acting on an object and the distance from the force to the point of rotational failure (in this case, the root mass). Critical moment was measured while toppling alders with a bulldozer.

Streamflows exceeding 14,000 cfs to 20,000 cfs would be required to remove the existing riparian berm, which is beyond the ability of controlled TRD streamflow releases.

Six alders (>20 years old) from a saturated portion of the riparian berm were mechanically toppled by a bulldozer at the Steiner Flat site (RM 91.8) in August 1995. The critical moment required to topple each alder in the riparian berm was measured using a tensiometer in line with the cable attached to the bulldozer. When the tree began to topple, force on the tensiometer was converted to a moment. Force exerted by the flow on the tree was computed for that given flow based on expected flood debris size (positioned against the upstream trunk) and flow velocity. The flow was incrementally increased until the force of the flow equaled the force (moment) measured in the field (see McBain and Trush, 1997, for assumptions, equations, and calculations).

Of the six trees toppled, four provided acceptable data for this analysis; equipment failure impaired the other two tests. The critical moments of failure for the four trees were: 54,000 ft-lbs (diameter at breast height = 0.80 foot), 97,600 ft-lbs (diameter at breast height = 1.0 foot), 100,000 ft-lbs (diameter at breast height = 1.1 feet), and 96,600 ft-lbs (diameter at breast height = 1.2 feet). The consistency of failure moments, particularly of the later three, provides reasonable confidence in the force required to push the trees over.

The estimated critical discharge for tree failure was primarily dependent on the size of debris pile lodged against the tree because the debris has a large surface area (larger coefficient of drag) and acts on the tree at the maximum distance from the rotation point (increases moment). Debris-pile dimensions were classified as follows: large debris (15 feet by 7.5 feet), small debris (10 feet by 5 feet), and a single log (8 feet by 2 feet). The range of predicted critical discharges is listed in Table 5.9. The small debris-pile class best approximates typical debris piles observed on the mainstem, suggesting that flows in the 14,000 to 20,000 cfs range are required to topple the most exposed mature alders. Larger flows would be required to topple most trees in the riparian berm up to a point at which the size of debris pile and the water elevation were sufficient to begin the domino effect on the remainder of the riparian berm.

5.4.4.6 Riparian Encroachment at Bank-Rehabilitation Sites

The pilot bank-rehabilitation projects provided newly exposed alluvial surfaces on which to observe initial stages of woody riparian colonization and possibly encroachment. Beginning in 1995, the Bucktail (RM 105.6), Steiner Flat (RM 91.8), and Sheridan Creek (RM 82.0) bank-rehabilitation sites were monitored to document woody riparian plant initiation and establishment. Five cross sections were surveyed at each site for band transect sampling. Density, frequency, bank position, annual cohort, and descriptive growth characteristics were measured for all sampled transects. After each winter high-flow period and each summer low-flow period, plant initiation and mortality were documented and related by plant abundance and bank position to annual growth stage of specific plant species, hydrograph

Table 5.9. Critical discharges needed to push over mature alders in a riparian berm as a function of debris size.

Debris Jam Classification	Debris Dimension	Alder #2 (D=0.8 ft) Discharge (cfs)	Alder #4 (D=1.0 ft) Discharge (cfs)	Alder #5 (D=1.1 ft) Discharge (cfs)	Alder #6 (D=1.2 ft) Discharge (cfs)
Large jam	15 ft x 7.5 ft	10,100	10,800	9,250	11,800
Small jam	10 ft x 5 ft	15,900	18,300	16,200	19,400
Single log	8 ft x 2 ft	31,800	41,000	37,000	42,100

component, and hydraulic geometry. Response of sampled plants was related to local fluvial processes during the water year (scour, inundation, etc.).

A simplifying assumption was that channelbed scour to depths less than the critical rooting depth would not impair survival. What was observed on the bars was not as straightforward. On January 8, 1996, we inspected the Sheridan Creek site following a 3,400-cfs peak flow in late December 1995. Willow seedlings of the WY1995 cohort were stressed, with roughly half their roots freshly exposed or removed (where the sand had been scoured from interstitial areas among larger particles). The channelbed had not reached a surface mobility threshold, although smaller particles (up to 1 $^{3}/_{16}$ inches) had moved. This event demonstrated that seedlings under age 1 could be killed or weakened by flows that fail to mobilize the entire surface layer of bars. A slightly higher discharge would presumably increase scour of the sand matrix as well as mobilize larger surface particles.

Annual channelbed dynamics were associated with narrow-leaf willow seedling initiation or establishment in WY1995 and WY1996 on three bank-rehabilitation sites. For the three sites, few narrow-leaf willows of the WY1995 and WY1996 cohorts survived into the summer of 1997 (Table 5.10). To interpret channelbed dynamics over these water years, the following annual hydrographs were utilized: Lewiston gage site for the Bucktail site (Figure 5.43); the Douglas City gage for the Steiner Flat site (Figure 5.44); and the Junction City gage for the Sheridan Creek site (Figure 5.45).

Streamflows exceeding 6,000 cfs to 8,500 cfs remove most new seedlings initiating on lower portions of point bars, while flows exceeding 10,000 cfs remove nearly 100% of new seedlings.

The Sheridan Creek site has a broad gently sloping right bank that annually supports abundant narrow-leaf willow seedlings. Willows germinated on the exposed bar surface down to low-water surface in WY1995, WY1996, and WY1997. For example, the upper portions of the newly formed bar surfaces were exposed in mid-June during narrow-leaf willow seed dispersal allowing widespread germination. The WY1995 cohort experienced channelbed mobilization its first winter. Discharge peaked near 8,500 cfs and mobilized at least the surface layer and portions of the subsurface. By May 1996, most had died. Although the Junction City gage did not survive the January 1, 1997, flood, peak discharge was estimated by indirect measurement to be 30,000 cfs, well above the threshold for significant subsurface scour. At Sheridan Creek, no willows from the three cohorts survived scouring on the open bar. A similar series of events occurred for willow cohorts at the Steiner Flat site, although 2 plants from the WY1993 cohort survived the January 1, 1997, flood (Table 5.10). At the Bucktail site, seedlings were killed by bar deposition, not scour. Further deposition resulting from the January 1, 1997 flood eliminated the WY1996 cohort.

Table 5.10. Narrow-leaf willow (*Salix exigua*) abundance at: (A) Sheridan Creek (RM 82.0) cross section 2+35; (B) Steiner Flat (RM 91.8) cross section 4+31; and (C) Bucktail (RM 105.6) cross section 12+00. NA = Not applicable.

A.	Narrow-leaf Willow (*Salix exigua*) Cohort Abundance							
	1995 Sample			1996 Sample			1997 Sample	
Annual Cohort	Spring	Summer 8/15/95	WY 96 Q_{peak} = 8,800 cfs	Spring 5/14/96	Summer 7/28/96	WY 97 Q_{peak} = 30,000 cfs	Spring 5/1/97	Summer
WY1993	NA	5		13	19		0	NA
WY1995	NA	5,207		192	114		0	NA
WY1996	NA	NA		0	914		0	NA
WY1997	NA	NA		NA	NA		0	NA

B.	Narrow-leaf Willow (*Salix exigua*) Cohort Abundance							
	1995 Sample			1996 Sample			1997 Sample	
Annual Cohort	Spring	Summer 8/8/95	WY 96 Q_{peak} = 7,300 cfs	Spring 5/4/96	Summer 7/26/96	WY 97 Q_{peak} = 24,000 cfs	Spring 4/30/97	Summer
WY1993	NA	0		0	1		2	NA
WY1995	NA	994		76	129		9	NA
WY1996	NA	NA		11	100		0	NA
WY1997	NA	NA		NA	NA		0	NA

C.	Narrow-leaf Willow (*Salix exigua*) Cohort Abundance							
	1995 Sample			1996 Sample			1997 Sample	
Annual Cohort	Spring	Summer 7/25/95	WY 96 Q_{peak} = 6,370 cfs	Spring 5/4/96	Summer 7/25/96	WY 97 Q_{peak} = 6,700 cfs	Spring 4/30/97	Summer
WY1993	NA	27		0	7		0	NA
WY1995	NA	1,444		57	19		0	NA
WY1996	NA	NA		1	1		0	NA
WY1997	NA	NA		NA	NA		0	NA

5.4.4.7 Conclusions

Narrow-leaf willow is the most common species establishing on exposed alluvial surfaces and the species most likely to encroach onto bank-rehabilitation sites. Without flow variability and large-magnitude floods to periodically eliminate vegetation near the water's edge and on bars, bank-rehabilitation sites along the mainstem can be expected to revert quickly to degraded conditions. Bar inundation to discourage and (or) constrain germination coupled with frequent channelbed surface mobilization is the most feasible approach to prevent widespread riparian encroachment. Bar inundation alone would not suffice. Once established willows reach their second and third years, removal with TRD releases become increasingly difficult because the lateral distribution, density, and interlocking of roots increases the plant's resistance to scour removal. By coordinating (1) critical rooting depth

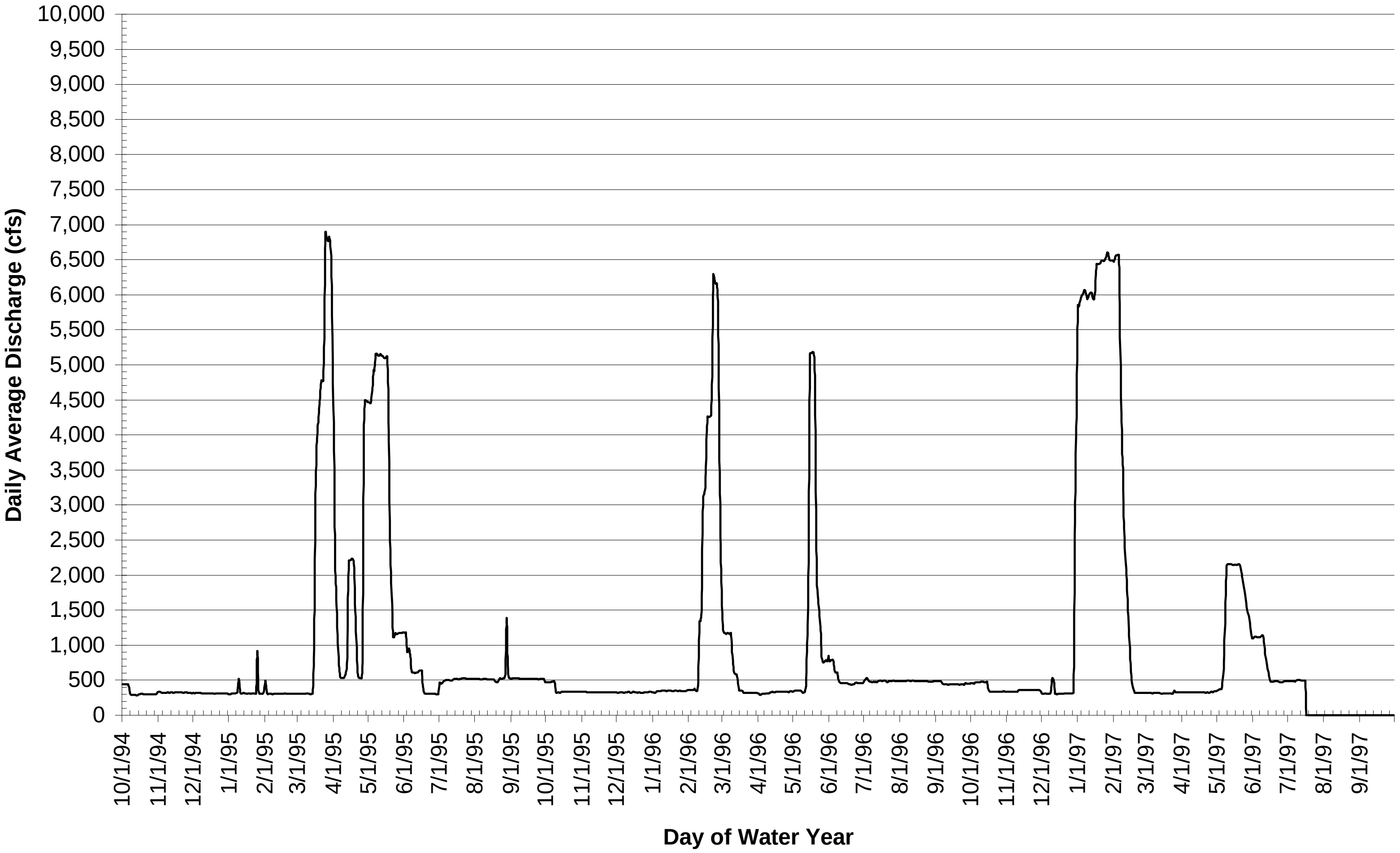


Figure 5.43. Trinity River at Lewiston (RM 110.9) daily average discharge for WY 1995-1997.

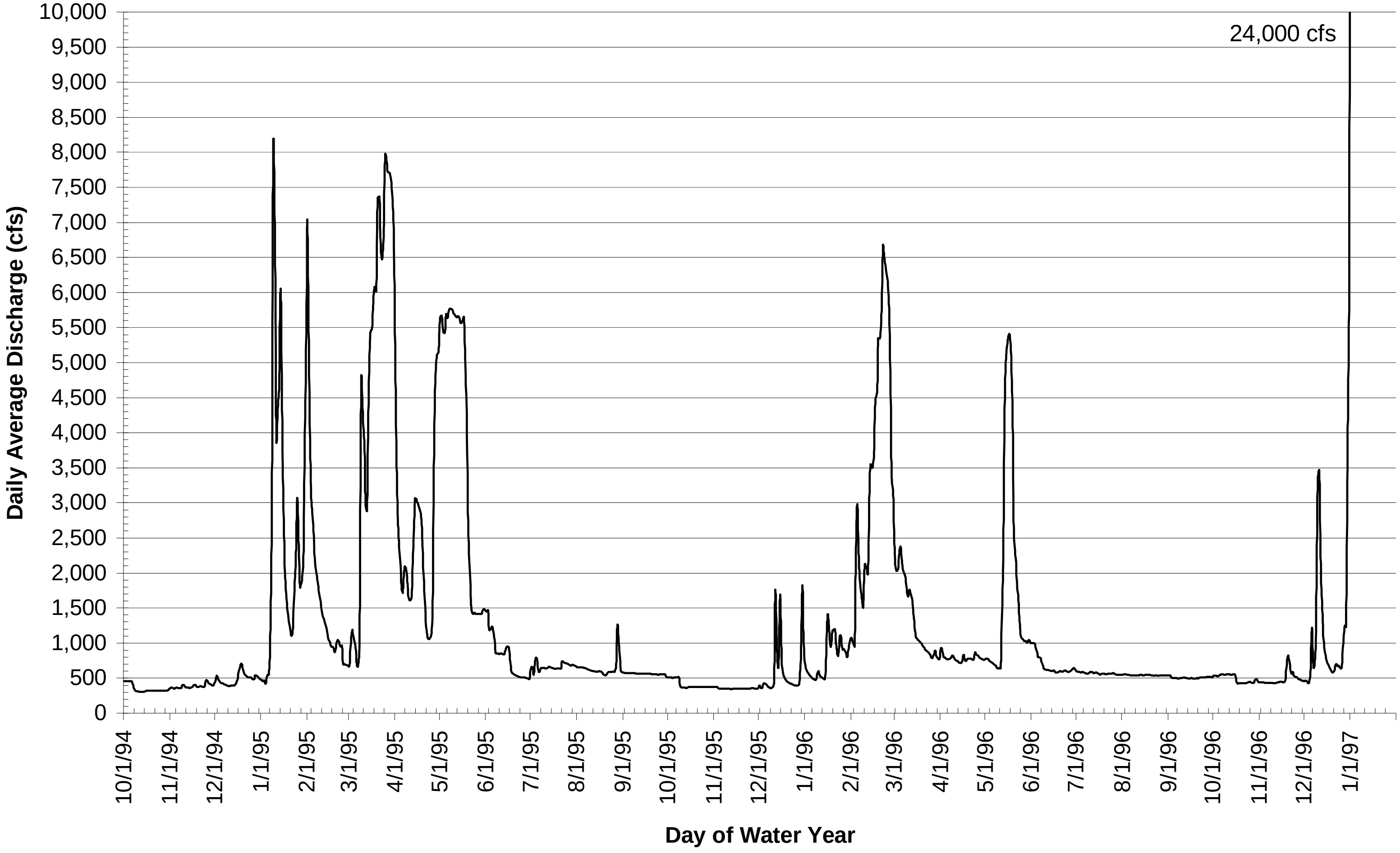


Figure 5.44. Trinity River near Douglas City (RM 92.2) daily average discharge for WY 1995-1997.

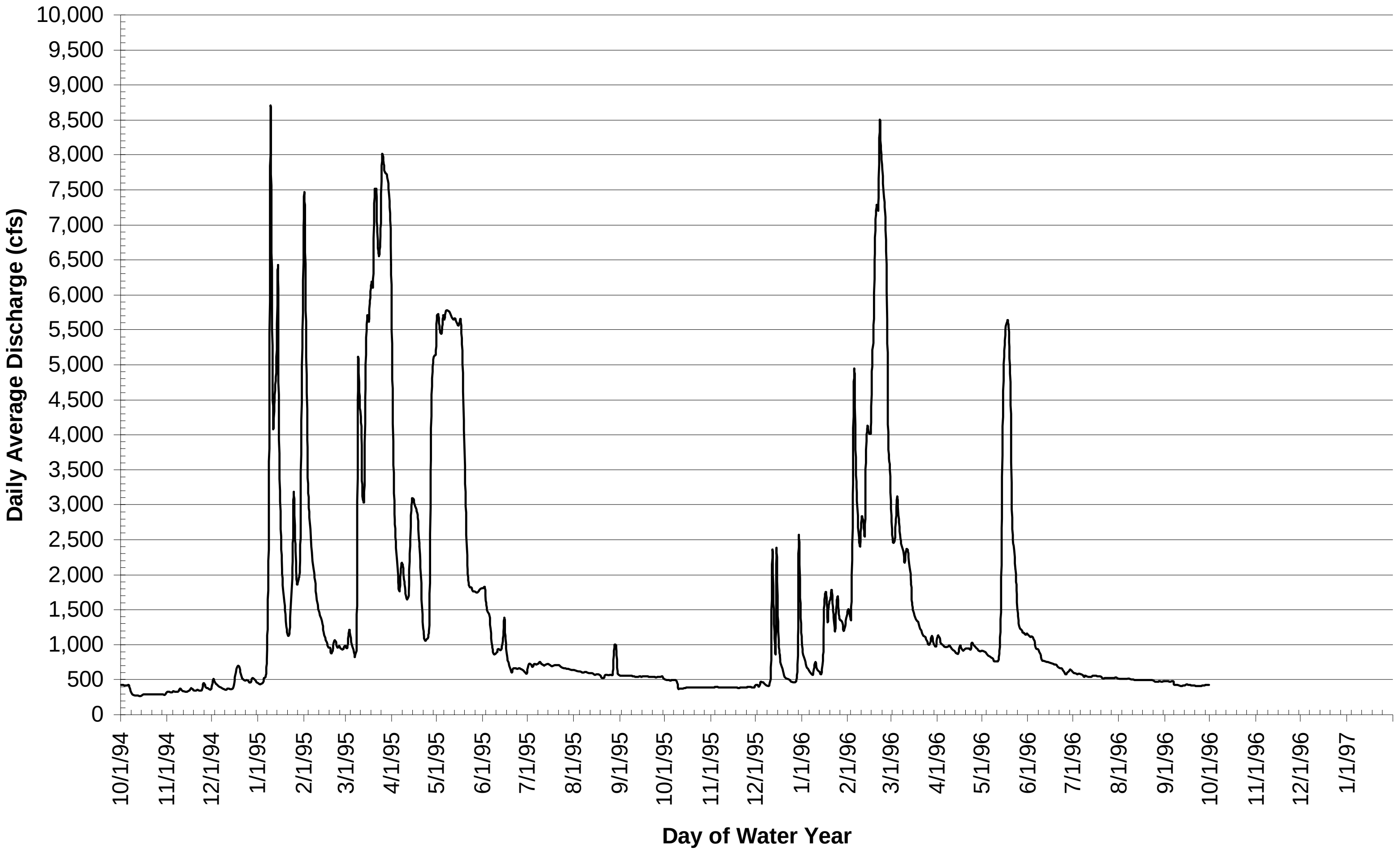


Figure 5.45. Trinity River at Junction City (RM 79.6) daily average discharge for WY 1995-1996.

and mobilization/scour predictions, (2) timing and magnitude of bar inundation, and (3) seasonal vertical migration of the capillary zone, Lewiston Dam releases can be tailored to induce mortality and thus discourage riparian encroachment. A peak flow threshold necessary to remove mature riparian trees within the riparian berm may begin at 14,000 cfs, but more realistically would require 16,000 to 20,000 cfs for single trees, and probably 30,000 cfs for local riparian berm removal. The WY1997 flood at Junction City, where peak flows reached 30,000 cfs, showed that riparian berms were tenacious; no riparian berm was entirely removed.

Lewiston Dam releases should also be tailored to encourage natural riparian regeneration on functional floodplains. Larger flows exceeding 8,500 cfs will encourage channel migration, floodplain formation, fine sediment deposition on floodplains, and scour channels on floodplains, all of which will provide favorable rooting conditions for riparian vegetation. Additionally, a gradually receding limb to the flood hydrograph will foster cottonwood survival on higher geomorphic surfaces by allowing their roots to track the receding capillary fringe (Mergliano, 1996; Rood and Mahoney, 1990; Segelquist et al., 1993).

> "Water temperature affects every aspect of the life of a fish, including incubation, growth, maturation, competition, migration, spawning, and resistance to parasites, diseases, and pollutants."

5.4.5 Alluvial River Attributes: Summary

Other attributes described in Section 4.8 did not receive the attention that the attributes discussed above received. Attribute No. 1 is a sum of all other attributes. Presently, there is essentially no channel migration or functional floodplain to study. Therefore, Attributes No. 6 (periodic channel migration) and No. 7 (functional floodplain) will be important measurable responses in an adaptive environmental assessment and management plan and must be considered in mechanical channel rehabilitation. Attribute No. 8 (infrequent channel-resetting floods) may be key in generating future channel complexity. Without piggybacking dam releases onto tributary floods, the primary opportunity for tributary flood peaks exceeding 20,000 cfs will be below Indian Creek. McBain and Trush (pers. comm.) have been examining the physical effects of the January 1997 flood on the riparian berms and terraces. Attribute No. 10 has not been addressed. Groundwater recharge in the floodplain is an unknown, and needs to be investigated. Off- channel wetlands aren't known to exist in the floodplain corridor that has been essentially excavated between the valley walls during gold mining, although a few scour channels have off- channel depressions. These are also being investigated by McBain and Trush. The role of the snowmelt recession limb in sustaining seasonal wetlands and scour channels for aquatic organisms deserves close examination in the future.

5.5 <u>Flow-Temperature Relations</u>

5.5.1 Introduction

Water temperature affects every aspect of the life of a fish, including incubation, growth, maturation, competition, migration, spawning, and resistance to parasites, diseases, and pollutants (Armour, 1991). This section describes temperature–flow relations in the Trinity River through the use of a water-temperature model and empirical data. Simulation results were used to: (1) recommend dam releases that maintain water temperatures suitable to protect outmigrating steelhead, coho salmon, chinook salmon smolts; (2) recommend releases to protect holding and spawning adult chinook salmon (i.e., meet California Regional Water Quality Control Board - North Coast Region (CRWQCB-NCR) temperature targets); and (3) evaluate flow–temperature relations conducive to juvenile salmonid growth.

Since construction of the TRD, the magnitude, timing, and duration of flows downstream from Lewiston have been dramatically altered; consequently, seasonal temperature regimes have changed (see Section 4.3.6). The storage of snowmelt runoff from the watershed above the dams has resulted in warmer springtime water temperatures throughout the Trinity River below Lewiston than in comparison with pre-TRD temperatures (TRBFWTF, 1977). Summer and fall water temperatures at Lewiston have become colder as a result of operations of upstream dam facilities that release water from the cold lower stratum (hypolimnion) of Trinity Lake (TRBFWTF, 1977). An additional consequence of dam operations is that wintertime water temperatures near Lewiston are now warmer than pre-TRD.

> "Since construction of the TRD, the magnitude, timing, and duration of flows downstream from Lewiston have been dramatically altered; consequently, seasonal temperature regimes have changed."

5.5.1.1 Temperature Effects on Smoltification

Parr-smolt transformation (smoltification) during the spring involves changes in the behavior and physiology of juvenile anadromous salmonids that prepare them for survival in salt water (Folmar and Dickhoff, 1980; Wedemeyer et al., 1980). Environmental cues such as increasing photoperiod (day length) and water temperature (warming trend) stimulate production of Na^+-K^+ ATPase (ATPase), an enzyme associated with smoltification (Zaugg and Wagner, 1973; Zaugg and McLain, 1976). Although photoperiod and water temperature are primarily responsible for initiating smoltification in juvenile coho salmon and steelhead, studies suggest that water temperature alone is the primary influence on the timing and duration of emigration and smoltification of chinook salmon (Folmar and Dickhoff, 1980; Wedemeyer et al., 1980; Hoar, 1988). In all three species, water temperature acts as a modifier of physiological responses to photoperiod; when water is slow to warm in the spring, the ATPase activity is extended and smolts emigrate over a longer time period (Hoar, 1988). The extended migration periods associated with gradual warming may result in increased growth, a benefit because larger smolts have higher survival rates in seawater (Hoar, 1988). Conversely, if water temperatures warm quickly in the spring ATPase activity shortens, allowing smolts less time to migrate to seawater (Wedemeyer et al., 1980; Hoar, 1988). Klamath River estuary studies conducted by the California Department of Fish and Game (Wallace and Collins, 1997) found juvenile chinook salmon to be significantly larger in 1993, when water temperatures upstream from the estuary were cooler, in comparison with a similar time period of warmer water temperatures in 1994.

If smolts do not reach seawater while physiologically ready for seawater adaptation, they revert to parr, and migratory behavior diminishes (Hoar, 1988). Parr may again smolt when water temperature and photoperiod again become favorable either in the fall or the following spring (Hoar, 1988). Survival of parr in freshwater, however, may be jeopardized if they are subjected to poor water quality, competition, or predators (Cada et al., 1997).

Water temperatures that are known to interrupt the smoltification process vary by species and are primarily known from controlled experiments (See reviews by Wedemeyer et al., 1980; and Folmar and Dickhoff, 1980). From literature reviews, Zedonis and Newcomb (1997) identified three categories of thermal tolerance for salmonid smolts in the Trinity River (Table 5.11). The three categories – optimal, marginal, and

Table 5.11. Water temperature requirements for steelhead, coho salmon, and chinook salmon smolts (Values are from Zedonis and Newcomb (1997)).

Species	Category of Thermal Tolerance [a]	Water Temperature (°F)	Source
Steelhead	Optimal	42.8 to 55.4	Zaugg and Wagner (1973), Adams et al (1973), Zaugg et al. 1972
	Marginal	55.4 to 59	Kerstetter and Keeler (1976), Zaugg et al. (1972)
	Unsuitable	> 59	Adams et al. (1973), Zaugg et al. (1972)
Coho Salmon	Optimal	50 to 59	Clarke (1992)
	Marginal	59 to 62.6	Clarke (1992)
	Unsuitable	> 62.6	Clarke (1992)
Chinook Salmon	Optimal	50 to 62.6	Clarke (1992), Clarke and Shelbourne (1985)
	Marginal	62.6 to 68	Inferred between Clarke (1992) and Baker et al. (1995)
	Unsuitable	> 68	Baker et al. (1995)

[a] Categories of Optimal, Marginal, and Unsuitable refer to the relative likelihood of maintaining smoltification.

unsuitable – were defined by the relative likelihoods that smolts will revert to parr or lose their ability to hypoosmoregulate (osmoregulate in seawater).

Steelhead have been the subject of many experiments that examined the relation between water temperature and smoltification. Zaugg and Wagner (1973) concluded that water temperatures greater than 55.4° F may interfere with steelhead parr-smolt transformation. Zaugg (1981) also observed a reduction in migratory tendencies under natural photoperiod conditions after steelhead were exposed to water temperatures of 55.4° F for 20 days versus those exposed to 42.8° F. Kerstetter and Keeler (1976) found that water temperatures near 59° F were responsible for reduced gill ATPase activity in TRFH steelhead. They further speculated that high springtime water temperatures were responsible for sharp declines in the number of wild migrating steelhead smolts captured in traps during the spring in the lower Trinity River at Weitchpec.

Coho salmon smolts also require cool water temperatures to smolt. Zaugg and McLain (1976) found that elevated freshwater temperatures (59° and 68° F) shortened the period of elevated ATPase levels in comparison with that of fish reared in 42.8° and 50° F freshwater. They also found that coho salmon reared at a constant water temperature (42.8º F) maintained elevated ATPase levels through July, but when these fish were exposed to warmer water temperatures, their ATPase levels initially increased and then declined (gradually at 50º F, more quickly at 59º F , and rapidly at 68º F). Conversely, Zaugg and McLain (1976) demonstrated that ATPase levels increased when coho salmon reared in 59º F water were transferred into lower water temperatures. Clarke et al. (1981) found that the ability to hypoosmoregulate was greater for coho salmon reared in freshwater at 50º F versus 59º F. More recently, Clarke (1992) recommended rearing coho salmon at temperatures between 50º F and 59º F and reported that water temperatures below 62.6º F are required for survival in seawater.

In the Trinity River, chinook salmon smolts emigrate later in the spring than do either coho salmon or steelhead smolts, and typically encounter the warmest water temperatures (USFWS, 1998). In hatchery experiments, water temperatures warmed to 51.8º to 53.6º F were shown to support chinook smoltification (Muir et al., 1994). Clarke and Shelbourn (1985) found that chinook salmon reared in freshwater between 50º F and 62.6º F displayed the best ability to hypoosmoregulate. Baker et al. (1995) used data obtained over an 8-year period from 15 release groups of hatchery fall-run chinook salmon smolts to model smolt mortality under natural conditions as they migrated through a portion of the Sacramento–San Joaquin Delta. The estimated survival rate for smolts emigrating in water temperatures of 73.4º F was only 50 percent, whereas smolts emigrating in 68º F water experienced 90 percent survival. The results of their analysis corresponded well with prior laboratory studies (Brett, 1952) to determine the temperature at which 50 percent mortality is observed for a given acclimation temperature.

5.5.1.2 Smolt Emigration and Flow

Not only does increased flow have an effect on water temperature and smoltification, but it also reduces the travel time of smolts to seawater and thus increases survival rates (Bell, 1991). The physiological changes that a smolting salmonid undergoes reduce its swimming stamina, making emigration a relatively passive behavior (Folmar and Dickhoff, 1980). Because smolts often exhibit this passive emigration behavior, the increased average water velocities associated with increased flows transport the fish more quickly to the ocean, making chances of survival in seawater greater (Cada et al., 1997). Kjelson and Brandes (1989), using 10 years of data, found a strong correlation between estimated smolt survival rates, increased flow, and reduced water temperature in the Sacramento River. In the Snake River, peak emigrations of wild spring chinook salmon coincided with peak river flow (Achord et al., 1996), and in the Columbia River, flow was significantly correlated to the rate of chinook salmon smolt emigration (Raymond, 1979; Brege et al., 1996; Giorgi et al., 1997). Achord et al. (1996) suggested that increased releases after mid-May could benefit emigrating chinook smolts by increasing emigration rates. Cada et al. (1997), in a fairly extensive review of the literature, concluded that a positive relation between increased flows and smolt survival was a reasonable conclusion on the basis of the scientific evidence.

> "Not only does increased flow have an effect on water temperature and smoltification, but it also reduces the travel time of smolts to seawater and thus increases survival rates."

5.5.1.3 Trinity River Smolt Emigrations

Smolt emigration timing for steelhead, coho salmon, and chinook salmon in the Trinity River varies by species (Figure 5.46) (Zedonis and Newcomb, 1997; USFWS, 1998). From 1992 to 1995, at least 80 percent of steelhead, coho salmon, and chinook salmon smolts passed the Trinity River trap site near the town of Willow Creek (RM 21.1) by May 22, June 4, and July 9, respectively (Figure 5.46 B, C, D) (USFWS, 1998). In 1992 and 1994, years when water temperatures were warmer, chinook salmon appeared to migrate past the trap 1 to 2 weeks earlier (See Figures 5.46 A and D).

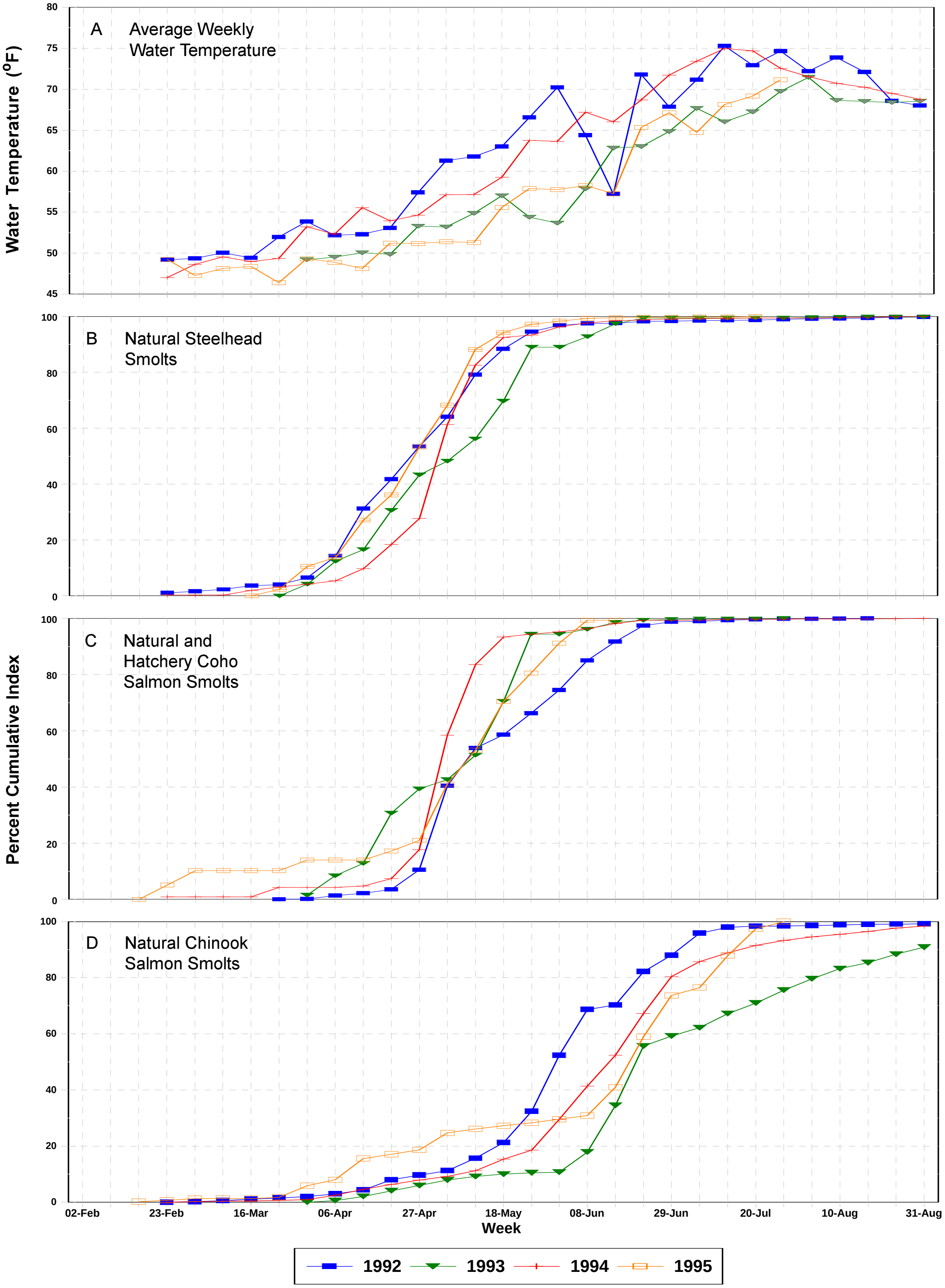


Figure 5.46. Average weekly water temperatures and cumulative abundance indicies for emigrating natural steelhead, natural and hatchery coho salmon, and natural chinook salmon. Data collected at the Willow Creek trap (RM 21.1) on the Trinity River, 1992 to 1995. Data collected by the USFWS, Arcata, CA.

5.5.1.4 Adult Salmon Holding and Spawning

Early-arriving adult salmon and steelhead require cold water temperatures to survive. During the spring, summer, and fall, adult chinook salmon and steelhead immigrate to areas below Lewiston Dam, and hold until the onset of spawning. In the absence of appropriate water temperatures, several direct and indirect factors can lead to poor survival of adults and developing eggs. In a literature review, Boles (1988) concluded that water temperatures between 38° and 60° F were adequate for protection of holding adults; at water temperatures above 60° F, prespawning mortality and temperature-mediated diseases or reduced egg or sperm viability can occur. During spawning, however, a water temperature less than or equal to 56° F is recommended to decrease the prevalence of infectious diseases and fungus (Ordal and Pacha, 1963, as cited by Boles, 1988). In response to these water-temperature requirements, the CRWQCB-NCR, with assistance from CDFG, NMFS, Hoopa Valley Tribe, and the Service, established water-temperature objectives for the first 40 miles below Lewiston Dam (Table 5.12) (CRWQCB-NCR, 1994).

> "In the absence of appropriate water temperatures, several direct and indirect factors can lead to poor survival of adults and developing eggs."

5.5.1.5 Temperature Effects on Juvenile Salmonid Growth

Salmonid growth is highly influenced by water temperature and food availability. At very low water temperatures, fish exhibit little or no growth, and require very little food to sustain bodily functions. As water temperatures increase, digestive enzyme efficiency increases, and depending on food abundance and quality, growth rates increase (Rich, 1987). Under laboratory conditions and maximum food rations, the water temperature at which maximum growth occurs is higher than for fish fed lower rations such as those found in natural stream settings (DEQ, 1995). At very high temperatures, however, excessive metabolic activity and synergistic effects of additional stresses (e.g., low dissolved oxygen) can result in little or no growth, disease, or death (DEQ, 1995). Lower lethal, upper lethal, and preferred temperatures (°F) for rearing juvenile chinook salmon, coho salmon and steelhead are provided in Table 5.13. Preferred water temperatures are close to the optimum for maximum growth efficiency (Groot and Margolis, 1991).

5.5.2 Methods

> A water-temperature model (SNTEMP) and empirical water-temperature data were used to develop release recommendations to meet the temperature needs of anadromous salmonids of the Trinity River.

A water-temperature model of the Trinity River was used to investigate influences of Lewiston Dam releases on downstream water temperatures during the spring, summer, and fall months. The model uses the Stream Network Temperature Model (SNTEMP) (Theurer et al., 1984) as its foundation, and is a 7-day average daily model (Zedonis, 1997). Given a Lewiston Dam release and water temperature, the model can predict mainstem temperatures at any location downstream from Lewiston Dam to the confluence with the Klamath River, a distance of approximately 112 river miles (Zedonis, 1997). Comparison of observed and predicted water temperatures at three sites (Douglas City, Confluence of the North Fork Trinity River, and Weitchpec Falls) indicated that the model predicted temperatures well (Figures 5.47, 5.48, and 5.49). Following calibration, the model proved accurate to -0.70° + 2.93° F at the 90 percent confidence interval, throughout the river.

Table 5.12. Water temperature objectives for the Trinity River during the summer, fall, and winter as established by the CRWQCB-NCR.

Date	Temperature Objective (°F)	
	Douglas City (RM 93.8)	North Fork Trinity River (RM 72.4)
July 1 through Sept 14	60	-
Sept 15 through Sept 30	56	-
Oct 1 through Dec 31	-	56

The SNTEMP model requires the input variables of dam discharge and release-water temperatures to predict downstream water temperatures. Dam discharge is reliably known, but the Lewiston Dam release-water temperatures can vary substantially depending on trans-basin diversions, releases to the Trinity River, and meteorology (e.g., air temperature and relative humidity). As described in Section 4.3.6, increased diversions and releases down the Trinity River act synergistically to maintain cold Lewiston Dam release water temperatures by shortening the residence time of water in Lewiston Reservoir.

5.5.2.1 Hypothetical-Year Type Simulations

Three hypothetical-year types, representing hot-dry, median, and cold-wet hydrometeorological conditions, were modeled (Zedonis, 1997). Each year type consisted of 52 independent weeks of hydrological and meteorological variables having differing exceedence probabilities (Table 5.14). Exceedence levels for these variables were determined from 27 years of weekly data (1965 to 1992). Thus, these year types are not used to evaluate a year as a whole (i.e., one would not expect to observe consecutive weeks of these conditions over a long period of time), but are used to show the sensitivity of combinations of variables (e.g., meteorology, tributary accretion, and dam release magnitude and release temperature) on water temperatures.

From April 1 to July 15, water temperatures of the Trinity River from Lewiston Dam to the confluence with the Klamath River at Weitchpec were evaluated with Lewiston Dam releases that ranged from 150 to 6,000 cfs. Evaluations of flow–temperature relations during this time period used the 7-day average minimum water temperature observed at the Lewiston gage (located 1.0 mile below Lewiston Dam) from 1987 to 1994. Minimum release temperatures were used to reflect cold release temperatures that would be present with high Lewiston Dam releases (e.g., 2,000 cfs) and the typically large diversions (2,000 to 3,600 cfs) that occur from April through July (Paul Fujitani, pers. comm.).

Temperature–flow relations during the summer and fall, a time when the CRWQCB-NCR objectives are in effect, were evaluated with 7-day average maximum and minimum water temperatures observed below Lewiston Dam from 1987 to 1994. Dam releases ranging from 150 to 1,000 cfs were evaluated under hot-dry, median, and cold-wet year type conditions. Both minimum and maximum release temperatures were evaluated to reflect varied diversion patterns and reduced Trinity River flows, typically 450 cfs, that may result in a wide range of release water temperatures. Because the CRWQCB-NCR objectives have been in effect since 1992, empirical data also are available from which to ascertain releases and release temperatures needed to meet the objectives.

Table 5.13. Lower lethal, upper lethal, and preferred temperatures (°F) for selected species of juvenile salmonids. Incipient lethal temperature (ILT) refers to abrupt transfer of fish between waters of different temperatures.

Species	Lethal Temperatures (ºF)		Preferred Temperature (ºF)	Source	Method
	Lower	Upper			
Chinook Salmon	33.4[a]	77[b]	53.6 to 57.2	Brett (1952)	ILT
Coho Salmon	35.0[a]	76.1[b]	53.6 to 57.2	Brett (1952)	ILT
Steelhead	32.0	75.0	50 to 55.4	Bell (1991)	

[a] Acclimation temperature was 50 F and no mortality occurred in 5,500 minutes.

[b] Acclimation temperature was 59 F and 50% mortality occurred in 10,000 minutes (1 week).

In addition to the above analyses, longitudinal water-temperature profiles were developed for releases that ranged from 50 to 6,000 cfs. These simulations were used to identify how releases influence the numbers of river miles that are within or near the preferred temperature range of juvenile salmonids during the spring and summer.

5.5.2.2 Historical-Year Type Simulations

Simulations for hydrometeorological conditions of WY1975 through WY1994 also were used to identify how release flows and release temperatures affect meeting water-temperature criteria in Tables 5.11 and 5.13. Release-water temperatures used in SNTEMP were simulated using a two-dimensional reservoir water quality model called the Box Exchange Transport Temperature and Ecology of a Reservoir (BETTER) model (Kamman, pers. comm; Trinity County, 1992). The BETTER model accounts for operations of the Trinity River Division (e.g., diversions and Trinity Dam release-water temperatures) and represents the most accurate prediction of release temperatures currently available. Simulated temperatures were generated for each representative year of the five water-year classes. Predicted release temperatures were then used for similar year types using SNTEMP to simulate river temperature conditions for the 20-year record (Table 5.15). Simulated annual release-water temperatures for representative years are illustrated in Figure 5.50.

5.5.3 Results

5.5.3.1 Hypothetical-Year Type Simulation

Simulations show that release magnitudes and meteorological conditions do not have a significant influence on river water temperatures during early April, but have a substantial influence as tributary accretion decreases and meteorological conditions warm from May to mid-July (Figure 5.51 and 5.52). This influence is particularly noticeable during hot-dry conditions. When discharge is at approximately 2,000 cfs or greater, water temperatures are less variable between year types. For example, water temperatures at Weitchpec would range from 61° to 63 °F for all three year types (hot-dry, median, and cold-wet) on July 1 with a dam release of 2,000 cfs (Figure 5.53). As releases are increased to 6,000 cfs, the effects of meteorology and tributary accretion are minimized.

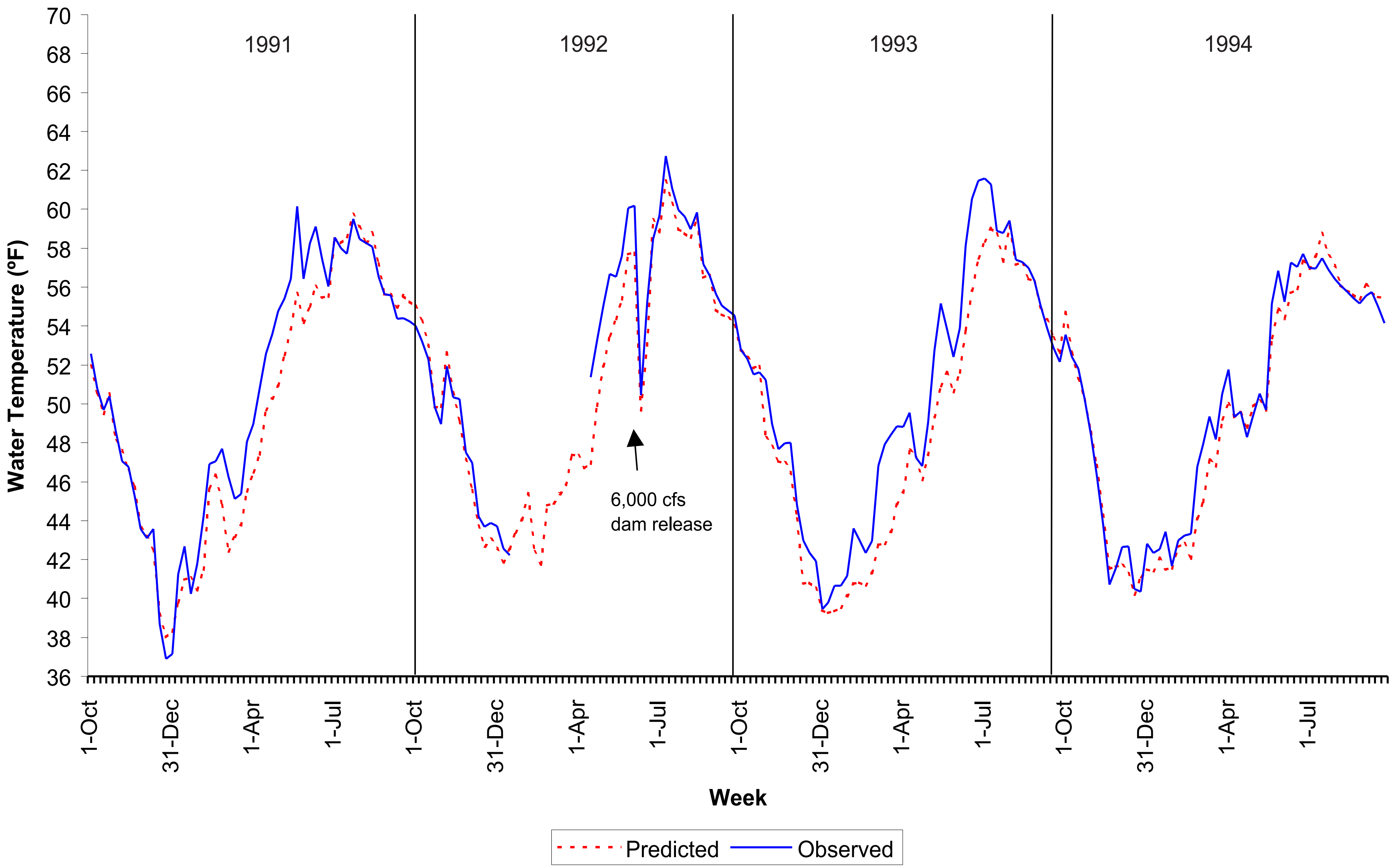


Figure 5.47. Trinity River water temperature model calibration results, 1991 through 1994. Predicted and observed water temperatures at Douglas City (RM 93.7).

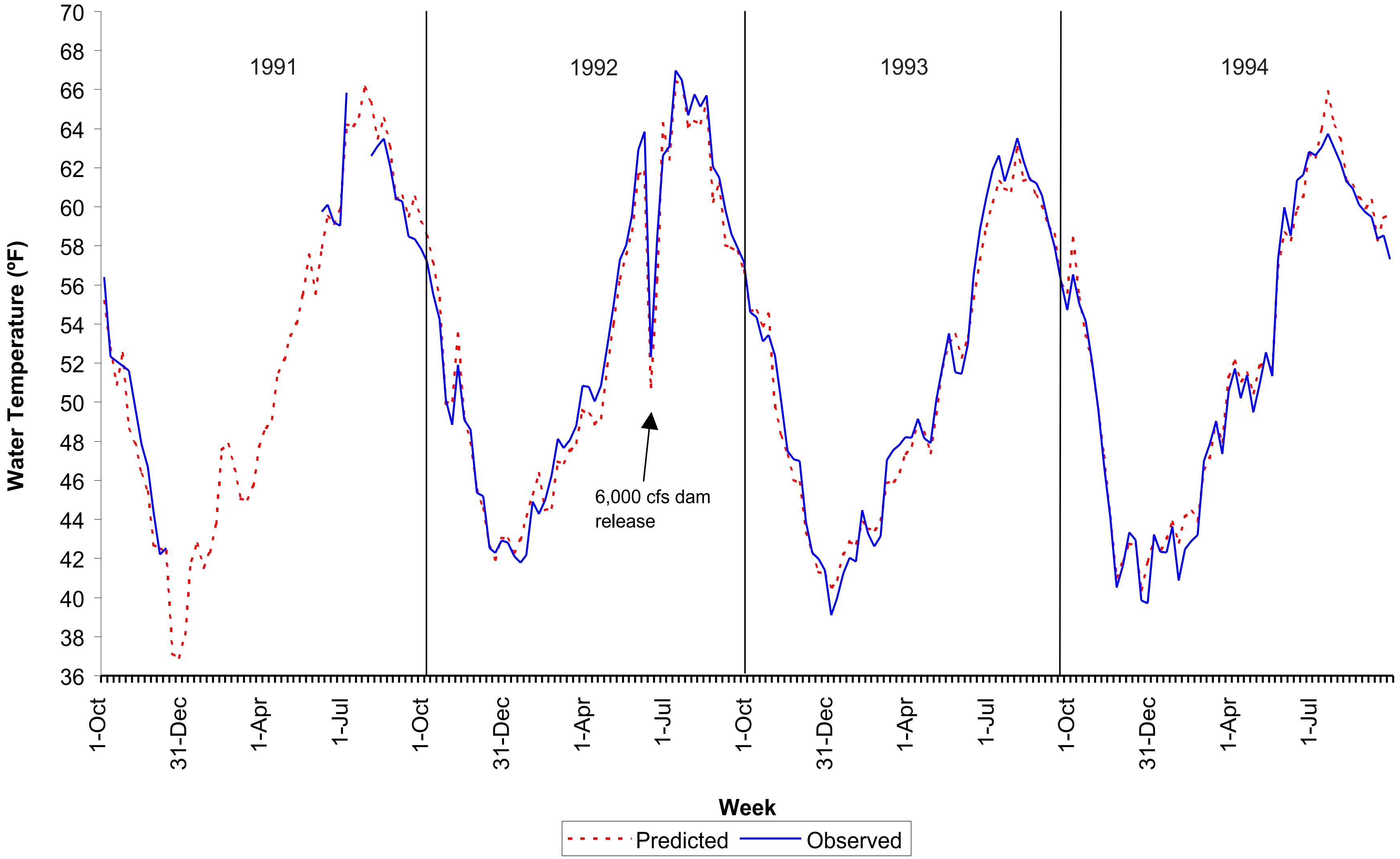


Figure 5.48. Trinity River water temperature model calibration results, 1991 through 1994. Predicted and observed water temperatures near the confluence of the North Fork Trinity River (RM 73.8).

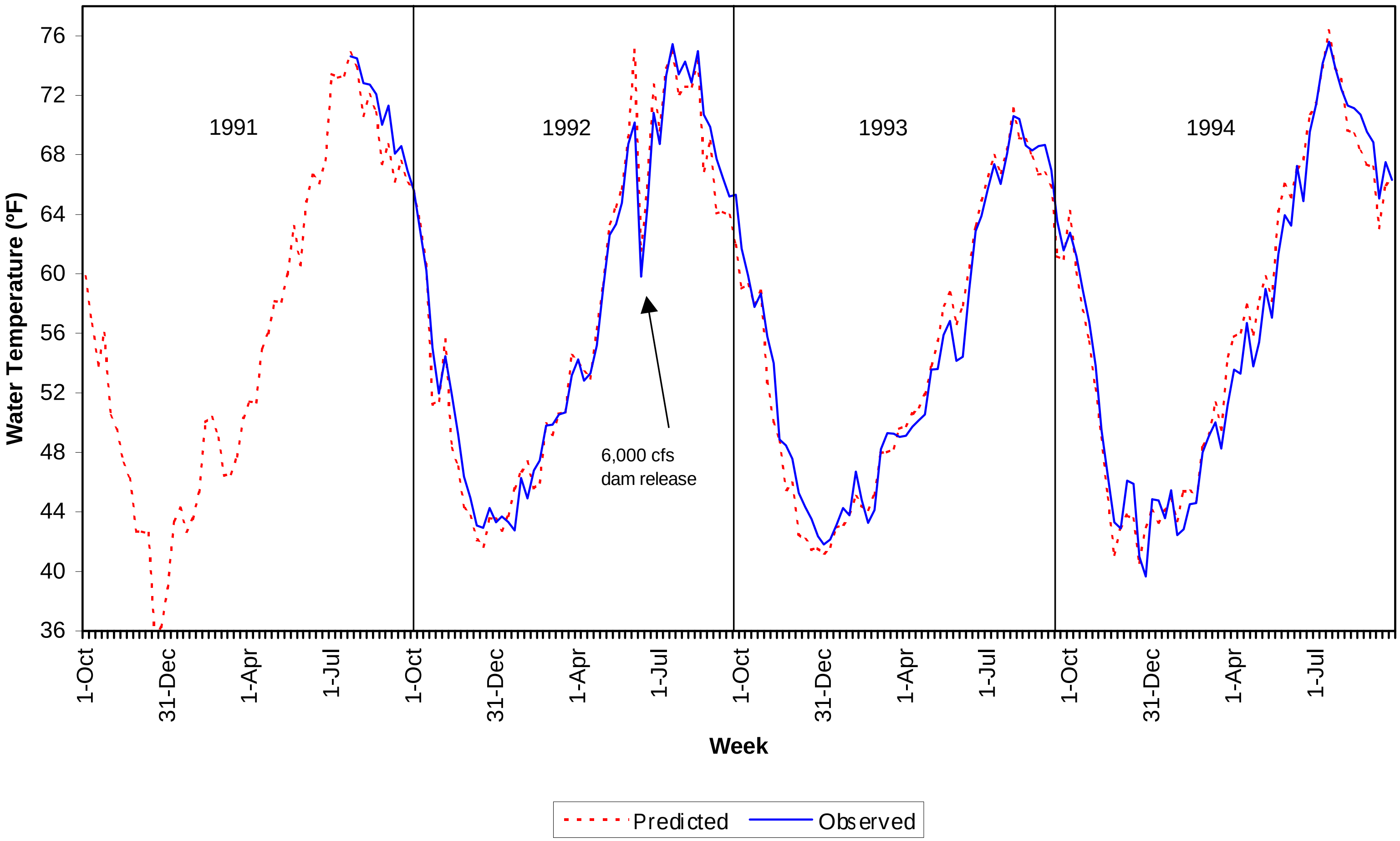


Figure 5.49. Trinity River water temperature model calibration results, 1991 through 1994. Predicted and observed water temperatures at Weitchpec Falls (RM 0.7).

Table 5.14. Hydrometeorological components of hypothetical year types as a function of percent probability of exceedance.

	Hypothetical Year Types		
Variables	**Hot-dry**	**Median**	**Cold-wet**
Meteorologic	10	50	90
Air temperature			
Percent Possible Sun	10	50	90
Wind Speed[a]	50	50	50
Relative Humidity	90	50	10
Hydrologic	90	50	10
Tributary Accretion			

[a] Because of the low sensitivity of wind speed on water temperatures, this variable was the same for all year types.

Empirical data show that large releases in June 1992 resulted in reduced water temperatures throughout the entire mainstem Trinity River (Zedonis, 1997). An experimental release of 6,000 cfs had substantial effects on water temperatures at Weitchpec (Figure 5.49). Average weekly water temperatures decreased from 70.2° to 59.8 °F for the week of June 3 to June 10. Extensive shading (both topographic and vegetative), the small increase of channel width relative to increased flows (stage–discharge relation), reduced travel time, and small accretions along the mainstem were probable reasons for reduced heat gain during this release (Zedonis, 1997).

Releases required to meet the temperature criteria presented in Table 5.11 can vary substantially depending on hydrometeorological conditions (Table 5.16). For example, releases required to meet a target of 59 °F would range from 150 cfs for cold-wet conditions, 2,600 cfs for median conditions, and 3,000 cfs for hot-dry conditions.

> "... increased releases generally result in an increase in the number of river miles within or near the species' preferred rearing water-temperature range."

Longitudinal profiles show that increased releases tend to stabilize the thermal regime of the river regardless of meteorological conditions or season. For example, a 6,000-cfs dam release, when compared with a 150 cfs release, results in less variable water temperatures throughout the river during the weeks of April 1 (Figure 5.53) and July 1 (Figure 5.54). Less variable temperature regimes associated with increased releases generally result in an increase in the number of river miles within or near the species' preferred rearing water-temperature range (see Figures 5.53 and 5.54); this is particularly noticeable during early summer.

The magnitude of releases, release water temperatures, and meteorological conditions also have an influence on downstream water temperatures during the summer and fall, such as at Douglas City (Table 5.17). Simulations using a minimum release-water temperature (47° to 50° F), indicate that the CRWQCB-NCR objective of 60° F is met

Table 5.15. Categorization of year types from 1975 through 1994 and years for which the BETTER model results were available and applied.

Water Year Class	BETTER Modeled Year	Years that the BETTER Release Water Temperatures were Applied
Extremely Wet	1983	1978, 1982, 1983
Wet	1986	1975, 1980, 1984, 1986, 1993
Normal	1989	1989
Dry	1990	1976, 1979, 1981, 1985, 1987, 1988, 1990, 1992
Critically Dry	1977	1977, 1991, 1994

with a release of approximately 150 cfs for cold-wet conditions and 300 cfs for median and hot-dry conditions. With a maximum dam release water temperature (51° to 56° F), releases that range from 150 to over 600 cfs would be required to meet the objectives from cold-wet to hot-dry conditions. After September 15 when the temperature objective shifts to 56° F at Douglas City, releases less than 300 cfs would meet the objectives provided that release-water temperatures were near 47° F. Under hot-dry conditions and warmer releases (51.3° F), releases near 450 cfs meet the objective.

To meet the CRWQCB-NCR objective of 56° F at the confluence of the North Fork Trinity River using minimum release-water temperatures (46.6° F), a flow between 300 and 450 cfs would be required during hot-dry conditions, whereas a flow of 150 and 300 cfs would meet the objective during cold-wet and median year type conditions, respectively (Table 5.17). With maximum release-water temperatures (51.1° F), releases required to meet the objective would range from less than 150 cfs in cold-wet conditions to greater than 450 cfs during hot-dry conditions. After mid-October, air temperatures are generally cooler, and flows less than 150 cfs would be sufficient to meet the objective through December for hot-dry, median, and cold-wet hydrometeorological conditions.

Empirical data indicate that a release of 450 cfs generally meets the objectives (Table 5.18). For the years 1992 to 1994 and 1996 to 1997, average weekly releases ranged from 300 to 600 cfs, and releases near 450 cfs were most prevalent. During these 5 years, the temperature objectives were exceeded in only 5 weekly periods. Exceedence of the objectives occurred during three weekly periods in July of 1992 and 1993 when release-water temperatures were equal to or greater than 53° F and flows were near 450 cfs. In mid-September of 1993, the objective was exceeded when dam releases were near 50° F and flows were 300 cfs.

Assuming constant release-water temperatures, longitudinal profiles indicate that even a small augmentation of releases can increase the number of miles of river falling within or near the preferred temperature range for juvenile salmonids (Figure 5.55). For example, under hot-dry hydrometeorological conditions and a 50 cfs dam release, water temperatures would be below the 57.2° F upper preferred temperature for approximately 3 miles of river below Lewiston Dam. Under similar hydrometeorological conditions and a 450 cfs dam release, the number of

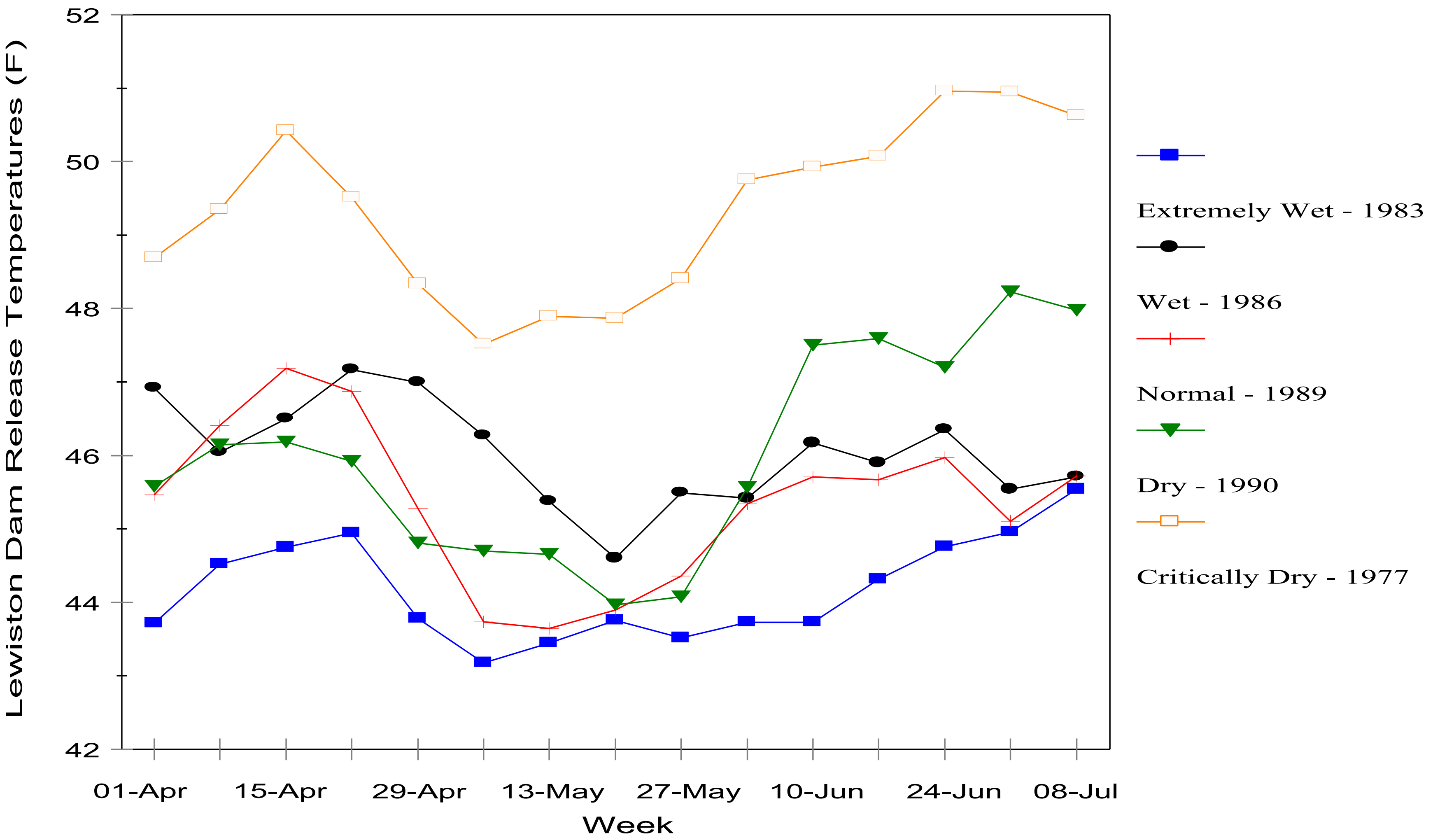


Figure 5.50. BETTER model predicted temperatures for five historic years, representing five water-year classes.

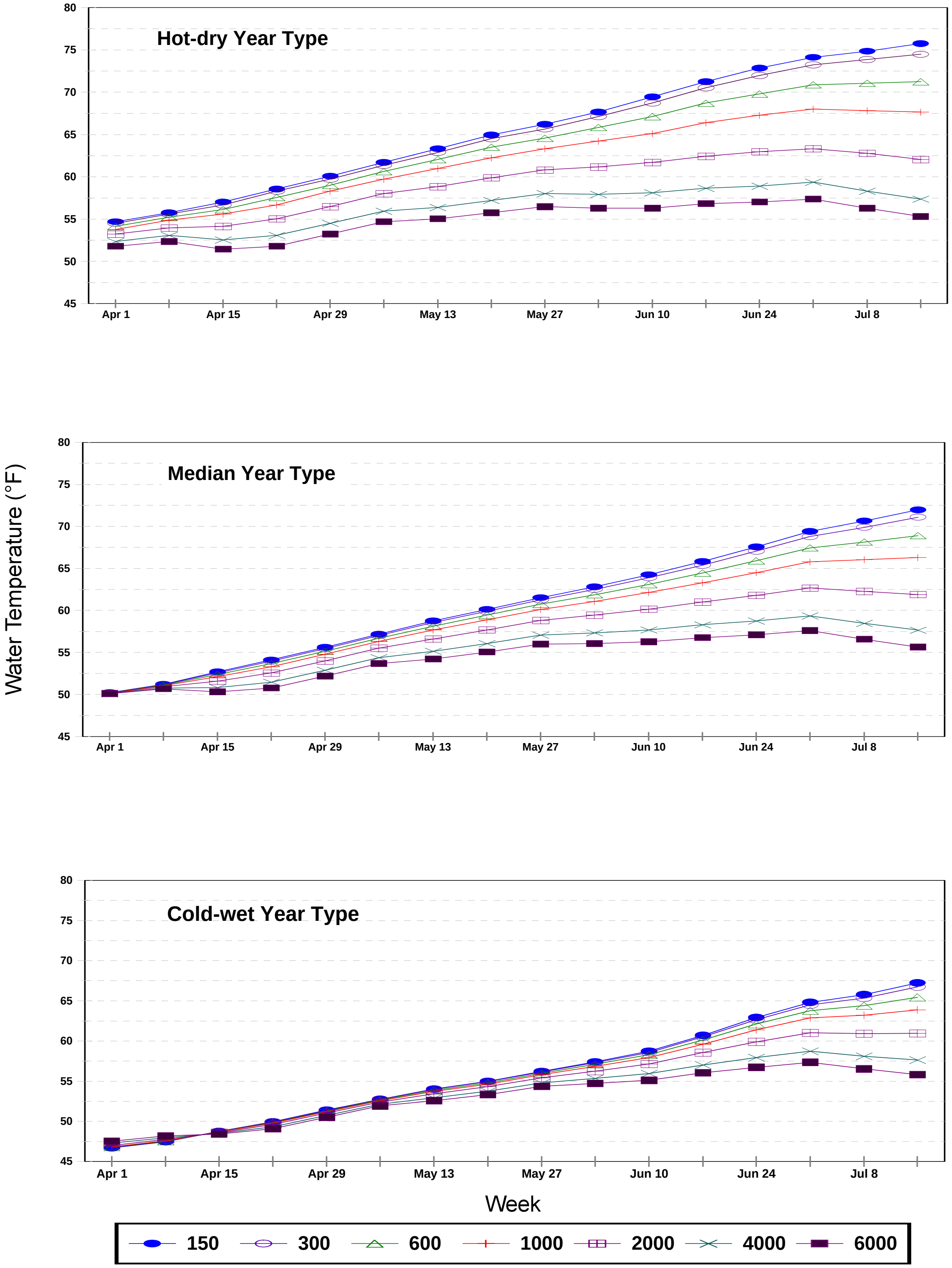


Figure 5.51. Stream Network Water Temperature Model (SNTEMP) temperature predictions (7-day average) for the Trinity River near Weitchpec (RM 5.3) with Lewiston Dam releases between 150 and 6,000 cfs and hot-dry (HD), median (Med), and cold-wet (CW) year type conditions. Release water temperatures used were 7-day average minimum water temperatures observed below Lewiston Dam from 1987 to 1994.

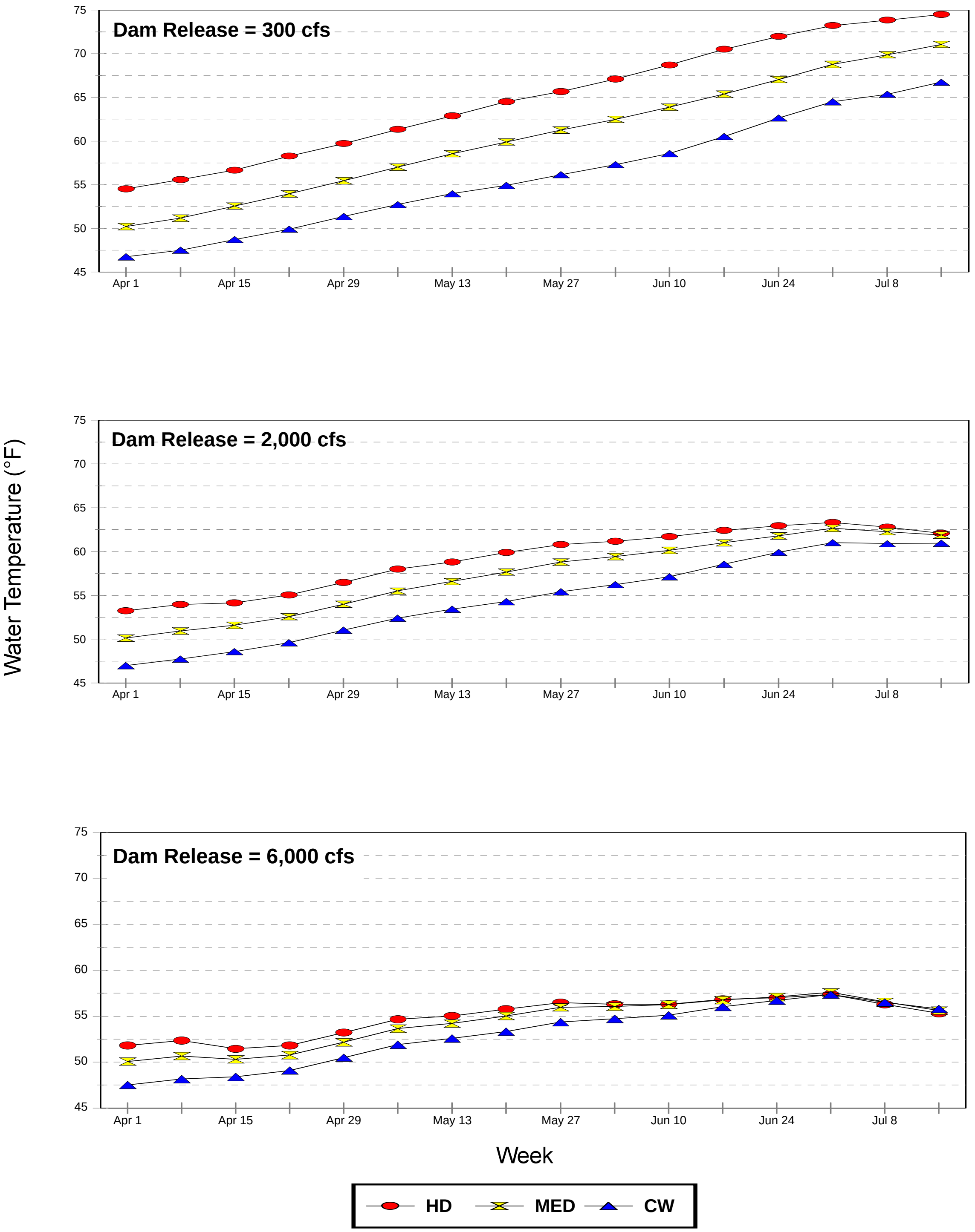


Figure 5.52. Comparison of SNTEMP model output for three different dam releases for hot-dry (HD), median (Med), and cold-wet (CW) hypothetical year conditions during the spring and early summer near Weitchpec (RM 5.3). Release water temperatures used were 7-day average minimum water temperatures observed below Lewiston Dam from 1987 to 1994.

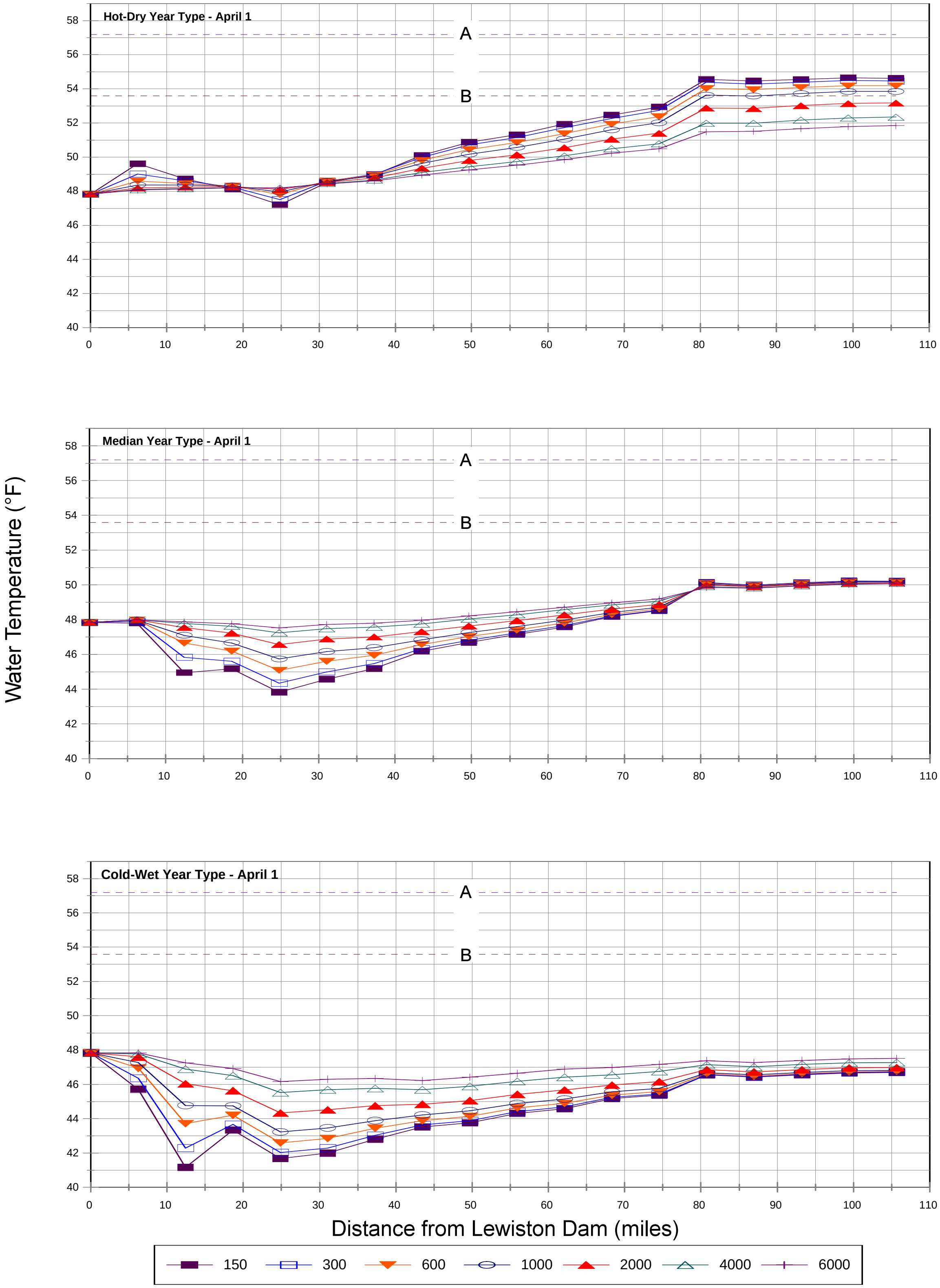


Figure 5.53. Longitudinal profiles of predicted water temperatures for April 1 with Lewiston Dam releases of 150 to 6,000 cfs and hot-dry, median, and cold-wet hydrometeorological conditions. Upper "A" and lower "B" preferred water temperatures of chinook and coho salmon juveniles. Temperature criteria are from Table 5.13.

Table 5.16. Approximate dam releases at Lewiston, under hot-dry, median, and cold-wet hydrometeorological conditions, to meet temperature targets during salmon and steelhead smolt outmigration through the lower Trinity River.

Smolt Species	Approx. Date of at least 80% Emigration at the Willow Creek Trap Site	**Optimal Temperature Conditions**				**Marginal Temperature Conditions**			
		Water Temperature Target (°F)	Approximate Dam Release Magnitude (cfs) to Meet the Target			Water Temperature Target (°F)	Approximate Dam Release Magnitude (cfs) to Meet the Target		
			Year Type				Year Type		
			Hot-dry	Median	Cold-wet		Hot-dry	Median	Cold-wet
Steelhead	May 22	< 55.4	> 6,000	6,000	< 150	< 59	2,500	1,200	< 150
Coho Salmon	June 4	< 59	3,000	2,600	< 150	< 62.6	1,500	300	< 150
Chinook Salmon	July 9	< 62.6	2,000	1,900	1,200	< 68	800	700	< 150

miles increases to about 18; under median and cold-wet hydrometeorological conditions the number of miles within the preferred water-temperature range increases.

5.5.3.2 Historical-Years Simulation Results and Alternative Release Patterns

Simulations using historical hydrometeorological conditions and BETTER-modeled simulated release-water temperatures allow prediction of river-water temperatures that would have resulted from different release schedules. Through an iterative process, release magnitudes can be identified that could have been used to meet temperature criteria at Weitchpec in historical years (Figure 5.56). Simulations for a wet year (1984) show that releases as small as 150 cfs would have met the temperature criteria in early April, but that releases near 4,000 cfs would have been needed to meet temperature targets in late May. Toward the end of the chinook salmon smolt emigration period, a release near 2,000 cfs would meet the optimal criteria.

Simulation results also show the variability of releases required to meet temperature criteria as a function of meteorology. On May 27, releases between 2,000 and 4,000 cfs would have been required to meet optimal criteria, whereas only a week later (June 3) a release of approximately 1,000 cfs would have met the same temperature criteria because of cooler meteorology.

Not surprisingly, longitudinal profiles of historical year simulations exhibit the same relation as that of the hypothetical-year type simulations, and therefore results are not presented. During early April, release magnitude does not have a significant influence on thermal habitat, but as summer approaches, increased releases can increase the amount of habitat falling within preferred temperature range of rearing juvenile salmonids (See Figures 5.53 and 5.54).

5.5.4 Conclusions

The SNTEMP model of the Trinity River is useful for predicting system thermal behavior under a variety of operations scenarios. The model illustrates the dynamic relation between meteorology, tributary

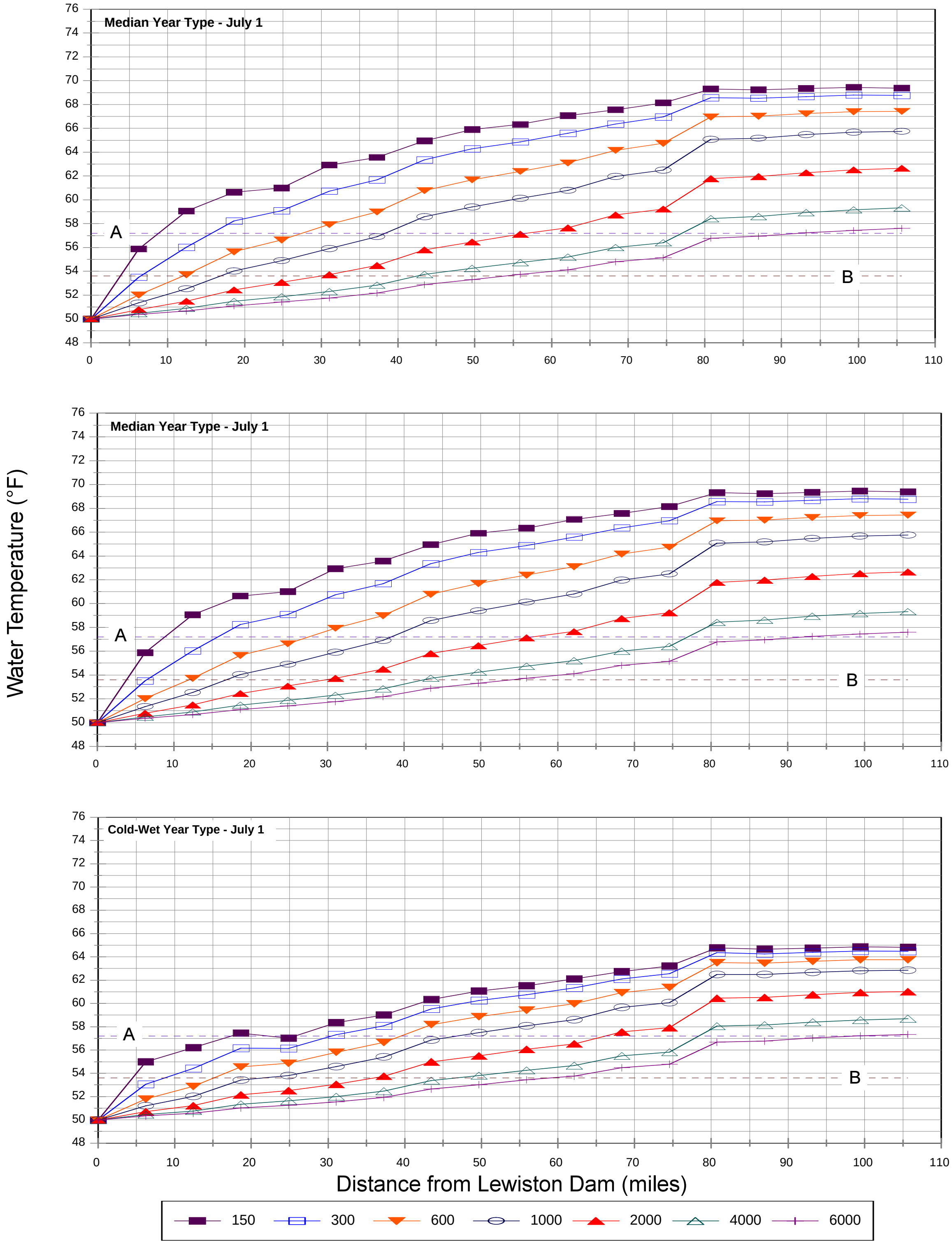


Figure 5.54. Longitudinal profiles of predicted water temperatures for July 1 with Lewiston Dam releases of 150 to 6,000 cfs and hot-dry, median, and cold-wet hydrometeorological conditions. Upper "A" and lower "B" preferred water temperatures of chinook and coho salmon juveniles. Temperature criteria are from Table 5.13.

Table 5.17. Stream Network Water Temperature Model (SNTEMP) temperature predictions (7-day average) for the Trinity River at CRWQCB-NCR Objective locations - Douglas City (RM 93.8) and the confluence of the North Fork Trinity River (RM 72.4). Bolded values indicate the temperature would not be met. CW = cold water year; MED = median year; HD = hot dry year.

WaterTemperaturePredictions(°F)																	
	Dam		**LewistonDamReleases(cfs)**														
	Release	**Target**	**150**			**300**			**450**			**600**			**1000**		
Week	**Temp**	**Temp**	**CW**	**Med**	**HD**	**CW**	**Med**	**HD**	**CW**	**Med**	**HD**	**CW**	**Med**	**HD**	**CW**	**Med**	**HD**
DouglasCity-MinimumReleaseWaterTemperatures																	
01-Jul	50.0	60	57.1	**60.2**	**63.9**	55.7	57.7	59.6	54.9	56.3	57.4	54.1	55.2	56.1	53.1	53.7	54.1
08-Jul	48.7	60	57.6	**60.8**	**64.0**	55.6	57.6	59.2	54.4	55.7	56.7	53.6	54.5	55.2	52.3	52.8	53.1
15-Jul	47.7	60	58.2	**61.5**	**64.2**	55.7	57.5	58.8	54.1	55.3	56.0	53.2	53.9	54.5	51.6	52.0	52.2
22-Jul	47.3	60	58.6	**61.9**	**64.2**	55.8	57.5	58.6	54.0	55.1	55.7	53.0	53.7	54.1	51.3	51.7	51.8
29-Jul	48.6	60	59.0	**62.6**	**64.9**	56.3	58.2	59.4	54.7	56.0	56.6	53.7	54.6	55.0	52.2	52.7	52.9
05-Aug	47.7	60	58.8	**62.1**	**64.0**	55.7	57.4	58.3	53.9	55.0	55.6	52.9	53.7	54.1	51.3	51.7	52.0
12-Aug	46.9	60	58.2	**61.3**	**63.1**	54.9	56.5	57.4	53.0	54.1	54.7	52.0	52.8	53.2	50.5	50.9	51.1
19-Aug	47.1	60	57.6	**60.6**	**62.1**	54.4	56.1	56.8	52.7	53.8	54.3	51.8	52.6	52.9	50.3	50.8	50.9
26-Aug	47.1	60	56.5	59.7	**61.0**	53.6	55.4	55.9	52.0	53.3	53.7	51.2	52.2	52.4	49.9	50.5	50.7
02-Sep	47.1	60	55.3	58.4	59.9	52.8	54.6	55.4	51.4	52.7	53.2	50.7	51.7	52.0	49.6	50.2	50.4
09-Sep	47.1	60	54.0	57.5	58.8	51.9	54.0	54.5	50.7	52.3	52.6	50.1	51.3	51.6	49.2	49.9	50.2
16-Sep	46.9	56	52.7	**56.4**	**57.6**	51.0	53.2	53.8	50.0	51.6	52.0	49.5	50.7	51.1	48.7	49.5	49.6
23-Sep	46.9	56	51.2	55.1	**56.3**	49.9	52.3	52.9	49.2	51.0	51.4	48.9	50.2	50.5	48.3	49.2	49.3
DouglasCity-MaximumReleaseWaterTemperature																	
01-Jul	56.1	60	58.5	**62.0**	**66.0**	58.1	**60.6**	**63.1**	58.0	**60.2**	**61.7**	57.7	59.2	**60.6**	57.4	58.4	59.2
08-Jul	55.6	60	59.2	**62.9**	**66.4**	58.5	**61.0**	**63.1**	58.4	**60.2**	**61.5**	57.8	59.2	**60.3**	57.2	58.2	58.8
15-Jul	52.9	60	59.6	**63.2**	**66.2**	58.1	**60.3**	**61.9**	57.4	58.8	59.8	56.5	57.7	58.5	55.5	56.2	56.7
22-Jul	52.7	60	**60.1**	**63.8**	**66.4**	58.4	**60.5**	**61.9**	57.5	58.9	59.6	56.6	57.7	58.3	55.5	56.1	56.5
29-Jul	52.7	60	**60.3**	**64.1**	**66.6**	58.4	**60.6**	**61.9**	57.4	58.9	59.6	56.5	57.7	58.3	55.4	56.1	56.5
05-Aug	52.0	60	**60.1**	**63.6**	**65.8**	57.9	60.0	**61.0**	56.8	58.1	58.8	55.9	56.9	57.4	54.7	55.4	55.6
12-Aug	53.1	60	**60.2**	**63.6**	**65.7**	58.2	**60.2**	**61.3**	57.2	58.5	59.2	56.4	57.5	58.3	55.4	56.1	56.5
19-Aug	52.3	60	59.3	**62.6**	**64.2**	57.3	59.3	**60.1**	56.3	57.6	58.2	55.6	56.6	57.0	54.6	55.2	55.6
26-Aug	51.6	60	58.1	**61.5**	**62.8**	56.2	58.2	59.0	55.2	56.6	57.1	54.5	55.7	55.9	53.7	54.4	54.5
02-Sep	51.4	60	56.9	**60.2**	**61.7**	55.3	57.3	58.1	54.5	55.9	56.4	53.9	55.0	55.4	53.2	53.9	54.1
09-Sep	52.9	60	56.0	59.9	**61.2**	55.2	57.6	58.3	54.8	56.5	56.9	54.4	55.8	56.1	54.0	54.9	55.0
16-Sep	51.1	56	54.2	58.1	**59.4**	53.3	55.8	**56.5**	52.9	54.7	55.1	52.6	54.0	54.3	52.2	53.1	53.2
23-Sep	51.3	56	52.7	56.5	**58.1**	52.4	55.0	55.8	52.3	54.2	54.6	52.1	53.6	54.0	51.9	52.9	53.1
NorthForkTrinityConfluence-MinimumReleaseWaterTemperatures																	
01-Oct	46.6	56	51.2	**57.0**	**59.2**	50.6	54.9	**56.3**	49.8	53.2	54.2	49.8	52.5	53.3	49.2	51.1	51.6
08-Oct	46.6	56	49.1	54.7	**57.4**	48.8	53.0	54.8	48.5	51.8	53.2	48.4	51.1	52.2	48.1	49.9	50.6
15-Oct	45.9	56	47.3	52.2	55.0	47.2	50.9	52.8	47.0	50.1	51.5	47.0	49.5	50.6	46.9	48.6	49.3
22-Oct	46.4	56	45.4	50.0	52.3	45.6	49.4	51.0	45.7	48.9	50.1	45.9	48.6	49.6	46.2	48.2	48.8
29-Oct	46.2	56	43.5	47.5	50.3	43.7	47.4	49.4	44.0	47.3	48.9	44.2	47.2	48.5	44.7	47.1	48.0
05-Nov	46.2	56	42.3	45.6	48.3	42.6	45.8	47.9	42.9	46.0	47.7	43.1	46.1	47.5	43.7	46.3	47.3
12-Nov	45.5	56	41.1	43.6	45.8	41.4	44.0	45.9	41.6	44.4	45.9	41.9	44.6	45.9	42.5	45.0	46.0
19-Nov	43.3	56	40.0	41.8	44.0	40.2	42.1	44.0	40.4	42.4	44.0	40.6	42.6	44.0	41.0	43.0	44.0
26-Nov	42.6	56	39.2	40.5	42.7	39.4	40.9	42.8	39.5	41.2	42.9	39.8	41.5	43.0	40.1	41.9	43.0
03-Dec	43.2	56	38.9	39.8	41.9	39.1	40.4	42.3	39.2	40.8	42.6	39.5	41.2	42.8	39.9	41.8	43.1
10-Dec	43.5	56	38.5	39.3	41.3	38.8	39.9	41.9	38.9	40.5	42.4	39.2	40.9	42.6	39.7	41.7	43.1
17-Dec	42.6	56	38.3	38.7	41.1	38.5	39.3	41.6	38.6	39.8	41.9	38.9	40.2	42.1	39.3	40.9	42.4
24-Dec	40.6	56	38.3	38.4	40.5	38.4	38.8	40.6	38.4	39.0	40.7	38.6	39.3	40.8	38.8	39.7	41.0
NorthForkTrinityConfluence-MaximumReleaseWaterTemperatures																	
01-Oct	51.1	56	51.7	**57.6**	**59.8**	51.7	**56.3**	**57.8**	51.7	55.3	**56.5**	51.7	54.8	55.7	51.7	53.8	54.4
08-Oct	51.1	56	49.7	55.4	**58.1**	50.0	54.6	**56.5**	50.3	54.0	55.5	50.5	53.7	54.9	50.8	53.1	53.9
15-Oct	50.5	56	47.9	53.0	55.8	48.4	52.6	54.6	48.8	52.3	53.9	49.1	52.1	53.4	49.6	51.8	52.7
22-Oct	50.0	56	45.8	50.6	52.9	46.4	50.6	52.3	46.9	50.6	52.0	47.3	50.6	51.8	48.1	50.6	51.4
29-Oct	49.8	56	43.7	48.0	50.9	44.3	48.6	50.8	44.8	48.9	50.7	45.2	49.1	50.7	46.2	49.5	50.6
05-Nov	52.0	56	42.7	46.4	49.3	43.3	47.6	50.1	44.0	48.5	50.6	44.6	49.1	50.9	45.9	50.1	51.4
12-Nov	53.1	56	41.5	44.6	47.2	42.2	46.4	48.8	42.9	47.5	49.7	43.6	48.5	50.5	45.1	49.9	51.4
19-Nov	52.3	56	40.4	42.9	45.6	41.1	44.7	47.5	41.7	45.9	48.5	42.4	47.0	49.3	43.7	48.6	50.4
26-Nov	51.1	56	39.6	41.5	44.2	40.2	43.2	46.0	40.7	44.4	47.1	41.3	45.4	47.9	42.5	47.1	49.1
03-Dec	48.9	56	39.1	40.5	42.9	39.6	41.8	44.5	40.0	42.9	45.4	40.4	43.8	46.2	41.5	45.2	47.2
10-Dec	47.5	56	38.7	39.7	42.0	39.1	40.9	43.4	39.5	41.8	44.3	39.8	42.6	45.0	40.7	44.0	45.9
17-Dec	46.0	56	38.4	39.1	41.7	38.8	40.1	42.8	39.1	40.9	43.5	39.4	41.7	44.1	40.2	42.9	44.8
24-Dec	45.3	56	38.4	38.9	41.3	38.7	39.8	42.3	39.0	40.5	42.9	39.3	41.1	43.4	40.0	42.3	44.2

Table 5.18. Average weekly dam release temperatures and volumes from 1992 to 1994 and 1996 to 1997 in relation to meeting the CRWQCB-NCR water objectives established in 1991. Objectives (target temperatures) are 60° F at Douglas City for July 1 to Sept 14; 56° F at Douglas City from Sept 15 to Sept 30; and 56° F at the confluence of the North Fork Trinity River for Oct 1 to Dec 31. Bolded values indicate the target objective was exceeded. na = not available.

	1992				1993				1994			
	Dam Release		Water Temp. (F) at the Target Location	Target Temp (F)	Dam Release		Water Temp. (F) at the Target Location	Target Temp (F)	Dam Release		Water Temp. (F) at the Target Location	Target Temp (F)
Week	Temp (F)	Flow (cfs)			Temp (F)	Flow (cfs)			Temp (F)	Flow (cfs)		
01-Jul	na	317	59.7	60	**55.7**	**436**	**61.6**	**60**	49.7	468	57.0	60
08-Jul	**53.0**	**317**	**62.7**	**60**	**55.6**	**447**	**61.3**	**60**	50.0	483	57.0	60
15-Jul	**53.4**	**421**	**61.1**	**60**	55.6	460	58.9	60	49.9	466	57.5	60
22-Jul	na	467	59.9	60	51.7	467	58.8	60	50.2	470	56.9	60
29-Jul	52.6	438	59.6	60	53.2	458	59.4	60	49.6	469	56.4	60
05-Aug	51.1	435	59.0	60	51.5	489	57.4	60	50.0	469	56.1	60
12-Aug	53.3	511	59.8	60	51.8	470	57.3	60	49.7	469	55.8	60
19-Aug	52.7	520	57.2	60	51.0	447	57.0	60	50.2	479	55.4	60
26-Aug	51.3	520	56.6	60	51.9	451	56.4	60	50.2	445	55.2	60
02-Sep	51.9	533	55.6	60	50.6	600	55.0	60	50.2	447	55.6	60
09-Sep	51.3	532	55.1	60	49.3	457	53.9	60	na	443	55.7	60
16-Sep	51.0	531	54.8	56	50.5	459	52.9	56	51.6	441	55.0	56
23-Sep	51.2	530	54.6	56	49.1	381	52.1	56	50.4	435	54.1	56
01-Oct	50.6	532	54.6	56	**49.9**	**309**	**56.6**	**56**	na	na	na	56
08-Oct	50.1	467	54.3	56	49.5	299	55.0	56	na	na	na	56
15-Oct	49.6	390	53.1	56	48.8	311	54.2	56	na	na	na	56

	1996				1997			
	Dam Release		Water Temp. (F) at the Target Location	Target Temp (F)	Dam Release		Water Temp. (F) at the Target Location	Target Temp (F)
Week	Temp (F)	Flow (cfs)			Temp (F)	Flow (cfs)		
01-Jul	49.0	500	58.0	60	48.6	484	56.6	60
08-Jul	49.0	480	59.2	60	na	498	57.4	60
15-Jul	47.8	488	57.6	60	na	489	57.5	60
22-Jul	49.4	490	57.7	60	na	487	57.9	60
29-Jul	50.1	485	57.9	60	50.8	491	56.7	60
05-Aug	50.2	491	57.4	60	51.6	487	57.7	60
12-Aug	49.8	489	56.7	60	51.8	483	57.6	60
19-Aug	49.6	486	55.9	60	51.5	487	57.0	60
26-Aug	49.6	483	55.3	60	51.3	599	55.9	60
02-Sep	49.5	471	53.8	60	51.3	492	55.8	60
09-Sep	49.7	440	54.0	60	50.7	454	55.0	60
16-Sep	49.9	440	53.1	56	51.2	461	54.4	56
23-Sep	49.8	448	53.0	56	51.8	462	54.6	56
01-Oct	49.5	463	55.8	56	51.5	na	na	56
08-Oct	49.5	475	54.5	56	49.7	na	na	56
15-Oct	49.3	361	51.1	56	49.5	na	na	56

Note: empirical data presented here may not match model output data from Table 5.17 because hydrometeorological input data may differ.

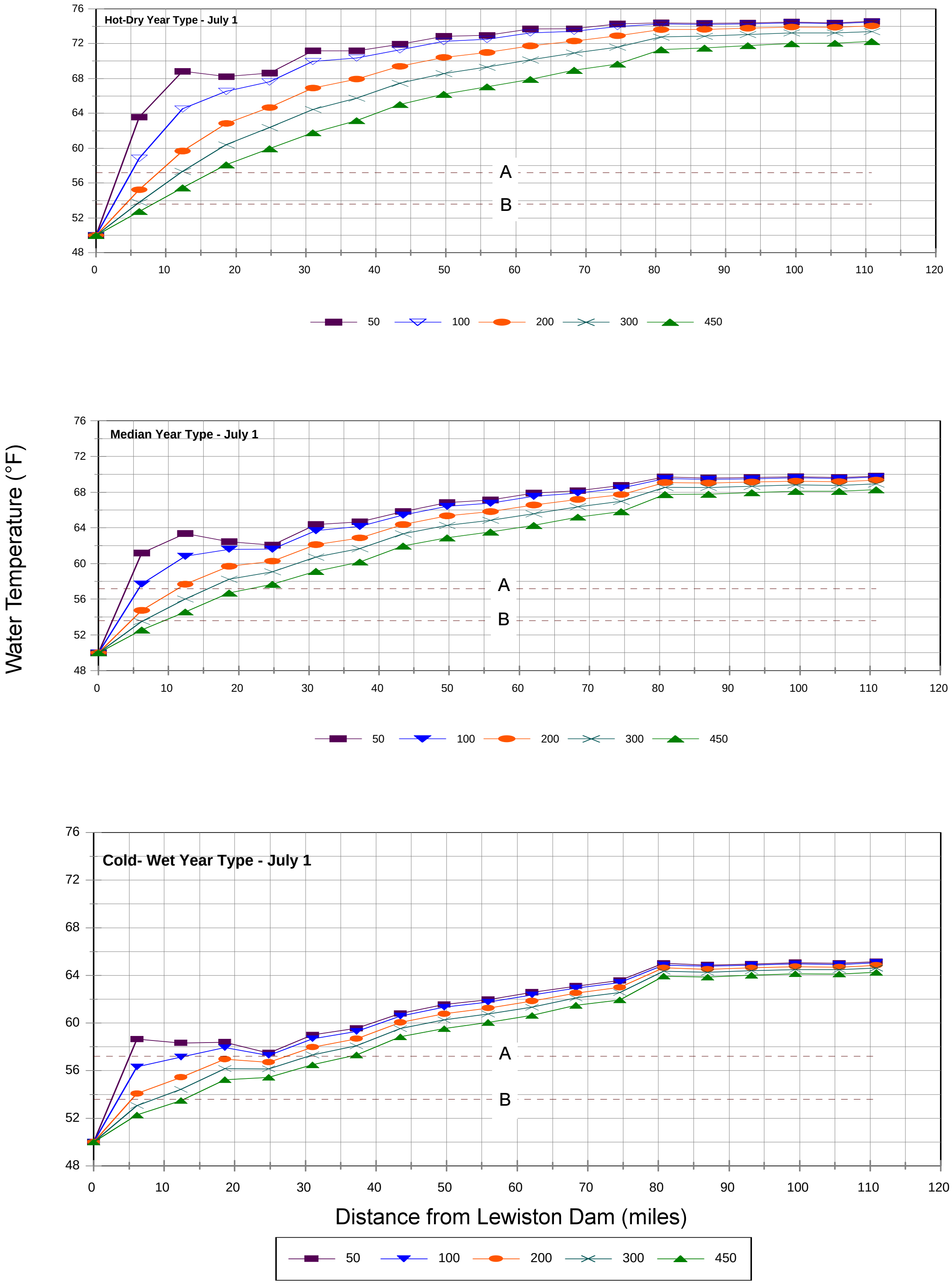


Figure 5.55. Longitudinal profiles of predicted water temperatures for July 1 with Lewiston Dam releases from 50 to 450 cfs and hot-dry, median, and cold-wet hydrometeorological conditions. Upper "A" and lower "B" preferred water temperatures of chinook and coho salmon juveniles. Temperature criteria are from Table 5.13.

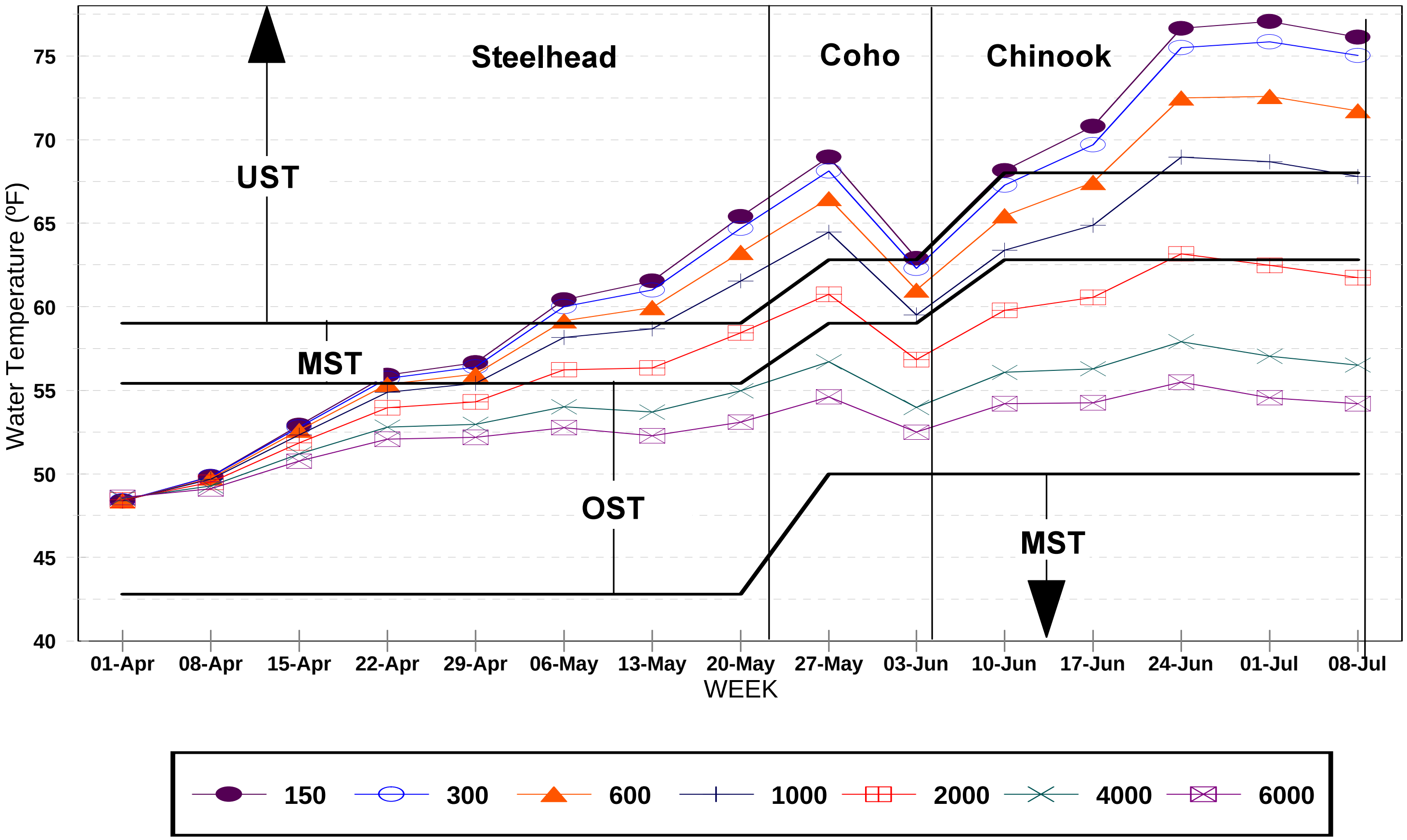


Figure 5.56. Predicted water temperatures for a historic WET year (1984) at Weitchpec (RM 0.0) with Lewiston Dam releases ranging from 150 to 6,000 cfs. Results are based on constant release temperatures. UST = unsuitable smolt temperatures, MST = marginal smolt temperatures, and OST = optimal smolt temperatures.

dynamic relation between meteorology, tributary hydrology, dam release temperatures, and release magnitudes that influence downstream water temperatures.

Hypothetical- and historical-year type simulations both provided valuable information on how the Trinity River system is likely to behave under a variety of scenarios. Hypothetical-year type simulations showed sensitivity of downstream water temperatures over varied releases and a broad set of hydrometeorological conditions. Unlike hypothetical-year types, use of historical years allowed prediction of releases that would have been needed to meet spring water-temperature criteria. Use of historical years provides a necessary link to basin hydrology (i.e., water-year classes) and therefore should be used in development of final recommendations for spring temperature objectives.

> "Increasing dam releases during the spring and early summer can improve or restore temperature conditions in the river that promote better growing conditions and smolt survival."

Simulations and empirical data show that water temperatures throughout the Trinity River are influenced by dam releases during the spring. Additionally, an examination of water temperatures before and after the construction of the TRD show that spring and early summer water temperatures have become warmer throughout the Trinity River as a result of storage/diversion of snowmelt runoff from the watershed above Trinity Dam (see Section 4.3.6). Increasing dam releases during the spring and early summer can improve or restore temperature conditions in the river that promote better growing conditions and smolt survival. Furthermore, increased dam releases and associated increased water velocities should decrease emigration time to the Pacific Ocean, and therefore increase the survival rates of smolts.

Additional benefits of increased magnitude and duration of spring releases would include: (1) improved water temperatures for migrating spring-run chinook salmon and summer steelhead adults and for outmigrating run-back adult steelhead in the Trinity and Klamath Rivers; (2) improved water-temperature and water-quality (dissolved oxygen) regimes within the Trinity and Klamath Rivers for life stages that rear or hold during the summer; and (3) improved flow conditions in the Trinity and Klamath Rivers for hatchery-produced salmonids.

Because spring- and fall-run chinook salmon require cold water to survive and successfully spawn, but can no longer access cold-water areas above Lewiston Dam, there is a need to artificially maintain a cold-water segment below Lewiston Dam. CRWQCB-NCR water- temperature objectives (Table 5.12) would provide necessary thermal refugia for adult salmon and steelhead. To meet these objectives, it is recommended that flows of 450 cfs be maintained during the summer and early fall. Although this flow can be high for this time of the year in comparison with pre-TRD flows, it is needed to ensure maintenance of suitable water temperatures for adult salmon and steelhead. Empirical data from 1992 to 1997 (Table 5.18) show that releases near 450 cfs met the temperature targets under conditions of extremely warm air temperatures. Only when release-water temperatures were above approximately 53° F (during the early summer) were the temperature targets not met with a release of 450 cfs.

Simulations showed the influence of variables on water temperature under conditions not portrayed by empirical data. Simulations suggest that dam releases that range from 150 to 600 cfs would be required to meet the temperature targets, depending on hydrometeorology and release-water temperatures. Similar to what is shown by empirical data, model results indicate that a 450 cfs release would generally meet the

> "CRWQCB-NCR water-temperature objectives would provide necessary thermal refugia for adult salmon and steelhead."

objectives under hot-dry conditions and when release-water temperatures are colder than approximately 53° F during early summer.

Additional evidence in support of maintaining 450-cfs releases during the summer and early fall is provided from spawning surveys (CDFG, 1996a, 1996b). Surveys conducted by the CDFG from 1992 to 1996 have shown a more even longitudinal distribution of spawning between Lewiston Dam and the confluence of the North Fork Trinity River (CDFG, 1996a, 1996b) with Lewiston Dam releases of 450 cfs, as opposed to 300 cfs. A wider distribution of spawners was likely a result of acceptable water temperatures extending farther downstream during the time when fish begin selecting spawning sites. Spreading spawners throughout more habitat could lessen the likelihood that fish would spawn on previously constructed redds. Another benefit of maintaining 450-cfs releases during the summer and early fall is that it provides several more miles of river below Lewiston Dam that fall within or near the preferred temperature range for juvenile salmonids.

5.6 Chinook Salmon Potential Production

5.6.1 Introduction

A potential production model, SALMOD, was developed for naturally produced young-of-year chinook salmon in the Trinity River reach from Lewiston Dam downstream 25 miles. The model evolved through a planned process of: (1) developing a conceptual model of the factors that significantly and directly affect spring-run and fall-run chinook salmon potential production; (2) specifying the important functional relations in mathematical models and combining them into a computer model; (3) verifying that the combined calculations were reasonable; (4) calibrating model output to available data for the period 1989 to 1991 and assembling additional data appropriate for the Trinity River study area; and

(5) validating the model by a means of a prediction–monitoring–improvement annual sequence in 1992 and 1993 (Williamson et al., 1993). Model validation was defined as making predictive estimates (in two workshops each year in late January and late March) of chinook salmon production for various proposed flow regimes and then gathering biological data from early March to early June to improve the model. Numbers of naturally produced coho salmon and steelhead were so low in the Trinity River at the time of the study that it was not considered cost effective to gather the biological data needed for calibration and validation for those two species. Consequently, SALMOD describes only chinook salmon in the Trinity River application.

SALMOD is a conceptual chinook salmon life-history model used for estimating the relative magnitude of potential production among alternative water management regimes (release magnitudes and temperatures) and habitat rehabilitation activities.

The conceptual model was developed using input from Trinity River fish experts (Williamson et al., 1993). The assembled experts believed that naturally produced chinook salmon potential production in the Trinity River was primarily controlled by: (1) physical habitat limitation effects on movement, mortality, and fish food production; (2) water- temperature-related effects on mortality and individual growth; and (3) seasonal-factor effects on movement and maturation. Specific assumptions included in the computer model are that young-of-year chinook salmon growth, maturation, movement, and mortality are directly related to physical space, hydraulic properties of habitat, and water temperature, which in turn are manageable by means of timing and amount of reservoir releases to the study area. According to the assembled experts, other potential effects were considered to be either insignificant or indirect for the Trinity River and were not represented in the mathematical and computer models. Because of lack of data, it was not considered feasible (although highly desirable) to attempt to build a complete life-history model that would include the highly variable effects on growth and mortality due to diseases, parasites, and predation in the study area and owing to water temperature, commercial harvest, sport fishing, and ocean conditions outside the study area.

Mesohabitat units in SALMOD correspond to mesohabitat mapping (Morhardt et al., 1983) and attendant habitat - flow mathematical relations measured by TRFE personnel. In SALMOD, the stream is represented by a set of mesohabitat units, each one having unique characteristics (habitat type and length) that define the quantity of habitat available at different flows and thus the "habitat capacity" of that mesohabitat unit to support a number of fry (<2 inches) and pre-smolt salmon (Williamson et al., 1993). In the model, mesohabitat units of the same habitat type produce the same amount of habitat per unit stream length at each of the various flows. The model tracks distinct weekly cohorts of fish that start as eggs deposited in a redd in a mesohabitat unit and subsequently mature and grow to sac fry and emergent fry as a function of water temperature. In SALMOD, larger fry and pre-smolts remain in the mesohabitat unit in which they emerged and smaller fry and pre-smolts are forced to move downstream if sufficient additional habitat is not available.

Modeled processes include: (1) egg deposition with redd superimposition (McNeil, 1967); (2) temperature-related egg maturation (Crisp, 1981) and young-of-year growth (Shelbourne et al., 1973); (3) season-induced movement (McDonald, 1960), freshet-induced movement (Godin, 1981) and habitat-induced movement (Chapman, 1962; Mesick, 1988); and (4) base mortality (TRFH estimates), movement-related mortality (hypothesized), and temperature-related mortality (USBOR, 1991). The model uses a weekly time step and mean weekly parameter values for a biological year defined as spawning/egg deposition (starting September 2) to mass pre-smolt exodus (ending June 9; around June 10 several million chinook salmon pre-smolts are released at the TRFH). Model output from SALMOD for the Trinity River estimated the weekly number and mean length of fry, pre-smolt, and immature smolt chinook salmon emigrating from the study area up to the time of the hatchery release. A detailed description of SALMOD's processes, input and output is given by Bartholow et al. (1999).

The study area, extending approximately 25 river miles from Lewiston Dam downstream to the confluence with Dutch Creek, was chosen as the most important young-of-year production portion of the Trinity River drainage (where most of the chinook salmon spawning redds occur). A maximum sustainable density of both fry and pre-smolts (separate habitat capacity for each) for a unit area of high-quality habitat in the Trinity River was estimated from field measurements of available habitat and the 90th percentile of observed fry and pre-smolt densities. Required parameters for which Trinity River data were not available were solicited from the local river-system experts, gathered from pertinent literature, or used as variables during calibration. The calibration process involved comparing observed to simulated values and adjusting model parameters to more closely match (1) timing of peak young-of-year abundance and (2) size and relative number of outmigrants through time. A comparison was made of observed and uncalibrated, simulated annual production estimates in Bartholow et al. (1993). There are several limitations to SALMOD as applied to the Trinity River:

1. Only measured channel form and hydraulics were incorporated into SALMOD because estimates of future channel form and hydraulics were not available. Future changes to channel morphology must be measured or estimated to provide model input necessary to generate new habitat versus flow relations (e.g., Figure 5.17).
2. At unmeasured flows, flow-habitat values were linearly interpolated between the values for the measured flows. The original study (1990 to 1994) was designed to evaluate flows in the range of 300 to 3,000 cfs within the existing riparian-bermed channel (Williamson et al., 1993). Hydraulic measurements and direct habitat estimates (without hydraulic modeling) for planned reservoir releases of 150, 350, 450, 800, 1,500, 2,000, and 3,000 cfs were made by TRFE personnel using habitat-suitability criteria from Hampton (1988). Later measurements at 24 percent of the transects during a short-duration 4,500-cfs planned reservoir release provided evidence that habitat values did not decrease at flows above 3,000 cfs (Figure 5.18). For this analysis, we assumed that habitat estimates for all flows above 3,000 cfs were virtually the same as that measured for 3,000 cfs.
3. Only the 25 miles from Lewiston Dam downstream to Dutch Creek were included in the initial application of SALMOD. All production estimates are based on simulations of young-of-year chinook salmon exiting this segment of the river and are not an estimate of the total production from the Trinity River.
4. Freshet-induced movement parameters relating to flow triggers, proportion moving, average distance moved, and mortality rates were poorly estimated. After several years of effort to better quantify these parameters, a decision was made by workshop participants in March 1993 to reduce to zero the movement effects of freshets on the basis of sampling data from screw traps (Glase, 1994a) and fyke nets (CDFG, 1992b, 1994a, 1995).
5. The effects of flow and physical habitat on fish food production were not incorporated in the models because of the high effort and likely poor resolution (i.e., inherent extremely high intra-annual variation) of a separate model of invertebrate production.

Subsequent evaluations using SALMOD have been reported for the effects of spatial scale and spawning (Bartholow, 1996), weekly flow regimes (Bartholow and Waddle, 1994, 1995), and reservoir storage (Waddle and Sandelin, 1994).

5.6.2 Methods

A stream network hydrologic analysis was used to estimate tributary accretions downstream from Lewiston Dam, with either known releases (historical data) or projected flow releases as the flow in the first river segment. The SNTEMP model calibrated to the Trinity River (Zedonis, 1997) used historical meteorology data for each of 17 years (1976 to 1992) to estimate changes in river-water temperature from initial reservoir release temperatures for 7 Trinity River segments from Lewiston Dam to Dutch Creek. Initial reservoir release temperatures came from several sources, including measured temperatures (for the historical data); projected temperatures from a linear regression that used Julian day of year and natural logarithm of flow as the independent variables (Bartholow and Waddle, 1995); and projected temperatures from the BETTER-Lewiston Reservoir model (Trinity County, 1992). The historical and regression-model temperatures were used to construct a 17-year historical sequence. The BETTER-Lewiston Reservoir model was used to construct a representative year for each of the five water-year classes and is described in Section 5.5.

Representative individual years were chosen for each of the five recommended water-year class flow regimes. The 369 TAF Critically Dry water year was represented by WY1977 (October 1, 1976, to September 30, 1977); the 453 TAF Dry water year, 647 TAF Normal water year, 701 TAF Wet water year, and 815 TAF Extremely Wet water year were represented by WY1990, WY1989, WY1986, and WY1983, respectively. These years were selected as representative of their respective total annual flow ranges for the historical record from 1976 to 1992. The values calculated for a particular year are intended to represent the potential production for a particular water-year class and associated meteorological-year class and assumed reservoir release temperatures. Using representative years does not allow examination of previous years' effects (e.g., from the prolonged drought of the late 1980's and early 1990's). However, each year's young-of-year salmon production is at least somewhat independent of the previous year's production (generally low autocorrelation between successive years was expected).

Returning adult chinook salmon estimates from CDFG's Klamath River "megatable" (CDFG, 1996c) gave the minimum (4,000), mean (33,000), and maximum (68,000) observed seeding values used. A few parameters in SALMOD (Bartholow et al., 1999) were updated from previously reported values to include an additional 3 years of Trinity River Restoration Program data collection. Weekly mean values from CDFG's carcass surveys for the period 1989 to 1995 were used to quantify the characteristics of returning spawners, including distribution by river zone, percent adult females, percent pre-spawn mortality, and total number (CDFG, 1992a, 1992b, 1994a, 1995, 1996a, 1996b).

SALMOD was initially used to compare the effects of various flow regimes (annual volumes with a mean weekly release and attending river-water temperatures) on young-of-year chinook salmon potential production within the present riparian-bermed channel along the 25 mile study area. The five flow schedules derived from the water volumes identified in the 1981 Secretarial Decision (described in Chapter 6) are referred to as: (1) 140 TAF constant flow schedule with 194 cfs release year round; (2) 220 TAF constant flow schedule with 305 cfs release year round; (3) 287 TAF spring-outmigration flow schedule; (4) 340 TAF sediment-transport flow schedule; and (5) 340 TAF spring-outmigration flow schedule. In addition, the flow regimes developed and presented in Chapter 8 for five water-year classes (369 TAF Critically Dry water year; 453 TAF Dry water year; 647 TAF Normal water year; 701 TAF Wet water year; and 815 TAF Extremely Wet water year) were compared.

Model runs examined the combined effects and sensitivity of potential production to changes in spawning, fry rearing, and pre-smolt rearing micro-habitats. This was done by doubling or halving spawning habitat (by doubling and halving required redd size), fry-rearing habitat (by doubling and halving fry habitat capacity), and pre-smolt rearing habitat (by doubling and halving pre-smolt habitat capacity). These model runs used the largest number of spawners (68,000), the best identified individual flow regime (the 647 TAF Normal water year), and regression-model water temperatures to simulate what could have been produced under the various conditions present during the 17-year period from 1976 to 1992. This gives an indication of what could perhaps be accomplished in the future by improved microhabitat conditions within a rehabilitated channel.

Flows and associated temperatures outside the range of dates September 2 through June 9 (when chinook salmon are present in the study area) do not affect SALMOD estimates of potential production. Variations in potential production owing to different reservoir release water temperatures and exactly the same reservoir discharges throughout the period September 2 to June 9 became a focal point. To search for a near-optimal water temperature for growth and survivorship, model runs used the instream flow regimes from the Trinity River Flow Evaluation with BETTER model reservoir release water temperatures for the representative water years, except that springtime reservoir release water temperatures were forced to 46°, 50°, 54°, 57° or 61° F for the period March 4 to June 17. To identify a nearly global maximum young-of-year production from the current Trinity River channel morphology, additional model runs were made that incorporated the mean and maximum observed number of spawners, the near-optimal water temperature for growth and survivorship and a doubling of spawning, fry rearing, and pre-smolt rearing habitat.

5.6.3 Results

5.6.3.1 Secretarial Decision Flow Schedules

As the annual flow volumes increased, the coefficient of variation for potential production generally decreased, suggesting that increased flows may also lower the risk of poor production across years.

The chinook salmon young-of-year potential production for the five Secretarial Decision flow schedules is presented in Table 5.19. Assuming that 4,000 adults return to spawn in the study area with the same Secretarial Decision flow schedule for all 17 years and regression-model water temperatures, potential production increased from 633,000 young-of-year outmigrants with historical (1976 to 1992) flows and river temperatures to 887,000 (+40 percent) for the 340 TAF spring outmigration flow schedule. Potential production also would increase for other Secretarial Decision flow schedules from the 140 TAF constant flow schedule (+9 percent), the 220 TAF constant flow schedule (+29 percent), the 287 TAF spring outmigration flow schedule (+36 percent), and the 340 TAF sediment-transport flow schedule (+34 percent). Assuming the lowest observed number of 4,000 spawners, potential production of naturally produced young-of-year chinook salmon was limited to less than 900,000 under all Secretarial Decision flow schedules.

Assuming the mean level of 33,000 spawners with the same Secretarial Decision flow schedules for all 17 years and regression-model water temperatures, potential production increased from 1,901,000 outmigrants under historical flows and river temperatures to 2,360,000 (+24 percent) in the 220 TAF constant-flow schedule. Production also increased for the 140 TAF constant-flow schedule (+16 percent), the 287 TAF spring-outmigration flow schedule (+19 percent), the 340 TAF sediment-transport flow schedule (+13 percent), and the 340 TAF spring-outmigration flow schedule (+23 percent).

Assuming 68,000 spawners with the same Secretarial Decision flow for all 17 years and regression-model water temperatures, potential production increased from 2,217,000 under historical flows and river temperatures to 2,721,000 (+23 percent) for the 220 TAF constant-flow schedule. Production also increased for all flows from the 140 TAF constant-flow schedule (+18 percent), the 287 TAF spring-outmigration flow schedule (+18 percent), the 340 TAF sediment-transport flow schedule (+12 percent), to the 340 TAF spring-outmigration flow schedule (+21 percent).

With the exception of the combination of 4,000 spawners and the 340 TAF sediment-transport flow schedule, as the annual flow volume increased the coefficient of variation decreased, suggesting that increased flows may also lower the risk of poor production across years (Table 5.19). In comparison with the lowest (4,000) observed spawning escapement, 33,000 spawners increased potential production of natural young-of-year chinook salmon by 150 percent to a mean of 2.26 million, and 68,000 spawners increased potential production of natural young-of-year chinook salmon by an additional 16 percent to a mean of 2.62 million. These values represent the production potential within the confining riparian berms of the existing channel.

5.6.3.2 Water-Year Class Flow Regimes

The chinook salmon young-of-year potential production within the existing channel for the five water-year class flow regimes are presented in Table 5.20. Assuming that 4,000 adults return to spawn in the study area with the same projected water-year class flow regime for all 17 years

Table 5.19. Mean potential production of young-of-year (1,000's) chinook salmon from the mainstem Trinity River study area for instream flow schedules derived from the 1981 Secretarial Decision annual flow volumes.[a]

Spawning Escapement	Historical Flows and Temperatures	Secretarial Decision Flow Schedules				
		140[b]	220[c]	287[d]	340[e]	340[f]
4,000	633 0.440[g]	692 0.191[g]	818 0.174[g]	864 0.160[g]	850 0.163[g]	887 0.154[g]
33,000	1,901 0.454[g]	2,213 0.247[g]	2,360 0.228[g]	2,254 0.212[g]	2,151 0.199[g]	2,329 0.191[g]
68,000	2,217 0.463[g]	2,622 0.276[g]	2,721 0.252[g]	2,619 0.228[g]	2,471 0.218[g]	2,681 0.206[g]

[a] Secretarial Decision Flow Volumes: 140,000 af, 220,000 af, 287,000 af, 340,000 af.

[b] 140,000 af with constant flow and regression model reservoir temperatures.

[c] 220,000 af with constant flow and regression model reservoir temperatures.

[d] 287,000 af with spring outmigration flow and regression model reservoir temperatures.

[e] 340,000 af with sediment transport flow and regression model reservoir temperatures.

[f] 340,000 af with spring outmigration flow and regression model reservoir temperatures.

[g] C.V. = Coefficient of variation for Water Years 1976-1992.

and regression-model water temperatures, potential production increased from 633,000 under historical flows and river temperatures to 901,000 (+42 percent) for the 369 TAF Critically Dry water year, to 917,000 (+45 percent) for the 701 TAF Wet water year, and then decreased to 898,000 (+42 percent) for the Extremely Wet water year. As with the Secretarial Decision flows, the low number of spawners limited the study area's potential production of naturally produced young-of-year chinook salmon to a mean of less than 920,000 outmigrants across the various water-year classes.

Assuming 33,000 spawners in the study area with the same projected water-year class flow regimes for all 17 years and regression-model water temperatures, potential production increased from 1,901,000 for historical flows and river temperatures to 2,337,000 (+23 percent) for the 369 TAF Critically Dry water year, to 2,607,000 (+37 percent) for the 647 TAF Normal water year, and decreased to 2,430,000 (+28 percent) for the Extremely Wet water year. In comparison with a spawning escapement of 4,000 fish, 725 percent more spawners (33,000) increased potential production by a mean of 176 percent to 2.50 million across the various water-year classes. In comparison with Secretarial Decision flow schedules, potential production of naturally produced young-of-year chinook salmon increased from a mean of 2.26 million to 2.50 million (+11 percent).

Increasing to 68,000 the number of spawners in the study area with the same projected water-year class flow regime for all 17 years and regression model water temperatures, potential production increases from 2,217,000 for historical flows and river temperatures to 2,623,000 (+18 percent) for the 369 TAF Critically Dry water year, to 3,124,000 (+41 percent) for the 647 TAF Normal water year, and then decreasing to 2,814,000 (+27 percent) for the Extremely Wet water year. In comparison with a spawning escapement of 33,000 fish, 106 percent more spawners increases the potential

Table 5.20. Mean potential production of young-of-year (1,000's) chinook salmon from the mainstem Trinity River study area for recommended flow regimes (TAF) from the Trinity River Flow Evaluation.[a]

Spawning Escapement	Historical Flows and Temperatures	Water-Year Class				
		Critically Dry 369[b]	Dry 453[c]	Normal 647[d]	Wet 701[e]	Extremely Wet 815[f]
4,000	633 0.440[g]	901 0.115[g]	908 0.133[g]	914 0.136[g]	917 0.131[g]	898 0.130[g]
33,000	1,901 0.454[g]	2,337 0.103[g]	2,540 0.144[g]	2,607 0.151[g]	2,593 0.140[g]	2,430 0.129[g]
68,000	2,217 0.463[g]	2,623 0.119[g]	3,021 0.163[g]	3,124 0.168[g]	3,077 0.154[g]	2,814 0.140[g]

[a] Study Evaluation Flow Volumes: 369,000 af, 453,000 af, 647,000 af, 701,000 af, 815,000 af.

[b] 369,000 af critically dry year flows with regression model reservoir temperatures.

[c] 453,000 af dry year flows with regression model reservoir temperatures.

[d] 647,000 af normal year flows with regression model reservoir temperatures.

[e] 701,000 af wet year flows with regression model reservoir temperatures.

[f] 815,000 af extremely wet year flows with regression model reservoir temperatures.

[g] C.V. = Coefficient of variation for Water Years 1976-1992.

production on average by 17 percent to 2.93 million across the various water-year classes. In comparison with Secretarial Decision flow schedules, potential production also increases by 17 percent to 2.93 million.

Most of the alternatives, including all the water-year class flow regimes, had a constant reservoir release of 450 cfs from September 2 until October 15 and 300 cfs from October 16 until April 21. With the exception of the 140 TAF and the 220 TAF constant flow schedules, this left only the period April 22 to June 9 for variations in flow and water temperature to affect potential production. This considerably narrowed the range of potential production outcomes from the SALMOD evaluations.

Peak potential production for the optimal water temperature of 54° F was obtained with the 647 TAF Normal water-year conditions. Potential production in both numbers and biomass was lowest in the Critically Dry and Extremely Wet water years.

5.6.3.3 Sensitivity to Water Temperatures

Model results from representative individual years for the five water-year class flow regimes are given in Table 5.21. Maximum potential production in terms of both numbers and biomass occurs with spring (March 4 through June 9) water temperatures of 54° F and the next highest potential production occurs at 50° F. All five water-year class flow regimes in combination with a 61° F release gave the minimum potential production (numbers and usually biomass). Potential production values at the best constant spring temperatures of 54° F and the extreme water-year class flow regimes (Critically Dry, Dry, and Extremely Wet) provide less than a 10 percent improvement over the mean production

Table 5.21. Potential production in number (1,000's), mean length (in), and biomass (lbs) of young-of-year chinook salmon from the mainstem Trinity River. The alternatives use 33,000 spawners and either historic flows and temperatures or the flow regimes from the Trinity River Flow Evaluation with BETTER model reservoir release-water temperatures for 1977, 1990, 1989, 1986, and 1983 except for forced constant spring water temperatures.[a]

		Critically Dry	Dry	Normal	Wet	Extremely Wet
Historical Flows and Temperatures	Number Mean Length Weight	1,412 2.49 7,782	2,540 2.39 12,319	2,069 2.42 10,492	2,288 2.35 10,593	637 2.11 2,247
46.4°F	Number Mean Length Biomass	1,313 2.29 5,789	1,994 2.28 8,353	2,137 2.24 8,481	1,351 2.24 5,362	1,270 2.26 5,320
50.0°F	Number Mean Length Biomass	2,216 2.31 10,260	2,643 2.37 12,820	3,239 2.30 14,282	2,647 2.31 11,671	2,296 2.31 10,124
53.6°F	Number Mean Length Biomass	2,561 2.39 12,985	2,733 2.43 14,460	3,494 2.42 17,716	3,085 2.37 14,963	2,695 2.36 13,071
57.2°F	Number Mean Length Biomass	1,583 2.36 7,679	1,607 2.41 8,148	1,753 2.41 8,889	1,783 2.35 8,254	1,779 2.35 8,236
60.8°F	Number Mean Length Biomass	1,215 2.35 5,626	1,313 2.37 6,369	990 2.36 4,802	1,205 2.32 5,578	1,234 2.34 5,712

[a] Beginning weekly reservoir water temperatures were forced to 46.4°, 50.0°, 53.6°, 57.3°, or 60.8° F for the period March 4 to June 17.

values for 33,000 spawners shown in Table 5.20. The Normal and Wet water years with the representative year conditions show 25 percent and 16 percent increases in number of young-of-year, respectively. The calculated biomass is highest for the Normal and Wet water years as well.

For the assumed water temperatures in Table 5.21, potential production in both numbers and biomass was poorest in the Critically Dry and Extremely Wet water years. Normal water year gave the highest potential production in terms of biomass for assumed temperatures of 46°, 50°, 54°, and 57° F. Peak potential production for the optimal water temperature of 54° F was obtained with the 647 TAF Normal water-year conditions. For all three levels of spawning escapement, peak young-of-year potential production was also associated with the 647 TAF Normal water year.

5.6.3.4 Sensitivity to Spawning and Rearing Habitat

The combined effects of doubling spawning, fry rearing, and pre-smolt habitat indicate an increase in mean potential production numbers of 68 percent, whereas halving spawning, fry rearing, and pre-smolt habitat would decrease mean potential production by 52 percent for 68,000 spawners (Table 5.22). Doubling and then halving spawning habitat showed an 11-percent increase and a 25-percent decrease in mean potential production. Doubling fry rearing habitat would increase mean potential production by 31 percent and halving fry rearing habitat would decrease mean potential production by 30 percent . Doubling or halving pre-smolt rearing habitat showed an 8-percent increase and a 10-percent decrease in mean potential production respectively. Note that SALMOD was calibrated to the existing habitat and channel data, and this sensitivity analysis is only an approximation of habitat and channel changes that may result from any rehabilitation strategy. More realistic estimates should be made by calibrating SALMOD to a channel form either as measured after the fact or as predicted by physical process models.

5.6.3.5 Optimizing Potential Production

Additional model runs were made with the goal of examining the potential synergistic and optimizing combined effects of: (1) an increase in spawners from the mean to the maximum number observed in the 17-year historical period (33,000 to 68,000); (2) optimal reservoir release-water temperatures for growth and survivorship (54° F) from the representative years; and (3) an increase in the amount of spawning, fry rearing, and pre-smolt rearing habitat from current conditions to double the current amount (Table 5.23). The highest production was found in the Normal water year, with similar number and biomass production in the paired Dry and Wet water years and in the paired Critically Dry and Extremely Wet water years. Doubling spawning, fry rearing, and pre-smolt rearing habitat resulted in a mean increase in numbers produced of 54 percent. More than doubling the number of spawners resulted in a mean increase of 20 percent. With near optimal temperatures for growth and survivorship, a doubling of production in the Trinity River study area was predicted by simultaneously doubling habitat and the number of spawners (mean increase of 101 percent) (Table 5.23).

> The level of mean production with a combination of optimal temperatures, doubling of habitat, and doubling of spawners is more than triple (327 percent) the mean production calculated with historical flows and temperatures.

5.6.4 Conclusions

For all water-year class flow regimes, the low number of 4,000 spawners severely limits potential production of naturally produced young-of-year chinook salmon (maximum <920,000 outmigrants). With 33,000 spawners, mean potential production increased from 1.9 million with historical flows and temperatures to 2.3 million with the Critically Dry water-year flow regime and 2.6 million with the Normal water-year flow regime (Table 5.20). With the 68,000 spawning escapement, mean potential production increased from 2.2 million with historical flows and temperatures to 2.6 million with the Critically Dry water-year flow regime and 3.1 million with the Normal water-year flow regime. Under existing river-channel conditions with 33,000 spawners and near optimal water-temperature conditions of 54° F, the simulations indicate that potential production can reach 3.5 million pre-smolts with Normal water year of 647 TAF within the existing riparian-bermed channel (Table 5.21).

Model sensitivity runs using the Trinity River Fish and Wildlife Restoration Program's escapement goal of 68,000 naturally produced adult spawners (62,000 fall-run and 6,000 spring-run) and the proposed 647 TAF Normal water-year flow regime indicate that management changes to both rearing and spawning habitat has a major, synergistic payoff that can increase young-of-year chinook salmon production to a mean of 5.2 million (Table 5.22). With a doubling of the current amount of spawning and rearing habitats and near-optimum water temperatures during the spring, potential production reached 5.3 million outmigrants with 33,000 spawners and 7.0 million outmigrants with 68,000 spawners (Table 5.23). The level of mean production (5,856,000)

Table 5.22. SALMOD sensitivity analysis estimates of chinook salmon potential production in the mainstem Trinity study area. The alternatives use 68,000 spawners, regression model water temperatures, and the 647 TAF normal water-year flow regime and doubling or halving existing spawning and rearing habitat.

	Trinity River Study Area Young of Year Outmigrants (1000's)								
	Habitat Remains as Is	Double Spawning Habitat	Halve Spawning Habitat	Double Fry Rearing Habitat	Halve Fry Rearing Habitat	Double Pre-smolt Rearing Habitat	Halve Pre-smolt Rearing Habitat	Double Both Spawning and Rearing Habitat	Halve Both Spawning and Rearing Habitat
Mean	3,124 Base	3,470 +11%	2,341 -25%	4,092 +31%	2,185 -30%	3,361 +8%	2,809 -10%	5,242 +68%	1,637 -52%
Minimum	2,026 Base	2,489 +23%	1,165 -42%	2,612 +29%	1,441 -29%	2,129 +5%	1,859 - 8%	3,640 +80%	857 -58%
Maximum	4,075 Base	4,453 +9%	3,325 -18%	5,130 +26	2,880 -29%	4,681 +15%	3,563 -13%	6,724 +65%	2,215 -46%

Table 5.23. Optimizing potential production in number (1000's), mean length (in.), and biomass (lbs.) of young-of-year chinook salmon from the mainstem Trinity River. All alternatives use 54° F reservoir releases, either 33,000 or 68,000 spawners, and either current habitat conditions or double the habitat for spawning, fry rearing and pre-smolt rearing. Flows and temperature are from the recommended flow regimes from the Trinity River Flow Evaluation with BETTER model reservoir release-water temperatures for 1977, 1990, 1989, 1986, and 1983 except for forced constant spring water temperatures. Beginning weekly reservoir water temperatures were forced to 46.4°, 50.0°, 53.6°, 57.3°, or 60.8° F for the period March 4 to June 17.

Number of Spawners & Habitat	Number Mean Length Weight	Critically Dry	Dry	Normal	Wet	Extremely Wet
33,000 & Current Habitat	Number Mean Length Biomass	2,561 2.39 12,985	2,733 2.43 14,460	3,494 2.42 17,716	3,085 2.37 14,963	2,695 2.36 13,071
33,000 & Double the Habitat	Number Mean Length Biomass	4,062 2.42 21,491	4,217 2.46 22,313	5,339 2.44 28,248	4,620 2.39 22,408	4,228 2.39 20,507
68,000 & Current Habitat	Number Mean Length Biomass	2,941 2.35 14,262	3,319 2.41 16,830	1,229 2.39 20,514	3,810 2.34 17,641	3,182 2.35 14,733
68,000 & Double the Habitat	Number Mean Length Biomass	5,144 2.39 26,083	5,499 2.43 29,097	7,019 2.41 35,591	6,206 2.36 30,102	5,410 2.36 26,239

with a combination of optimal temperatures, doubling of habitat, and doubling of spawners (Table 5.23) is more than triple (327 percent) the mean production calculated with historical flows and temperatures.

Sensitivity-analysis simulations indicate that rearing habitat is severely limiting young-of-year production in the existing channel, and that spawning habitat is limited to a lesser extent (Table 5.22). Although these results are useful and suggest that management efforts and expenditures on increasing rearing habitat versus spawning habitat provide a greater advantage, we caution that SALMOD was calibrated to the existing channel and does not account for habitat effects induced by sediment-flushing or channel-forming events. SALMOD can be most valuable for management when coupled with state-of-the-art models for predicting channel response during annual reservoir operation evaluations.

5.6.5 Recommendations

SALMOD is useful for estimating the relative magnitude of potential production among various flow and temperature regimes. Although the best technology currently available has been used for estimating Trinity River naturally produced young-of-year chinook salmon potential production, appropriate levels of caution and skepticism should be applied to SALMOD output interpretations. The model estimates presented here are not intended to be used as absolute-value predictions of

> "Sensitivity-analysis simulations indicate that rearing habitat is severely limiting young-of-year production in the existing channel, and that spawning habitat is limited to a lesser extent."

chinook salmon young-of-year production with a particular regime of flows, water temperatures, and number of spawners. For that reason, percent change (not absolute number differences) from historical flow and water-temperature conditions is a more appropriate index for relative value comparisons of potential production given alternative water-year class flow regimes. In future applications of SALMOD to the Trinity River, the model should be further validated with additional data collected since 1994 and be used to help design and evaluate a rigorous, ongoing biological monitoring program as part of the Adaptive Environment Assessment and Management process. Biological monitoring program data sets most needed are statistically valid estimates of: (1) outmigrant numbers and mean length through time; (2) timing of the peaks of spawning, fry emergence, and outmigration; and (3) density and mean length of fish using various habitat types in the study area through time.

State-of-the-art models for predicting flow regimes, reservoir and river water temperatures, hydraulics, sediment transport, and channel form can be integrated and provided as inputs to SALMOD. The long term, positive effects of sediment-flushing and channel-forming flows should be addressed with a rigorous, ongoing geomorphological monitoring program and models for predicting channel morphology changes. Such a suite of models and complementary monitoring can insure that the best science is provided for annual evaluations of reservoir operations and channel-rehabilitation alternatives aimed toward restoration and maintenance of Trinity River chinook salmon.

State-of-the-art models for predicting flow regimes, reservoir and river water temperatures, hydraulics, sediment transport, and channel form can be integrated and provided as inputs to SALMOD. The long term, positive effects of sediment-flushing and channel-forming flows should be addressed with a rigorous, ongoing geomorphological monitoring program and models for predicting channel morphology changes. Such a suite of models and complementary monitoring can insure that the best science is provided for annual evaluations of reservoir operations and channel-rehabilitation alternatives aimed toward restoration and maintenance of Trinity River chinook salmon.

CHAPTER 6 Evaluation of the 1981 Secretarial Decision Volumes

This chapter assesses how adequately the annual instream volumes identified in the 1981 Secretarial Decision (140, 220, 287, and 340 TAF [Section 2.5]) protect different life stages of salmonids and provide habitats sufficient to restore the Trinity River salmon and steelhead stocks. Each of these release schedules was assessed for its ability to meet the following factors: fish habitat requirements (Section 5.1), summer/fall temperature criteria (Section 5.5), smolt outmigration and temperature requirements (Section 5.5), and thresholds of physical riverine processes that create and maintain diverse fish habitats necessary to restore anadromous fish populations (Sections 5.3 and 5.4). These factors and the flow criteria to meet these factors (Table 6.1) were prioritized in the following order:

1. Year-round releases of 300 cfs to provide spawning and rearing habitats for salmon and steelhead;
2. Releases of 450 cfs from July 1 to October 14 to meet the summer/fall temperature objectives;
3. Spring/summer releases to provide improved conditions for smolt outmigration (approximately 2,000 cfs); and
4. Releases necessary to meet physical river processes that create and maintain river habitats (approximately 2,000 to 8,500 cfs).

"This chapter assesses how adequately the annual instream volumes identified in the 1981 Secretarial Decision (140, 220, 287, and 340 TAF [Section 2.5]) protect different life stages of salmonids and provide habitats sufficient to restore the Trinity River salmon and steelhead stocks."

Table 6.1. Physical and biological objectives and corresponding thresholds/criteria used to evaluate a river system's ability to provide, create, and maintain suitable salmonid habitats. Attribute numbers from Section 4.8 corresponding to riverine processes are given in parentheses.

Physical and Biological Objectives:			Thresholds and/or Criteria
Salmonid Habitats	Spawning and rearing flow	Year-round	300 cfs
	Summer/fall temperature objectives	July 1 - Oct 15	450 cfs
	Spring outmigration temperature (°F): optimal/marginal	Apr 22 - May 22	55.4 / 59.0
		May 27 - June 4	59.0 / 62.8
		June 10 - July 9	62.8 / 68.0
Physical Riverine Processes	Sediment transport (5)/a		2,000 - 6,000 cfs
	Bed mobilization (3)/b		3,000 - 6,000 cfs
	Channel perturbation and scour (4, 8)/c		6,000 - 8,500 cfs
	Stream flow fluctuation/variation (2)/d		historical contrast
	Channel migration and floodplain construction (6, 7)/e		historical contrast
	Riparian dynamics (9)/f		empirical data

/a effectiveness at transporting tributary derived sediments downstream.

/b threshold for most mobile deposits is approx. 3,000 cfs (Trinity Restoration Association, 1993). Threshold for channel wide mobility is approx. 6,000 cfs (Wilcock et al., 1995, Trinity Restoration Association, 1993).

/c threshold for $>2D_{84}$ scour on mobile deposits is approx. 6,000 cfs (Wilcock et al., 1995, Trinity Restoration Association, 1993); threshold for $>2D_{84}$ scour on point bar faces on channel rehabilitation sites is approx. 8,500 cfs (McBain and Trush, 1997).

/d the degree of seasonal and inter-annual variation, access to the floodplain.

/e qualitative estimation based on professional judgement.

/f based on riparian response monitoring on pilot restoration sites (McBain and Trush, 1997).

These prioritized flow criteria guided the development of release schedules for each annual instream volume. First, the daily average schedule was developed to determine the maximum, constant daily release possible for the entire year within each volume. If the average daily schedule release met the first criterion of 300 cfs for spawning and rearing habitat, that schedule was manipulated to meet the remaining criteria without sacrificing other criteria. These schedules are provided in Table 6.2. Each criterion represents an important component critical to the survival of salmonids on the mainstem Trinity River and is briefly discussed below.

Fish Habitat Requirements

The minimum release of 300 cfs is necessary to insure suitable depths and velocities for rearing and spawning salmonids. This recommended physical habitat require-

Table 6.2. Weekly Release schedules for each instream volume: Flows by week (in cfs) constituting the Secretarial Decision flow schedules.

		140	220	287	340[a]	340[b]
October	2	194	305	450	450	450
	9	194	305	450	450	450
	16	194	305	300	300	300
	23	194	305	300	300	300
	30	194	305	300	300	300
November	6	194	305	300	300	300
	13	194	305	300	300	300
	20	194	305	300	300	300
	27	194	305	300	300	300
December	4	194	305	300	300	300
	11	194	305	300	300	300
	18	194	305	300	300	300
	25	194	305	300	300	300
January	1	194	305	300	300	300
	8	194	305	300	300	300
	15	194	305	300	300	300
	22	194	305	300	300	300
	29	194	305	300	300	300
February	5	194	305	300	300	300
	12	194	305	300	300	300
	19	194	305	300	300	300
	26	194	305	300	300	300
March	4	194	305	300	300	300
	11	194	305	300	300	300
	18	194	305	300	300	300
	25	194	305	300	300	300
April	1	194	305	300	300	300
	8	194	305	300	300	300
	15	194	305	300	300	300
	22	194	305	300	300	300
	29	194	305	300	543	300
May	6	194	305	2,000	5,357	1,714
	13	194	305	471	729	2,000
	20	194	305	450	450	1,700
	27	194	305	450	450	1,086
June	3	194	305	450	450	1,000
	10	194	305	450	450	450
	17	194	305	450	450	450
	24	194	305	450	450	450
July	1	194	305	450	450	450
	8	194	305	450	450	450
	15	194	305	450	450	450
	22	194	305	450	450	450
	29	194	305	450	450	450
August	5	194	305	450	450	450
	12	194	305	450	450	450
	19	194	305	450	450	450
	26	194	305	450	450	450
September	2	194	305	450	450	450
	9	194	305	450	450	450
	16	194	305	450	450	450
	23	194	305	450	450	450

[a] sediment transport flow [b] spring outmigration flow.

> “The management of dam releases to restore these [physical riverine] processes will address fundamental fish habitat problems, reverse habitat degradation, and provide the maintenance and creation of diverse and complex fish habitats.”

ment was determined by the integration of PHABSIM conclusions (Section 5.1), temperature considerations (Section 5.5), and life-history timing (Section 3.1.1). The full explanation of why this release was selected is presented in Chapters 7 and 8. Daily releases were evaluated on the basis of each schedule’s ability to provide the minimum 300-cfs baseflow.

Summer/Fall Temperature Objectives

Summer and fall temperature objectives (Section 5.5), established in 1991 to protect holding and spawning adult salmonids, were developed by the CRWQCB-NCR in cooperation with the Service, CDFG, HVT, and NMFS. Releases of 450 cfs are required to meet the CRWQCB-NCR objectives under warm meteorological conditions and likely release temperatures (Section 5.5). Empirical data in recent years indicate that 450 cfs meets these objectives (Section 5.5). Secretarial Decision release schedules were evaluated on the basis of each schedule’s ability to provide 450 cfs from July 1 to October 14, which is the period when these objectives must be actively managed.

Spring Outmigration Requirements

Outmigration, a critical life-history stage, occurs during the historical snowmelt period, when increased flows maintained lower water temperatures and reduced the travel time of smolts leaving the river (Sections 3.1.1 and 4.1.5). Releases that mimic the snowmelt hydrograph in the spring and early summer improve conditions for smolt survival. Temperature criteria for spring outmigration were used to assess each release schedule’s ability to improve spring outmigration conditions and thereby improve smolt survival (Table 6.1, Section 5.5). Output from the SNTEMP model was used to assess each schedule’s ability to meet these spring outmigration temperature objectives under median hydrological and meteorological conditions (Table 6.3).

Physical Riverine Processes

The Trinity River once functioned as a mixed alluvial river (McBain and Trush, 1997). Complex, diverse fish habitats that once were created and maintained by physical riverine processes (listed by attributes in Section 4.8) have degraded because these processes have been altered. The management of dam releases to restore these processes will address fundamental fish habitat problems (Sections 4.3.5 - 4.6), reverse habitat degradation, and provide the maintenance and creation of diverse and complex fish habitats. The flow thresholds necessary to initiate or effectively realize these riverine processes were empirically or qualitatively defined (Table 6.1, Sections 5.3 - 5.4). In evaluating each Secretarial Decision flow regime relative to these thresholds, riverine attributes with similar thresholds/criteria were grouped together (Table 6.1).

6.1 140 TAF Flow Schedule

The 1981 Secretarial Decision to increase fishery flows in the Trinity River established an annual volume of 140 TAF in critically dry water years, which is equal to an average daily flow of 194 cfs. This average daily release cannot meet the first criterion of 300 cfs for spawning and rearing flows. This schedule fails to meet the summer/fall temperature objectives (Table 6.4). Optimal spring outmigration temperatures are met in only 1 of 12 weeks under median conditions (Table 6.3);

> “This average daily release cannot meet the first criterion of 300 cfs for spawning and rearing flows . . . . The river channel and its fish habitats would continue to degrade under this [140 TAF] schedule.”

Table 6.3. Spring outmigration temperature analysis: Evaluation of the Secretarial Decision flow schedules against spring outmigration temperature criteria.

		Spring Outmigration Temperature Criteria (°F) optimal/marginal	**Secretarial Flow Schedule Alternative**				
Month	**Week**		**140**	**220**	**287**	**340a**	**340b**
April	22	55.4/59	OPT	OPT	OPT	OPT	OPT
	29	55.4/59	M	M	M	OPT	M
May	6	55.4/59	M	M	M	OPT	M
	13	55.4/59	M	M	M	M	M
	20	55.4/59	--	--	--	--	M
	27	59/62.8	M	M	M	M	M
June	3	59/62.8	M	M	M	M	M
	10	62.8/68	M	M	M	M	M
	17	62.8/68	M	M	M	M	M
	24	62.8/68	M	M	M	M	M
July	1	62.8/68	--	--	--	--	--
	8	62.8/68	--	--	--	--	--

Overall Totals	**Total # of weeks**		**Total number of weeks criteria are met**				
		Criteria Standard	**140**	**220**	**287**	**340a**	**340b**
	12	optimal	1	1	1	3	1
	12	marginal	9	9	9	9	10

a - sediment transport flow
b - spring outmigration flow
-- - does not meet criteria
M - meets marginal criteria
Opt - meets optimal criteria

marginal outmigration temperatures are met in 9 of the 12 weeks. There would be insufficient water to address any thresholds of the physical riverine processes (Table 6.4).

Although the 140 TAF schedule was not implemented during the TRFE, the influence of such low releases on the river channel and on fishery populations is demonstrated by the historical consequences of releasing an average 162 TAF during the first 10 years of TRD operations (Table 4.4). The diminished releases resulted in the severe habitat degradation previously documented in this report and were largely responsible for the decline of the Trinity River anadromous fishery observed since the 1960's (Section 3.1.2). The river channel and its fish habitats would continue to degrade under this flow schedule.

Table 6.4. Physical and biological objectives analysis: Evaluation of the 1981 Secretarial Decision flow schedules against criteria defining a riverine system able to create and maintain suitable salmonid habitats, and against criteria used to define habitat suitability. Attribute numbers corresponding to riverine processes follow in parentheses.

Secretarial Decision Flow Schedule (TAF)	**Physical and Biological Objectives**									
	Salmonid Habitat				Physical Riverine Processes					
	Spawning and Rearing	Summer/Fall Temperature Objectives	Optimal Spring Outmigration Temperatures	Marginal Spring Outmigration Temperatures	Sediment Transport (fine/coarse) (5)	Bed Mobilization (3)	Channel Perturbation and Scour (4, 8)	Stream Flow Fluctuation/ Variation (2)	Channel Migration and Floodplain Construction (6, 7)	Riparian Dynamics (9)
140	-	-	-	2	-/-	-	-	-	-	-
220	3	-	-	2	-/-	-	-	-	-	-
287	3	3	-	2	1/-	-	-	1	-	-
340a	3	3	1	2	3/1	2	1	1	1	1
340b	3	3	-	2	2/1	1	-	1	-	1

a - sediment transport flow
b - spring outmigration flow.
- - does not meet
1 - usually does not meet
2 - usually meets
3 - always meets

6.2 220 TAF Flow Schedule

When distributed equally throughout the year, an annual volume of 220 TAF would result in an average daily release of 305 cfs. This daily schedule does meet the 300-cfs release recommended for spawning and rearing salmonids. However, there is insufficient water to meet any remaining criteria (Table 6.4). The summer/fall water temperature objectives could be met for a period of 12 days if the extra 5 cfs/day were redistributed: however, the summer/fall objectives span a total period of 106 days because of the extended adult holding period. A total of 94 days with releases at 300 cfs during this time period would result in potential impacts to holding adult salmonids, as well as rearing juvenile coho salmon and steelhead. Optimal spring outmigration temperatures would be met in one of the 12 weeks under median conditions; marginal outmigration temperatures would be met in 9 of 12 weeks (Table 6.3).

> "This [220 TAF] daily schedule does meet the 300-cfs release recommended for spawning and rearing salmonids. However, there is insufficient water to meet any remaining criteria."

While this daily release is over 100 cfs greater than the average daily release available with the 140 TAF flow schedule, these releases would not meet the thresholds of the physical riverine processes that create and maintain fish habitats (Table 6.4). The encroachment of bands of riparian vegetation would continue unabated under such constantly low releases, exacerbating the problems of riparian berm formation and channelization and resulting in continued fish habitat degradation.

6.3 287 TAF Flow Schedule

The 287 TAF flow schedule provides enough volume to meet both the first and second priorities, and, to a minor degree, the third and fourth priorities. This schedule provides the minimum releases of 300 cfs year-round. This schedule also allows an increase to 450 cfs from July 1 to October 14 to assist the upstream migration of adult salmonids and provide appropriate water temperatures for holding and spawning adult salmon. The remaining water is then used to increase releases to 2,000 cfs in early May for 1 week to assist outmigrating smolts (Table 6.2). Releases then decline over the following week to 450 cfs for the rest of May and June.

Although this flow schedule would address a greater variety of objectives than the 220 and 140 TAF schedules, its utility is still limited. The minimum 300-cfs release required during the spawning and rearing periods would be provided. The summer/fall temperature objectives would be met. Optimal spring outmigration temperatures would only be met in 1 week under median conditions, but marginal temperatures would be met in 9 of the 12 weeks (Table 6.3). The highest scheduled release (2,000 cfs) would aid outmigrating smolts, but this peak release would be insufficient to sustain physical riverine processes necessary to create and maintain fish habitat (Table 6.4), other than minimal flushing of fine sediment from the channelbed surface. The River channel and its fish habitats would continue to degrade.

> "Although this [287 TAF] flow schedule would address a greater variety of objectives than the 220 and 140 TAF schedules, its utility is still limited."

6.4 340 TAF Flow Schedule

Annual releases of 340 TAF constitute an increase in annual instream volume nearly three times greater than what occurred immediately following construction of the TRD (Section 2.2). Although this increase appears significant, the 340 TAF volume, when compared with the 84-year period of record, is equivalent to the third driest year on record in the Trinity River (Table 4.4).

> "The 340 TAF volume would provide yet more flexibility than the previously described schedules . . . . However, the third and fourth criteria could not be simultaneously met with this volume of water."

The 340 TAF volume would provide yet more flexibility than the previously described schedules. The first and second prioritized criteria would be met. The third and fourth criteria minimally overlap, and therefore two different release schedules were applied to this volume:

1. the sediment-transport release, which is designed to transport and redeposit gravels and transport fine sediment through the river system, and
2. the spring-outmigration release, which is designed to improve conditions for outmigrating juvenile salmonids during the spring and early summer. Releases would increase dramatically in May and slowly taper off, mimicking natural snowmelt hydrology.

However, the third and fourth criteria could not be simultaneously met with this volume of water (Table 6.4).

6.4.1 Fine Sediment Transport Release Scenario - 340 TAF

The sediment-transport release schedule provides a baseflow of 300 cfs from mid-October until late May. Releases are increased to 6,000 cfs for 5 days to flush fine sediments through the river system, then decreased to 1,500 cfs the following week. From mid-June to mid-October, releases are held at 450 cfs, which somewhat improves conditions for outmigrating smolts and addresses the summer/fall temperature objectives.

Both the spawning and rearing release of 300 cfs and the summer/fall temperature objectives would be met with this schedule. Optimal temperatures for spring outmigration would be met in 3 of the 12 weeks, and marginal outmigration temperatures in 9 of the 12 weeks (Table 6.3).

This schedule would provide a 6,000-cfs release for 5 days, capable of removing fine sediment from the bed surface. Although removal of sand to any depth is a positive step, a full rehabilitation effort requires that even higher releases remove finer substrate particles deeper within the riverbed surface (Sections 5.3 and 5.4). On the Trinity River, chinook salmon eggs have been found buried at depths as great as 1.5 feet beneath the surface (USFWS, 1986). The removal of sand deposits from the upper 0.5 foot of the bed is insufficient to cleanse spawning gravels to depths at which eggs are buried. Releases greater than 6,000 cfs are required to support the processes that will fully restore spawning, rearing, and overwintering habitat (Table 6.1, Sections 5.3 and 5.4).

This schedule does transport fine sediment and coarse sediment better than the other schedules. Some bed mobilization occurs, which aids in the cleansing of spawning gravels. However, these releases are not of sufficient duration to flush the existing excessive fine sediments through the system that have accumulated over the years and would not adequately rehabilitate fish habitats. Some other physical riverine process requirements would be minimally met, but this schedule would

> "...these releases are not of sufficient duration to flush the existing excessive fine sediments through the system that have accumulated over the years and would not adequately rehabilitate fish habitats."

be insufficient to achieve a dynamic alluvial river system that is necessary to restore and maintain anadromous fisheries.

6.4.2 Spring Outmigration Release Scenario - 340 TAF

In the spring outmigration (or snowmelt) scenario, releases increase to 2,000 cfs during the week of May 6 and remain at this magnitude through May 13. Releases gradually begin to decrease during the week of May 20, mimicking the natural recession of the snowmelt hydrograph. By June 15, releases are stabilized at 450 cfs through October 15. Releases are then decreased to 300 cfs until early May.

This schedule would provide both the spawning and rearing release of 300 cfs and the summer/fall temperature objective release of 450 cfs. It would provide optimal temperatures for spring outmigration in 1 week out of 12, and marginal outmigration temperatures in 10 of the 12 weeks (Table 6.3). This schedule would provide some flushing of fine sediments from the channelbed surface (Table 6.4). Other physical riverine process requirements would be minimally met, but this schedule would be insufficient to achieve a dynamic alluvial river system along the entire mainstem that is necessary to restore and maintain anadromous fisheries.

6.5 Summary of Secretarial Decision Schedules

On the basis of empirical studies and model evaluations of the Secretarial Decision flow schedules and the best available scientific information, the following conclusions were drawn:

- **The criteria are not fully met with the given volumes of water.**

  The first two criteria (spawning and rearing releases and summer/fall temperature objectives) are not both met with flow schedules less than 287 TAF. The remaining criteria cannot be both fully met with the 340 TAF volume.

- **Channel processes would not reach critical thresholds.**

  The largest of the Secretarial Decision volumes, 340 TAF, would initiate only limited surface sediment removal, minimal coarse sediment transport, and very minimal channelbed mobilization. The remainder of the physical channel processes, which were critical to the maintenance of pre- TRD habitats, would not be reestablished to restore and maintain fishery resources.

- **Riparian vegetation would further encroach upon the channel.**

  Under all 1981 Secretarial Decision schedules, riparian vegetation encroachment would continue, as would fine sediment accumulations along the river banks and in the channel, further channelizing water flow and degrading fish habitat.

- **Minimal flushing releases would further reduce already unsuitable spring flows.**

  At best, implementation of release schedules based on 340 TAF provides only enough flow to mimic the natural spring conditions that existed pre-TRD in critically dry water years. These annual release schedules do not provide enough water to allow high spring flows of sufficient duration to ensure optimal conditions for outmigrating salmon and steelhead. The implementation of flushing releases (≥6,000 cfs), a necessary step toward rehabilitation of existing habitats, balancing the sediment budget, and prevention of riparian vegetation encroachment, would further reduce the availability of water necessary to maintain suitable conditions for outmigrating salmon.

> "Other physical riverine process requirements would be minimally met, but this schedule [340 TAF] would be insufficient to achieve a dynamic alluvial river system along the entire mainstem."

- **Habitat degradation and sedimentation would continue.**

  Habitat degradation and sedimentation, identified as the primary reasons for the declines of these fishery resources (USFWS, 1983; BLM, 1995), will continue under all 1981 Secretarial Decision schedules, owing to lack of sufficient volumes of water to address multiple needs within a single year.

- **Overall production potential will not be realized.**

  Pre-smolt production was similar for all six release schedules evaluated by SALMOD modeling at intermediate and high spawning escapements (Section 5.6). The SALMOD results suggest that peak pre-smolt production will be reached only at release levels in excess of those represented by any of the releases evaluated under the 1981 Secretarial Decision in conjunction with increasing spawning and rearing habitat.

- **Fisheries resources would decline under all secretarial decision volumes.**

Annual instream flow schedules averaging 162 TAF were released to the Trinity River in the first 10 years of operation and resulted in the severe habitat degradation and drastic decline of the Trinity River anadromous fisheries. The current annual instream flow of 340 TAF (and largest of the Secretarial volumes), while it has more benefits than lesser annual volumes, cannot meet all criteria essential to the restoration and maintenance of fish habitats and dependent salmonid populations. Instream annual flows equal to or less than 340 TAF would result in the continued degradation of the fisheries resources of the Trinity River.

All criteria used to evaluate the 1981 Secretarial Decision schedules are necessary to restore the fishery resources of the Trinity River. Since these 1981 volumes were identified, our understanding of river systems and the processes that maintain rivers has greatly improved. Insufficient water is available within these volumes to meet all criteria necessary to reverse the degradation of the mainstem habitat below the TRD. A restoration strategy specific to the Trinity River incorporating our current understanding of river systems must be developed to guide recommendations to rehabilitate fish habitats and restore fishery populations.

> Insufficient water is available within these volumes to meet all criteria necessary to reverse the degradation of the mainstem habitat below the TRD and restore the fishery resources of the Trinity River.

CHAPTER 7 Restoration Strategy

Anadromous salmonids in the Trinity River evolved in a sinuous alluvial channel that has become relatively straight and static since TRD operation. If naturally produced salmonid populations are to be restored and maintained, the habitat on which they depend must be rehabilitated. The most practical strategy to achieve fish habitat rehabilitation is a management approach that integrates riverine processes and instream flow-dependent needs (Figure 7.1). This management approach physically reshapes selected channel sections, regulates sediment input, and prescribes reservoir releases to (1) allow fluvial processes to reshape and maintain a new dynamic equilibrium condition and (2) provide favorable water temperatures. This strategy does not strive to recreate the pre-TRD mainstem channel morphology. Several sediment and flow constraints imposed by the TRD cannot be overcome or completely mitigated. The new alluvial channel morphology will be smaller in scale, but it will exhibit almost all the dynamic characteristics of the 10 alluvial attributes (presented in Section 4.8) necessary to restore and maintain fisheries resources.

The recommended restoration strategy is founded on the following conclusions drawn from the investigations detailed in Chapter 5 and on the best available scientific knowledge of alluvial river channels and riverine ecology:

1. At least a two-fold increase in smolt production is a desirable goal to restore and maintain anadromous salmonid populations toward pre-TRD levels.
2. The carrying capacity for fry and juvenile salmonids cannot be substantially increased within the confined riparian berms of the existing channel through reservoir releases alone. Flows that only mobilize spawning gravels cannot reshape channel morphology to significantly improve spawning habitat and do little to increase rearing habitat.

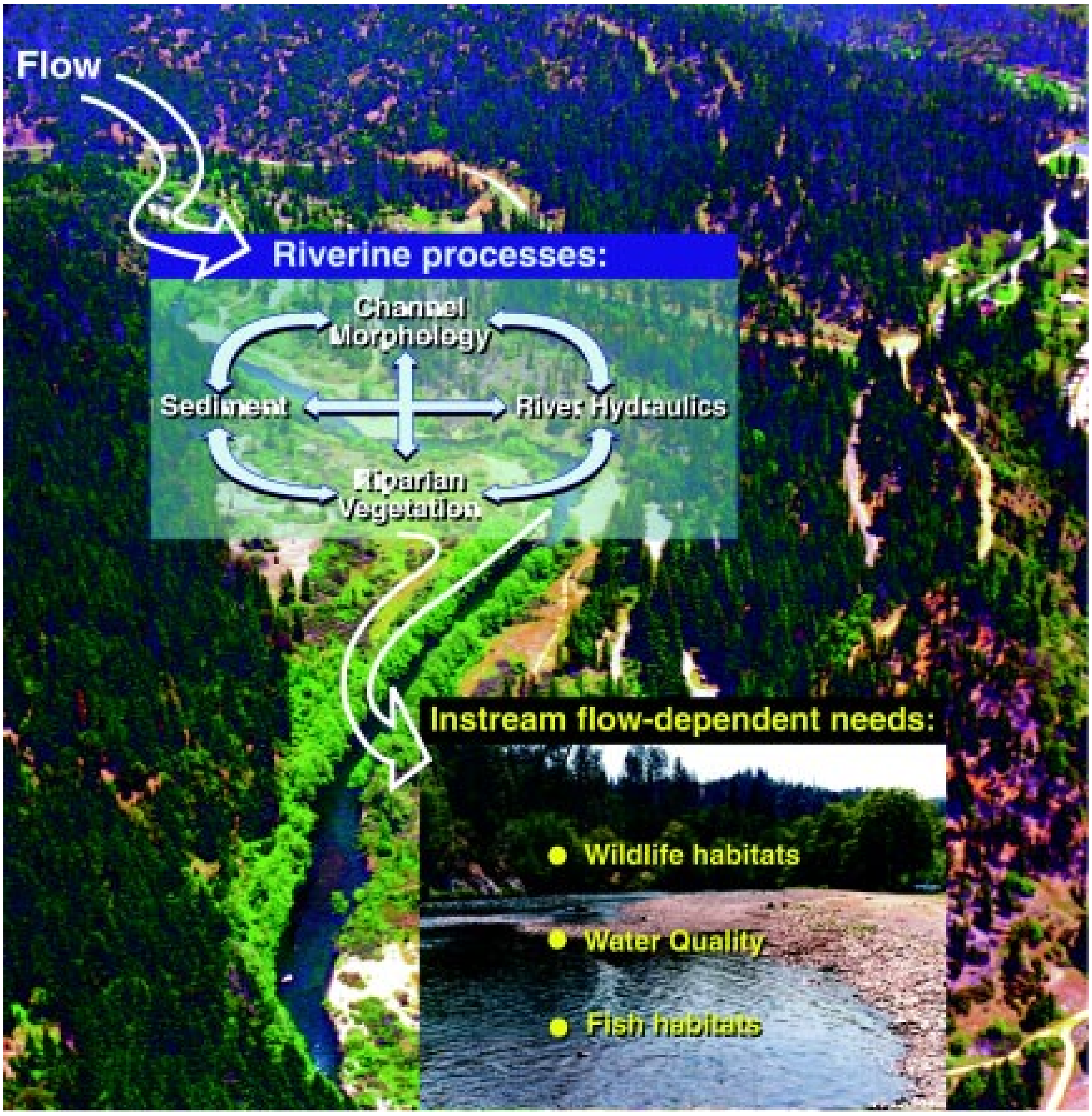


Figure 7.1. A framework for conceptualizing instream flow issues in the Trinity River.

3. Several habitat types are now rare in the mainstem above the North Fork Trinity River confluence as a result of unnatural channel confinement by riparian berms. Specifically, the limited availability of suitable low-velocity habitats severely limits fry survival from mid-winter through spring.

4. Management of TRD releases to provide optimal seasonal temperature regimes within the existing channel as a singular management action cannot increase smolt production necessary to restore and maintain salmonid populations.

5. Only through the combination of mechanical reconstruction, managed releases, and sediment management can the alluvial channel be rehabilitated

and maintained. The anticipated alluvial channel, however, will be a smaller version of the pre-TRD channel.

6. This new, but smaller, channel morphology should increase rearing habitat, allowing at least a doubling of anadromous salmonid smolt production.

7.1 Management Prescriptions

Management prescriptions can be categorized by:
(1) increased annual flow regimes and variable reservoir releases; (2) mainstem channel reconstruction; and
(3) fine and coarse sediment management. Each has unique objectives within the overall restoration strategy. All prescriptions are evaluated based on an Adaptive Environmental Assessment and Management (AEAM) program (see Section 8.4).

7.1.1 Annual Reservoir Releases

Prescribe flows based on a Water Year Classification to Restore Inter-Annual Flow Variation: No single baseflow can provide all habitat for all salmonid life stages, and no single high flow can create and maintain a dynamic alluvial channel morphology. Therefore, annual releases should be scheduled by water-supply conditions because high-runoff years serve geomorphic and ecological functions differently than do low-runoff years. Water supply forecasting must be based on Trinity River Basin annual runoff to restore inter-annual flow variation. Operational water releases to the Trinity River are officially measured by BOR from April 1 to March 31. Hydrographs in this report are depicted or described from October to September for ease of presentation.

> A primary cause of declining salmonid productivity has been habitat degradation caused by the TRD. Salmonid recovery must be based on a combination of habitat rehabilitation, flow management to improve fluvial processes and water temperatures, and sediment management to improve habitats dependent on alluvial deposits.

Restore Snowmelt Hydrograph Components: Although the downstream tributaries generate sizable winter floods and contribute significant baseflows, they do not mitigate the loss of the pre-TRD snowmelt runoff. Life-history strategies of aquatic and riparian species evolved to cope with and depend on characteristics of the snowmelt hydrograph. Managing reservoir releases to restore the elements of the snowmelt runoff hydrograph, both the snowmelt peak and recession components, is critical to river system integrity.

Prescribe Variable Releases to Rejuvenate and Maintain Alluvial Processes: Physical thresholds (including their magnitude, duration, frequency, and timing) for the alluvial attributes should be provided by the recommended hydrograph components. Each water-year class, Extremely Wet, Wet, Normal, Dry, and Critically Dry, should be assigned a unique annual flow regime. Each must be formulated by assembling hydrograph components capable of achieving specific, quantifiable geomorphic and ecological functions.

Prescribe Releases that Provide Suitable Habitat for All Life Stages of Anadromous Salmonids: Salmonid populations must now rely on the mainstem channel below Lewiston Dam for suitable adult holding, spawning, incubation, and juvenile rearing habitat. The future mainstem channel must substantially increase the availability of suitable microhabitats (depths and velocities) for these life stages from Lewiston Dam to the North Fork Trinity River confluence. Because the depth and velocity preferences vary by life stage and species, a wide range of microhabitats is important for restoration and maintenance of all native fish species and stocks.

Prescribe Releases That Meet Salmonid Temperature Needs: The mainstem below Lewiston Dam must: (1) provide suitable seasonal water temperatures for holding and spawning of anadromous salmonids down to the North Fork Trinity River confluence; (2) improve growth and survival of smolt outmigrants by providing a suitable temperature regime for all three species to Weitchpec; and (3) provide a seasonal thermal regime suitable for year-round rearing of juvenile steelhead and coho salmon.

7.1.2 Selected Mainstem Channel Modifications

Mainstem channel modification will be required in selected reaches to encourage alluvial processes, such as frequent channelbed mobilization and alternate bar formation. The degree of morphological adjustment will depend on channel location. The mainstem from Lewiston Dam to the North Fork Trinity River confluence was divided into four reaches based on present-day alluvial characteristics and future alluvial potential. The two mainstem reaches downstream from the Indian Creek confluence will have greater opportunities for alluvial recovery, as tributaries contribute more flow and coarse sediment. All reaches will require selected removal of the riparian berm down to the original pre-TRD channelbed surface. Closer to Lewiston Dam, channel modification will require selected riparian berm removal and construction of skeletal alternate bars, the latter to encourage rapid deposition and channel readjustment given the limited coarse sediment supply. These projects will also construct functional floodplain surfaces to encourage natural riparian regeneration.

7.1.3 Fine and Coarse Sediment Management

Given that watershed recovery will require a long healing period, as in the Grass Valley Creek watershed, preventing excess fine sediment from entering the mainstem must remain a priority. Coarse bed material supplementation upstream from Rush Creek will be required to rehabilitate a dynamic alluvial channel morphology. The annual volume of supplementation will be a function of peak releases, with wetter water years requiring greater supplementation. To rehabilitate, rather than maintain, mainstem channel morphology above Rush Creek, coarse bed material supplementation must exceed mainstem transport capacity.

7.2 Summary

A dynamic alluvial channel morphology cannot be accomplished solely by prescribing releases. Mechanically removing riparian berms, minimally reshaping the existing channel in selected reaches, introducing coarse bed material above Rush Creek, and reducing or preventing sand input from tributaries also will be necessary. Mechanical intervention functionally simulates a single large winter flood that efficiently eliminates riparian berms and reinstates depositional processes. This evolving alluvial channel morphology at recent channel-rehabilitation projects, and at future projects, can only be sustained with variable annual releases. Otherwise, woody riparian plants will rapidly recolonize these freshly exposed channelbeds, in a manner similar to the rapid encroachment that followed dam closure.

> The riparian berm cannot be removed by TRD dam releases; therefore, habitat rehabilitation must be preceded by a one-time sequence of mechanical berm removal at strategic locations. Subsequent long-term habitat creation and maintenance must be accomplished by flow and sediment management prescriptions rather than mechanical means.

The future mainstem below Lewiston Dam must provide more rearing, holding, and spawning habitat than existed before dam closure. If an alluvial morphology can be rehabilitated for the Trinity River mainstem, salmonid habitat improvement sufficient to at least double smolt production will not be possible without adequate seasonal water temperatures. Past mid-July, the pre-TRD mainstem was a place for salmonids to avoid; afternoon water temperatures could reach the high 70's (°F) to low 80's by Junction City. Since the TRD, hypolimnial dam releases have generated cool water temperatures sufficient to allow juvenile salmonid rearing throughout the summer. Prescribed releases will provide suitable water temperatures for salmonid smolts down the length of the river during the spring. These temperatures will also support increased survival and growth of rearing juvenile salmonids above the North Fork Trinity River confluence, while maintaining appropriate temperatures for holding adult spring-run chinook and summer-run steelhead.

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CHAPTER 8 Recommendations

Integration of information collected during studies performed as part of the TRFE and contemporary scientific knowledge of alluvial river channels and riverine ecology have guided the recommendations for restoring and maintaining the fishery resources of the Trinity River. Rehabilitation of the mainstem Trinity River and restoration and maintenance of its fishery resources requires (1) increased annual instream volumes and variable reservoir release schedules, (2) fine and coarse sediment management, and (3) mainstem channel rehabilitation. These actions and resulting recommendations are derived from the best available science. Our achievements will be evaluated over time to document success as well as to make necessary refinements based on our evolving scientific understanding of the consequences of our actions. These refinements will allow us to improve both the rate and efficiency by which we achieve our goals. The process employed to achieve these refinements is described in Section 8.4, Recommended Adaptive Environmental Assessment and Management Program.

> "Rehabilitation of the mainstem Trinity River and the restoration and maintenance of its fishery resources requires (1) increased annual instream allocations and variable reservoir release schedules, (2) fine and coarse sediment management, and (3) mainstem channel rehabilitation."

8.1 Annual Instream Flow Regimes

Recommended flow regimes and release schedules were developed on the basis of a water-year classification and the hydrograph components necessary to meet objectives for each water-year class. Individual hydrograph components were assembled into recommended annual hydrographs on the basis of the targeted fluvial processes and habitat conditions, which often vary by water-year class.

Variability is a keystone to management strategy because no single annual flow regime can be expected to perform all functions needed to maintain an alluvial river system and restore the fishery resources. Inter-annual flow variability (Attribute No. 2, see Section 4.8) is achieved by recommending unique annual flow releases for each water-year class. Unregulated runoff into Trinity Lake will be used to designate the water-year class in each year (Table 8.1), in order that the various targeted fluvial processes will be met with appropriate frequencies. Annual flow regimes vary by water-year class, because they were derived on the basis of the total amount of water necessary to meet the management objectives for each water-year class.

> "...no single annual flow regime can be expected to perform all functions needed to maintain an alluvial river system and restore the fishery resources."

8.1.1 Management Objectives by Water-Year Class

Flow releases must satisfy desired fluvial processes and habitat conditions for each water-year class. The restoration strategy (Chapter 7) broadly describes these release objectives, but it does not assign each of these objectives to a water-year class. Targeted fluvial processes and desired habitat conditions (microhabitat and temperature objectives) were assigned to each water-year class (Tables 8.2 and 8.3). Some processes and habitat conditions, such as favorable spawning and rearing microhabitat, were assigned to all water-year classes. Others, such as floodplain inundation (Attribute No. 7, Section 4.8), were assigned only to the wetter water-year classes.

8.1.2 Hydrograph Components and Releases Necessary to Meet Management Objectives

The studies (Chapter 5) provided three sets of flow-related management objectives: (1) releases to provide suitable salmonid spawning and rearing microhabitat (Table 8.3); (2) snowmelt peak and recession hydrograph components to satisfy fluvial geomorphic and woody riparian objectives that are necessary for the creation and maintenance of diverse salmonid habitats (Table 8.2); and (3) releases to meet appropriate water-temperature objectives for holding/spawning chinook salmon and outmigrating salmonid smolts (Table 8.3). Releases from the TRD were specified that would achieve these management objectives.

8.1.2.1 <u>Rearing and Spawning Microhabitat Management Objectives</u>

On the basis of the analysis of habitat availability in the existing channel, and considering all anadromous salmonid life stages, a release of 150 cfs provides the greatest amount of microhabitat in the mainstem Trinity River from Lewiston Dam to Weitchpec (Chapter 5.1). As with any use of PHABSIM habitat modeling, the weighted usable area indices must be interpreted in the context of fish life-history patterns and habitat needs, streamflow patterns (both existing and historical), water temperature, and changing channel morphology, according to the procedures of the Instream Flow Incremental Methodology (Bovee, 1982). When considering fish life histories and water-temperature needs, specifically holding and spawning temperature preferences (Chapter 5.5), a 300-cfs release provides suitable microhabitat and macrohabitat for spawning and rearing chinook salmon, coho

> "....a 300-cfs release provides suitable microhabitat and macrohabitat for spawning and rearing chinook salmon, coho salmon, and steelhead in the Trinity River above the North Fork Trinity River in the current channel morphology."

Table 8.1. Trinity River water-year classifications and probability of each water-year class occurring.

Water-Year Class	Probability of Occurrence
Extremely Wet	0.12
Wet	0.28
Normal	0.20
Dry	0.28
Critically Dry	0.12

salmon, and steelhead in the Trinity River above the North Fork Trinity River in the current channel morphology (Segment I, Figure 5.1). Recommended releases focus on this segment because it is most affected by releases from Lewiston Dam. Maintaining 300 cfs as the winter baseflow provides spawning habitat throughout the chinook salmon, coho salmon, and steelhead spawning seasons and protects early life stages throughout incubation and emergence periods for all salmonid species (Figure 3.1). Recommendations based on current rearing and spawning microhabitat data will have to be re-evaluated through an adaptive management process (Section 8.4) after channel morphology changes (Section 8.3).

8.1.2.2 Fluvial Geomorphic Management Objectives

Fluvial geomorphic management objectives are based on the alluvial-attribute thresholds (Sections 5.3 and 5.4). The majority of these objectives can be met during the snowmelt peak and snowmelt recession hydrograph. The snowmelt peak and recession hydrograph components historically varied and therefore recommendations also vary for each water-year class (Figure 8.1; Sections 5.3 and 5.4). Recommended snowmelt peak magnitudes were based on threshold shear stresses estimated as necessary for achieving Attribute Nos. 3 and No. 4. Critically Dry years were not expected to achieve either attribute. The 5-day peak release during all water years except Critically Dry provides sufficient duration to transport coarse bed material originating from tributaries in most years (refer to Attribute No. 5 of McBain and Trush (1997) for greater detail). Staggered timing of snowmelt peak runoff was based on historical timing by average water-year class (Figure 5.27).

Following the snowmelt peak, Extremely Wet and Wet snowmelt hydrographs have two distinct segments to their descending limbs (with distinct differences in rate of change in declining discharge) separated by a short duration "bench" at 6,000 cfs. Both segments (the latter designated the snowmelt recession hydrograph component) mimic the same rate of change as unimpaired snowmelt hydrographs (Figure 8.1, Appendix J). So that cottonwood seedling roots can better follow the declining groundwater table, flow recession rates mimic the unimpaired snowmelt hydrograph, which will likely promote the annual recruitment of cottonwoods (Rood and Mahoney, 1990; Segelquist et al., 1993; Merigliano, 1996). The 6,000-cfs "bench" promotes transport of fine bed material once peak flows have mobilized the surface layer of the channelbed and

> "The majority of these [fluvial geomorphic management] objectives can be met during the snowmelt peak and snowmelt recession hydrograph."

Table 8.2. Primary fluvial geomorphic management objectives for the Trinity River by water-year class (Attributes from Section 4.8).

Year Class	Management Objectives
Extremely Wet	• Mobilization of matrix particles (D_{84}) on alternate bar surfaces (Attribute 3) • Channelbed scour greater than 2 D_{84}'s depth and redeposition of gravels on face of alternate bars (Attribute 4) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage (Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Periodic channel migration (Attribute 6) • Floodplain creation, inundation, and scour (Attribute 7) • Channel avulsion (Attribute 8) • Woody riparian mortality on lower alternate bar surfaces and woody riparian regeneration on upper alternate bar surfaces and floodplains (Attribute 9) • Maintain variable water table for off-channel wetlands and side channels (Attribute 10)
Wet	• Mobilization of matrix particles (D_{84}) on alternate bar surfaces (Attribute 3) • Channelbed scour greater than 1 D_{84}'s depth and redeposition of gravels (Attribute 4) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage (Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Periodic channel migration (Attribute 6) • Floodplain creation, inundation and occasional scour (Attribute 7) • Woody riparian mortality on lower alternate bar surfaces and woody riparian regeneration on upper alternate bar surfaces and floodplains (Attribute 9) • Maintain fluctuating water table for off-channel wetlands and side channels (Attribute 10)
Normal	• Mobilization of matrix particles (D_{84}) on general channelbed surface and along flanks of alternate bar surfaces (Attribute 3) • Channelbed scour and redeposition of gravels (Attribute 4) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage (Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Frequent floodplain inundation (Attribute 7) • Woody riparian vegetation mortality along low water edge of alternate bar surfaces and woody riparian regeneration on upper alternate bar surfaces and floodplains (Attribute 9) • Maintain fluctuating water table for off-channel wetlands and side channels (Attribute 10)
Dry	• Channelbed surface mobilization of in-channel alluvial features (e.g., spawning gravel deposits) (Attribute 3) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage(Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Discourage germination of riparian plants on lower bar surfaces for a portion of the seed release period (Attribute 9) • Maintain variable water table for off-channel wetlands and side channels (Attribute 10)
Critically Dry	• Discourage germination of riparian plants on lower bar surfaces for the early portion of the seed release period (Attribute 9) • Minimally recharge groundwater (Attribute 10)

Table 8.3. Salmonid microhabitat and temperature objectives for the Trinity River by water-year class.

Water Year Class	Microhabitat Objectives	Temperature Objectives
Extremely Wet, Wet, and Normal	Provide the greatest amount of spawning and rearing microhabitat for anadromous salmonids in the existing channel, given the needs of the various life-stages.	Provide suitable temperatures for holding spring chinook and spawning spring and fall chinook by meeting temperature standards of: <60° F from July 1 to September 14 at Douglas City (RM 93.7), <56° F from September 15 to September 30 at Douglas City, and <56° F from October 1 to December 31 at the North Fork Trinity River confluence (RM 72.4). Provide optimal temperatures for anadromous salmonids throughout their outmigration by meeting temperature targets at Weitchpec (RM 0.0) of: <55.4° F prior to May 22 for steelhead smolts, < 59.0° F prior to June 4 for coho salmon smolts, and <62.6° F prior to July 9 for chinook salmon smolts.
Dry and Critically Dry	Provide the greatest amount of spawning and rearing microhabitat for anadromous salmonids in the existing channel, given the needs of the various life-stages.	Provide suitable temperatures for holding spring chinook and spawning spring and fall chinook by meeting temperature standards of: <60° F from July 1 to September 14 at Douglas City (RM 93.7), <56° F from September 15 to September 30 at Douglas City, and <56° F from October 1 to December 31 at the North Fork Trinity River confluence (RM 72.4). Facilitate early outmigration of smolts by allowing water temperatures to warm and provide at least marginal temperatures for anadromous salmonids throughout most of their outmigration by meeting temperature targets at Weitchpec (RM 0.0) of <59.0° F prior to May 22 for steelhead smolts, <62.6° F prior to June 4 for coho salmon smolts, and <68.0° F prior to July 9 for chinook salmon smolts.

alternate bars. The recession hydrograph components in Normal, Dry, and Critically Dry water-year classes also mimic unimpaired receding snowmelt rates (Appendix J).

Another "bench" in Extremely Wet, Wet, and Normal water years at a release of 2,000 cfs has two purposes: (1) to inundate exposed portions of alternate bars when seeds are viable and tributaries are contributing significant baseflows (refer to Attribute No. 9); and (2) to facilitate chinook smolt outmigration through July 9 (Figure 8.2). Similarly, a 36-day bench of 1,500 cfs in Critically Dry water years will discourage seedling germination on alternate bar flanks through inundation and will improve water temperatures for salmonids.

8.1.2.3 Water Temperature Management Objectives

Summer/Fall Temperature Control Flows

In 1991, the CRWQCB-NCR, in conjunction with the Service, CDFG, and the Hoopa Valley Tribe, established water-temperature objectives for the Trinity River to protect holding/spawning spring-run chinook salmon and spawning fall-run chinook salmon (Section 5.5). From July through mid-October a release of at least 450 cfs provides suitable water temperatures for holding and spawning spring-run chinook salmon and spawning fall-run chinook salmon in the Trinity River, above the confluence with the North Fork Trinity River (Figure 8.2; Section 5.5). Under a variety of hydro-meteorological

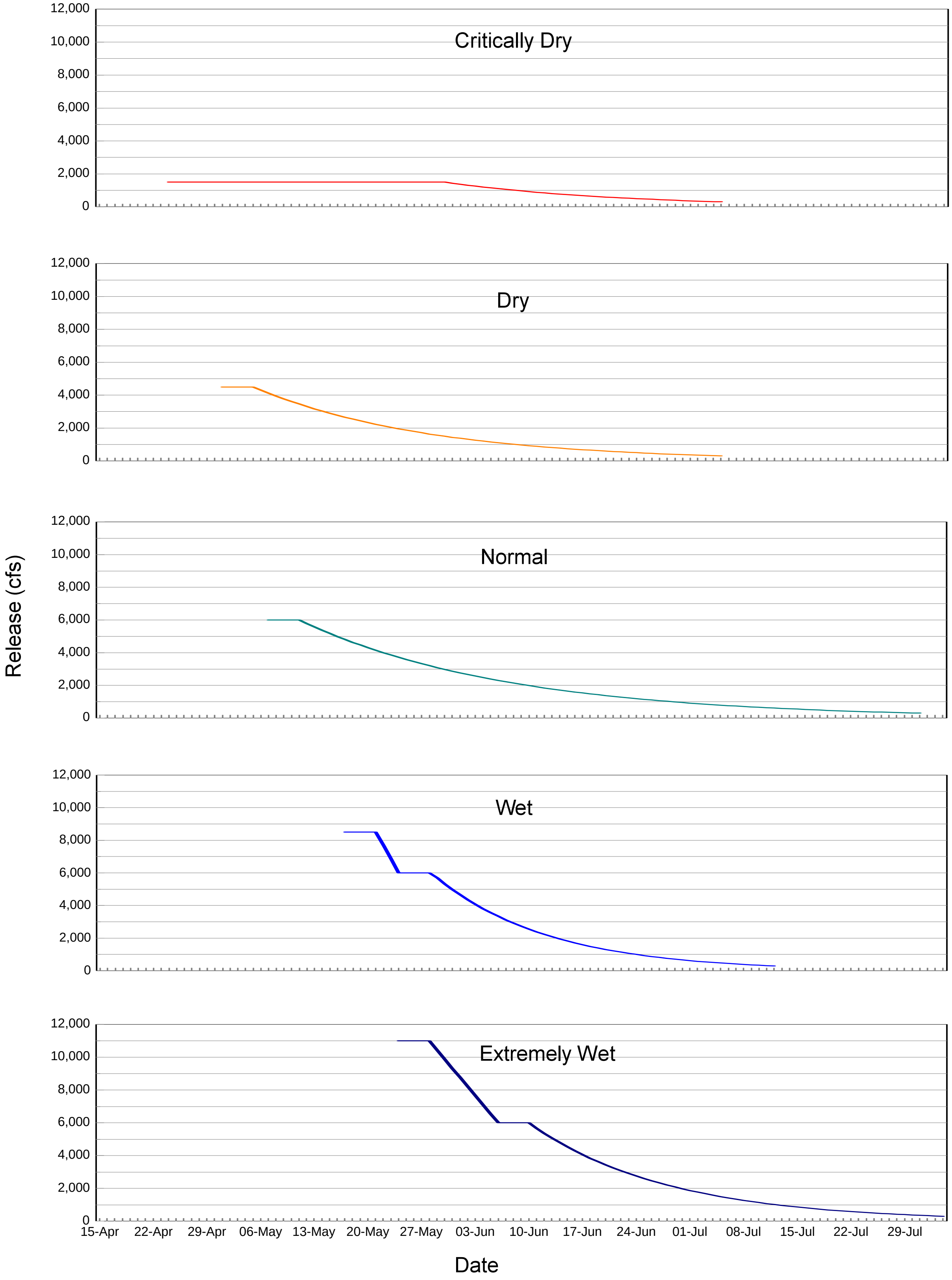

Figure 8.1. Lewiston Dam releases necessary to meet fluvial geomorphic objectives for each water-year class.

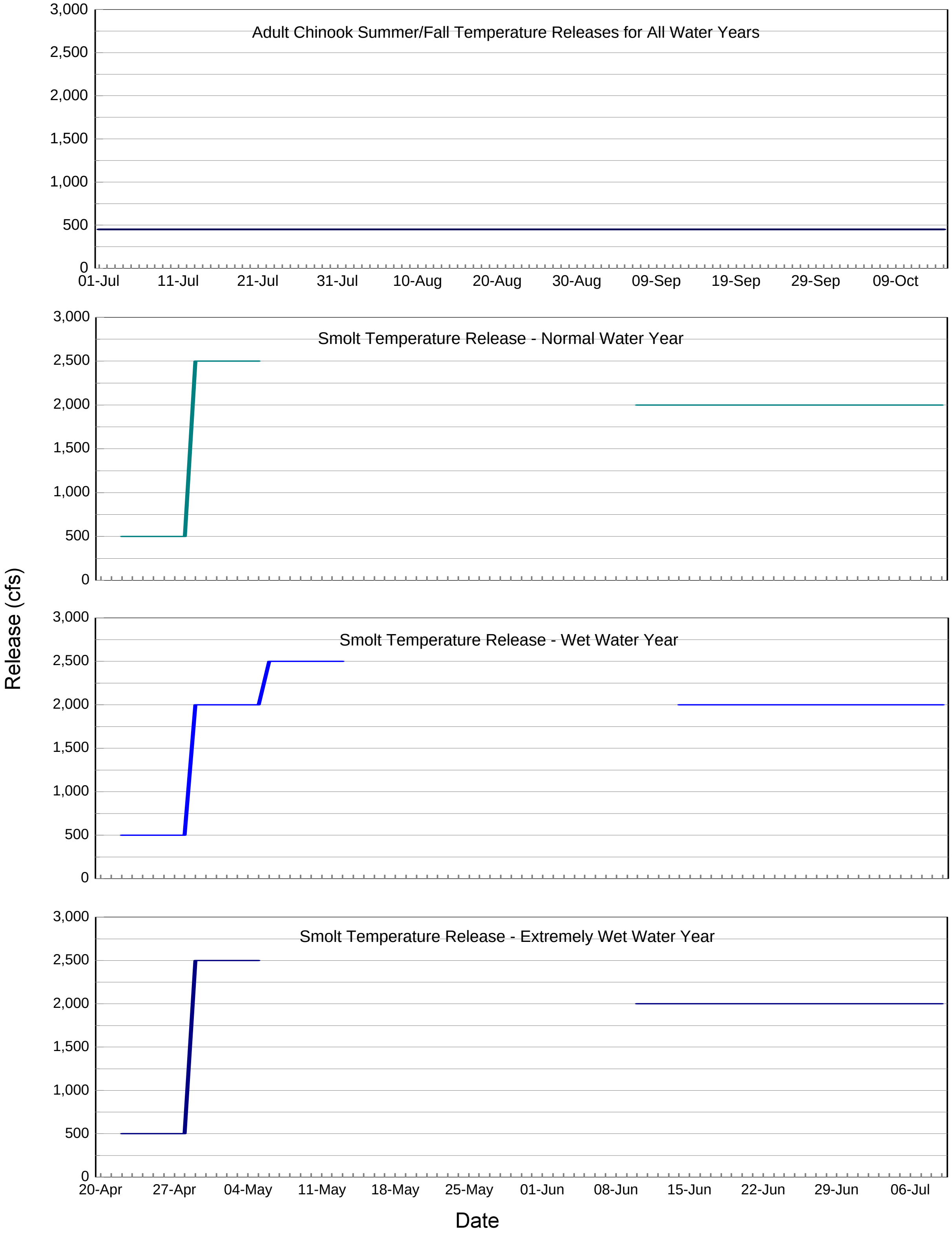

Figure 8.2. Lewiston Dam releases necessary to meet summer/fall adult chinook temperature objectives above the North Fork Trinity River confluence, and releases necessary to meet salmonid smolt temperature objectives at Weitchpec during Normal, Wet, and Extremely Wet water years. Releases for the time periods not graphed are covered by the fluvial geomorphic peaks.

conditions and dam release-water temperatures, releases of 450 cfs have met the temperature objectives established by the CRWQCB-NCR.

Salmonid Smolt Outmigration Flows

Because of the protracted outmigration period of the three anadromous salmonid species in the Trinity River, a variety of outmigrant temperature conditions are necessary throughout the spring/summer hydrographs (Chapter 5.5). Releases for the three water-year classes (Extremely Wet, Wet, and Normal) were scheduled to meet optimum salmonid smolt temperature criteria (Figure 8.2; Chapter 5.5). Because the timing of smolt outmigrations is similar to the timing of the recommended fluvial geomorphic releases, appropriate thermal regimes were provided under the fluvial geomorphic recommendation for much of the fluvial geomorphic hydrograph. Hydrographs were developed to meet optimal smolt temperatures prior to and at the end of the fluvial geomorphic releases during the Extremely Wet, Wet, and Normal water years (Appendix K).

> "Under a variety of hydrometeorological conditions and dam release-water temperatures, releases of 450 cfs have met the temperature objectives established by the CRWQCB-NCR."

Optimal smolt outmigration temperatures will not be provided during Dry and Critically Dry water years. The magnitude and timing of fluvial geomorphic releases during the Dry and Critically Dry water year hydrographs provided at least marginal salmonid smolt temperatures throughout much of the outmigration period (Appendix K). The lower geomorphic releases for these water-year classes provide flow and temperature conditions in the mainstem similar to those that exist lower in the Trinity River and in the lower Klamath River during these year classes (Appendix L). Allowing mainstem water temperatures to warm earlier in the outmigration period will cue salmonids to outmigrate before water temperatures in the lower watershed are likely to become too warm to ensure smolt survival.

> "Because of the protracted outmigration period of the three salmonid species in the Trinity River, a variety of outmigrant temperature conditions are necessary throughout the spring/summer hydrographs."

8.1.3 Assembly of Annual Hydrographs for Each Water Year

Annual hydrographs were assembled for each water class on the basis of the targeted microhabitat, fluvial processes (Figure 8.1), and desired temperature conditions (Figure 8.2). Total annual instream volumes, based on the recommended releases for each water-year class, ranged from 369 to 815 TAF (Table 8.4). Stepwise assembly of the Wet water year releases illustrates how management objectives were integrated into a single recommended release schedule (Figure 8.3). Throughout the year, a minimum recommended release of 300 cfs is required for spawning and rearing microhabitat. However, summer/fall temperature objectives require a greater release (450 cfs), which override the rearing microhabitat objectives in the summer and early fall. The benefits of providing suitable temperature regimes (as well as geomorphic processes) outweigh the short-term decrease in the amount of microhabitat. Similarly, smolt temperature objectives and the snowmelt peak and recession override rearing habitat objectives in the spring. The releases required to meet the snowmelt hydrograph also meet most of the smolt temperature objectives. The snowmelt ascending and receding limbs were modified in selected weeks as necessary to meet temperatures for steelhead smolt outmigration that were not initially met by the snowmelt hydrograph releases.

Table 8.4. Recommended annual water volumes for instream release to the Trinity River in thousands of acre-feet (TAF).

Water-Year Class	**Instream Volume**
Extremely Wet	815.2
Wet	701.0
Normal	646.9
Dry	452.6
Critically Dry	368.6
Average (weighted by water-year probability)	594.5

8.1.4 Recommended Release Schedules for Each Water-Year Class

Recommended daily releases from Lewiston Dam for each water-year class are presented in Appendix M.

8.1.4.1 Extremely Wet Water Year
(Table 8.5; Figure 8.4)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River. Under a variety of hydrometeorological conditions and dam release-water temperatures, releases of 450 cfs have met the temperature objectives established by the CRWQCB-NCR.

A release of 300 cfs from October 16 through April 21 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel (Table 8.5, Figure 8.4). A 300-cfs release provides more microhabitat for most salmonid life-stages than does the 450-cfs release, which is required from July to mid-October for temperature control. Although spawning microhabitat is greater at low releases, reducing releases below 300 cfs would increase the occurrence of dewatering spring-run chinook redds constructed during the preceding 450-cfs release. Maintaining a 300-cfs release protects early life stages of salmonids throughout the protracted period of incubation and emergence that occurs in the mainstem resulting from the successive and extended spawning of chinook salmon, coho salmon, and steelhead.

A release of 500 cfs from April 22 through April 28 provides optimal temperatures for steelhead (<55.4° F), as well as for coho salmon (<59.0° F) and chinook salmon (<62.6° F) smolts.

A release of 1,500 cfs from April 29 through May 5 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

> "Annual hydrographs were assembled for each water class on the basis of the targeted microhabitat, fluvial processes, and desired temperature conditions."

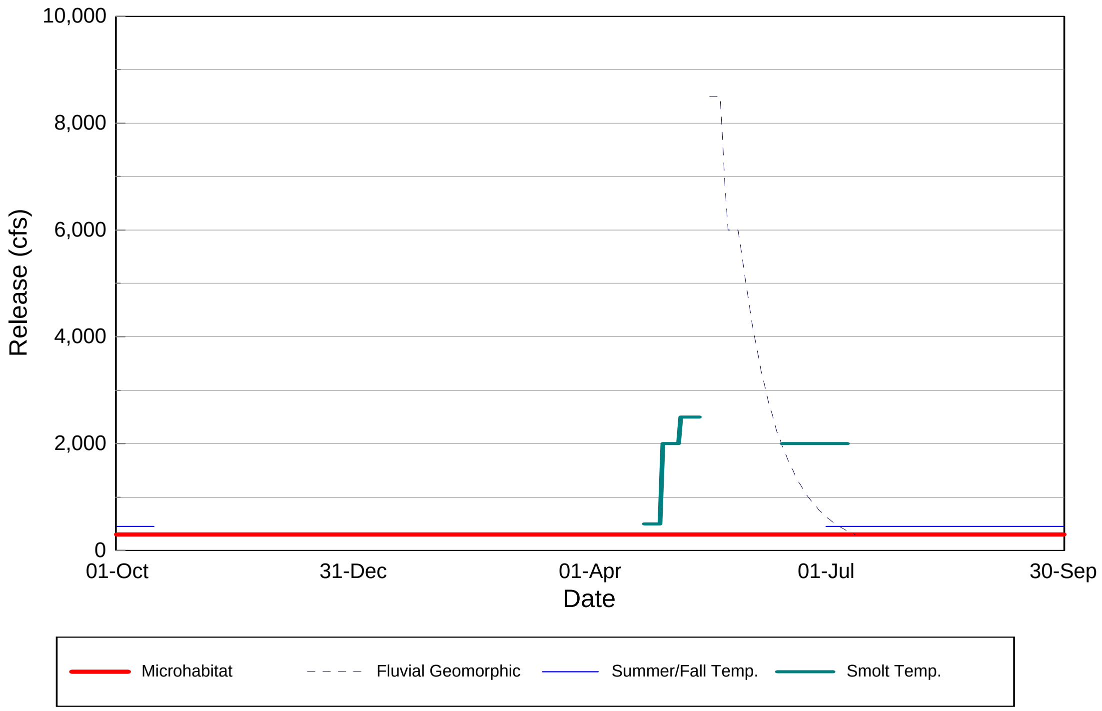

Figure 8.3. Releases necessary to meet microhabitat, fluvial geomorphic, summer/fall temperature, and smolt temperature management objectives during a Wet water year.

A release of 2,000 cfs from May 6 through May 19 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases are increased from 2,000 cfs on May 19 to 11,000 cfs on May 24 to meet fluvial geomorphic objectives for the Extremely Wet water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day peak release of 11,000 cfs from May 24 to May 28 targets fluvial geomorphic processes that will create major alterations in the channel and channelbed. This release magnitude and duration will mobilize most alluvial features, scour the channelbed to a depth $>2D_{84}$, transport sediment and route bedload, cause mortality of channel-encroaching plants and prevent germination of riparian plants, promote periodic channel migration and avulsion, and build floodplain features. The timing of the fluvial geomorphic peak release mimics the historical timing of snowmelt peaks during Extremely Wet water years. This release magnitude will also provide optimal temperatures for coho salmon and chinook salmon smolts throughout the mainstem.

Recommended releases decrease from 11,000 cfs on May 28 to 6,000 cfs on June 6. This rapid decrease mimics historical conditions that followed spring peak flows.

> "A 5-day peak release of 11,000 cfs . . . targets fluvial geomorphic processes that will create major alterations in the channel and channelbed."

A 5-day release of 6,000 cfs from June 6 to June 10 facilitates the transport of fine bed material (sand) once higher flows have

Table 8.5. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during an Extremely Wet water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall- run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 21	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 28	500	Spring baseflow	≤ 55.4º F at Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
Apr 29 - May 5	1,500	Spring baseflow/ Ascending limb	≤ 55.4º F at Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
May 6 - May 19	2,000	Spring baseflow/ Ascending limb	≤ 55.4º F at Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production Reduce travel time of outmigrating steelhead smolts
May 19 - May 24	2,000 - 11,000	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
May 24 - May 28	11,000	Snowmelt peak	Peak: Mobilize ≥2 D_{84} deep on flanks of alternate bars (more on lower channel than upper) cleanses gravels and transports all sizes of sediments Initiate channel migration at bank rehabilitation sites Duration: Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to the tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within the surface and subsurface chnnelbed Increase sinuousity through channel migration Create and maintain alternate bar morphology Create floodplains by bar building and fine sediment deposition Encourage establishment and growth of riparian vegetation on floodplains Scour up to 3 yr old woody riparian vegetation along low flow channel margins and scour younger plants higher on bar flanks	Increase fry production through improved egg-to-emergence success Increase fry production by creating and maintaining rearing habitat along channel margins Increase smolt production by increasing year-round rearing habitat quality and quantitiy, and reducing outmigration travel time Increase species and age diversity of riparian vegetation

Table 8.5. Continued.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
May 28 - Jun 6	11,000 - 6,000	Descending limb	Ramp to 6,000 cfs	Reduce fine sediment (<5/16 inch) storage within surface channelbed	Increase fry production through improved egg-to-emergence success
Jun 6 - Jun 10	6,000	Descending limb bench	Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface channelbed while minimizing coarse sediment (>5/16 inch) transport	Improve fry production through improved egg-to-emergence success Discourage riparian vegetation initiation along low water channel margins
Jun 10 - Jun 30	6,000 - 2,000	Descending limb	Descend at a rate mimicking pre-TRD descent	Inundate point bars Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonally variable water surface levels in side channels and off-channel wetlands	Prevent riparian vegetation initiation along low water channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook salmon growth Increase riparian vegetation and future LWD recruitment
Jun 30 - Jul 9	2,000	Descending limb bench	Provide optimal water temperatures (≤ 62.6º F) to Weitchpec for chinook salmon smolts	Provide optimal temperatures for increased survival of chinook smolts Inundate point bars	Improve chinook smolt production Prevent riparian initiation along low water channel margins
Jul 9 - Jul 22	2,000 - 450	Descending limb	Decline to summer baseflow	Minimize stranding of salmonid fry behind berms	Increase survival of steelhead fry Provide outmigration cues for chinook smolts
Jul 22 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

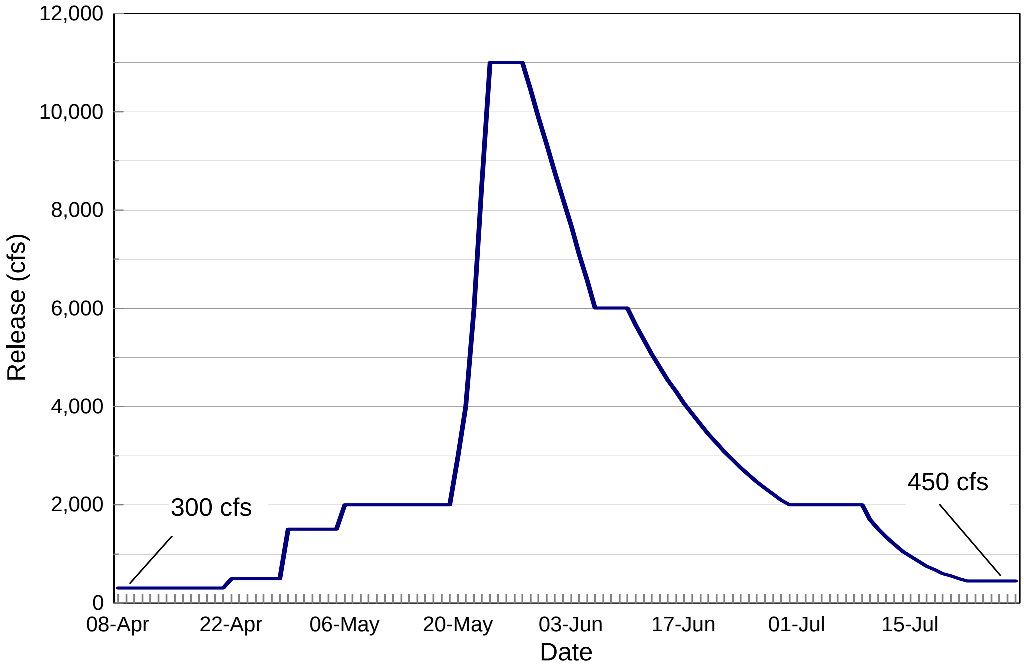

Figure 8.4. Recommended releases during an Extremely Wet water year. Releases are scheduled for 450 cfs from July 22 to October 15. Releases are scheduled for 300 cfs from October 16 to April 21.

mobilized the surface layer of the general channelbed and alternate bars, while minimizing transport of coarse bed material. This release will transport fine sediment (sand), cause mortality of riparian vegetation seedlings, and inundate the flanks of bars to discourage germination and prevent encroachment of riparian plants. This release provides optimal temperatures for chinook salmon smolts throughout the mainstem.

Recommended releases gradually decrease from 6,000 cfs on June 10 to 2,000 cfs on June 30. The rate of this decrease mimics historical conditions that followed spring flows of approximately 6,000 cfs during Extremely Wet water years. Releases during the descending limb of the Extremely Wet water year hydrograph transport fine sediment (sand) and inundate alternate bar features, cause mortality of riparian vegetation seedlings and prevent germination and encroachment on lower bar surfaces, and encourage natural riparian regenerataion on upper bar surfaces and floodplains. These release magnitudes provide optimal temperatures for chinook salmon smolts throughout the mainstem.

A release of 2,000 cfs from June 30 to July 9 provides optimal temperatures for chinook salmon smolts throughout the mainstem. Alternate bar features will be inundated, causing mortality of riparian vegetation seedlings and preventing germination of riparian vegetation on lower bar surfaces. Some fine sediment (sand) transport occurs at this release magnitude.

> "Releases during the descending limb of the Extremely Wet water year hydrograph transport fine sediment (sand) and inundate alternate bar features, cause mortality of riparian vegetation seedlings and prevent germination and encroachment on bar surfaces."

> “The gradual decrease [from 2,000 to 450 cfs] minimizes stranding potential of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.”

Recommended releases decrease from 2,000 cfs on July 9 to 450 cfs on July 22 to reach summer temperature-control releases. The gradual decrease minimizes stranding of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from July through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

8.1.4.2 <u>Wet Water Year</u> (Table 8.6; Figure 8.5)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 21 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

A release of 500 cfs from April 22 through April 28 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout most of the mainstem.

> “A 5-day peak release of 8,500 cfs . . . targets several fluvial geomorphic processes [that will] mobilize most alluvial features, scour channelbed to a depth $>1D_{84,}$ transport fine sediment and route bedload, cause mortality of channel-encroaching plants and prevent germination on bar surfaces, initiate periodic channel migration, and inundate/create floodplains.”

A release of 2,000 cfs from April 29 through May 5 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout most of the mainstem.

A release of 2,500 cfs from May 6 through May 13 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases increase from 2,500 cfs on May 13 to 8,500 cfs on May 17 to meet fluvial geomorphic objectives for the Wet water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day peak release of 8,500 cfs from May 17 to May 21 targets several fluvial geomorphic processes. This release magnitude and duration will mobilize most alluvial features, scour channelbed to a depth $>1D_{84,}$ transport fine sediment and route bedload, cause mortality of channel-encroaching plants and prevent germination on bar surfaces, initiate periodic channel migration, and inundate/create floodplains. The timing of the fluvial geomorphic peak release mimics the historical timing of the snowmelt peak during wet water years. This release provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases decrease from 8,500 cfs on May 21 to 6,000 cfs on May 24. This rapid decrease mimics historical conditions that followed spring peak flows.

A 5-day release of 6,000 cfs from May 24 to May 28 facilitates the transport of fine bed material (sand) once higher flows have mobilized the coarse surface layer of the

Table 8.6. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Wet water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall- run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 21	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 28	500	Spring baseflow	≤ 55.4º F to Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
Apr 29 - May 5	2,000	Spring baseflow/ Ascending limb	≤ 55.4º F to Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
May 6 - May 13	2,500	Spring baseflow/ Ascending limb	≤ 55.4º F to Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production Reduce travel time of outmigrating steelhead smolts
May13 - May 17	2,500 - 8,500	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
May 17 - May 21	8,500	Snowmelt peak	Peak Threshold : Mobilize ≥1 D_{84} deep on flanks of alternate bars (more on lower channel than on upper) cleanses gravels and transports all sizes of sediments Initiate channel migration at bank rehabilitation sites Duration:Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface and subsurface channelbed Increase sinuousity through channel migration Create and maintain alternate bar morphology Create floodplains by bar building and fine sediment deposition Encourage establishment and growth of riparian vegetation on floodplains Scour up to 2 yr old woody riparian vegetation along low flow channel margins	Increase fry production through improved egg-to-emergence success Increase fry production by creating and maintaining rearing habitat along channel margins Increase smolt production by increasing year-round habitat quality and quantity and reducing outmigration travel time Increase species and age diversity of riparian vegetation

Table 8.6. Continued.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
May 21 - May 24	8,500 - 6,000	Descending limb	Ramp to 6,000 cfs	Reduce fine sediment (<5/16 inch) storage within surface channelbed	Increase fry production through improved egg-to-emergence success
May 24 - May 28	6,000	Descending limb bench	Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface channelbed while minimizing coarse sediment (>5/16 inch) transport	Increase fry production through improved egg-to-emergence success Discourage riparian vegetation initiation along low water channel margins
May 28 - Jun 14	6,000 - 2,000	Descending limb	Descend at a rate mimicking pre-TRD descent Descend at a rate less than 0.1 ft/day	Inundate point bars Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonally variable water surface levels in side channels and off-channel wetlands	Prevent riparian vegetation initiation along low water channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook salmon growth
Jun 14 - Jul 9	2,000	Descending limb bench	Provide optimal water temperatures (≤62.6º F) to Weitchpec for chinook salmon smolts	Provide optimal temperatures for increased survival of chinook smolts Inundate point bars	Improve chinook smolt production Prevent riparian initiation along low water channel margins
Jul 9 - Jul 22	2,000 - 450	Descending limb	Decline to summer baseflow	Minimize stranding of salmonid fry behind berms	Increase survival of steelhead fry Provide outmigration cues for chinook smolts
Jul 22 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

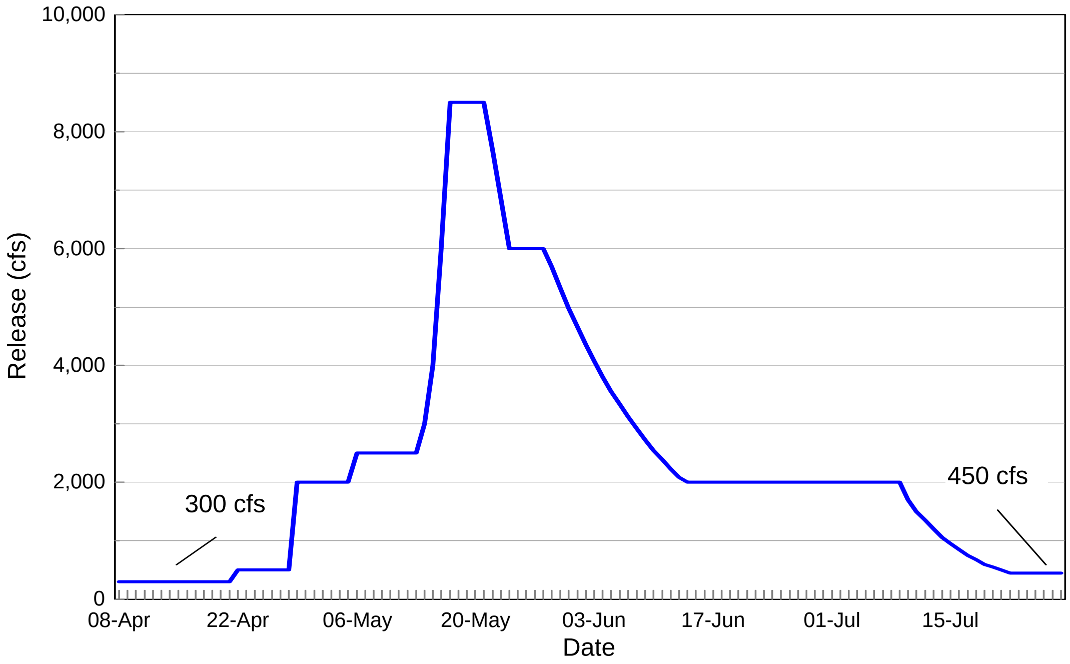

Figure 8.5. Recommended releases during a Wet water year. Releases are scheduled for 450 cfs from July 22 to October 15. Releases are scheduled for 300 cfs from October 16 to April 21.

general channelbed and alternate bars, while minimizing transport of coarse bed material. This release will transport fine sediment (sand), cause mortality of riparian vegetation seedlings, and inundate the flanks of bars to discourage germination and prevent encroachment of riparian plants. This release provides optimal temperatures for chinook salmon smolts throughout the mainstem.

Recommended releases gradually decrease from 6,000 cfs on May 28 to 2,000 cfs on June 14. The rate of this decrease mimics historical conditions that followed spring flows of approximately 6,000 cfs during Wet water years. Releases during the descending limb of the wet water year hydrograph transport fine sediment (sand) and inundate alternate bar features, causing mortality of riparian seedlings and preventing germination and encroachment on bar surfaces. During this period, release magnitudes provide optimal temperatures for coho salmon and chinook salmon smolts throughout the mainstem.

A release of 2,000 cfs from June 14 to July 9 provides optimal temperatures for chinook salmon smolts throughout the mainstem and for salmonid rearing temperatures throughout most of the mainstem. Alternate bar features will be inundated, causing mortality of riparian seedlings and preventing germination of riparian plants on lower bar surfaces. Some fine sediment (sand) transport occurs at this release.

Recommended releases decrease from 2,000 cfs on July 9 to 450 cfs on July 22 to reach summer temperature-control releases. The gradual decrease minimizes stranding potential of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from July 22 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

8.1.4.3 **Normal Water Year** (Table 8.7; Figure 8.6)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 21 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

> "A 5-day release of 6,000 cfs . . . mobilizes most alluvial features, transports fine sediment (sand), causes mortality of riparian seedlings and prevents germination on bar surfaces, and inundates floodplains."

A release of 500 cfs from April 22 through April 28 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts.

A release of 2,500 cfs from April 29 through May 5 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts.

Recommended releases increase from 2,500 cfs on May 5 to 6,000 cfs on May 7 to meet fluvial geomorphic objectives for the Normal water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day release of 6,000 cfs from May 7 to May 11 targets fluvial geomorphic processes. This release magnitude and duration mobilizes most alluvial features, transports fine sediment (sand), causes mortality of riparian seedlings and prevents germination on bar surfaces, and inundates floodplains. The timing of the fluvial geomorphic peak mimics the historical timing of the snowmelt peak during Normal water years. This release magnitude provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases gradually decrease from 6,000 cfs on May 11 to 2,000 cfs on June 10. The rate of this decrease mimics historical decreases in flow that followed spring flows of approximately 6,000 cfs during normal water years. Releases during the descending limb of the normal water year hydrograph transport fine sediment (sand) and inundate alternate bar features, causing mortality of riparian seedlings and preventing germination and encroachment on bar surfaces. During this period, releases provide optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

A release of 2,000 cfs from June 10 to July 9 provides optimal temperatures for rearing steelhead, and coho salmon and chinook salmon smolts throughout the mainstem. Alternate bar features will be inundated, causing mortality of riparian seedlings and preventing germination of riparian plants on lower bar surfaces. Some fine sediment (sand) transport occurs at this release magnitude.

Recommended releases decrease from 2,000 cfs on July 9 to 450 cfs on July 22 to reach summer temperature-control releases. The gradual decrease minimizes stranding of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from July 22 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

Table 8.7. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Normal water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall- run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 21	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 28	500	Spring baseflow	≤ 55.4º F at Weitchpec	Provide optimal temperatures for enhanced survival of steelhead smolts	Improve steelhead smolt production
Apr 29 - May 5	2,500	Spring baseflow/ Ascending limb	≤ 55.4º F at Weitchpec	Provide optimal temperatures for enhanced survival of steelhead smolts	Improve steelhead smolt production
May 5 - May 7	2,500 - 6,000	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use Provide optimal temperatures for survival of steelhead smolts	Reduce travel time of outmigrating steelhead smolts Improve steelhead smolt production
May 7 - May 11	6,000	Snowmelt peak	Peak Threshold: Mobilize D_{84} on most alluvial features (general channel mobility) Duration: Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to the tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within the surface channelbed Create and maintain alternate bar morphology Create floodplains by bar building and fine sediment deposition Encourage establishment and growth of riparian vegetation on floodplains Scour up to 1 yr old woody riparian vegetation along channel margins	Increase fry production through improved egg-to-emergence success Discourage riparian vegetation initiation along low water channel margins Increase smolt production by increasing year-round rearing habitat quality and quantity, and reducing outmigration transport time

Table 8.7. Continued.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
May 11 - Jun 10	6,000 - 2,000	Descending limb	Descend at a rate mimicking pre-TRD descent Descend at a rate less than 0.1 ft/day	Inundate point bars to prevent riparian initiation and encroachment along channel margins Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonal variation of water surface levels in side channels and off-channel wetlands	Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook growth Increase riparian vegetation and future LWD recruitment
Jun 10 - Jul 9	2,000	Descending limb bench	Provide optimal water temperatures (≤ 62.6º F) to Weitchpec for chinook salmon smolts	Provide optimal water temperatures for survival of chinook salmon smolts Inundate point bars to prevent riparian initiation along channel margins	Improve chinook smolt production Prevent riparian initiation along channel margin
Jul 9 - Jul 22	2,000 - 450	Descending limb	Decline to summer baseflow	Minimize salmonid fry stranding behind berms	Increase survival of steelhead fry Provide outmigration cues for chinook salmon smolts
Jul 22 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

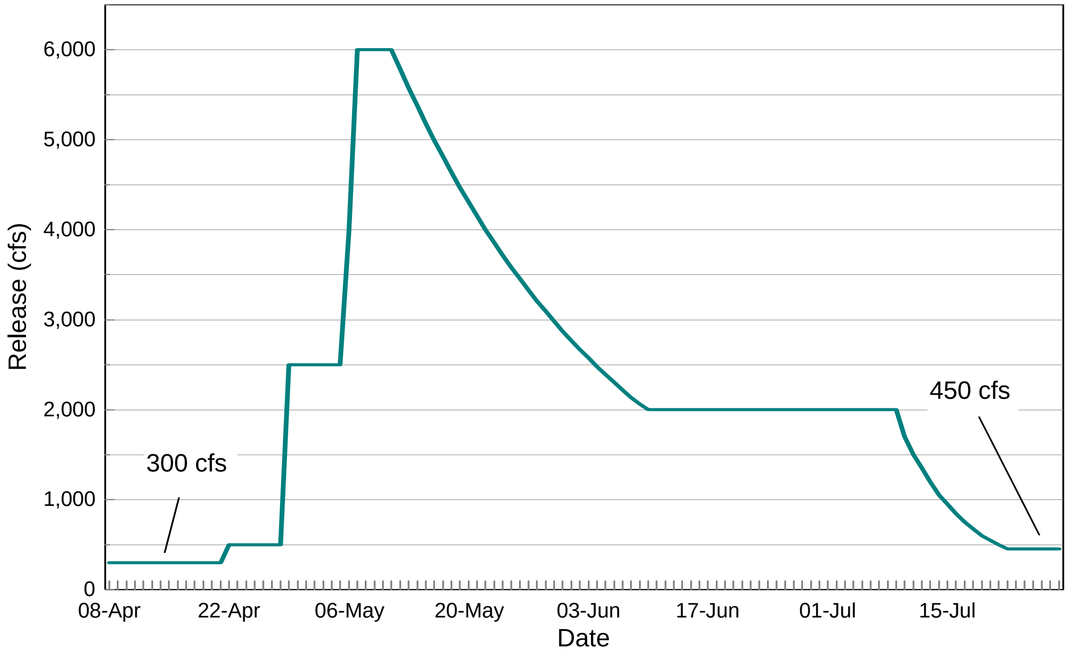

Figure 8.6. Recommended releases during a Normal water year. Releases are scheduled for 450 cfs from July 22 to October 15. Releases are scheduled for 300 cfs from October 16 to April 21.

8.1.4.4 **Dry Water Year** (Table 8.8; Figure 8.7)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 26 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

Recommended releases increase from 300 cfs on April 26 to 4,500 cfs on May 1 to meet fluvial geomorphic objectives for the Dry water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day release of 4,500 cfs from May 1 to May 5 targets fluvial geomorphic processes. This release magnitude and duration mobilizes in-channel alluvial features, transports some fine sediment (sand), causes mortality of riparian seedlings, and prevents germination on bar surfaces. The timing of the fluvial geomorphic peak release mimics the historical timing of the snowmelt peak during Dry water years. This release provides at least marginal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Releases gradually decrease from 4,500 cfs on May 5 to 450 cfs on June 26. The rate of this decrease mimics historical conditions that followed spring flows of approximately 4,500 cfs during Dry water years.

> "A 5-day release of 4,500 cfs from May 1 to May 5 targets fluvial geomorphic processes . . . [that] mobilizes inchannel alluvial features, transports some fine sediment (sand), causes mortality of riparian seedlings, and prevents germination on bar surfaces."

Table 8.8. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Dry water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall-run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 26	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 26 - May 1	300 - 4,500	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
May 1 - May 5	4,500	Peak flow	Peak Threshold: Mobilize D_{84} on bar flanks features (median bars, pool tails) Duration: Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to the tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface channelbed	Increase salmonid fry production through improved egg-to emergence success Discourage riparian vegetation initiation along low flow channel margins
May 5 - Jun 26	4,500 - 450	Descending limb	Descend at a rate mimicking pre-TRD descent Provide non-lethal water temperatures to Weitchpec for coho smolts (≤ 62.6º F) until June 4 , and for chinook smolts (≤ 68º F) until mid-June	Inundate point bars Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonal variation of water surface levels in side channels and off-channel wetlands Improve salmonid smolt production by providing temperatures necessary for survival of steelhead, coho, chinook smolts	Prevent riparian initiation along channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook growth Increase survival of steelhead fry Provide outmigration cues for chinook salmon smolts
Jun 26 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

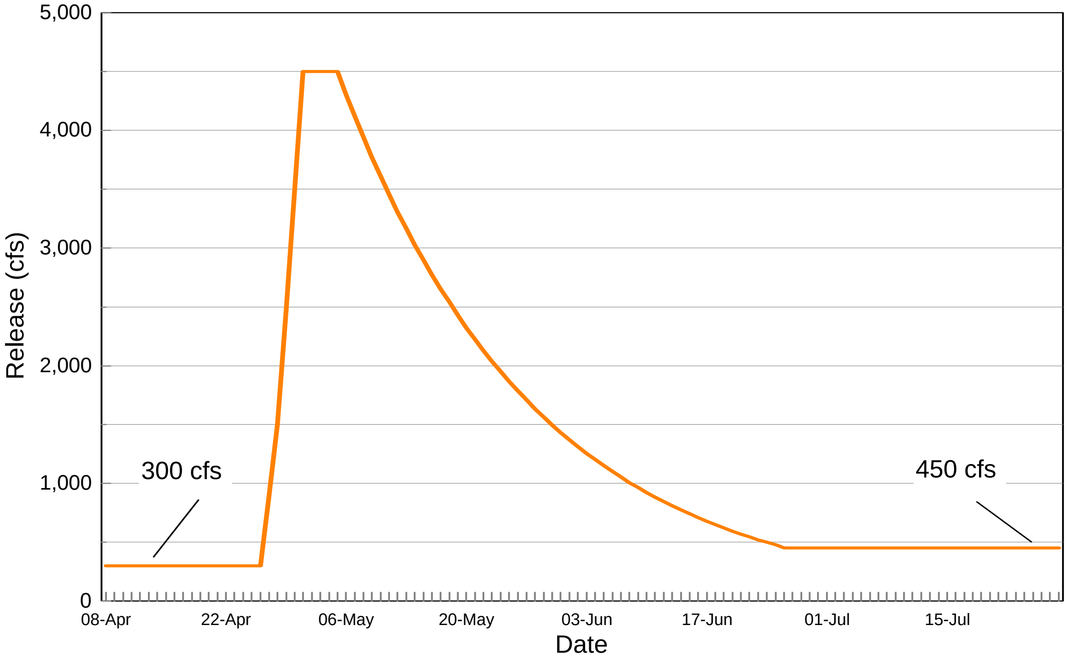

Figure 8.7. Recommended releases during a Dry water year. Releases are scheduled for 450 cfs from June 26 to October 15. Releases are scheduled for 300 cfs from October 16 to April 26.

Releases during much of the descending limb of the dry water year hydrograph inundate alternate bar features, causing mortality of riparian seedlings and preventing germination on bar surfaces, and transport small volumes of fine sediment (sand). The gradual reduction of releases minimizes stranding of fry and juvenile salmonids. Releases during this period provide at least marginal temperatures for coho salmon and chinook salmon smolts throughout the mainstem until mid-June. The gradual reduction of releases allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from June 26 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

8.1.4.5 **Critically Dry Water Year** (Table 8.9; Figure 8.8)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 22 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

Recommended releases increase from 300 cfs on April 22 to 1,500 cfs on April 24 to attain peak release magnitudes for the Critically Dry water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

> “A 36-day peak release of 1,500 cfs . . . inundates most alternate bar surfaces, preventing germination of riparian plants for a portion of the seed-release period.”

Table 8.9. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Critically Dry water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall-run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 22	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 24	300 - 1,500	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
Apr 24 - Apr 29	1,500	Peak flow	Provide non-lethal water temperatures to Weitchpec for steelhead smolts (≤ 59º F) until May 22 , and for coho salmon smolts (≤ 62.6º F) until May 29 Inundate bar flanks (1,500 cfs)	Sustain steelhead and coho salmon smolt production by providing non-lethal temperatures for survival Discourage riparian vegetation establishment along channel margins	Transport limited amounts of surface fine sediment (<5/16 inch)
May 29 - Jun 26	1,500 - 450	Descending limb	Descend at a rate mimicking pre-TRD descent Provide non-lethal water temperatures to Weitchpec for coho smolts (≤ 62.6º F) until June 4, and for chinook smolts (≤ 68º F) until mid-June	Minimize river stage change to preserve egg masses of yellow legged frogs Inundate point bars Improve salmonid smolt production by providing temperatures necessary for survival of steelhead, coho, chinook smolts	Prevent riparian initiation along low water channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Maintain seasonal variable water surface levels in side channel and off-channel wetleands Sustain/ improve salmonid smolt production Provide outmigration cues for chinook salmon smolts
Jun 26 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

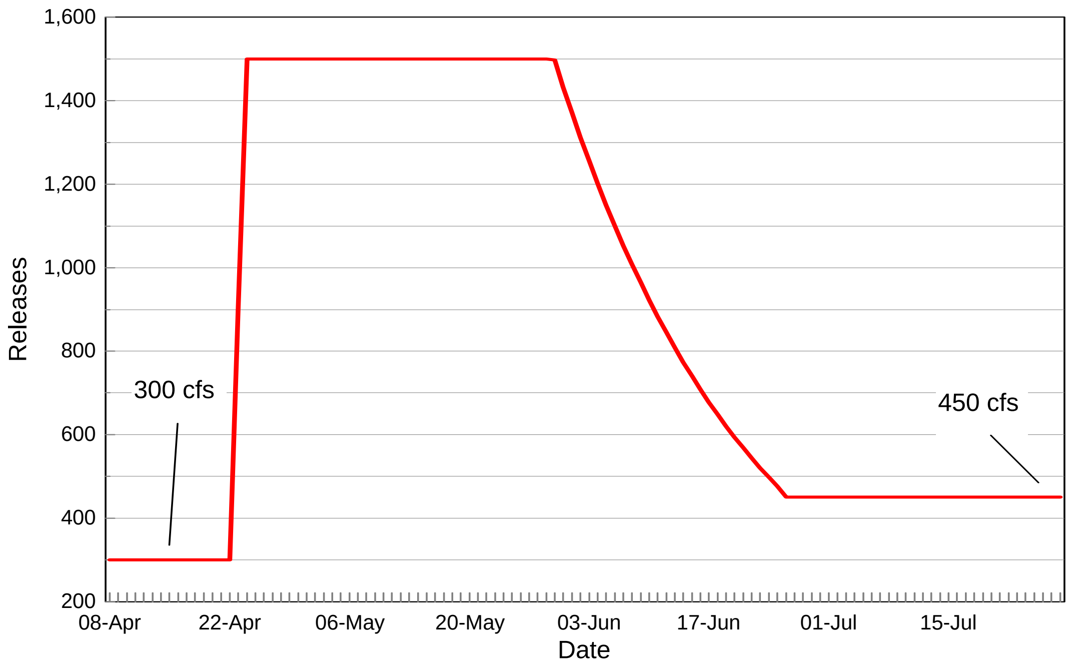

Figure 8.8. Recommended releases during a Critically Dry water year. Releases are scheduled for 450 cfs from June 26 to October 15. Releases are scheduled for 300 cfs from October 16 to April 22.

A 36-day peak release of 1,500 cfs from April 24 to May 29 inundates most alternate bar surfaces, preventing germination of riparian plants for a portion of the seed-release period. The timing of the fluvial geomorphic peak release mimics the historical timing of the snowmelt peak during Dry water years.

Releases gradually decrease from 1,500 cfs on May 29 to 450 cfs on June 26. The rate of this decrease mimics historical conditions during Critically Dry water years (the dry water year descending limb was used because data representing Critically Dry water years were sparse). Releases during part of this period inundate lower alternate bar features, preventing germination of riparian plants on the bars. The gradual reduction of releases will also minimize the probability of stranding of fry and juvenile salmonids. During this period, releases provide at least marginal temperatures for coho salmon and chinook salmon smolts throughout most of the mainstem until late June. The gradual reduction of releases also allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

> "Releases during part of this period [the decline from 1,500 to 450 cfs] inundate lower alternate bar features, preventing germination of riparian plants on the bars. The gradual reduction of releases will also minimize the probability of stranding of fry and juvenile salmonids."

A release of 450 cfs from June 26 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

> "Instead of attempting to mimic winter floods and the associated fluvial processes during winter, these fluvial process requirements are met on a reduced scale during the snowmelt peak . . . . Recommended summer baseflows are stable and comparatively greater than those that historically occurred, but necessary to meet the thermal requirements of holding spring-run chinook salmon and spawning spring- and fall-run chinook salmon."

8.1.5 Comparison of Recommended Releases with Unregulated Hydrographs and Downstream Flows

Release schedules developed for each water-year class show the differences in recommended schedules to unregulated hydrographs at Lewiston (Figures 8.9 to 8.13). Although some components of the recommended hydrographs are similar to unregulated flows (timing of the snowmelt peak and the shape of the descending limb of the snowmelt hydrograph), other components (winter and summer flows) are dissimilar.

Frequent winter storm events, especially during Wet and Extremely Wet water years (Figures 8.9 and 8.10), were responsible for major reshaping of the pre-TRD channel morphology and maintaining the riparian community in an early seral stage, which promoted the alluvial nature of the river. Recommended releases during the winter are comparatively low to meet the microhabitat needs of spawning and rearing salmonids that must spawn and rear in the mainstem below Lewiston Dam. Instead of attempting to mimic winter floods and the associated fluvial processes during winter, these fluvial process requirements are met on a reduced scale during the snowmelt peak. This change in the timing of each year's peak flow decreases the potential of scouring redds and causing mortality of developing eggs and sac fry.

Recommended summer baseflows are stable and comparatively greater than those that historically occurred, but necessary to meet the thermal requirements of holding spring-run chinook salmon and spawning spring- and fall-run chinook salmon. As a result of construction and operation of the TRD, deep thermally stratified pools that provided summer/fall holding habitat no longer exist and releases must now be managed to provide suitable thermal regimes during this period. The lost habitats above Lewiston Dam also historically provided cool refuge because this reach of the river was largely dominated by snowmelt.

Although recommended releases for a water-year class remain the same, intra- and inter-annual flow variability will occur because of flow accretion. The unregulated flow accretion of the tributaries between Lewiston Dam (RM 111.9) and Douglas City (RM 87.7) for water years 1945 to 1951 was determined by subtracting the flow at Lewiston from the flow at Douglas City. The resulting accretion for each water year was then added to the recommended releases of the appropriate water-year class to illustrate the effect of tributary accretion below Lewiston Dam (Figures 8.14A-G). The resulting hydrographs show that substantial intra-annual flow variability will occur within the mainstem. This flow variability, especially during the late fall and winter spawning seasons, will reduce superimposition of redds by distributing spawners as flows fluctuate. Tributary accretion will also help achieve/improve some fluvial geomorphic objectives, as indicated by reduction of recommended channel-rehabilitation sites in reaches farther downstream from Lewiston Dam.

> "Although recommended releases for a water year class remain the same, intra- and inter-annual flow variability will occur because of flow accretion."

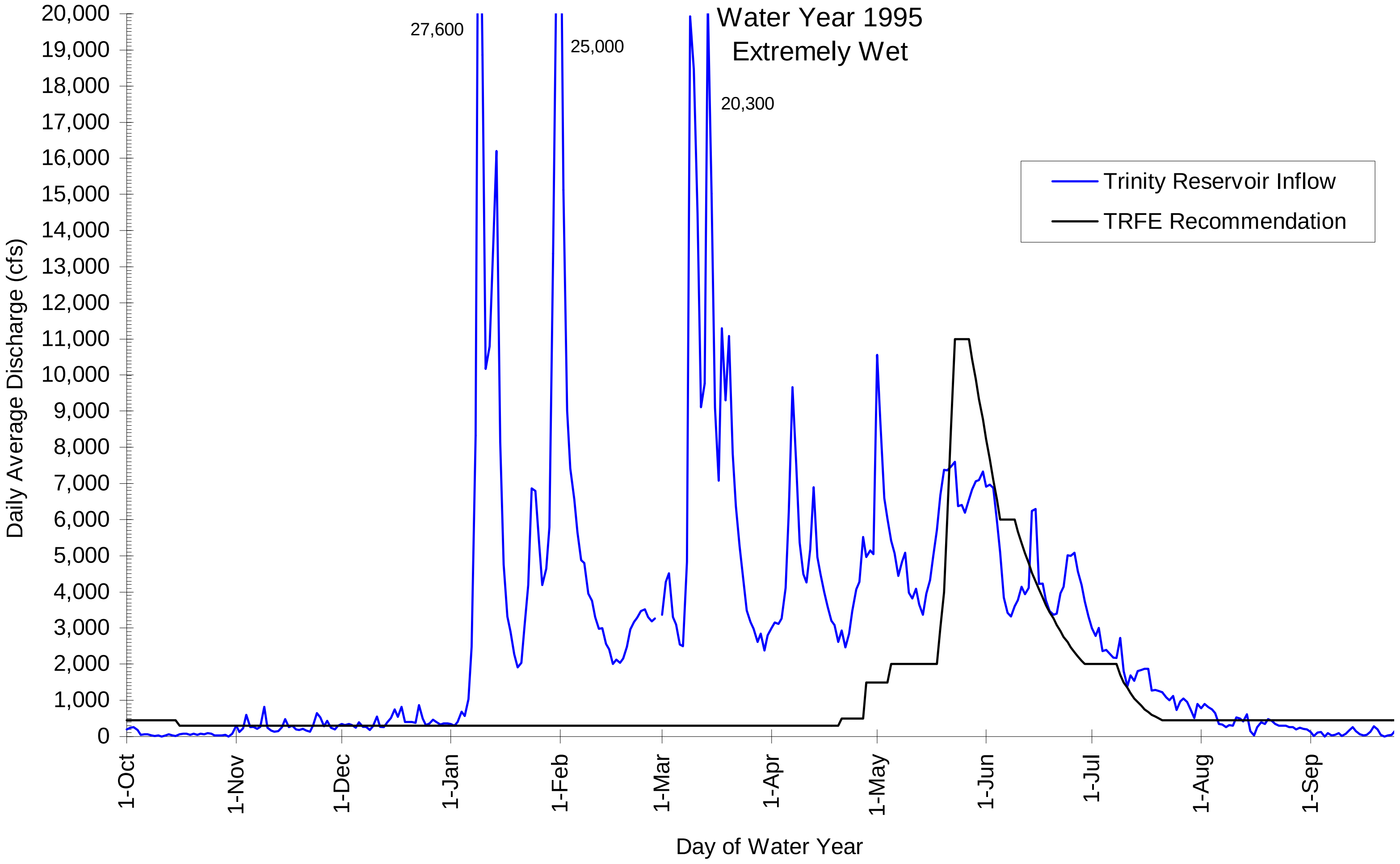

Figure 8.9. Recommended releases during an Extremely Wet water year compared to unimpaired inflow into Trinity Lake for WY 1995. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

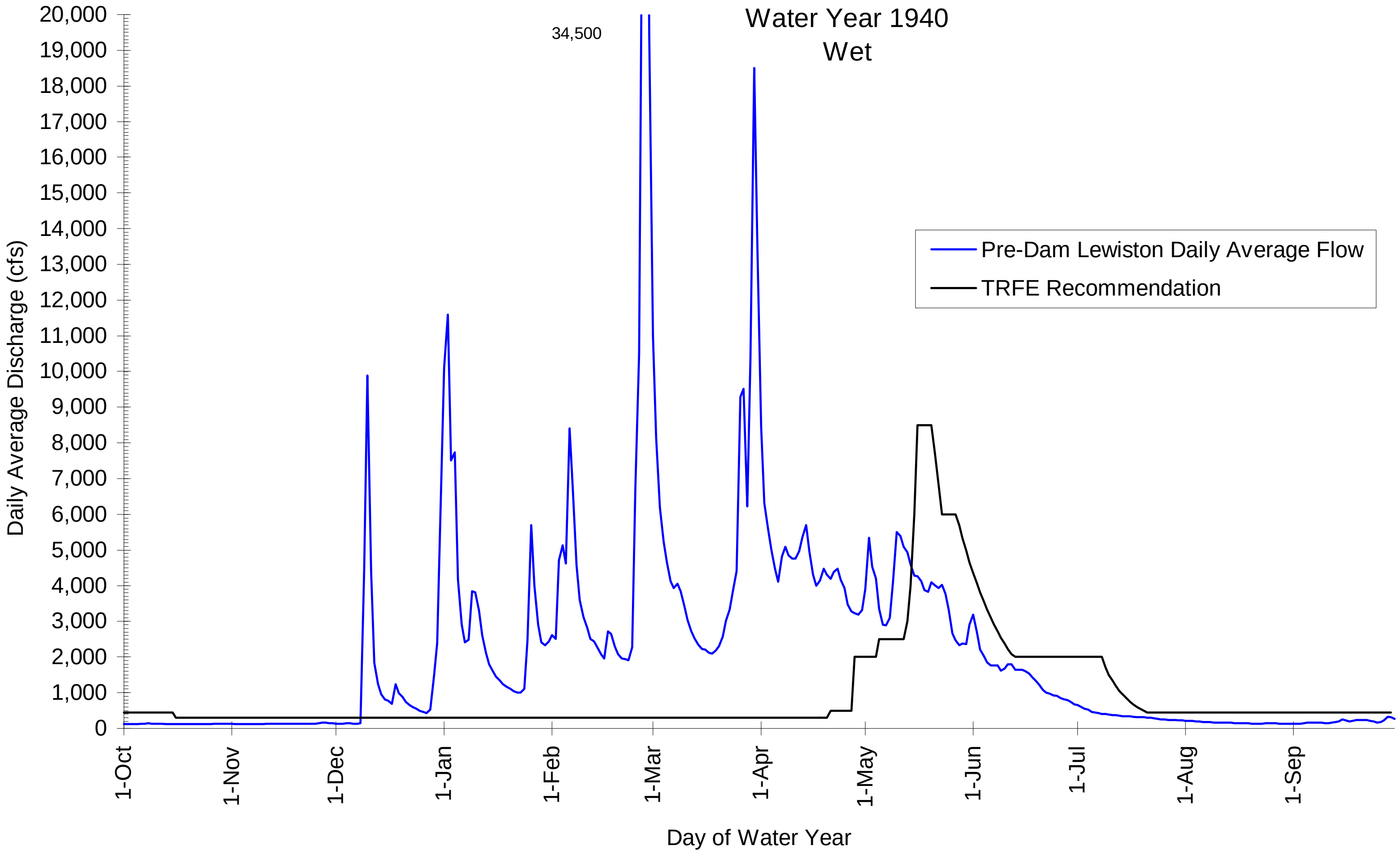

Figure 8.10. Recommended releases during a Wet water year compared to flow in WY 1940. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

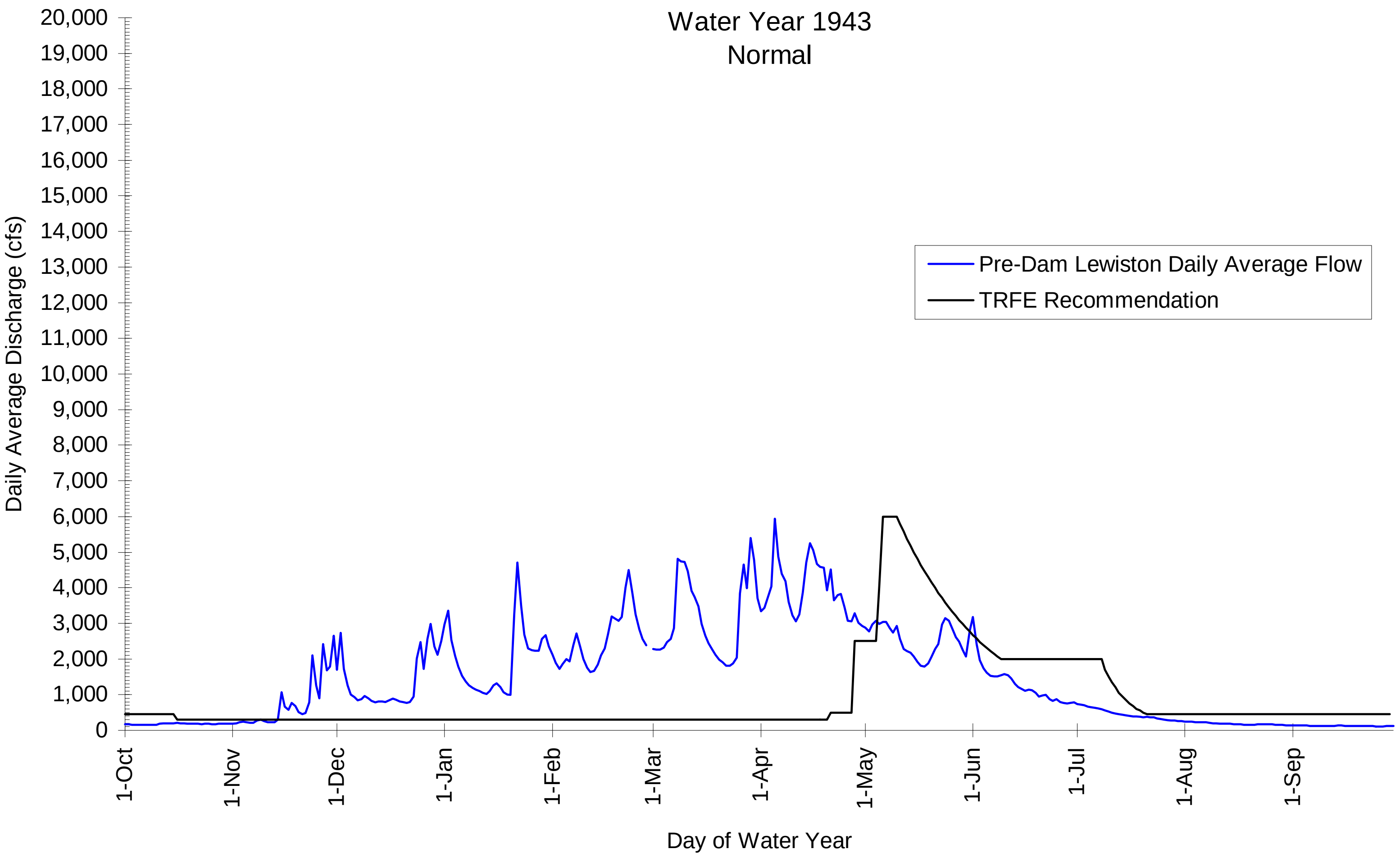

Figure 8.11. Recommended releases during a Normal water year compared to flow in WY 1943.

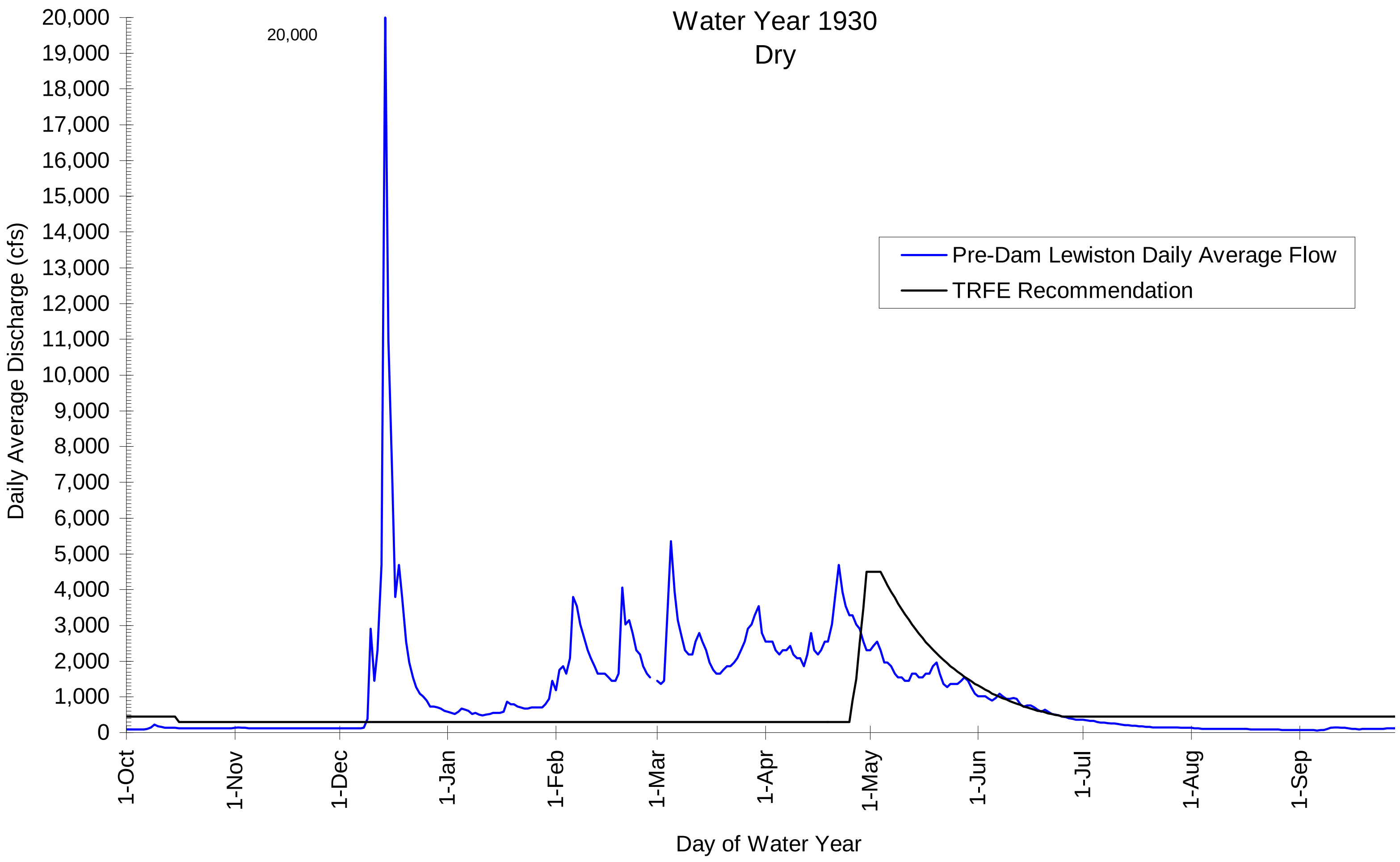

Figure 8.12. Recommended releases during a Dry water year compared to flow in WY 1930. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

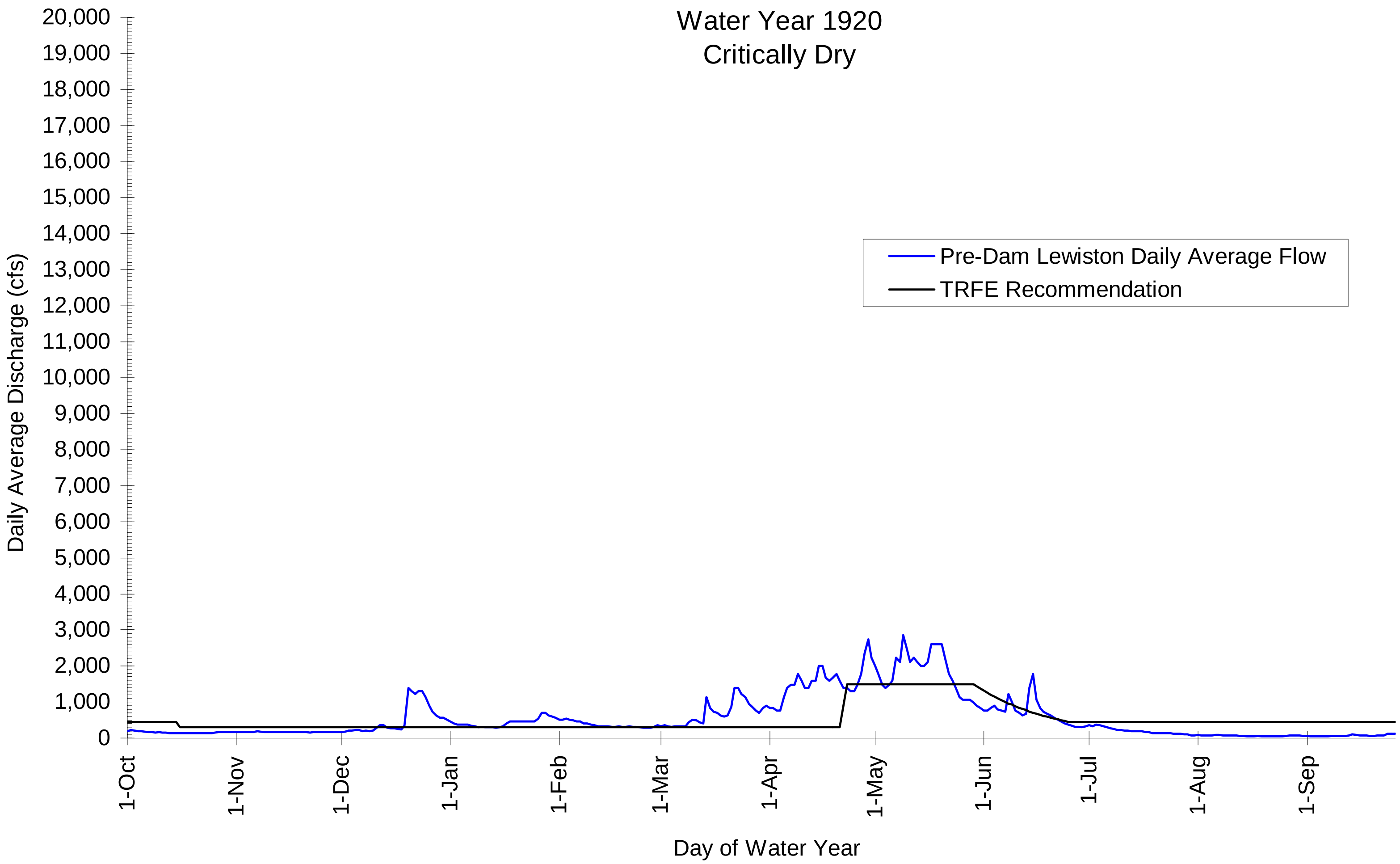

Figure 8.13. Recommended releases during a Critically Dry water year compared to flow in WY 1920.

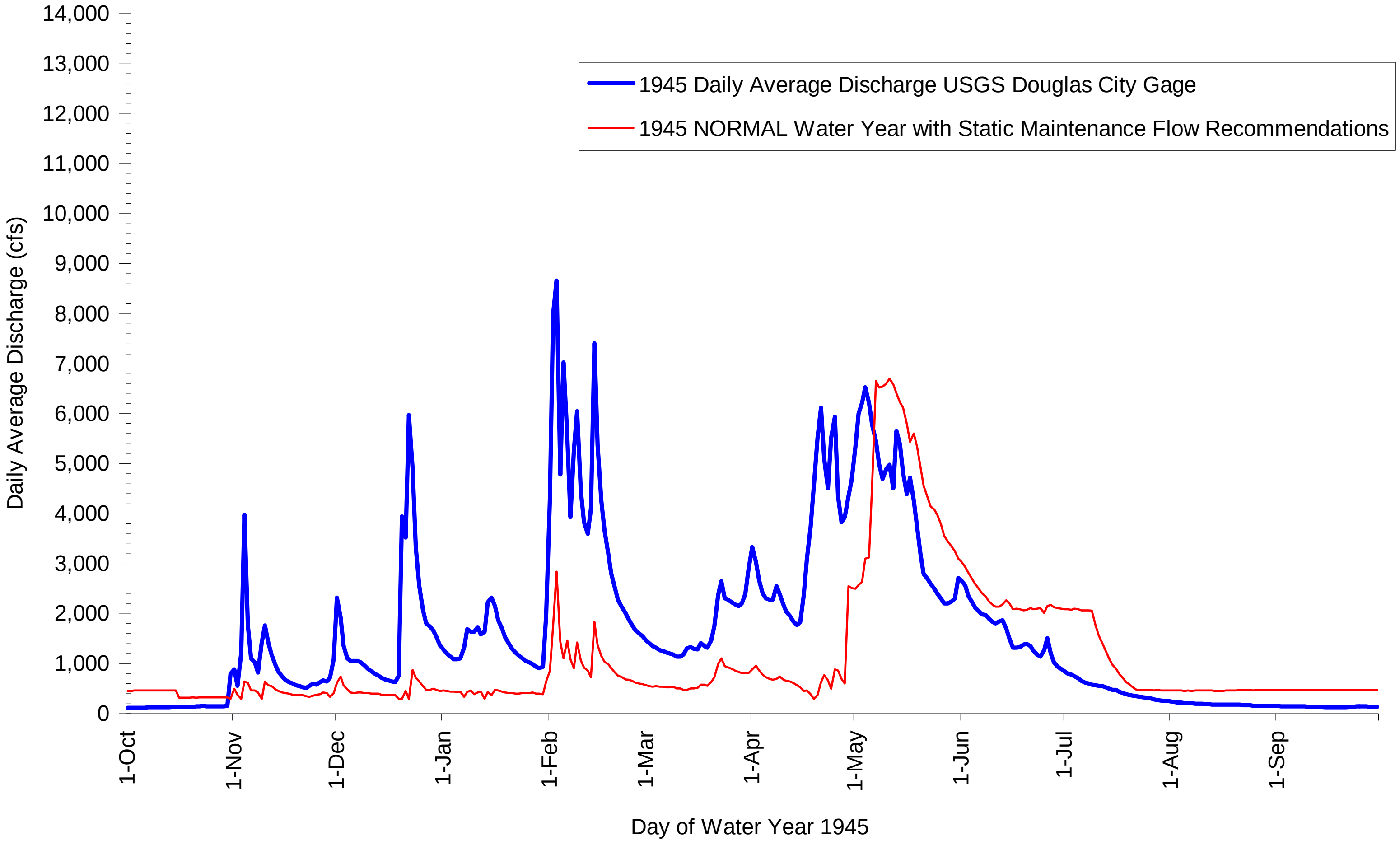

Figure 8.14a. Hypothetical discharge at Douglas City gaging station with normal water-year class release from the TRD and tributary accretion for water year 1945.

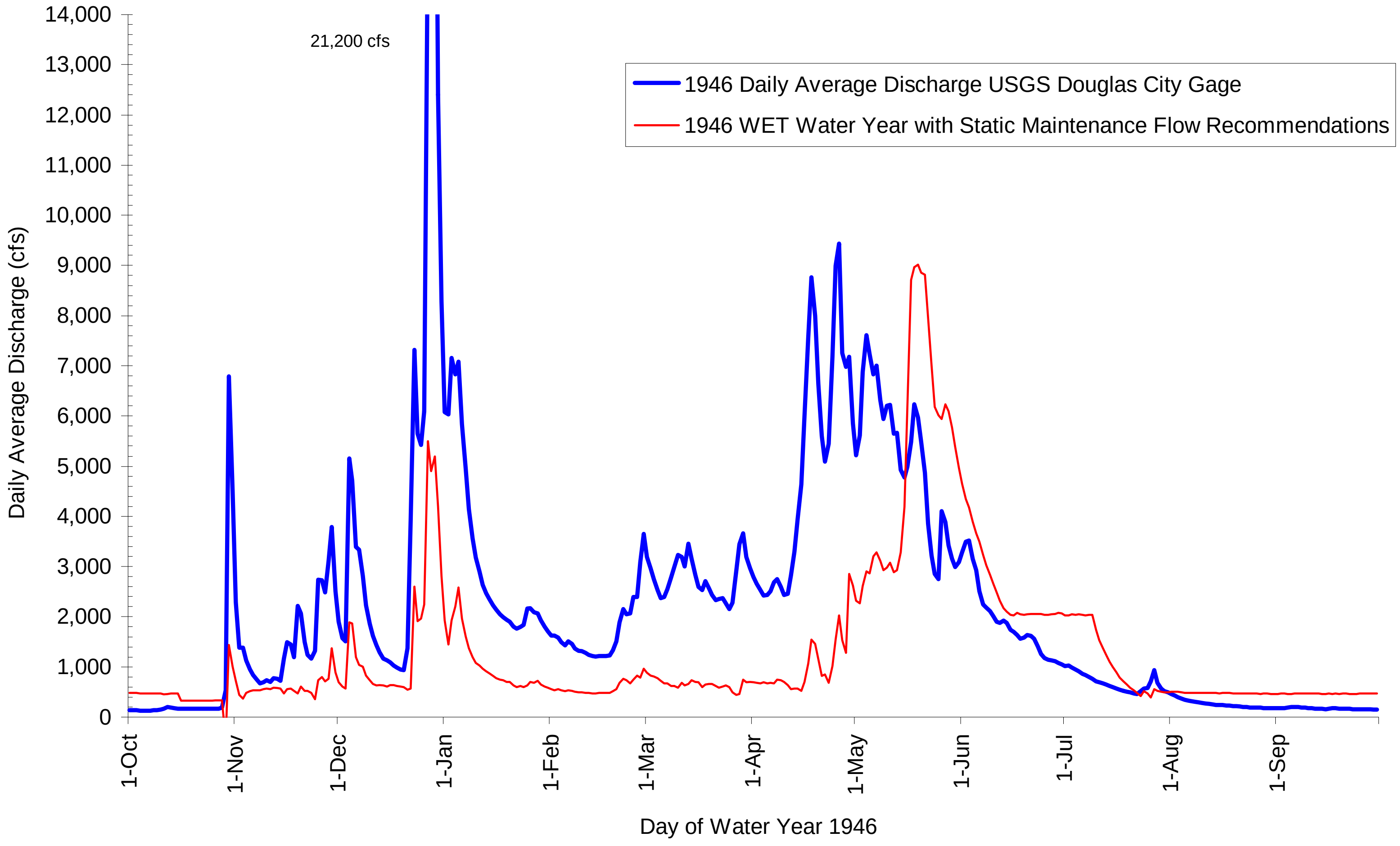

Figure 8.14b. Hypothetical discharge at Douglas City gaging station with wet water-year class release from the TRD and tributary accretion for water year 1946. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

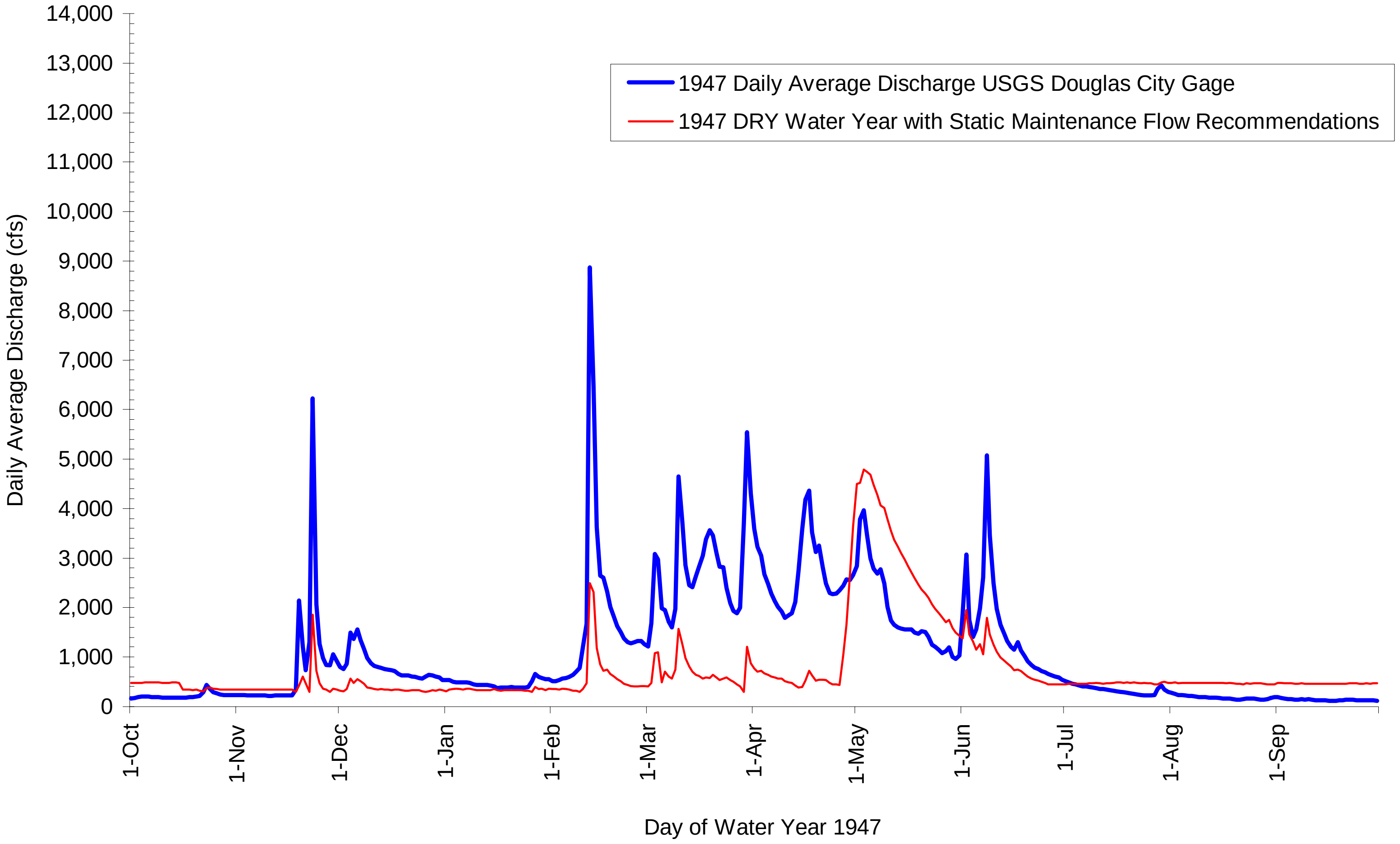

Figure 8.14c. Hypothetical discharge at Douglas City gaging station with dry water-year class release from the TRD and tributary accretion for water year 1947.

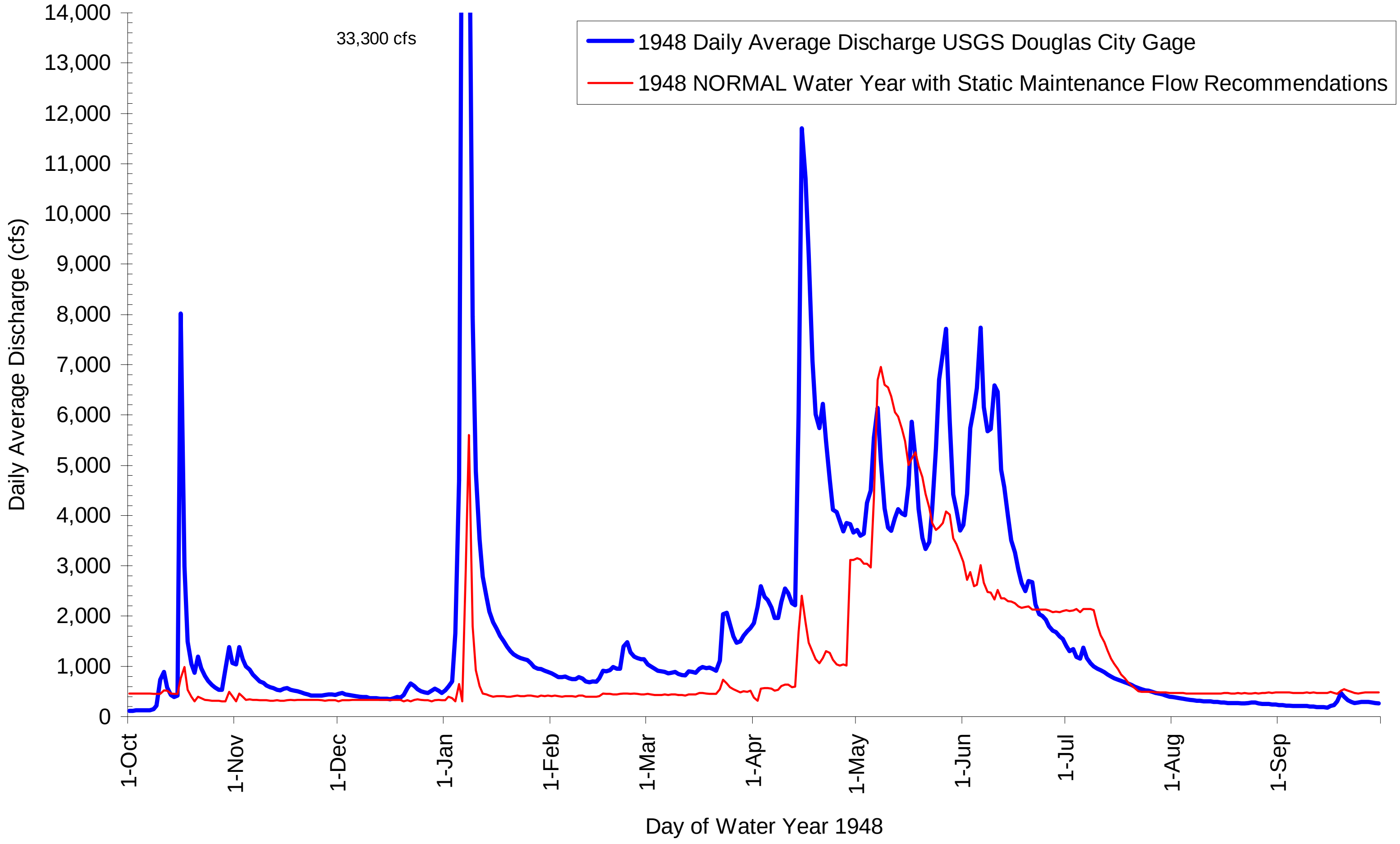

Figure 8.14d. Hypothetical discharge at Douglas City gaging station with normal water-year class release from the TRD and tributary accretion for water year 1948. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

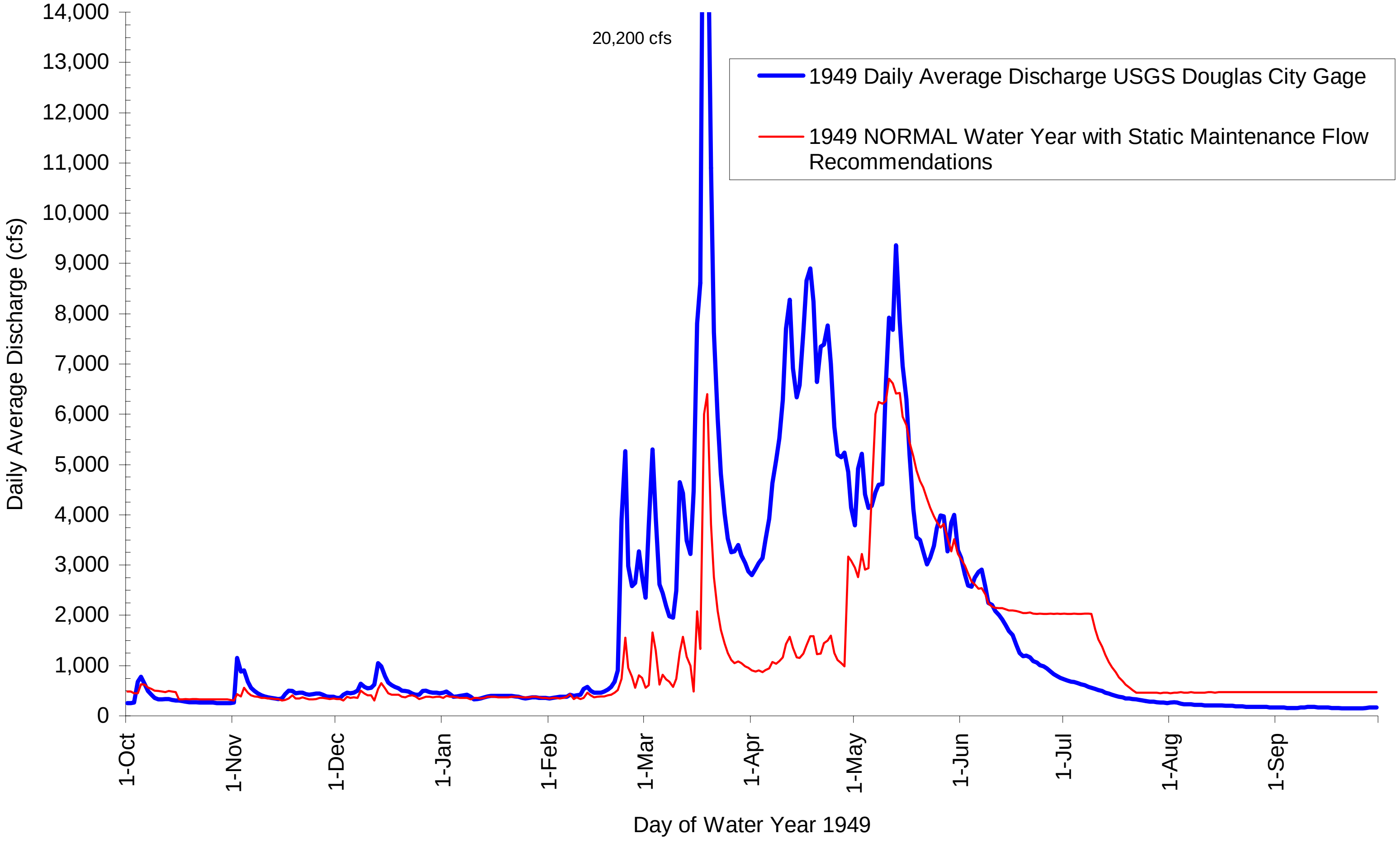

Figure 8.14e. Hypothetical discharge at Douglas City gaging station with normal water-year class release from the TRD and tributary accretion for water year 1949. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

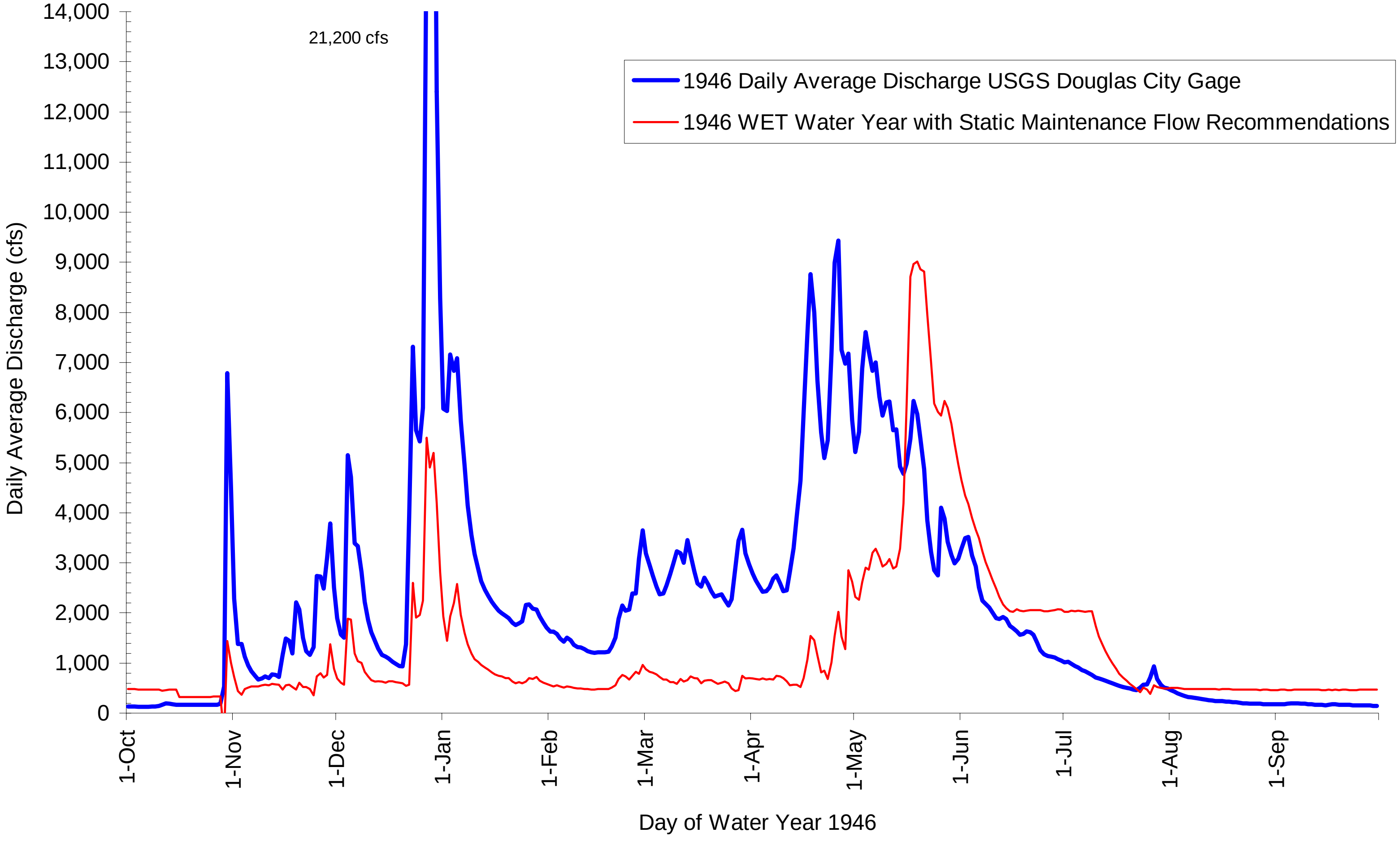

Figure 8.14f. Hypothetical discharge at Douglas City gaging station with wet water-year class release from the TRD and tributary accretion for water year 1946. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

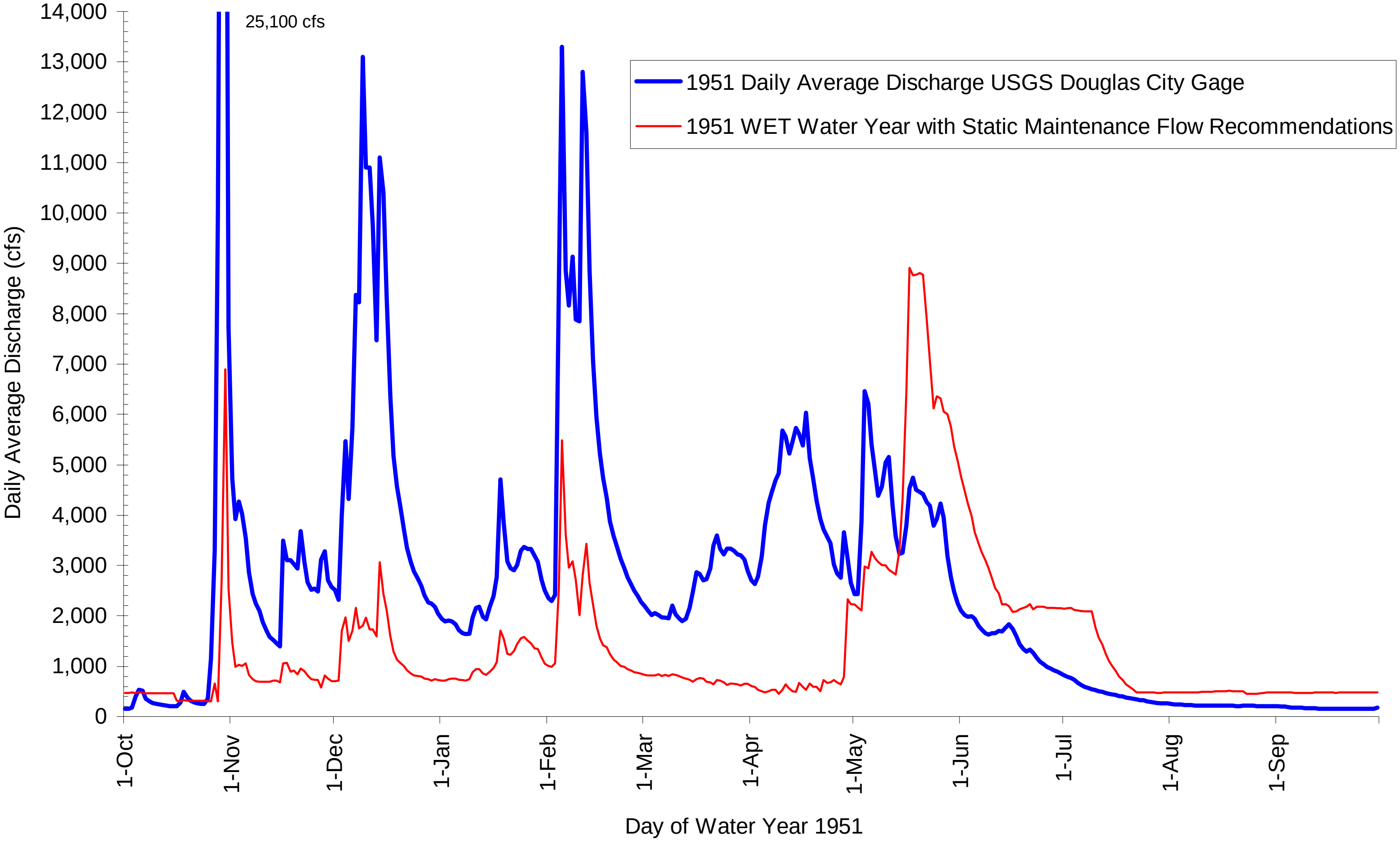

Figure 8.14g. Hypothetical discharge at Douglas City gaging station with wet water-year class release from the TRD and tributary accretion for water year 1951. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

8.2 Sediment Management Recommendations

Sediment management recommendations involve four separate actions: (1) immediate placement of coarse sediment (>$^5/_{16}$ inch) to restore spawning gravels lost through mainstem transport between Lewiston Dam and Rush Creek; (2) annual supplementation of coarse sediment (>$^5/_{16}$ inch) to balance the coarse sediment budget in the Lewiston Dam to Rush Creek reach; (3) fluvial reduction of fine sediment (<$^5/_{16}$ inch) storage in the mainstem; and (4) mechanical reduction of fine sediment (<$^5/_{16}$ inch) storage in the mainstem. Additionally, recommended channel-rehabilitation projects (Section 8.3) will remove a significant amount of the fine sediment that is now stored (more than 1 million yd^3) in the riparian berms between Lewiston and the North Fork Trinity River confluence. Floodplains created as part of these projects will encourage fine sediment transported during high flows to deposit on the floodplains, thereby reducing in-channel storage.

> "High releases through 1993 to 1998 depleted spawning gravels immediately below Lewiston Dam, causing channelbed degradation . . . "

8.2.1 Short-Term Coarse Sediment Supplementation

There are two sites that require immediate coarse sediment supplementation: a 1,500 foot reach immediately downstream from Lewiston Dam (RM 111.9), and a 750 foot reach immediately upstream from the USGS cableway at Lewiston (RM 110.2) (Figure 8.15). The Lewiston Dam site last received spawning gravel supplementation in 1998. However, supplementation immediately below the Dam has not been sufficient to offset gravel transport. High releases in 1993 through 1998 caused channelbed degradation to a depth of approximately 2 feet. Restoring 2 feet of bed elevation in the Lewiston Dam reach will require approximately 10,000 yd^3 of properly graded gravel material.

The USGS cableway reach has also lost spawning gravels, degrading substantially (approximately 2 feet) over the past several years. Restoring 2 feet of bed elevation in this reach will require approximately 6,000 yd^3 of properly graded gravel material. Because the immediate benefit of gravel added to both sites will be for spawning and rearing habitat, the sizes should range from $^5/_{16}$ inch to 5 inches. The first source for gravel should be the 2,000 yd^3 of screened gravel stored at the Old Lewiston Bridge. Additional gravel may be obtained at dredge tailings downstream from Lewiston. Dredge tailings on the south bank near Lewiston (RM 108.5) and on the west bank at Gold Bar (RM 106.3) are the nearest sources. A secondary benefit realized by utilizing these dredge tailings will be the conversion of these areas to functioning floodplains with riparian vegetation.

8.2.2 Annual Coarse Sediment Introduction

Maintaining a coarse sediment balance in the reach from Lewiston Dam to Rush Creek will require annual augmentation to replace sediment transported by peak flows. Estimates of coarse sediment (>$^5/_{16}$ inch) transport during high flows for each water-year class were used to calculate replacement volumes (Table 8.10). Dredge tailings downstream from Lewiston (RM 108.5) and Gold Bar (RM 106.3) should again be used as the sediment source. Tailing materials should be screened to a size of $^5/_{16}$ to 5 inches to maximize immediate spawning benefits. Two placement methods are recommended: (1) mechanical placement in the two riffles described above in the short-term supplementation sites; and (2) insertion into the large standing wave at the Lewiston Gaging station (RM 110.9) during peak releases. Placement of gravel in the riffles should occur after annual peak releases to replace coarse bed material transported during the peak release. Coarse sediment should be

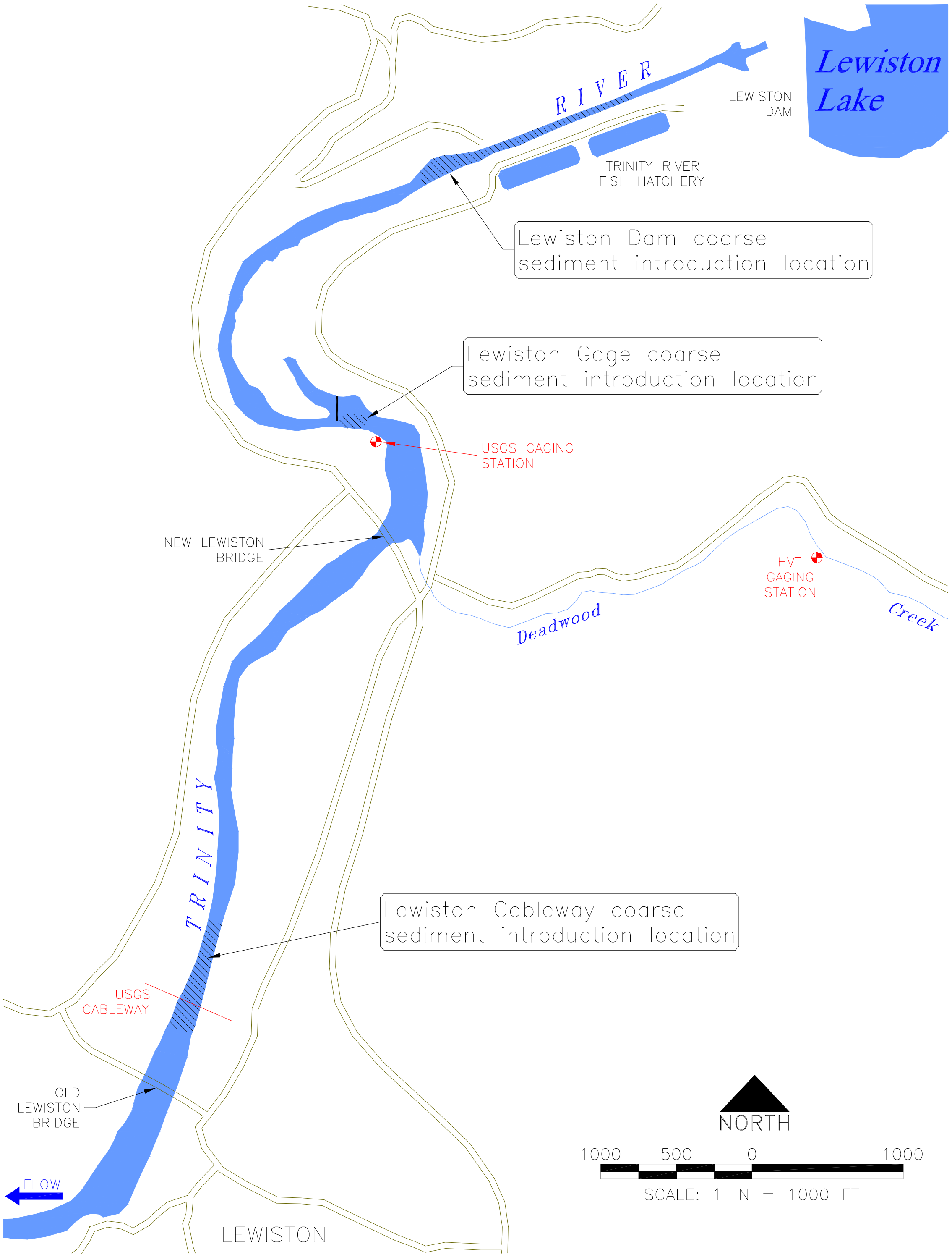

Figure 8.15. Trinity River (RM 109.8 - 111.5) priority coarse sediment supplementation locations.

Table 8.10. Annual coarse sediment replacement estimates for the Lewiston Dam to Rush Creek reach. Actual volume will be determined by modeled and measured transport each year.

Water Year	Coarse Sediment Introduction (yd^3/year)
Extremely Wet	31,000 - 67,000
Wet	10,000 - 18,000
Normal	1,800 - 2,200
Dry	150 - 250
Critically Dry	0

placed into the standing wave at the Lewiston Gaging station during peak releases to facilitate fluvial distribution downstream.

8.2.3 Fine Sediment Reduction: Sedimentation Ponds

Buckhorn Dam and Hamilton Ponds have reduced fine sediment supply from the Grass Valley Creek watershed. Their operation and maintenance should be continued. A fundamental problem, however, has been rapid filling of Hamilton Ponds during high-flow events, and subsequent reduced trapping efficiency, allowing fine sediment to transport into the Trinity River. Funding and a sediment removal contract needs to be continually in place so that sediment deposited in the ponds can be removed during the storm season to maintain trapping efficiency. Most sediment trapped by the Hamilton Ponds is sand; however, the coarse sediment (>$^5/_{16}$ inch) should be screened from deposits and returned to the Trinity River at the mouth of Grass Valley Creek to help maintain adequate coarse sediment supply downstream and reduce the volume of spoils removed from Hamilton Ponds.

Hoadley Gulch (RM 109.8) is a small tributary entering the Trinity River 2 miles downstream from Lewiston Dam that contributes substantial quantities of sand to the Trinity River during large storm events. The volume of sand yielded to the Trinity River from Hoadley Gulch has not been quantified; therefore, no comparison of volume can be made with the sediment-transport capacity of the Trinity River. The relative importance of Hoadley Gulch's sand contribution in comparison with other tributaries (e.g., Rush Creek) should be evaluated to determine if a sedimentation pond is warranted.

8.2.4 Fine Sediment Reduction: Pool Dredging

Measurements and observations in pools downstream from Grass Valley Creek show that fine sediment storage is decreasing. Recommended flow regimes should further decrease in-channel fine sediment storage. Therefore, pool dredging is not recommended, but may be considered under the adaptive environmental assessment and management program (see Section 8.4).

> "Funding and a sediment removal contract needs to be continually in place so that sediment deposited in the ponds can be removed during the storm season to maintain trapping efficiency."

8.3 Channel Rehabilitation

Channel-rehabilitation recommendations fall into four categories:

1. Bank rehabilitation on a forced-meander bend (Figure 8.16);
2. Alternate bar rehabilitation over longer reaches (Figure 8.17);
3. Side channel construction over short reaches (Figure 8.18); and
4. Tributary delta maintenance. Local removal of the very coarse sediment (boulders) that causes aggradation and hydraulic backwater effects upstream from deltas.

The Service and Hoopa Valley Tribe identified 44 potential channel-rehabilitation sites (Appendix G, Plate 1), 3 potential side channel-rehabilitation sites (Appendix G, Plate 2), and 2 tributary delta maintenance sites in the reach between Lewiston Dam and the North Fork Trinity River. These sites are located where channel morphology, sediment supply, and high-flow hydraulics would encourage a dynamic, alluvial channel (Table 8.11). A short implementation period for a significant number of these projects and an evaluation of whether they achieve their intended benefits is recommended. Those benefits— increasing quality and quantity of salmonid habitat— need to be balanced by logistics, contractor availability, and construction windows. Therefore, construction of 24 of the 44 channel-rehabilitation sites in the first 3 years is recommended. The remaining projects may proceed following a re-evaluation by the Adaptive Environmental Assessment Management Program (see Section 8.4).

The Lewiston Dam to Rush Creek and Rush Creek to Indian Creek reaches are distinctly different from those downstream owing to the considerable accretion of flows and sediment downstream from Indian Creek. As a result, unique strategies are recommended for each reach:

> "These [channel rehabilitation] sites are located where channel morphology, sediment supply, and high-flow hydraulics would encourage a dynamic, alluvial channel."

Lewiston Dam to Rush Creek (RM 111.9 to RM 107.5)

- Construct bank rehabilitation and alternate bar rehabilitation projects that include building skeletal point bars after riparian berms are removed to encourage development of alternate bars and increase coarse sediment supply in the reach. Skeletal bars would have a framework of large cobbles (> 5 inches), covered by several feet of finer material ($^5/_{16}$ to 5 inches).
- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.
- Maintain existing side channels. Because coarse sediment supply is less than in downstream reaches, plugging by sediment deposition is less likely than for side channels downstream from Indian Creek.
- Remove the coarse fraction (boulders) of Rush Creek delta deposit to lessen backwater effect and improve sediment-routing from upstream reach.
- Construct three bank rehabilitation projects and two alternate bar rehabilitation projects during years 1-3 to increase habitat in this important spawning and rearing reach. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

Rush Creek to Indian Creek (RM 107.5 to RM 95.3)

- Construct bank rehabilitation and alternate bar rehabilitation projects that include building

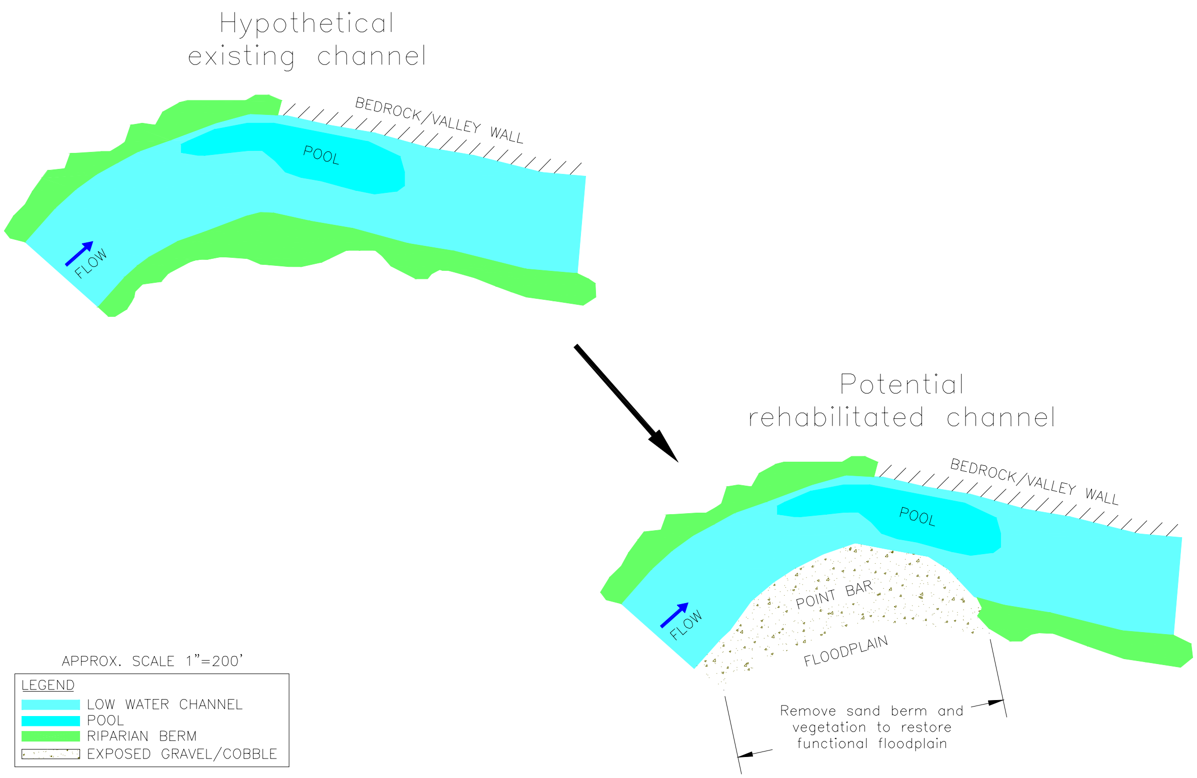

Figure 8.16. Trinity River conceptual single forced meander channel rehabilitations.

skeletal point bars after riparian berms are removed to encourage development of alternate bars and increase coarse sediment supply in the reach. Skeletal bars would have a framework of large cobbles (>5 inches), covered by several feet of finer material ($^{5}/_{16}$ to 5 inches).

- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.
- Maintain existing side channels. Because coarse sediment supply is less than in downstream reaches, plugging by sediment deposition is less likely than for side channels downstream from Indian Creek.
- Evaluate high-flow hydraulics of the two potential side channel sites, and construct these only if potential for self-maintenance is high.
- Remove the coarse fraction (boulders) of Indian Creek delta deposits to lessen the backwater effect and improve sediment-routing from upstream reach.
- Construct 7 of the 14 bank and alternate bar rehabilitation projects in years 1-3. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

Indian Creek to Dutch Creek (RM 95.3 to RM 86.3)

- Because coarse sediment supply and tributary flood events are increasing downstream from Indian Creek, construction of skeletal point bars may not be required. Simply removing the riparian berm at key

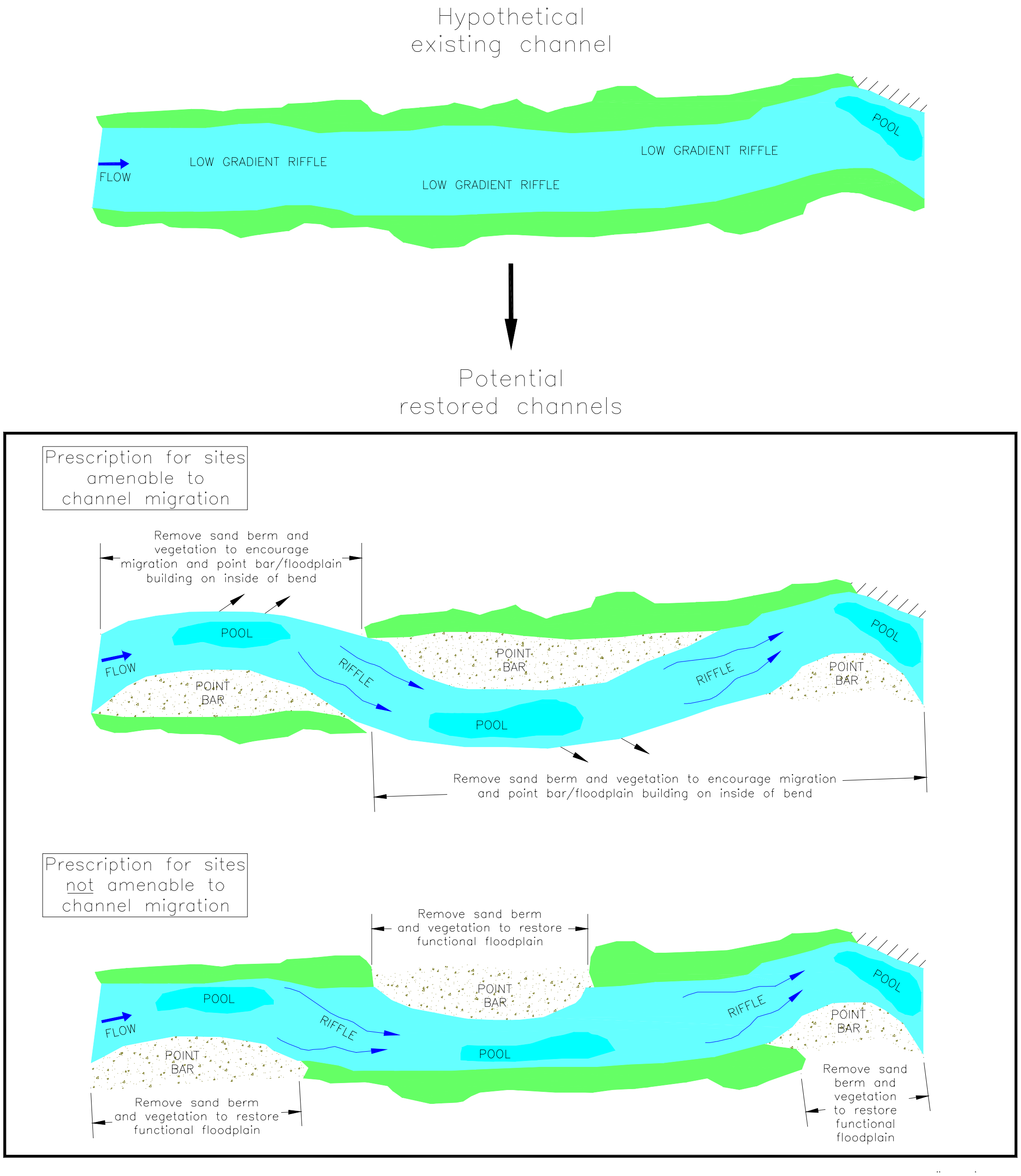

Figure 8.17. Trinity River conceptual alternate bar channel rehabilitation.

locations may induce alternate bars to form during high flows. If bar formation does not occur following first years of high flows, construction of skeletal bars (described above) should be considered in subsequent years.

- Construct five of the seven bank and alternate bar rehabilitation projects in years 1-3. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

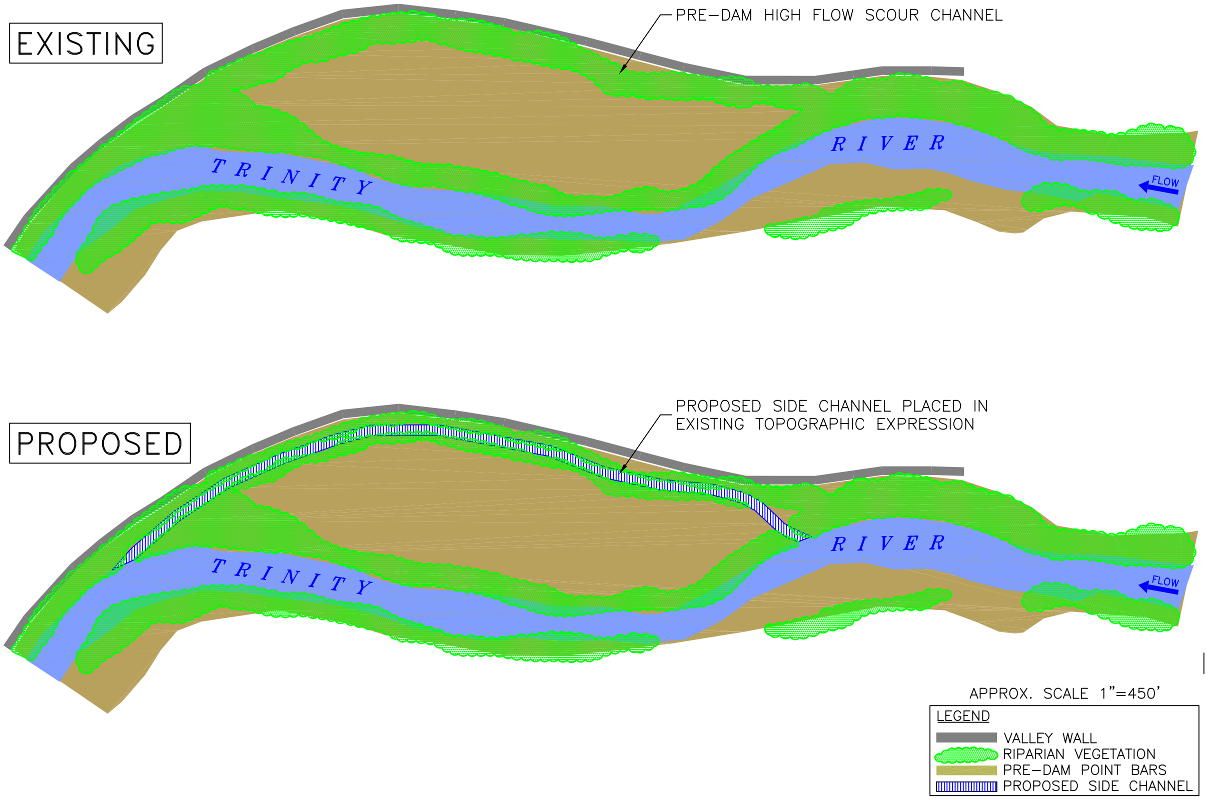

Figure 8.18. Trinity River conceptual side channel rehabilitation.

- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.
- Evaluate high-flow hydraulics of side channel site, and construct only if potential for self-maintenance is high.
- Evaluate whether constructed side channels should be abandoned. Because this mainstem segment is considerably more dynamic than upstream segments, maintenance of side channels will be costly.

Dutch Creek to North Fork (RM 86.3 to RM 72.4)

- Bank and alternate bar rehabilitation projects in this reach are not likely to require skeletal bars to be constructed, because coarse sediment supply and flow accretions increase substantially downstream from Indian Creek. Simply removing the riparian berm at key locations will likely induce alternate bars to form during subsequent high flows. If bar formation does not occur following initial high flows, construction of skeletal bars (described above) should be considered in subsequent years.
- Construct 7 of the 18 bank and alternate bar rehabilitation projects in years 1-3. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

Table 8.11. Potential channel-rehabilitation sites between Lewiston Dam and the North Fork Trinity River.

Reach	River Mile	Potential bank rehabilitation sites	Potential alternate bar rehabilitation sites	Potential side-channel sites
Lewiston Dam to Rush Creek	111.9 - 107.5	3	2	0
Rush Creek to Indian Creek	107.5 - 95.3	7	7	2
Indian Creek to Dutch Creek	95.3 - 86.3	3	4	1
Dutch Creek to North Fork Trinity River	86.3 - 72.4	10	8	0
Total		23	21	3

- Evaluate high-flow hydraulics of potential side channel site, and construct only if potential for self-maintenance is high.

- Channel-rehabilitation projects should be larger in this reach than in upstream reaches because of increasing channel size and channel-forming flows. Reshaping floodplain areas and low terraces, especially in areas adjacent to dredge tailings, will be required.

- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.

- Abandon constructed side channels and incorporate these areas into floodplains.

- Incorporate constructing off-channel wetlands and oxbow ponds into rehabilitation projects, specifically in projects with adjacent dredge tailings.

8.4 AEAM Recommendations to Monitor and Refine the Annual Operating Criteria and Procedures (OCAP) and Other Recommendations for Restoring and Maintaining the Trinity River Fishery Resources

This Trinity River Flow Evaluation Report concludes that the river channel has degraded to such an extent that simply managing flow releases from the existing reservoirs cannot achieve the salmonid restoration goals mandated by Congress. The primary hypothesis is that a combination of managed high-flow releases, mechanical riparian berm removal, and gravel augmentation will redirect geomorphic processes so that a more complex channel form will evolve, creating the mosaic of aquatic habitats necessary to enhance freshwater salmonid production. Although many of the anticipated changes will be monitored on an annual or semiannual basis, longer-term monitoring and assessment must also occur concurrently due to the prolonged life-histories of salmonids. Over a longer time period, adult returns and the numbers of fish contributing to ocean and inriver fisheries will be a measure of success.

This Trinity River Flow Evaluation Report concludes that the river channel has degraded to such an extent that simply managing flow releases from the existing reservoirs cannot achieve the salmonid restoration goals mandated by Congress.

Reservoir releases and channel-rehabilitation projects should substantially increase carrying capacity (usable salmonid rearing habitat area) within the rehabilitated channel. What is not known is the rate of change or time frame needed to achieve this new channel equilibrium. AEAM (Appendix N) will facilitate achieving the salmonid restoration goals. The management actions prescribed include channel rehabilitation in combination with annual reservoir releases based on forecasted water supply and the recommended flow regime for the water-year class based on the hydrographs presented in this chapter. These water year flow regimes, each with unique hydrograph components, provide the inter-annual variability necessary to drive the fluvial processes toward a new channel configuration while maintaining the hydraulic and temperature conditions at levels that are greater in quality than those existing since the closure of the dams.

8.4.1 Goals and Objectives for the Trinity River

One of the stated goals for the Trinity River is "... the development of recommendations regarding permanent instream fishery flow requirements and Trinity River Division operating criteria and procedures for restoration and maintenance of the Trinity River fishery" (Central Valley Project Improvement Act, Title XXXIV of P.L. 102-575). This report recommends five flow regimes (Appendix M), including operating criteria and procedures for each water-year class. Primary objectives of the recommendations are:

1. Manage the reservoir releases to provide a much improved (near optimum) temperature regime. An optimum temperature regime increases fish residence time and growth rates, resulting in larger smolts exiting the system. Larger smolts have better survival leading to an increase in number of returning adults.

2. Manage the river corridor to increase the shallow-edgewater and backwater habitats necessary for many anadromous young-of-year salmonids.

3. Manage reservoir releases to control vegetation establishment on alluvial features. Schedule reservoir releases to scour seedlings on bars following the seed fall during the spring-summer period. Investigate superimposing reservoir releases on tributary flows when the opportunity is present.

4. Manage reservoir releases within the evolving channel to optimize hydraulic conditions for spawning, incubation, and young-of-year production for a given water year and channel form. As the channel changes from the present trapezoidal form toward the desired alternating point bar configuration, the slope of the hydrograph should be adjusted annually to maximize suitable conditions for a given year.

8.4.2 Hypotheses

The premise of the Trinity River Flow Evaluation Report recommendations is that a combination of mechanical alterations and vegetation removal in addition to

The primary hypothesis of this flow evaluation is that a combination of managed high-flow releases, mechanical riparian berm removal, and gravel augmentation will redirect geomorphic processes so that a more complex channel form will evolve, creating the mosaic of aquatic habitats necessary to enhance freshwater salmonid production.

managed high-flow releases in the spring will promote geofluvial processes leading to a new channel form that is expected to provide significantly increased spawning and rearing habitat for anadromous salmonids. The assumptions, hypotheses, and logic upon which the recommended management actions presented in this report are based are summarized in Appendix O. Only the most prominent hypotheses are presented.

One of the central hypotheses is that habitat diversity in the upper river, both on the meso- and micro-habitat scale, will increase following the implementation of the recommendations. Although the changes in habitat diversity are expected to be obvious, there will remain a question as to degree of change. A methodology must be embraced to quantify the existing habitat diversity and the annual change created as the management recommendations are implemented. This will enable comparative evaluations to be made and elucidate the effectiveness of specific restoration measures.

A second hypothesis central to the recommendations is that juvenile salmonid rearing habitat, believed to be limiting smolt production in the Trinity River, will increase in both quantity and quality following the creation of a more complex and dynamic channel form. Rearing habitat area, which at present is highly variable depending on streamflow, will increase (at least a doubling) and become more stable over a wide range of flows.

The third central hypothesis is that salmonid smolt survival will improve as a result of better temperature conditions that increase growth and promote extended smoltification and reduced travel time associated with emigration.

Before proceeding with AEAM, this set of hypotheses and series of events is transformed into a set of measurable responses. By way of examples, we offer three initial quantification steps.

First, describe the existing channel geometry in two dimensions by sub-sampling along surveyed transects or grids. Sub-sampling should be sufficient to describe the bathymetry of the alternate bar pool sequences at upper, lower and middle portions of the river from Lewiston Dam to the North Fork Trinity River confluence. Transects should be geo-referenced so that monitoring measurements can be repeated. These measurements are needed to quantify the degree of bar formation, lateral movement, and establishment of woody vegetation attained on an annual basis. The straight trapezoidal channel should evolve toward a more sinuous alternate bar form having increased shallow water area and low-velocity backwaters critical for rearing young salmonids.

Second, the amount of habitat area available to provide suitable spawning and rearing conditions should be measured annually. Geomorphology, vegetation conditions, and salmonid habitat must be quantified using the same sampling strategy. The same strategy allows extrapolation describing 40 miles between Lewiston Dam and the North Fork Trinity River confluence.

Third, the length and weight of chinook salmon young-of-year can be sampled every few weeks from hatching through emigration from the stream study segment. Substantial trapping effort at the downstream end of the study segment is needed to estimate the total number of chinook salmon pre-smolts leaving the segment. These two sets of measurements can be used to estimate growth increments through the season and young-of-year production within the river. In addition to the hypotheses and water year rehabilitation objectives, the state of the knowledge is presented in Appendix O as a solid science foundation for the AEAMP to build upon.

8.4.3 Document Channel Form, Riparian Vegetation, and Salmonid Population Trends

Through comparison of annual measurements and the use of simulation modeling, progress toward the habitat and production objectives can be quantitatively expressed. Progress toward the program objectives and any trends identified should be reported annually to the stakeholders. This report may address the following questions:

Are salmonid population numbers (quantify as population estimates not just abundance indices) improving?

Is anadromous salmonid habitat improving?

Are native riparian communities establishing on different geomorphic surfaces? Are reservoir releases removing germinated vegetation?

Are the riparian berms continuing to build, are they remaining stable, or are they beginning to break down from Lewiston Dam to the North Fork Trinity River confluence?

Are channel reaches migrating laterally and becoming more dynamic?

Are floodplains forming?

Are alternate bars forming?

How does Trinity River water affect water quality of the Klamath River? There is evidence that water-quality conditions in the Klamath River may be, at times,

Causal Analysis – A Complement to Time Series

Monitoring often produces a time-series representation of the changes in a system. However, time is rarely the cause of the changes. AEAM focuses on causal analysis of monitoring data. Ordinarily the object of the monitoring occupies the x-axis, and is plotted against time (y-axis). While indicative of the trends in a system, time-series fail to directly expose the causes of the more obvious trends. Causal analysis replaces time on the abscissa with causative factors (e.g., habitat). A strong functional relationship indicates causation of trends in the system. The figures demonstrate the difference between a time-series and a causal analysis.

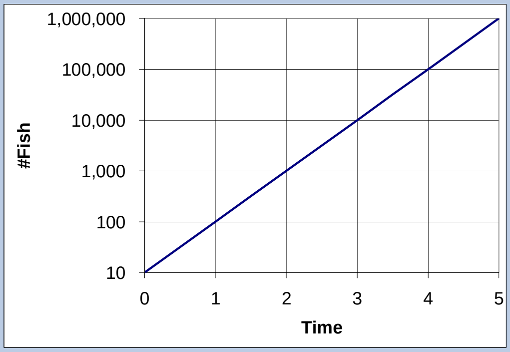

Figure 1. Time Series.

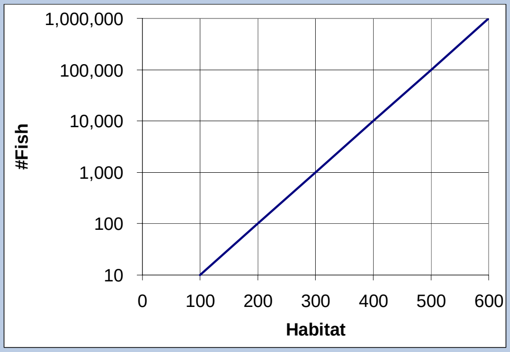

Figure 2. Causal Analysis.

While both figures show an increasing trend in the number of fish, Figure 2 illustrates a direct response in fish numbers given an increase in habitat area. Such causal analyses give management a stronger indication of the system controls.

substantially worse than those in the Trinity River. Will the difference in water quality occur during spring outmigration, especially in dry years? If so, how is this affecting smolt survival? What about other life stages?

8.4.4 Management Actions

The recommendations for management actions incorporate different schedules for flow releases under five defined water-year classes (determined by water-supply conditions measured each spring from mid-February through April). All year classes include a recommendation of high-flow releases in late April to mid-July and a program of gravel placement in the mainstem. These releases are recommended in addition to proposed riparian-berm-removal projects. The intent of riparian-berm-removal projects is to remove the densely vegetated riparian berms at selected sites along the river from Lewiston Dam downstream to the North Fork confluence.

Different April-July flow-release schedules are proposed for Normal, Wet, and Extremely Wet years such that in 6 out of 10 years the channel is predicted to change in cross section and planform. The goal is a meandering alternate bar configuration within the old floodplain. These water-year classes, each with unique hydrograph components, provide the inter-annual variability necessary to affect fluvial processes. A rehabilitated channel, although smaller in scale than the pre-TRD channel, could sustain perhaps two to four times the amount of salmonid rearing habitat now present. Results from SALMOD suggest that young-of-year production can be substantially increased if the rehabilitated channel attains a four-fold increase in the total available rearing habitat throughout the 40-mile reach below Lewiston Dam, all other things being equal (same average ocean survival and number of returning spawners and no further degradation of water quality, etc.).

The current recommendations were made in part, based on microhabitat studies in the existing channel. The existing baseline conditions can be quantitatively expressed as historical time series starting with streamflow and reservoir release records. The resulting hydrologic time series is input for SNTEMP (Theurer et al., 1984), PHABSIM (Milhous et al., 1989), and the Time Series Library (TSLIB) (Milhous et al., 1990) to produce a weekly estimate of the total usable habitat available throughout the study segment. The habitat time series is input to the SALMOD (Bartholow et. al., 1999) to produce a weekly time series of salmonid production estimates. This includes estimates of growth, downstream distribution, and number exiting the study segment.

Although the habitat-response hypotheses could be tested using the one-dimensional hydraulic and habitat models within PHABSIM, an alternative now exists. This alternative utilizes two-dimensional hydraulic models that provide major advancements in riverine habitat assessments. Many in the instream-flow-modeling community believe that two-dimensional hydraulic models are superior to their one-dimensional counterparts for simulating velocity distribution throughout river channel reaches (Ghanem et al., 1994; Leclerc et al., 1995). These advantages are particularly evident in complex river channels of the type it is hypothesized that the Trinity River will become as a result of the proposed management. These models are spatially explicit, allowing calculation of different measures of habitat environmental heterogeneity, and offer the potential to describe both spatial and temporal heterogeneity, in a single habitat metric. This new technology is recommended for evaluating habitat response to the proposed Trinity River AEAM actions.

8.4.5 Implement Actions

The AEAM program (see Section 8.4.2) will initiate its yearly cycle by convening each year in mid-February following initial water-supply forecasts provided by

Reclamation. Along with its other duties, the objective of the AEAM Program is to prescribe the precise magnitude and duration of reservoir releases confirming or modifying the OCAP for that year. These releases are based on the recommendations provided earlier in this chapter as well as other relevant information. The goals of the release schedule include mobilizing alluvial features established the previous year, scouring emergent riparian vegetation, and achieving sediment transport. Physical process modeling will aid the team in optimizing the reservoir release necessary to mobilize alluvial features and optimize lateral bank cutting. After the water year has been declared by Reclamation, these physical process models can simulate the remainder of the water year based upon the OCAP.

The degree of channel change can then be projected using the HEC-6 or other physical process models that predict aggradation or degradation of the channel. Kondolf and Micheli (1995) present a protocol for documenting changes in channel form. Reservoir release temperatures, downstream water temperature, usable habitat, and young-of-year chinook salmon production are all then simulated using the assumed reservoir release schedule and the physical model predicted channel changes. Annual estimates of returning adult chinook salmon spawners and the habitat state during the previous fall are important inputs to these simulations. Therefore, each annual production run is based on the latest empirical data (September-May) and simulated conditions for the remainder of the biological year (May-July).

8.4.6 Monitoring Program

Physical process numerical models are useful in two ways. First they require a systematic collection of data inputs. A well-designed monitoring program will yield the correct type, quality, quantity, and frequency of data. Second, they indicate where significant physical changes may occur, serving to focus monitoring activity in new, and perhaps unexpected, locations.

For example, the run mesohabitat type currently dominates the river above Dutch Creek. These runs are generally long and straight, confined by riparian berms on both sides. At the targeted rehabilitation sites, the removal of the riparian berm on one side of the river and the implementation of the prescribed flow regimes should produce alternate bar morphology with adjacent pools as is described in Section 4.1 of this report. Besides these major mesohabitat features, it is expected that additional mesohabitat types will also result, such as backwaters and riffle-pool transitional habitats. The number of different mesohabitat types and the proportion each represents should change significantly over current conditions, as should the range of hydraulic conditions present.

The annual evaluation of habitat changes at the mesohabitat level is straightforward. The types of pre-project mesohabitats present, the area each encompasses, and the proportion each represents in the reach will be compared with conditions in the previous year. A more detailed evaluation of habitat diversity is needed at the microhabitat scale.

The premise is that all habitat types are potentially important to the health of the anadromous salmonid community. Therefore, the monitoring objective is to quantitatively describe the mix of heterogeneous microhabitat types without regard to which species or life stage may or may not use a particular type. This is done by defining discrete, non-overlapping combinations of microhabitat characteristics and treating these in the same manner as individual species in developing community metrics.

Bain and Boltz (1989) introduced the concept of developing habitat suitability criteria to define habitat use guilds. The same concept can be applied to defining microhabitat types. For example, depth can be classified as shallow, moderate, or deep; likewise, velocities can be partitioned into slow, medium, and fast classifications; cover could be designated by function (e.g., velocity shelter) or simply by presence or absence. Illustrated in Table 8.12 is an example set of divisions that could be

Table 8.12. Example divisions of velocity, depth, and cover to delineate microhabitat types for habitat diversity hypothesis testing.

Microhabitat Attribute	Classification	Range
Velocity	Slow	0.0 - 1.0 fps
	Moderate	1.01 - 2.0 fps
	Fast	2.01 - 4.0 fps
Depth	Shallow	0.1 - 1.0 ft
	Moderate	1.1 - 3.0 ft
	Deep	3.1 - 6.0 ft
Cover	Present	Present
	Absent	Absent

used to delineate sub-classes of variables. Each of the 18 combinations describes a unique microhabitat type (e.g. shallow, slow, no cover).

Because each combination of habitat attributes is unique, it can be treated much the same as a species in traditional community ecology. Thus, for a given streamflow, one could derive values for habitat richness (the number of unique microhabitat types present), habitat diversity (an index of the heterogeneity among microhabitat types present), and habitat evenness (the ratio between calculated microhabitat diversity and the maximum microhabitat diversity possible).

The habitat diversity-discharge relations, displayed graphically, will allow comparative evaluations to determine if microhabitat diversity is increasing in the rehabilitation reaches. These relations will also provide insight into the stability of microhabitat diversity. That would be an indicator of the constancy in abundance of diverse microhabitat conditions as stream discharge changes. A time series analysis will show the temporal variability of habitat diversity. Using the habitat diversity-discharge function and a hydrologic time series, an annual chronology of habitat diversity could be evaluated.

On an annual basis assess the abundance and health (size, growth, diseases, ATPase activity) of smolts utilizing cooler water-temperature conditions. Fish samples for measurement using rotary screw-taps or other capture techniques, at key locations (upper Trinity River, lower Trinity River, and near the estuary), could be taken. On a longer time scale, use adult returns as a measure of success.

Under controlled and natural settings, examine how water temperature affects smoltification of Trinity River parr and smolts. There may also be a need to examine the effects of low dissolved oxygen concentrations on parr and smolts, particularly during Dry and Critically Dry years.

8.4.7 Compare Predictions versus Observations

During early winter, model simulations are run again using the actual preceding 12 months of flow releases and downstream tributary inflows. Seldom do meteorological and precipitation patterns follow seasonal patterns exactly as in the past. Therefore, the physical process and biological models are more fairly tested by comparing outputs (predictions) based on actual (as near as they can be determined) streamflow distribution through the river

An Example

The Stream Network Temperature model (SNTEMP) predicts temperatures in the mainstem of the Trinity River at various points downstream of Lewiston Dam. Inputs into SNTEMP include meteorological data, mainstem and tributary flow rates, and outflow temperatures from Lewiston Dam. The output from SNTEMP is useful in determining if the temperature of the mainstem is within the desirable range for optimal growth rates and outmigration (smoltification) of anadromous fish.

As a water year progresses, management will monitor meteorological and other data prescribed by the monitoring program. In a cooler than average year, the flow in the mainstem will warm slowly compared to an average or warm year. Much of the flow in the late spring and early summer is necessary to maintain desirable temperatures in the mainstem. Meteorological and flow data, processed by the SNTEMP and other models, will reflect the cooler temperature in the mainstem. If predicted temperatures are below the desirable range, then reducing flow should continue to meet temperature requirements. Realizing efficient flow management is a matter of combining predictive models with a directed monitoring program.

segment. Habitat and salmonid production outputs are compared with measured channel form, smolt growth, and production.

8.4.8 Restate System Status

The system state and the degree of progress toward the stated management objectives are determined by comparison with the previous year's observations.

8.4.9 Adapt and Modify Actions as Needed

Scientific evidence is presented to the managers and stakeholders in support of or refuting the original hypotheses. Scientists revisit the hypotheses (or develop new hypotheses if originals are rejected) and recalibrate models awaiting the next round of forecasts, decisions, and simulations. If certain hypotheses are rejected or alternatives are proposed, alternate flow releases or other management actions are designed (within the bounds of the annual water year volume) and submitted to management prior to the winter-spring forecast period. Table 8.13 lists the models and the monitoring-data needs as described for the Trinity River.

8.5 Roles and Responsibilities

Implementation of the AEAMP is critical to the success of the Trinity River fishery restoration and maintenance effort. The authors recognize that all views of stakeholders should be considered in designing an implementation program. Our underlying principles are that "best science" underpin yearly and within-year operating decisions and that all Trinity River AEAM Program activities would comply with applicable laws and permitting requirements. Additionally, independent review must be consistent and panels would provide peer review of all technical studies, analyses, and evaluations generated by the program.

The program would be directed by the Secretary through a designee, who would serve as the principal contact for the AEAM and as the focal point for issues and decisions

Table 8.13. Data, techniques, and models for interdisciplinary analyses.

	Geomorphology	**Sedimentation**	**Temperature**	**Fish Population**	**Water Supply**	**Riparian Vegetation**	**Dam Safety**	**Inundation**
Data	Bar structure Bar mobilization Bar migration Berm/riparian destruction	X-section & aerial gradations Transport by size fraction Fate: scour/fill	Reservoir boundary condition	Number of spawners Presmolt outmigration Spawning locations Size of outmigrations Rearing habitat	Annual forecast January through May	Density Age Type Germination	Encroachment on rule curve envelope	Water stage recorders Bridges Urban encroachment
Techniques	Annual videography Ground Survey Aerial topography X-section at reference sites Longitudinal water surface & bed profiles Particle size fractions Gradations	Bed load/suspended load Discharge recording Tributary measurements Particle size fractions Gradations	Width/depth Shade Temperature recording Tributary measurements	Estimates of escapement and smolt production Estimates of useable habitat area		Seedling counts Ground survey	Rule curve operational limitations	
Models	HEC-2 (HEC-RAS) HEC-6	HEC-6	SNTEMP BETTER WQRRS	SALMOD	Empirical Forecast PROSIM TRNMOD	Vegetation establishment model, Mahoney and Rood (1998)	DMBRK/BREACH FLDWAV PROSIM	HEC-2 (HEC-RAS)
Simulation Predictions	Areas of bars/pools by reach	Scour and fill Gravel quality	Longitudinal profile Forecast time series	Weekly number and size leaving specific areas	Updated biweekly	Area of bars w/seedlings Durability by reach	Storage volume Reservoir elevation Number of encroachment events	Flood levels and duration downstream of Trinity

associated with the program. His/her responsibility would include ensuring that the Department of the Interior fulfills its obligations to restore and maintain the Trinity River Fishery.

Components of the Trinity AEAMP include a Trinity Management Council (TMC) supported by a Technical Modeling and Analysis Team (TMAT) and a rotating Scientific Advisory Board (SAB). The program would include consultation with other agencies and interested groups through periodic interaction through a Stakeholders Group. Scientific credibility would be assured through external peer review of operating plans, models, sampling designs, and projections as outlined in Figure 8.19. The general roles and responsibilities of these groups are summarized below.

8.5.1 Trinity Management Council

The TMC would be composed of fishery agency representatives. The Secretary's designee would serve as Executive Director. The TMC would approve fishery restoration plans and any proposed changes to annual operating schedules (described earlier in this chapter) submitted by the Technical Modeling and Analysis Team (see Section 8.5.2). The TMC would be the focal point for issues and decisions associated with the program. The Executive Director's responsibilities would include ensuring that the Department of the Interior fulfills its obligations for streamflow releases and rehabilitation of the river corridor habitats. The Executive Director in consultation with the Council members would review, modify, accept, or remand the recommendations from the TMAT in making decisions about any changes in reservoir releases, dam operations, and other management actions.

8.5.2 Technical Modeling and Analysis Team

The TMAT would consist of a permanent group of 4 to 8 scientists selected to represent the interdisciplinary nature of the decision process. Collectively, they must possess the skills and knowledge of several disciplines: water resources, engineering, geomorphology, water quality, fish population biology, riparian ecology, computer modeling, and data management. Depending upon the number of individuals selected and possible related duties, they may be assigned from 50 to 100 percent time to the TMAT. The TMAT responsibilities include design for data collection, methodology, analyses, modeling, predictions, and evaluating hypotheses and model improvements. This Team would have delegated from the Executive Director a budget and the responsibility for preparing requests for proposals (RFP) to conduct specialized data collections for model input and validation. Spatial coverage and sampling designs for long-term monitoring for status and trends would be developed in consultation with the management agencies and specific recommendations made to the TMC for funding. Funding for the long-term monitoring would remain with the TMC.

8.5.3 Scientific Advisory Board

The SAB would be appointed by the Executive Director. This group would be composed of prominent scientists appointed and appropriately compensated for 2 to 3 year

> "A riverine ecosystem perspective accurately describes the intent to improve anadromous salmonid habitat . . . . [and] to promote alluvial riverine characteristics . . . . These recommendations are intended to shift the ecological role of the mainstem below Lewiston Dam toward one that will provide the habitats necessary to restore the fishery resources of the Trinity River."

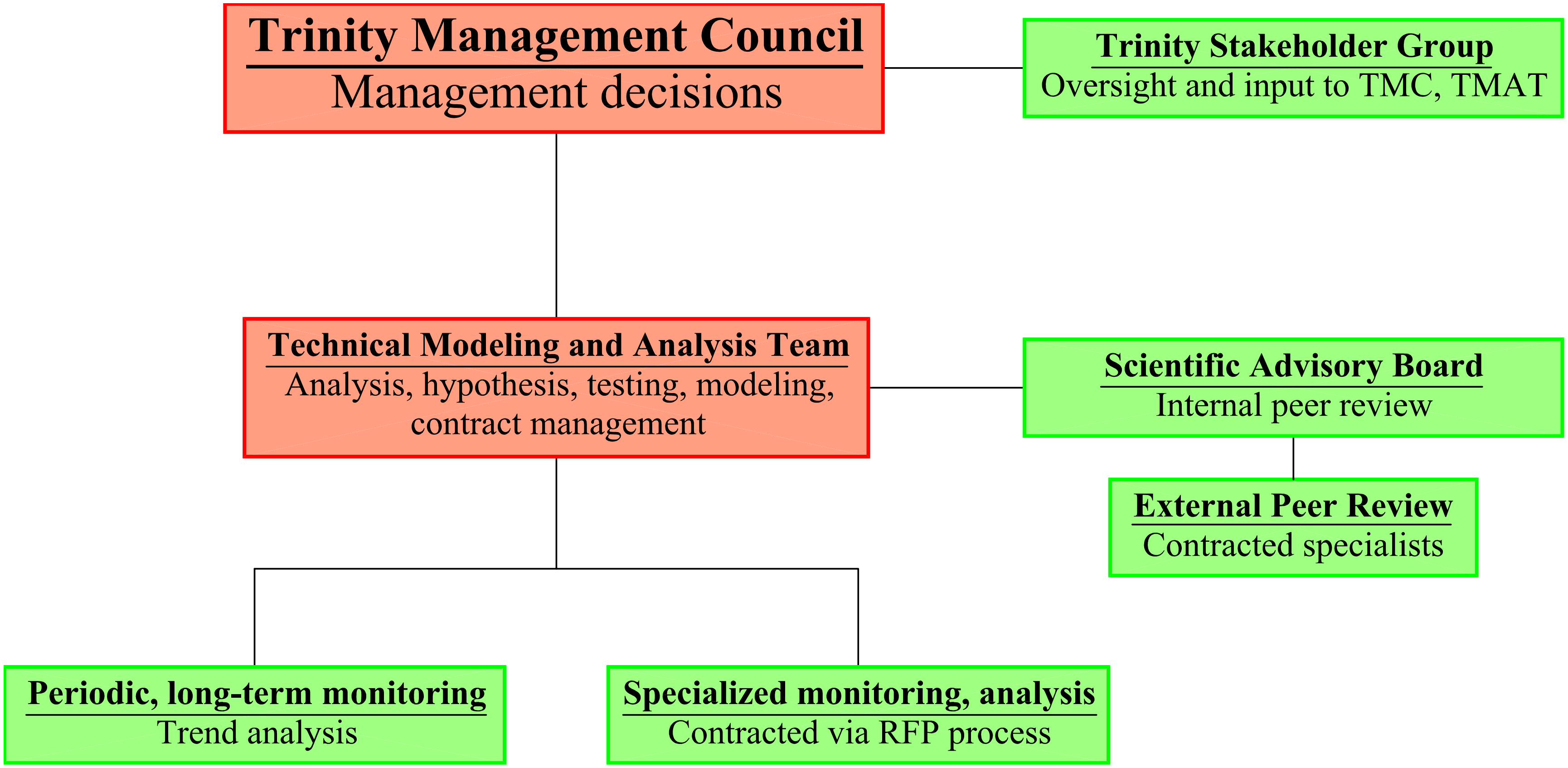

Figure 8.19. Organizational components of a successful Adaptive Environmental Assessment and Management (AEAM) program.

rotating terms. The SAB would be responsible for semiannual review of the analyses, models, and projections of the TMAT as well as providing a science review of the overall management plans and implementation of the annual operating criteria and procedures (described earlier in this chapter) as directed by the TMC. The SAB would also select outside peer reviewers and conduct the review and selection process for any contracted data collection, research, or model development.

8.6 Summary

Allowing the Trinity River to resume its alluvial nature through the integration of increased instream releases, fine and coarse sediment management, and mechanical channel alteration is necessary to restore its anadromous salmonid fishery resources. A riverine ecosystem perspective accurately describes the intent to improve anadromous salmonid habitat in the mainstem by managing releases from Lewiston Dam and supplementing coarse sediment in the mainstem to promote alluvial riverine characteristics in conjunction with flow and sediment inputs from unregulated tributaries.

These recommendations do not target the pre-TRD mainstem as its restoration goal because physical constraints imposed by the TRD cannot be entirely overcome; the primary constraints being the elimination of coarse sediment recruitment from the Basin above Lewiston Dam and the elimination of winter floods. A shift in the mainstem's ecological role occurred the first year of TRD operations to the detriment of the fishery resources of the river. These recommendations are intended to shift the ecological role of the mainstem below Lewiston Dam toward one that will provide the habitats necessary to restore and maintain the fishery resources of the Trinity River.

As the recommendations are implemented, it will be imperative to monitor their success and modify management actions in response to information gained during implementation. To this end, an Adaptive Environmental Assessment and Management (AEAM) program is recommended that is tailored to refine actions consistent with the flow requirement recommendations.

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APPENDIX A

1981 Secretarial Decision

SECRETARIAL DECISION

ALTERNATIVES FOR INCREASING RELEASES TO THE TRINITY

_________	1.	120,500 acre-feet annual releases in all years (no action alternative)
_________	2.	215,000 acre-feet annual releases in all years
_________	3a.	287,000 acre-feet annual releases in all years
_________	3b.	287,000 acre-feet annual releases in normal water years with reduction to 120,500 acre-feet in dry and critically dry years
__________	4a.	340,000 acre-feet annual release in all years
_________	4b.	340,000 acre-feet release in normal water years with reduction to 120,500 acre-feet in dry and critically dry years
_________	4c.	340,000 acre-feet annual release in normal years; 220,000 acre-feet dry years; 140,000 acre-feet critically dry years
_________	Modified 4c. *	WPRS will allocate CVP yield so that releases can be maintained at 340,000 acre-feet annually in normal years. FWS will prepare a detailed study plan to assess the results of habitat and watershed restoration. Prior to completion of the plan, releases will be 287,000 acre-feet. Releases will be incrementally increased to 340,000 acre-feet as habitat and watershed restoration measures are implemented. In dry years, releases will be 220,000 acre-feet; 140,000 acre-feet in critically dry years. * (It is understood that no water allocated to the fishery under this agreement may be permanently allocated for any other purpose until the report provided for in paragraph (3) of the 12/30/80 Memorandum of Agreement has been acted on by the Secretary.
_________	4d.	340,000 acre-feet annual release in all years until "interim water" is exhausted; thereafter, same releases as Alternative 4c.

1-14-81
DATE

Cecil D. Andrus
SECRETARY OF THE INTERIOR

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TRINITY RIVER FISHERY MITIGATION

I. INTRODUCTION

II. BACKGROUND

- A. HUPA AND YUROK FISHING RIGHTS
- B. TRINITY RIVER DIVISION
- C. DECLINE OF THE FISHERY
- D. TRINITY RIVER BASIN FISH AND WILDLIFE TASK FORCE
- E. IMPACT ON THE CENTRAL VALLEY PROJECT

III. ALTERNATIVES FOR INCREASING RELEASES TO THE TRINITY

1. 120,500 acre-feet annual releases in all years (no action alternative)

2. 215,000 acre-feet annual releases in all years

3a. 287,000 acre-feet annual releases in all years

3b. 287,000 acre-feet annual releases in normal water years with reduction to 120,500 acre-feet in dry and critically dry years

4a. 340,000 acre-feet annual release in all years

4b. 340,000 acre-feet release in normal water years with reduction to 120,500 acre-feet in dry and critically dry years

4c. 340,000 acre-feet annual release in normal years; 220,000 acre - feet dry years; 140,000 acre-feet critically dry years (identified in the EIS as the proposed action).

Modified 4c. Alternative 4c as modified by agreement between FWS and WPRS

4d. 340,000 acre-feet annual release in all years until “interim water” is exhausted; thereafter, same releases as Alternative 4c

ATTACHMENTS

Agreement Between FWS and WPRS for Implementing and Evaluating Increased Stream Flows for the Trinity Division, Central Valley Project, California

Final Environmental Impact Statement on the Management of River Flows to Mitigate the Loss of the Anadromous Fishery of the Trinity River, California (FES #80-52)

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SECRETARIAL ISSUE DOCUMENT

TRINITY RIVER FISHERY MITIGATION

I. INTRODUCTION

This SID concerns the operation of the Trinity River Division of the Central Valley Project in California. Since completion of the Division, over 80% of the mean runoff of the Trinity watershed above Lewiston Dam has been diverted to the Sacramento watershed for agricultural, hydroelectric, and other uses. This diversion has been accompanied by a severe decline in anadromous fish runs in the Trinity and Klamath Rivers. At issue are the quantity of water to be diverted and the quantity to be allowed to flow through its natural course for preservation and enhancement of anadromous fish runs on the Trinity and Klamath Rivers. Lead Assistant Secretary for this SID is the Assistant Secretary — Indian Affairs because of the federal trust responsibility to protect the fishing rights of the Hupa and Yurok tribes of the Hoopa Valley Indian Reservation.

This SID is a revision of a draft SID on the same subject distributed for review on January 8, 1980. Review of the earlier SID resulted in a decision by the Secretary, recorded in a memorandum dated April 18, 1980 (See Appendix 10 in the EIS), to increase releases from Lewiston Dam into the Trinity River during the current year (through April 30, 1981) and to prepare an environmental impact statement (EIS) prior to a decision by the Secretary on a permanent commitment of water for Trinity River Flows. The Fish and Wildlife Service (FWS) was directed to be the lead agency for the EIS, with the Bureau of Indian Affairs (BIA) and the Water and Power Resources Services (WPRS) directed to act as cooperating agencies. The draft EIS was released to the public on August 29, the comment period closed on October 17, the final EIS was filed with the Environmental Protection Agency on December 5, and a notice of availability was published in the Federal Register on December 12. The final EIS is attached to this SID. This SID constitutes the record of decision for the EIS. Because most of the information contained in the previous draft SD has been incorporated into the EIS, the discussion in the present SID has been substantially condensed.

The final EIS discusses eight alternatives, including the “no action” alternative. One of these, Alternative 4c, is identified as the proposed action. Following distribution of this SD in draft form on December 19, 1980, FWS and WPRS entered into an agreement, through which both agencies express a preference for a modified version of Alternative 4c. A copy of the agreement is attached to this SID. The primary purpose of the agreement is to aid in the implementation of Alternative 4c, in the event that the Secretary selects that alternative. The agreement contemplates a twelve year study period during which, in order to complement increased stream flows, an overall fish and wildlife management plan would be implemented by the member agencies of the Trinity River Basin Fish and Wildlife Task Force. All of the alternatives, except no action, assume that such a plan to improve habitat would be implemented. However, only the modified 4c specifies that the decision made based on this SID will be reviewed at a future date, i.e., 12 years after implementation.

II. BACKGROUND

A. HUPA AND YUROK FISHING RIGHTS

For hundreds of years the Hupa, Karuk, and Yurok Indian tribes have resided along the Trinity and Klamath Rivers and their tributaries and have utilized the fishery in the practice of their religion, in barter, and as a principal food source. The achievement of wealth and status and the pursuit of enterprise were vital aspects of the traditional cultures of these tribes, and these aspects of culture were largely based upon the abundance of salmon. To protect fundamental tribal rights, including utilization of the fishery, Federal reservations were created during the 1855-1891 period pursuant to Congressional authority. (See Sections C7.O and D5.3 of the EIS.)

Secretarial responsibilities regarding tribal fishing rights and tribal entitlement to water to provide a viable fishery have been extensively outlined in a memorandum dated March 14, 1979, from the Associate Solicitor, Division of Indian Affairs to the Assistant Secretary - Indian Affairs. This memorandum states, in part:

> "It has been clearly established in the courts that an important 'Indian purpose' for the creation of both the initial reservation and the subsequent extension was to reserve to the tribes occupying the reservation the right to take fish from the Klamath and Trinity Rivers. Mattz v. Arnett, 412 U.S. 481 (1973); Arnett v. 5 Gill Nets, 48 Cal. App.3d 459 (1975); Donahue v. Justice Court, 15 Cal. App.3d 557 (1971).
>
> "It is also well established that when federal reservations are created pursuant to Congressional authority, the Federal Government reserves the use of such water as may be necessary for the purposes for which the reservation was created. Winters v. United States, 207 U.S. 564 (1908); Arizona v. California, .373 U.S. 546 (1963); Cappaert v. United States, 426 U.S. 128 (1976); United States v. New Mexico, 98 5. Ct. 3012 (1978).
>
> "Both the tribal rights to fish and to the water needed to make the fishing right meaningful are tribal assets, which the Secretary has an obligation as trustee to manage for the benefit of the tribes. A trustee has a duty to exercise such care and skill as a person of ordinary prudence would exercise in dealing with his or her own property. Restatement (Second) of Trusts (1959) (hereinafter Trusts) Sec. 174. This obligation includes both the duty to preserve the trust assets and to make them productive. Trusts Sec. 181. The most fundamental duty of the trustee, however, is loyalty to the beneficiary. The trustee must administer trust assets solely in the interests of the beneficiary. Trusts Sec. 170.
>
> "These basic principles of trust law have been applied in recent years in the context of federal Indian law by the United States Supreme Court, United States v. Mason, 412 U.S. 392 (1973), by the federal trial court that has the Hoopa Valley Indian Reservation within its district, Manchester Band of Pomo Indians v. United States, 363 F. Supp. 1238 (N.D. Cal. 1973), by the Court of

> Claims in a case involving Indians living on that reservation, Coast Indian Community v. United States, 550 F.2d 639 (Ct. Cl. 1977), and by the federal district court for the District of Columbia with respect to Interior Department operating criteria for a dam that diverts water away from the Indian reservation where it is needed to preserve fish stocks for Indian use, Pyramid Lake Paiute Tribe of Indians v. Morton, 354 F. Supp. 252 (D. D.C. 1973)."

To summarize, the Hupa and Yurok Indians have rights to fish from the Trinity and Klamath Rivers and to adequate water to make their fishing rights meaningful. These rights are tribal assets which the Secretary, as trustee, has an obligation to manage for the benefit of the tribes. The Secretary may not abrogate these rights even if the benefit to a portion of the public from such an abrogation would be greater than the loss to the Indians.

Since 1977 the Department has been regulating Indian fishing on the Hoopa Valley Reservation in order to conserve the fish resources. In 1976, the United States Supreme Court declined to review the decision of a California appellate court in Arnett v. 5 Gill Nets that the State of California could not regulate Indian fishing on the Hoopa Valley Indian Reservation. Because the Yurok Tribe, which shares the reservation with the Hoopa Valley Tribe, has no organized tribal government, tribal regulation of the fishery was not possible. Since neither state nor tribal regulation was possible, the Interior Department used its regulatory authority to assure the preservation of the fishery on which the Indians of that reservation depend. In 1978, efforts to enforce these regulations met with bitter and sometimes violent resistance.

Prosecutions in the Court of Indian Offenses were vigorously defended by lawyers for the Indian fishers. Attorneys challenged the validity of the regulations, citing language in the preamble stating that a major problem affecting the fishery results from the substantial diversions of water from the Trinity River and that "regulation of the Indian fishery will provide only a small degree of protection for this resource." Defense attorneys argued that the Department has a trust obligation to halt other threats to the fishery rather than placing the entire conservation burden on the Indians. The Department decided that immediate action had to be taken with respect to such threats because of their potential to totally destroy the resource in a short time. The Indians were told that regulation of their fishing was needed to give the Department the time it needed to deal with the other problems.

The regulations currently in effect, which were promulgated in March 1979, permit the taking of fish for subsistence and ceremonial purposes, but, because of the decline in the state of the resource, do not permit the taking of fish for commercial purposes. If restoration of the fish habitat results in such increases in fish populations that the ban on commercial fishing can be lifted, then important economic and cultural benefits could be realized by the Hupa and Yurok Tribes (see Section D.5.3 of the EIS). To illustrate the potential economic benefit, the EIS predicts that the proposed action would allow Indians to catch an additional 10,260 salmon per year. Approximately 5,700 to 8,700 would be required to restore the tribes to the level of fish of North Fork Trinity River origin that were historically harvested for subsistence needs. Approximately 1,560 to 4,560 would then be available for commercial purposes. The economic benefits would depend on how the fish were marketed.

Any substantial economic benefits would help to improve the quality of life on the reservation, where unemployment is between 37 and 45 percent and the per capita income is less than half the national average (see Section C.7.4 of the EIS). Perhaps more important than economic benefits would be cultural benefits to the tribes if the fishery is restored. Regardless of whether the ban on commercial fishing is lifted, the fishery could provide for more of the subsistence needs of tribal members. For tribal members faced with the choice of leaving the reservation to gain employment or remaining on the reservation where employment opportunities are few but family and cultural ties are strong, the restoration of the fishery would likely result in more tribal members choosing to stay on the reservation, in effect, practicing "nature banking" as described in the EIS (EIS, p. C7 - 8). If the natural resource base of the reservation substantially contributes to the subsistence needs of tribal members, and if providing for subsistence needs is done in ways which are part of the tribes' cultural traditions, such as harvesting salmon, then the cultures of the tribes will be more resilient in reacting to outside forces of cultural change.

B. TRINITY RIVER DIVISION

As early as 1931 the water development potential of the upper Trinity River was recognized. Plans for diversions to the Central Valley were formulated as part of the California State Water Plan. With the strong urging of the State of California, the U.S. Bureau of Reclamation (now WPRS) released preliminary plans for development of the river as part of the Central Valley Project (CVP), and in 1955 the Trinity River Division of the CVP was Congressionally authorized (Trinity River Act, P.L. 84 - 386).

The Secretary has authority under the Trinity River Act to mitigate losses of fish resources and habitat and provide for certain downstream water uses. The mandate that the operation of the Division be integrated with other CVP features to achieve the fullest, most beneficial, and most economic use of the developed water is qualified by Section 2, which states:

> "Provided, that the Secretary is authorized and directed to adopt appropriate measures to insure the preservation and propagation of fish and wildlife, including, but not limited to the maintenance of the flow of the Trinity River below the diversion point at not less than one hundred and fifty cubic feet per second for the months of July through November . . ."

Recent opinions of DOI's Regional Solicitor in Sacramento and earlier reports of the Commissioner of Reclamation acknowledge the mandatory requirement of this proviso. The Secretary has acknowledged this responsibility in the April 18, 1980, memorandum noted earlier.

Construction of the Trinity River Division began in 1956, with water first impounded in 1960. Constructed features include: (1) Trinity Dam (Clair Engle Lake) on the Trinity River - with a capacity of 2.5 million acre-feet; (2) Lewiston Dam (and Reservoir), a flow regulating lake seven miles below Trinity Dam; (3) Trinity River Fish Hatchery immediately downstream from Lewiston Dam; (4) Whiskeytown Dam (and Lake) on Clear Creek, a tributary of the Sacramento River; and (5) two transmountain tunnels and four hydroelectric plants (two each in the Trinity and Sacramento Basins) - with a combined generating capacity of 397,000 kilowatts. (In the EIS, see Plate 2 of Appendix 1 and Section C.2.O.)

Diversions to the Sacramento River Basin commenced in 1963 and full operation began in 1964. Total annual releases downstream from Lewiston Dam were to be a minimum of 120,500 acre-feet, or <u>approximately 10 percent of average annual unimpaired flows</u>. The releases represent approximately 2 percent of the CVP's 8.1 million acre-feet of firm yield.

C. DECLINE OF THE FISHERY

Prior to construction of the Trinity River Division, the Trinity River was recognized as one of California's most famous and accessible fishing streams. Since 1963 when the Trinity River Division was placed into operation, salmon and steelhead runs in the Trinity River system have undergone severe declines: approximately 80 percent in the case of chinook salmon (from 50,000+ spawners to 11,100), and approximately 60 percent for steelhead trout (from 24,000+ to 10,000). This downward trend has occurred despite the provision from the time of project inception of flows to protect prime spawning and rearing habitat in 40 miles of the Trinity River below Lewiston Dam, the primary diversion structure, and the operation of a hatchery to replace 109 miles of upstream spawning and rearing habitat rendered inaccessible by the dam.

Both the quantity and the quality of fish habitat have been significantly diminished since pre-project periods. Temperature and turbidity levels have at times been higher than under pre-project conditions. Sand has filled poo1s and covered "riffles" important for the production of fish. Portions of the riverbed have become compacted and unusable for spawning and provide only limited fish food production. Reduced flows have also allowed the encroachment of riparian vegetation along the channel where it had not previously existed. A current estimate places spawning habitat losses at 80 to 90 percent even though a dozen spawning riffles have been rebuilt by the Trinity River Task Force. Given declines in salmon and steelhead numbers that have occurred since, overall fish habitat has likely declined by a larger proportion. The existing environment (post-project) can be described based on conditions measured by a 1978 flow study, documented in Hoffman, J. (USFWS), <u>Trinity River Instream Flow Study: Final Report to the Task Force</u> (1980). This study measured amounts of "weighted usable habitat" for adult, spawning and juvenile rearing purposes in selected representative study areas. The existing environment represents significant reduction in wetted area, spawning habitat, adult holding habitat, juvenile rearing habitat, increased (adverse) water temperatures at certain times, and decreased attraction and downstream transport flows relative to pre-project conditions.

Abusive logging practices, improper road construction, and floodplain development within the Trinity watershed have also contributed significantly to habitat degradation. Clearcutting has promoted increased sediment loading; removal of streamside vegetation has increased water temperatures; log jams at the mouths of tributary streams have blocked access for fish spawning and rearing. Logging within the basin has necessitated the construction of hundreds of miles of unpaved logging roads and skid trails. The resulting increased yield of sediment in the mainstem Trinity and its tributaries has reduced the biological productivity and fish carrying capacity of the stream.

Sustained high harvest pressure is also believed to have contributed to the decline of the fish runs on the Trinity. The bulk of the chinook salmon harvest occurs in the ocean fishery with commercial trollers accounting for an estimated 68 percent of the harvest and ocean sport fishers taking 20 percent of the fish. The remaining 12 percent are harvested in the river fishery, with Indians taking 10 percent and sport fishers the remaining 2 percent. The steelhead trout fishery is strictly a river fishery which is divided between sport (90 percent) and Indian harvesters (10 percent). The catch-spawning escapement ratio for fall run chinook is on the order of three to one, which means that, on the average, 25 percent of the adults return to spawn. For steelhead trout, it is estimated that perhaps 50 percent of the returning adults are taken.

In developing a stream management plan in this area it should be assumed that good management practices will be utilized regarding the ocean fishery. Data reflect that salmon harvest related to this system has been stable over the last decade, yet salmon populations continue to decline. This and other data has led to the hypothesis that the present declines in chinook salmon are, in the largest part, due to habitat loss and deterioration rather than the long term harvest rates. Therefore, further reduction of ocean harvest rates is not considered an alternative to increasing instream flows. It should also be noted that issues related to the allocation of the harvest between the ocean and Indian fisheries are currently in litigation. The outcome of this litigation will affect the allocation of benefits resulting from any increased flows.

Expanded hatchery operations have been advocated by some as an alternative to increased flow releases. Hatchery expansion could theoretically increase the size of salmonid runs, however, increased flow releases would also be required to provide adequate river conditions for fish passage to and from the Trinity River. Past experience indicates anadromous fish hatcheries and similar facilities in California have generally been unsuccessful in meeting their objectives. The one exception is the Nimbus Hatchery on the lower American River which has had the advantage of near optimal streamflows for rearing and migration since its construction. As sections BI.0 and C4.113 of the EIS notes, the success of the Trinity River Fish Hatchery cannot be positively demonstrated. Other reasons for preferring natural runs over hatchery bred fish are: the frequently devastating losses of young fish in hatcheries due to diseases; the greater genetic diversity maintained in wild stocks, the fact that hatcheries would be species specific (anadromous species) and would not contribute to the general needs of other fish and wildlife species which rely on the Trinity; and hatchery expansion would be inconsistent with Fish and Wildlife Service and California Department of Fish and Game policies which emphasize preservation of natural runs.

To summarize the condition of the fishery, the body of knowledge that has emanated thus far from the Trinity River Task Force has made clear beyond doubt that the decline in salmon and steelhead stocks is due fundamentally to three causative factors, and that the decline will continue toward virtual extirpation of the stocks unless significant corrective measures are applied. The fundamental causes of the fishery decline are excessive streambed sedimentation, inadequately regulated harvest, and insufficient streamflow. Restoration of salmon and steelhead populations to pre-project levels will require alleviation of each of these resource-limited factors. The course of action proposed in the EIS addresses what is believed to be the most critical of the limiting factors, i.e., insufficient streamflow. Restoration of streamflow is a necessary first step in rejuvenation of the fishery (For a thorough discussion of fishery issues, see Sections C.4 and D.5 of the EIS.)

D. TRINITY RIVER BASIN FISH AND WILDLIFE TASK FORCE

A state-federal work group and task force comprised of USBR, USFWS, and the California Department of Fish and Game (CDFG) was formed in 1971 to study more broadly the fish and wildlife problems of the basin. In 1972 funds were provided through the USBR to the CDFG and the USFWS to prepare a plan for identification and mitigation of fish and wildlife problems. Initial physical restoration of spawning areas near Lewiston was carried out in 1972 and 1973 under the auspices of the task force.

Trinity River conditions continued to worsen and in 1974 the public's growing concern regarding the decline of the endangered fishery activated the interest of Congressman Harold T. (Bizz) Johnson, in whose district the project is located. The membership of the Trinity River Basin Fish and Wildlife Task Force (Task Force) was subsequently expanded to develop and implement immediate and long-range restorative actions. Members of this multi-agency committee now included the USBR (i.e. WPRS), CDFG, USFWS, BIA, the California Department of Water Resources (DWR), Trinity County, Humboldt County, Hoopa Valley Business Council, the United States Forest Service (USFS), the United States Bureau of Land Management (BLM), and the United States Soil Conservation Service (SCS). The Task Force was expanded again in 1978 to include the California State Water Resources Control Board (SWRCB) and the National Marine Fisheries Service (NMFS) for a total of 13 entities.

The WPRS is the Task Force's lead agency and receives federal funds to carry out the Trinity River Basin Comprehensive Action Program with the assistance of other members of the Task Force. In Fiscal Year 1975, Congress authorized appropriations of $300,000 as the first part of a $7.6 million program scheduled for eight years. A five-year Interim Action Program was then begun in an effort to stem the further immediate decline of the fish and wildlife resources, while completing formulation of a comprehensive long-term cooperative management program.

Numerous Task Force studies and activities have been conducted, including watershed revegetation to control erosion, mechanical restoration of mainstem riffle and poo1 habitat, tributary stream improvement, hatchery operation assessments, sediment transport and removal studies, and fish population, migration and harvest assessments. In 1978, consultants were contracted to formulate specific management options for inclusion in the fish and wildlife program, to address questions of an institutional nature bearing on the program, and to prepare an overall management plan proposal for the Trinity River Basin. Substantial additional funding and personnel commitments at national, state, and local levels may be required to implement the management plan once it is completed and approved by the Task Force.

Without increased streamflows to improve fishery habitat and fish production, the actions outlined above (regarding land use and fish harvesting) will produce only limited improvements. Since the initiation of project operations in 1964, both CDFG and later the Task Force have made numerous attempts to secure an increase in flow releases down the Trinity River. In response, the minimum annual release of 120,500 acre-feet from Lewiston Reservoir was approximately doubled in 1974 and 1975 as part of a three-year experiment. The experimental release period, interrupted by a severe drought in 1976 and 1977, extended into early 1979. (These releases were extended on a voluntary basis by USBR into early 1980.) In a letter to CDFG dated March 3, 1977, the Regional Director, WPRS stated:

> "It appears that the Secretary (of the DOI) already has authority to provide added fish flows above the 'minimum' provided in the authorizing legislation. The level of flows required should be documented as a part of the Trinity River Basin Fish and Wildlife Action Program. At the same time such documentation of flow needs is satisfactorily completed, the Secretary can make the decision to provide the higher level of flows. I would support such a change in operation to provide those higher flows."

The Task Force, in an effort to provide the prerequisite documentation and complete the formulation of a basin management plan, initiated studies by private consultants (FK and VTN), CDFG, DWR, and USFWS. The USFWS study is the basis for a current flow regime of 286,700 acre - feet implemented in May 1980 and to be in effect through April, 1981 (as established by the Secretary). The FWS study plus the results of the other studies, as completed to date, are the basis of the alternatives considered in the EIS and presented to the Secretary in this SID.

The October 1980 report by Frederiksen, Kamine and Associates (FK) is the most recent of the studies completed for the task force. In its report FK has indicated that the anadromous fisheries of the Trinity River Basin could be restored with the implementation of a 14 - action program which includes increased downstream releases and watershed and habitat restoration efforts. FK recommends two levels of downstream releases, 260,000 acre-feet annually in normal and wet years, and 179,800 acre-feet in dry years. The recommendations which are currently under consideration are not identical to those recommended in the EIS and this SID, however, the 14 - action program including the FK recommendation for increased flows will be valuable to the task force in formulating its management program as well as FWS and WPRS in its assessment of the effectiveness of the flow releases and watershed and habitat restoration studies as detailed in the agreement executed between the two agencies.

E. IMPACTS ON THE CENTRAL VALLEY PROJECT

The Trinity River Division is an integral part of the CVP, and was the first major water development project in northwestern California constructed and operated to export water. Runoff water from the Trinity Basin is stored, regulated, and diverted through a system of dams, reservoirs, tunnels, and powerplants to the Sacramento River for use in water deficient areas of the Central Valley Basin. Currently, about one million acre-feet of water are exported annually from the Trinity Basin. This represents approximately 14 percent of the CVP's "firm yield" water supply of 8.1 million acre-feet. The diverted water supplies total irrigation needs equivalent to about 333,000 acres and approximately 100,000 additional acres through the use of return flows. The affected acreage is in the Sacramento, San Joaquin, and Santa Clara Valleys.

In addition to agricultural benefits, the Trinity Division also supplies a major source of hydroelectric generating capacity. The Trinity Division includes four powerplants which are operated in conjunction with the water demands for irrigation. Power generated is directly related to the demands for project water. Since the greatest diversions are made during the summer months when irrigation needs are greatest, these months also represent the period when maximum amounts of hydroelectric energy are generated. The energy provides "peaking power" to Central Valley users, which include primarily irrigation districts, municipalities, military installations, and other Federal agencies. The average annual generation of the Trinity Division is about 1.1 billion kwh. This compares with an average annual generation of 5.5 billion kwh for the CVP.

A decision to increase flow releases to the Trinity River for fishery conservation purposes reduces the supply of water available for irrigation and power production. The impact of a decrease in agricultural water supply under the various alternatives can be represented in terms of acres which could not be irrigated and corresponding agronomic losses. The range of impacts for the alternatives considered is summarized in the next section of this SID and is thoroughly discussed in Section D.3 of the EIS.

Increased flow releases to the Trinity River would also have a negative impact on CVP power benefits. Every acre foot of water which is diverted from the Trinity River Basin generates 1,100 kwh as the water passes through three powerplants. Approximately that amount of energy would be lost for each additional acre-foot of water released down the Trinity. (The actual loss is somewhat less because the Lewiston Powerplant, with a present 350 kw installed capacity, would generate a small amount of electrical energy as waters were released down the Trinity.)

Additionally, downstream releases during dry or critically dry years would reduce the dependable capacity of the Trinity powerplants. (Dependable capacity is that portion of the powerplant's installed capacity in kilowatts that can be relied upon to meet preference customer loads under adverse hydrologic conditions.) The loss in decreased generation can be expressed in terms of the cost of foreign oil required to replace the lost energy ($33 per barrel, based on April 1980 prices, or the cost of replacing generation through the use of coal, geothermal steam, or banked power transferred to Pacific Gas and Electric Company at times when CVP generation exceeds CVP demand). Because California's utility system is heavily based on oil-fired generation, power lost to Trinity releases would likely be replaced by combustion of oil, at least in the near term. The loss in decreased dependable capacity can be expressed in terms of the costs required to construct a new powerplant to replace the lost dependable capacity. These impacts are summarized in the next section of the SID and are thoroughly discussed in Section D.4 of the EIS.

III. ALTERNATIVES FOR INCREASING RELEASES TO THE TRINITY

As noted earlier in this SID, and as analyzed in the EIS, restoration of streamflow is a necessary first step in rejuvenation of the fishery. A number of other actions should also be taken, such as those recommended in the FK report (Proposed Trinity River Basin Fish and Wildlife Management Program). However, other actions will produce limited benefits without increased releases for streamflows. The draft SID which was circulated on January 8, 1980, led to a decision to prepare an environmental impact statement (EIS) prior to a decision by the Secretary on a permanent commitment of water to be released into the Trinity River to mitigate damage to the fishery. As a result of the scoping process, the options presented in the January 8 draft SID were modified somewhat. The alternatives analyzed in the EIS are as follows:

Alt. 1	120,500 acre-feet annual releases in all years (no action alternative)
Alt. 2	215,000 acre-feet annual releases in all years
Alt. 3a	287,000 acre-feet annual releases in all years
Alt. 3b	287,000 acre-feet annual releases in normal water years with reduction to 120,500 acre-feet in dry and critically dry years.
Alt. 4a	340,000 acre-feet annual release in all years
Alt. 4b	340,000 acre-feet release in normal water years with reduction to 120,500 acre-feet in dry and critically dry years
Alt. 4c	340,000 acre-feet annual release in normal years; 220,000 acre-feet dry years; 140,000 acre-feet critically dry years (identified in the EIS as the proposed action)
Alt. 4d	340,000 acre-feet annual release in all years until "interim water" is exhausted; thereafter, same releases as Alternative 4c

Section B of the EIS explains how these alternatives were developed as well as why other possible alternatives were discarded after initial consideration. Section B also contains a summary of the environmental impacts of each alternative (see pp. B-6 to B-13). These environmental consequences are thoroughly analyzed in Section D of the EIS. A brief summary is presented in this SID.

The FWS-WPRS agreement discussed earlier in this SID is in effect a modification of Alternative 4c, as follows:

Modified Alt. 4c. WPRS will allocate CVP yield so that releases can be maintained at 340,000 acre-feet annually in normal years. FWS will prepare a detailed study plan to assess the results of habitat and watershed restoration. Prior to completion of the plan, releases will be 287,000 acre-feet. Releases will be incrementally increased to 340,000 acre-feet as habitat and watershed restoration measures are implemented. In dry years, releases will be 220,000 acre-feet; 140,000 acre-feet in critically dry years.

The principal differences between the modified 4c and the original 4c is that in the modified version: (1) releases of more than 287,000 acre-feet in normal years would be conditioned on habitat and watershed improvements; and (2) the success of restoration efforts, including increased releases for streamflows, would be reviewed following a 12 year study period. All of the other alternatives, except no action, would involve an ongoing evaluation effort, but only the modified 4c specifies a time frame for the evaluation.

Increasing flow releases to the Trinity River would generally result in favorable environmental, social, and economic impacts in the Trinity River Basin. The primary effect of the proposed course of action, when coupled with an intensive streambed, watershed, and harvest management program, would be restoration of the anadromous fishery to levels approaching pre-project conditions.

A relative value index for habitat is useful for purposes of explaining the different impacts of the various alternatives on fish habitat. This approach must be exercised with caution, however, because of assumptions which must be made concerning the relationship among streamflows, habitat, and fish production. One of the assumptions used in developing this relative habitat index is that there is a direct linear relationship between flow and fish habitat and between fish production and fish habitat within the range of releases from 120,500 acre-feet to 340,000 acre-feet (see Section D5.211 in the EIS). Fishery habitat values, spawning run sizes, and partial increased economic values were estimated for each of the alternatives. These figures are shown in the table below.

Table 1
Chinook Salmon and Steelhead Trout Spawning
Escapement under Alternative Trinity Flow Releases

Alt.	Average Annual Release (ac-ft)	Relative Habitat Index Value	Chinook Salmon Spawning Escapement	Steelhead Spawning Escapement
1	120,500	.20	11,000	10,000
2	215,000	.54	32,100	17,600
3a	287,000	.81	42,600	21,300
3b	245,000	.65	36,400	19,100
4a*	340,000	1.00	50,000	24,000
4b	285,000	.80	42,200	21,200
4c	308,000	.88	45,300	22,800
4d	308,000	.88	45,300	22,800

*Spawning escapement predicted to be restored to estimated minimum pre-project levels based on Hoffman (USFWS), Trinity River Instream Flow Study (1980).

Salmon provides one-third of the economic value of the California commercial fishery and the North Coast constitutes the heart of this industry. Chinook salmon also help maintain an important sport fishery off the northern California coast. In addition, chinook salmon and steelhead trout represent the major contributors to the Trinity River sport fishery and are the heart of the Indian fishery. Restoration of this resource would benefit each of these major user groups.

The partial economic values for chinook salmon and steelhead trout fisheries attributable to the alternatives are displayed in the table below.

Table 2
Annual Net Increase in Economic Value of Trinity River
Chinook Salmon and Steelhead Trout Fishery
(millions of dollars) under Various Alternatives

Alternatives	Chinook Salmon	Steelhead	Total	Compensation b/
1 [a]	-0-	-0-	-0-	-0-
2	1.6	1.2	2.8	8.4
3a	2.3	1.8	4.1	12.3
3b	1.8	1.4	3.2	9.6
4a	2.9	2.2	5.1	15.3
4b	2.3	1.8	4.1	12.3
4c	2.5	2.0	4.5	13.5
4d	2.5	2.0	4.5	13.5

a/ The existing salmon fishery is valued at 0.8 million dollars and the steelhead fishery at 1.6 million dollars.

b/ The “willingness to pay” approach is useful in expressing the value of added commodities or uses. However, a different approach - “willingness to sell” - is needed to estimate the loss when a user is being asked to give up a commodity or use. For this SID, compensatory values are assumed to be three times the value that users are willing to pay.

Increasing flow releases to the Trinity River would also result in improved water quality in the mainstem downstream of Lewiston Dam and increased use of the Trinity River by recreationists engaging in fishing (other than for salmon and steelhead), swimming, canoeing, and whitewater rafting. Increased opportunity for whitewater rafting would afford a major recreational attraction. The best whitewater conditions occur in the early spring when heavy runoff enters the mainstem from tributaries; the release of higher flows from Lewiston Reservoir would extend the rafting season into the summer.

Increased fish numbers and fishing, better water quality, and increased recreation opportunities, would greatly benefit the tourism and recreational - support industries, a main source of income in both Trinity and Humboldt Counties.

Restoration of the anadromous fish runs, in addition to the economic benefits shown, would significantly benefit the Hupa and Yurok peoples who depend upon salmon and steelhead for their ceremonial and subsistence needs, as well as for commercial purposes.

The data presented in Table 1 indicate for each alternative, the probability that the fishery will recover to near project levels. The data in Table 2 indicate the economic benefits projected for each alternative. Tables 3 and 4 below, present data on the impacts on CVP water and power users. It might be noted that, as a result of the analysis conducted in preparing the EIS, the figures on agricultural impacts have changed substantially since the distribution of the previous SID on January 8, 1980.

Table 3 summarizes the analysis of projected agricultural economic losses, due to land which could not be irrigated, assuming that water conservation or alternative sources of water are not utilized to bring the land into production. Until the year 2000, there would be no specific Impacts on CVP water users during normal and dry water years under any of the alternatives, i.e., up to 340,000 acre-feet. During critically dry water years, all the alternatives would require placing deficiencies on water users; however, all water users or groups of users would share the deficiency. The deficiencies can be imposed under existing contracts. However, the situation will change when the ultimate requirements of project water users are to be met, beginning in the years 2000 - 2020. At that time, the deficiency criteria in water service contracts will need to be revised to reflect the impact on project yield if these releases continue at this level. (This assumes no construction of new facilities and a meeting of D -1485 requirements.)

The net values associated with land not developed under each of the eight alternatives range from 0 to 4.1 million dollars annually, assuming that lands of average value per acre are not developed for agricultural production, or, alternatively, from 0 to 1.0 million dollars annually, assuming that lands generating the lowest income (irrigated pasture) are not developed. The ranges of value are displayed below. (Note: figures incorporate agricultural costs resulting from non-development of agricultural return flows of 17.5 percent.)

Table 3
Agronomic Losses in the Year 2020 Associated with Implementation
of Alternative Flow. Releases

		Net Agronomic Value	
Alt.	Forgone (acres)	Average Value (millions of $'s)	Lowest Value (millions of $'s)
1	- 0 -	- 0 -	-0-
2	45,000	2.0	0.5
3a	79,000	3.4	0.9
3b	22,000	0.9	0.2
4a	95,600	4.1	1.0
4b	28,300	1.2	0.3
4c	42,300	1.8	0.5
4d	42,300	1.8	0.5

It should be noted when considering the loss figures indicated above that no residual value is assigned to lands not put into production. There is no way of predicting the uses that such lands would be put to and therefore no way of quantifying their residual value. However, some residual value would exist that would reduce the net losses described above.

Table 4 presents, data on the costs of replacing power losses, to both average annual generation and project dependable capacity.

Table 4
Power Losses Associated with Implementation
of Alternative Flow Releases (millions of dollars)

Alt.	Oil	Coal	Geothermal	Banked Power
1	- 0 -	- 0 -	- 0 -	- 0 -
2	7.0	5.1	3.6	3.1
3	12.2	9.1	6.4	5.6
3b	7.7	5.4	3.4	2.8
4a	16.2	12.1	8.6	7.4
4b	10.2	7.1	4.5	3.6
4c	11.3	7.9	5.0	4.1
4d	11.3	7.9	5.0	4.1

Some additional consequences (positive and negative) of the proposed action on the Central Valley Basin are not amenable to quantification. On the negative side is a reduction in the volume of Trinity River water entering the Sacramento River and thus potentially available for: (1) cooling Sacramento River water which tends in the late summer to fall to exceed the upper limit of the optimum range for salmon spawning, egg incubation and rearing; and (2) reducing the Sacramento River flow releases from Shasta Lake required for diluting high concentrations of copper and zinc in flows emanating from Spring Creek, a Sacramento tributary (it is anticipated that entry of these pollutants into Spring Creek from mining operations will ultimately need to be controlled through Implementation of the Clean Water Act). On the positive side, the reduction in the amount of colder Trinity River water flowing down the Sacramento River in spring could be a benefit since Sacramento River water temperatures tend to be below optimal for salmon at that time. Some additional minor benefit would accrue to reduced pumping in the Sacramento - San Joaquin Delta, where pumping operations of the CVP and the State Water Project have had massive adverse impacts on both fish and wildlife.

It is to be noted that for the purpose of judging the economic merit of the proposed course of action, application of the traditional benefit/cost analysis to the resource problem addressed in this EIS is not appropriate. Providing greater flows to the Trinity River below Lewiston Dam would be a loss - compensation measure, which is a feature of the Trinity River Division, not subject to a separate benefit/cost analysis. Moreover, as observed at the outset, there are responsibilities arising from congressional enactments, which are augmented by the federal trust responsibility to the Hupa and Yurok tribes, that compel restoration of the river's salmon and steelhead resources to pre-project levels.

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APPENDIX B

Agreement Between USFWS and WPRS

Agreement Between the
U.S. Fish and Wildlife Service
and the
Water and Power Resources Service
for
Implementing and Evaluating Increased Stream flows
for the Trinity Division,
Central Valley Project, California

This agreement is intended to affirm the commitment of the Fish and Wildlife Service (FWS) and the Water and Power Resources Service (WPRS) to work cooperatively to halt further fishery declines and to begin effective restoration in the Trinity River. It is consistent with the congressional intent in authorizing the Trinity River Division, Central Valley Project (CVP), California.

This agreement together with the Environmental Impact Statement (EIS) on the management of Trinity River flows is available for consideration by the Secretary in reaching a decision on Trinity River flows. This agreement is developed in recognition and support of the Trinity River Basin Fish and Wildlife Task Force (Task Force) and its goals and objectives of restoration of salmon and steelhead resources in the Trinity River Basin. It reflects a recognition that although it would be desirable to sustain environmental values through high releases to the Trinity River in all years, there are compelling needs and uses outside of the basin for water and power which require a reasonable compromise between water export and instream releases - especially in water-short years. It is suspected that the flows to be released in dry and critically dry years may be insufficient to support desirable levels of salmon and steelhead habitat. However, the flows to be allocated for dry and critically dry years will help to allow habitat below Lewiston Dam to be maintained at levels at least comparable to those which would have existed during dry and critically dry years in the absence of the project. FWS will carefully assess the flows provided under this agreement to determine their effectiveness in maintaining favorable Instream habitat conditions, and will also determine what management options are available for compensating for temporary reductions in fishery habitat during dry and critically dry years.

<u>Therefore</u>, it is mutually agreed as follows:

(1) WPRS will allocate CVP yield so the releases below Lewiston Dam for fishery preservation and propagation can be maintained at 340,000 acre-feet annually in all but dry z and critically dry water years when the release shall be 220,000 and 140,000 acre-feet, respectively. Dry and critically dry years will be based on Shasta Lake inflow.

Critically dry years shall mean any year in which either of the following conditions exists:

(a) The forecasted natural inflow to Shasta Lake for the current year is equal to or less than three million two hundred thousand (3,200,000)

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acre-feet as such forecast is made by WPRS on or before February 15
and reviewed as frequently thereafter as conditions and information warrant or

(b) The total accumulated actual deficiencies below four million (4,000,000) acre-feet in the prior water year or series of successive prior water years each of which has inflows of less than four million (4,000,000) acre-feet, together with the forecasted deficiency for the current water year, exceed eight hundred thousand (800,000) acre-feet.

Dry years shall mean any year that the forecasted natural inflow to Shasta Lake is less than four million (4,000,000) acre-feet and neither of the above conditions exists.

These definitions are consistent with the definitions used in the CVP power contract with Pacific Gas and Electric Company and many of the CVP water service contracts. Applying these definitions to the past 69 years of record would result in 12 percent of the years being defined dry and 9 percent being defined as critically dry years.

(2) During the first 12 years of these revised flow releases, the schedule of flows within any year shall be provided to WPRS by FWS in consultation with the California Department of Fish and Game (Fish and Game). FWS will evaluate the releases to determine how well they affect the propagation of fish consistent with fishery restoration objectives.

(3) At the end of 12 years following adoption and implementation of this agreement, FWS, after consultation with WPRS and Fish and Game, will submit a report to the Secretary, summarizing the effectiveness of restoration of flows and other measures including intensive stream and watershed management programs in rebuilding Trinity River salmon and steelhead stocks. The report will specifically address the adequacy of habitat at 140,000, 220,000, and 287,000 acre-feet annual release levels for all water year types and the need to maintain, increase or decrease the full 340,000 acre-feet CVP yield allocation. Recommendations concerning what measures should be continued, eliminated, or implemented to maintain compensation for fishery impacts attributable to the Trinity River Division will also be included. The report may also address the possible rescheduling of the allocated CVP yield by water year type and other measures necessary to better maintain favorable instream habitat conditions.

(4) The completion of a Fish and Wildlife Management Plan by the Task Force and its implementation is integral to successful restoration of the anadromous resources of the Trinity River Basin. FWS and WPRS will continue to work with the Task Force in completing the plan and assuring its successful implementation.

(5) FWS in consultation with WPRS and the Task Force will prepare, during the first year after adoption and implementation of this agreement, a detailed study plan to assess the results of the habitat and watershed restoration efforts as required in (3) above. Until the study plan is completed and approved by the Director, FWS, and the FWS is in a position to implement the study, fishery releases to the Trinity shall not exceed 287,000 acre-feet in any normal year. As instream and watershed management measures are put in place, flows will be incrementally increased up to a maximum of 340,000 acre-feet, both to sustain those measures and to facilitate the evaluation.

Lynn A. Greenwalt
Director, Fish and Wildlife Service

DEC 29 1980
Date

Commissioner - Water and Power
Resources Service

12/30/80
Date

Approved:

Cecil D. Andrus
Secretary of the Interior

1-14-81
Date

UNITED STATES GOVERNMENT

memorandum

DATE: JAN 16, 1981

REPLY TO ATTN OF: Commissioner of Indian Affairs

SUBJECT: Amendment to the Agreement Between the Fish and Wildlife Service and the Water and Power Resources Service Regarding Trinity River Streamflows.

TO: Commissioner, Water and Power Resources Service
Director, Fish and Wildlife Service

On January 14, 1981, the Secretary acted on the Secretarial Issue Document on Trinity River Fishery Mitigation, selecting alternative 4c, which had been recommended by all the Assistant Secretaries involved in this issue. On that date, the Secretary also approved the agreement between FWS and WPRS.

In order to provide for the ongoing involvement of the Bureau of Indian affairs and the Hoopa Valley Business Council in the implementation of this decision, I am requesting your approval of the attached amendment to the agreement. This amendment provides that FWS, in developing the annual schedule of flow releases and in preparing the report to the Secretary, will include both the BIA and the Hoopa Valley Business Council in the consultation which the agreement specifies is to include WPRS and the California Department of Fish and Game.

Your approval of this amendment would be appreciated.

William Hallett

Attachment

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Amendment to the Agreement
Between the
U.S. Fish and Wildlife Service
and the
Water and Power Resources Services
for
Implementing and Evaluating Increased Stream Flows
for the Trinity Division
Central Valley Project, California

This is an amendment to the agreement signed by the Director, Fish and Wildlife Service on December 29, 1980, and the Commissioner - Water and Power Resources Service on December 30, 1980, and approved by the Secretary of the Interior on January 14, 1981. Pursuant to this amendment, the consultation required by paragraphs (2) and (3) of the Agreement shall be expanded to include the Bureau of Indian Affairs.

Lynn A. Greenwalt
Director, Fish and Wildlife
Service

01-19-81
Date

R. Keith Higginson
Commissioner - Water and Power
Resources Service

1/19/81
Date

APPENDIX C

1991 Secretarial Decision

March 3, 1849

United States Department of the Interior
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

MAY 8, 1991

Memorandum

To: Secretary

From: Assistant Secretary - Fish and Wildlife and Parks
Assistant Secretary - Indian Affairs
Assistant Secretary - Water and Sciences

Subject: Trinity River Flows

By copy of your July 13, 1990, letter to the Hoopa Valley Tribe, you directed the Assistant Secretary for Fish and Wildlife and Parks to conduct a review of Trinity River flows that are currently governed by the 1981 Secretarial Issue Document. During the past 9 months, the Assistant Secretaries for Water and Sciences, Indian Affairs, and Fish and Wildlife and Parks have worked diligently to reach a consensus concerning flow requirements for the Trinity River. This memorandum and the attached Position Statement contain our recommendation on this issue.

We recommend that, during the period of 1992 through 1996, flow releases into the Trinity River be at least 340,000 acre-feet (AF) for each dry or, wetter water year and 340,000 AF in each critically dry year if at all possible. We further recommend that between 240,000 AF and 340,000 AF be released into the Trinity River in 1991 depending on the ramping formula contained in the attached position statement. The 1991 flow releases will be accomplished under Central Valley Project hardship provisions. A prompt decision is critical since reduced flows will go into effect in early May, 1991.

The attached Position Statement provides a detailed summary of the major legal, biological, and administrative factors that support our decision. Briefly, fishery needs, the Department's trust responsibility to the Hoopa Valley and Yurok Tribes, the biological integrity of the U.S. Fish and Wildlife Service's 12 year Trinity River Flow Evaluation, the needs of the Restoration Project, and the comprehensive administrative record concerning Trinity River flow requirements support our recommendation to increase flow releases into the Trinity River.

Constance B. Harriman
Assistant Secretary
for Fish and Wildlife
and Parks

Eddie F. Brown
Assistant Secretary
for Indian Affairs

Assistant Secretary
for Water and Sciences

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TRINITY RIVER FLOWS

The Bureau of Reclamation is directed to release into the Trinity River in 1991 between 240,000 AF and 340,000 AF depending on the inflow to Shasta Reservoir and using the ramping formula contained in the attached position statement. The Bureau of Reclamation is also directed to release into the Trinity River, during water years 1992 through 1996, at least 340,000 AF for each dry or wetter water year and 340,000 AF in each critically dry year if at all possible. The Assistant Secretaries for Fish and Wildlife and Parks, Indian Affairs, and Water and Sciences are directed to formalize the 1992 through 1996 flow release agreement by December 1, 1991.

Manuel Lujan Jr.

Secretary of the Interior

Attachment

Date: May 8, 1991

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REVIEW OF TRINITY RIVER FLOWS

POSITION STATEMENT
of the
Assistant Secretary for Fish and Wildlife and Parks
the
Assistant Secretary for Indian Affairs
and the
Assistant Secretary for Water and Sciences

ISSUE: The adequacy of fishery flow releases from Departmental reservoirs into the Trinity River, California

BACKGROUND:

- The Trinity River Division of the Central Valley Irrigation Project was completed by the Bureau of Reclamation (Bureau) in 1963, leading to an 80% decline in salmon and steelhead production from the Trinity River. This project reduced average stream flows from 1,200,000 acre-feet (AF) per year to 120,000 AF per year.

- The Hoopa Valley and Yurok Tribes rely on the harvest of anadromous salmonids produced in the Trinity River for subsistence, ceremonial, religious, and commercial purposes.

- The Service estimates that the economic impact of the Trinity River Division and other sources on the non-Tribal commercial and sport fisheries that rely on Trinity River salmon and steelhead has been in excess of 20 million dollars per year.

- In 1981 the Secretary of the Interior signed a Secretarial Issue Document (SID) directing the Bureau to implement the following schedule for flow releases into the Trinity River: 340, 000 AF during normal or wet water years (Shasta Reservoir inflow of at least 4,000,000 AF): 220,000 AF during dry water years (Shasta Reservoir inflow of between 3,200,000 AF and 4,000,000 AF); and 140, 000 AF during critically dry water years (Shasta Reservoir inflow of less than 3,200,000 AF).

- The SID also directs the Fish and Wildlife Service (Service) to evaluate these flows during a 12- year period (the evaluation began in 1985) to determine their efficacy in restoring the Trinity River fishery and to make long-term flow recommendations. Available hydrologic information indicated that 2 of the 12 years during the evaluation would be sub-normal water years. During the first 6 years of the flow evaluation (1986-1990), 5 years were designated as dry.

- An Environmental Impact Statement regarding the management of flows in the Trinity River was prepared in 1981. Information available in 1981 indicated that flow releases of 340,000 AF per year, combined with extensive streambed and watershed rehabilitation, would provide for full restoration of fish populations.

- In 1984, Congress passed the Trinity River Restoration Act directing the Department to fully restore the Trinity River fishery using such measures as erosion control, channel modification, harvest control, and hatchery modernization to augment flow modification. The Bureau and the Service began jointly implementing the Restoration Program in 1986.

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- The Hoopa Tribe filed an administrative appeal in 1988 seeking Secretarial intervention to resolve the Trinity River flow issue.
- The Hoopa Valley Tribe asserts that a minimum of 340,000 AF per year is required to attain fishery restoration and to meet the Secretary's trust responsibility.
- In July, 1990, Secretary Lujan asked A/S FWP to review Trinity River flows and the need for supplemental documentation if flows are altered.

STATUS

- SID-prescribed flow releases have been inadequate to sustain, much less restore fish production in the Trinity River. After peaking in 1986 due in large part to drastically curtailing harvest, fish populations have steadily declined to levels approximating pre-1981 levels.
- The Service has released preliminary results indicating that 340,000 AF provides 56% of optimum habitat , not 100% as had previously been postulated (240,000 AF provides 34% and 14,000 AF provides 15%). Even with full implementation of the Restoration Program, 340,000 AF would provide only 80% of needed habitat.
- In addition to adversely impacting fish habitat, SID-prescribed flows during this prolonged drought have resulted in poor migration survival of fish, have curtailed the anticipated flow related restoration of stream morphology, and have precluded the orderly progress of the flow evaluation and the Restoration Program.
- The Service has determined that SID-prescribed flows for sub-normal water years will not allow for the restoration and evaluation of the Trinity river fishery resources.
- The Bureau of Indian Affairs takes the position that the Secretary is authorized and required to manage the Trinity River fishery with the trust obligations of the United States, as reflected in their April 3, 1991, memorandum to the Commissioner of the Bureau.
- 1991 has been designated as a critically dry water year in Northern California. The April forecast of annual inflow to Shasta Lake is at 2,900,000 AF at the 90% exceedence level.
- The allocation of Trinity River salmon for commercial, sport, and tribal purposes has reached crisis proportion for 1991: minimum escapement levels may not be reached; tribal commercial fishing will not be allowed and subsistence fishing will be at emergency subsistence levels; in-river sport fishing may be prohibited; and ocean fishing will be at the lowest rate in recent history.
- The Sierra Club petitioned the National Marine Fisheries Service (NMFS) to force the Bureau to consult with NMFS regarding the operation of the CVP as it pertains to the threatened Sacramento winter chinook. The ongoing consultation is expected to culminate in the issuance of a Biological Opinion by December 1991.

- Water diverted from the Trinity River to the Sacramento River can only minimally influence the management of the threatened Sacramento River winter chinook due to the relative small quantity of water diverted, the physical constraints on diversion rate, and because it is significantly warmed during the diversion from Trinity Lake through Lewiston, Whiskeytown and Keswick Lakes. The Bureau's April 17, 1991, preliminary CVP operations analysis showed that decreasing Trinity River diversion to the Sacramento River by 100,000 AF would only increase Sacramento river temperatures by 0.1 degrees Fahrenheit (from 64.0 to 64.1 degrees in August). The target temperature for protecting winter chinook is 56 degrees.

- The Bureau has also been asked to consult with the Service regarding CVP operations in relation to endangered bald eagles at Trinity Lake. The Service's draft biological opinion states that 1991 CVP operations are not likely to jeopardize the continued existence of the bald eagle. In the opinion, the Service has not placed any criteria on flow releases or reservoir pool elevations for 1991.

- The Bureau has identified four scenarios for providing additional water to the Trinity River. Two of the flow releases scenarios for increasing 240,000 AF to 340,000 AF in 1991 would not impact winter chinook.

- The original Environmental Impact Statement (EIS) on managing Trinity River flows and the January 1991 tiered Environmental Assessment appear to provide the needed documentation under the National Environmental Policy Act for Secretary to make an informed decision. All of the alternatives being considered in the review fall within the original scope of the 1981 EIS. The Secretary also has the authority to revise Trinity River flows pending completion of additional environmental documentation if it is needed.

- Congress has submitted legislative report language (House Repot102-21, Part 1) related to the Emergency Drought Relief Act (H. R. 355) recommending that 340,000 AF be released into the Trinity River in 1991 and future years as a measure of fulfilling the Government's trust responsibilities to the Hoopa Valley Tribe.

POSITION OF MAJOR CONSTITUENTS

- The Trinity River Task Force, comprised of 14 agencies/groups including the Service, Bureau, Bureau of Indian Affairs, and the Hoopa Valley Tribe, unanimously recommended that the Secretary release 340,000 AF into the Trinity River in 1991 if at all possible.

- Congressmen Riggs (CA) has written to the Secretary recommending that 340,000 AF be released into the Trinity River during 1991.

- The Hoopa Valley Tribe has filed an administrative appeal for the release of 340,000 AF or more during 1991 and during the balance of the flow evaluation period.

- The Klamath River Restoration Task Force recommends that 340,000 AF be released into the Trinity River during the remainder of the flow evaluation period.

- The Klamath Fishery Management Council, Trinity County (county of origin for Trinity River water), Humboldt County, and various commercial and sport fishing groups all support 340,000 AF.

- Numerous Irrigation Districts and CVP power users have stated that SID-prescribed flows for the Trinity River should not be exceeded without adequate NEPA review.

DEPARTMENTAL REVIEW:

- A Departmental review team comprised of representatives from the Service, Bureau, and Bureau of Indian Affairs has been working extensively since October, 1990 to develop a consensus recommendation for Trinity River flows. The team recommends that:

  - for water year 1991 the following criteria be used to determine flow releases: 1) if the most up-to-date forecast (not to extend beyond the June 1 forecast) for projected inflow to Shasta Reservoir equals or exceeds 3,200,000 AF, releases into Trinity River should not be less than 340,000 AF; 3) if the most up-to-date forecast (not to extend beyond the June 1 forecast) for projected inflow to Shasta Reservoir is between 2,900,000 AF and 3,200,000 AF, flow releases into Trinity River should be based on the ramping formula:

$$TR = (SI \div 3) - 726,667$$

Where: TR = Trinity River Release in AF
SI = Shasta Reservoir Inflow in AF

and, 3) if the forecast for inflow to Shasta Reservoir is less than or equal to 2,900,000 AF, releases into Trinity River should not be less than 240,000 AF.

  - for water years 1992-1996: at least 340,000 AF should be released into the Trinity River in dry or wetter years (i.e. when inflow to Shasta Reservoir is equal to or greater than 3,200,000 AF)., and at least 340,000 AF should be released into the Trinity River in critically dry years if at all possible. "If at all possible" means if the water is physically available and can be released into the Trinity River consistent with existing Federal Statutes and Regulations.

- If the Secretary does not take an action on this matter, the existing SID prescribes that 140,000 AF will be released into the Trinity River in 1991. This flow would lead to further declines in Trinity River fish production and would further hamper restoration and evaluation efforts.

- If flow changes are to be made for 1991, the decision is needed by early May 1991. The most critical component of the annual flow regime is the May flows needed to protect migrating juvenile fish.

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APPENDIX D

Chinook Salmon Run Size Review

CH2M HILL

MEMORANDUM

TO: **Mark Hampton, USFWS, Weaverville, CA.**

FROM: **Tim Hammaker, CH2MHill, Redding CA.**

DATE: **March 26, 1995**

SUBJECT: **Chinook Salmon Run Size Review**

PROJECT: **SWW33785.36.TH**

The attached tables provide a summary of the historic chinook salmon data reviewed in regards to Trinity River run sizes. Table D-1 summarizes the various pre-Trinity Division Project run-size estimates. There was no attempt to account for historic angler harvest and Indian harvest as these numbers are not generally available. In order to standardize for pre and post-dam run information spawning escapement estimates were chosen for comparison. These estimates include adults and grilse as the original authors generally did not separate these components. The literature revels that spawning estimates/run size estimates were conducted by several authors for the years: 1944, 1945, 1955, and 1956. These estimates are seen in bold on attached Table D-1. Moffett and Smith (1950) also provided an anecdotal reference to an estimate of 15,000 chinook salmon which passed above Lewiston for the year 1946. This estimate was also included in Table D-1 for a summary of spawning escapements above Lewiston. Fredriksen, Kamine and Associates (1980) expanded Moffett and Smith's (1950) estimated 1944 and 1945 estimated escapements to derive escapements for Trinity River downstream of Lewiston for those years. The original estimated spawning escapements have been reported, revised, and otherwise modified over the years as shown in the additional references shown in Table D-1. For the summary of pre-project estimated spawning escapements the original estimate or what appears to be a reasonable expansion of the original estimates were used to provide a "pre-dam" mean spawning escapement.

From Table D-1 it is estimated that the "pre-dam" spawning escapement, based on the four "good" estimates, ranged from 19,000 to 67,115 with a mean of 38,154 natural spawning chinook salmon above the North Fork. Of this total, the estimated spawning escapement above Lewiston ranged from 9,000 to 36,913 with a mean of 18,432 chinook salmon. The estimate for chinook salmon below Lewiston ranged from 10,000 to 30,134 natural spawners with a mean of 18,834. The authors of the historic spawning estimates generally agreed that approximately 50% of the chinook run spawned above Lewiston.

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Table D-2 provides a summary of the "post-dam" spawning escapements for chinook salmon. The 1963 estimate by LaFaunce (1965) is probably one of the better estimates for the Trinity for the years immediately following the construction of the dams. However the estimate for 1963 would have included salmon from the 1960 and 1961 brood years which would have been affected by the construction of the dams. While the 1963 estimate is included in the summary for the "post-dam" spawning estimates, this number may slightly inflate the estimate for chinook salmon below the dams for years subsequent to construction. Other spawning estimates used in the "post-dam" summary include 1968, 1969, 1971, 1973 made by various authors prior to CDFG's Klamath Basin fall chinook salmon spawner escapement estimates which began in 1978. The CDFG estimates were also included in the Summary Table D-2 to provide an average estimated total spawning escapement (including grilse) for the river for the post-dam interval. Those values used to summarize the spawning escapement in Table D-2 are shown in bold.

The "post-dam" spawning escapement summary indicates that the Trinity River downstream of Lewiston had an estimated range of 5,249 to 113,007 with a mean of 27,650 chinook salmon for the years 1963 through 1994. However, based on estimates of Trinity River Hatchery (TRH) origin coded wire tagged chinook salmon carcasses recovered from inriver, for the years 1992 and 1994, and 1987, a very significant hatchery component of inriver spawners can be demonstrated. For the years of 1992, 1993, and 1994 CDFG's preliminary estimates of the proportion of TRH origin spawners were 32.8%, 14.3%, and 54.2% of the basin run size respectively. Coupled with an estimate of TRH origin spawners of 59% of inriver spawners for 1987 (M. Hampton, USFWS, pers. comm.) indications are that a significant number of inriver spawners are of hatchery origin.

Using the mean proportion of these TRH origin estimated spawners (32.8%, 54.2% and 59% = mean of 48.6%) an adjustment was made for the post-dam spawning escapement estimate (including grilse). CDFG's estimate of proportion of TRH origin spawners for 1993 (14.3%) was not used for the "adjustment" as this number reflected a severe IHN outbreak in the hatchery which resulted in a release of only 650,000 fall chinook smolts for that year class. This adjustment is shown on Table D-2 as the final row in that table. The "adjusted" natural inriver spawning escapement ranges from 2,551 to 54,921 with a mean of 13,465 chinook salmon for the period from 1963 to the present. Comparing that mean estimate of approximately 13,000 native spawners to the estimated mean pre-dam estimated spawning escapement below Lewiston of approximately 19,000 spawners (Table D-1) it appears that the "post-dam" average has averaged approximately 68% of historic numbers. While these averages may be simplistic it does indicate that generally speaking spawning escapement in the Trinity River below Lewiston has not been as great as that for the same reach prior to construction of the dams when accounting for the TR Hatchery component of inriver spawning.

Additional Tables are enclosed which summarize the CDFG's "Mega Table" for the years 1978 through 1994. Figure D-3 (graph) shows the "un-adjusted" in basin run and the "adjusted" run estimate using the TRH origin adjustment factor described above. Please note that this chart shows an adjusted in basin run-size which takes the Trinity inriver spawning escapement added to the angler harvest and then adjusts this term by the 48.8% estimated TRH proportion of the inriver run. Other Charts are self-explanatory and are from the "Mega Table". At the present time I have not completed review of the coho salmon and steelhead historic run sizes.

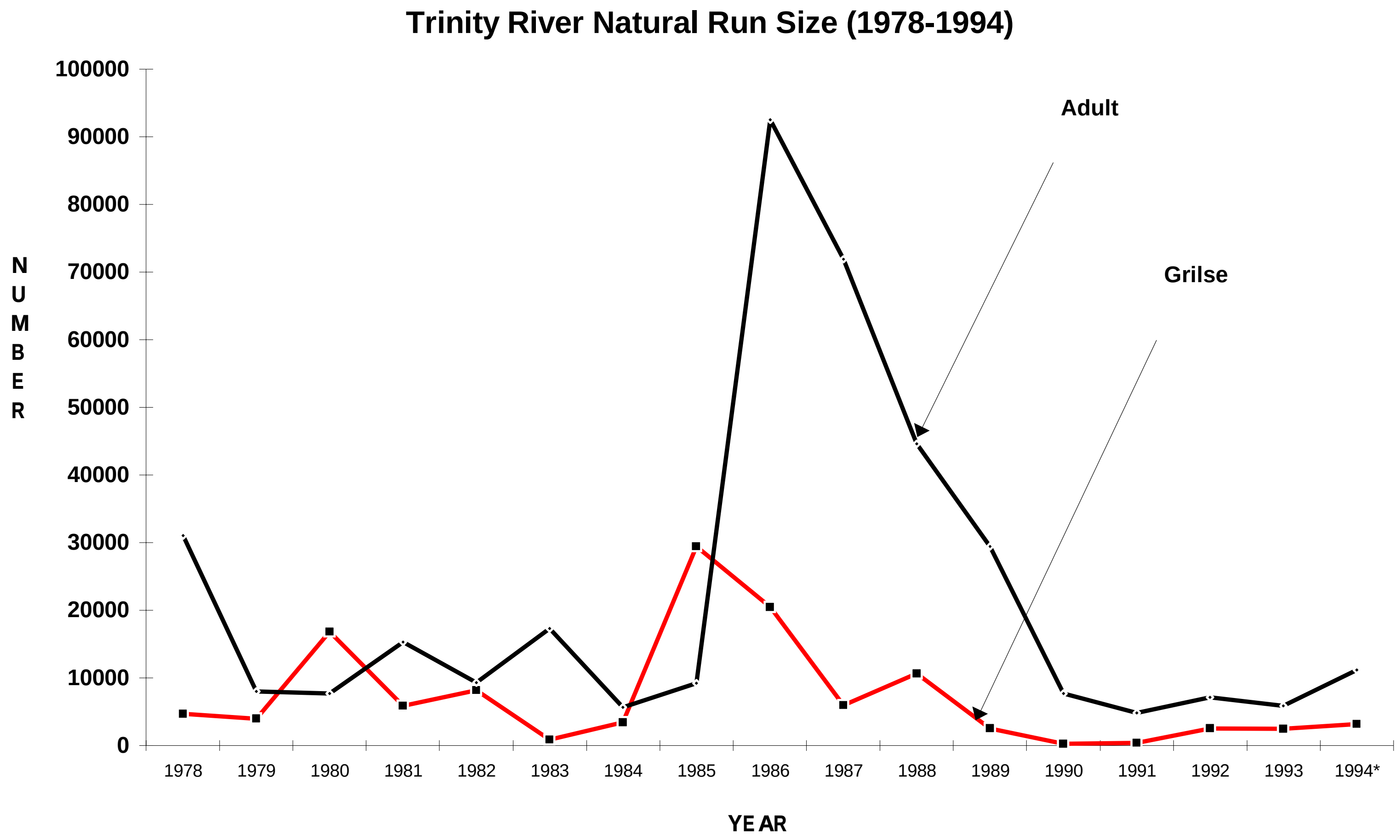

Figure D-1. Trinity River Natural Run Size (1978-1994)

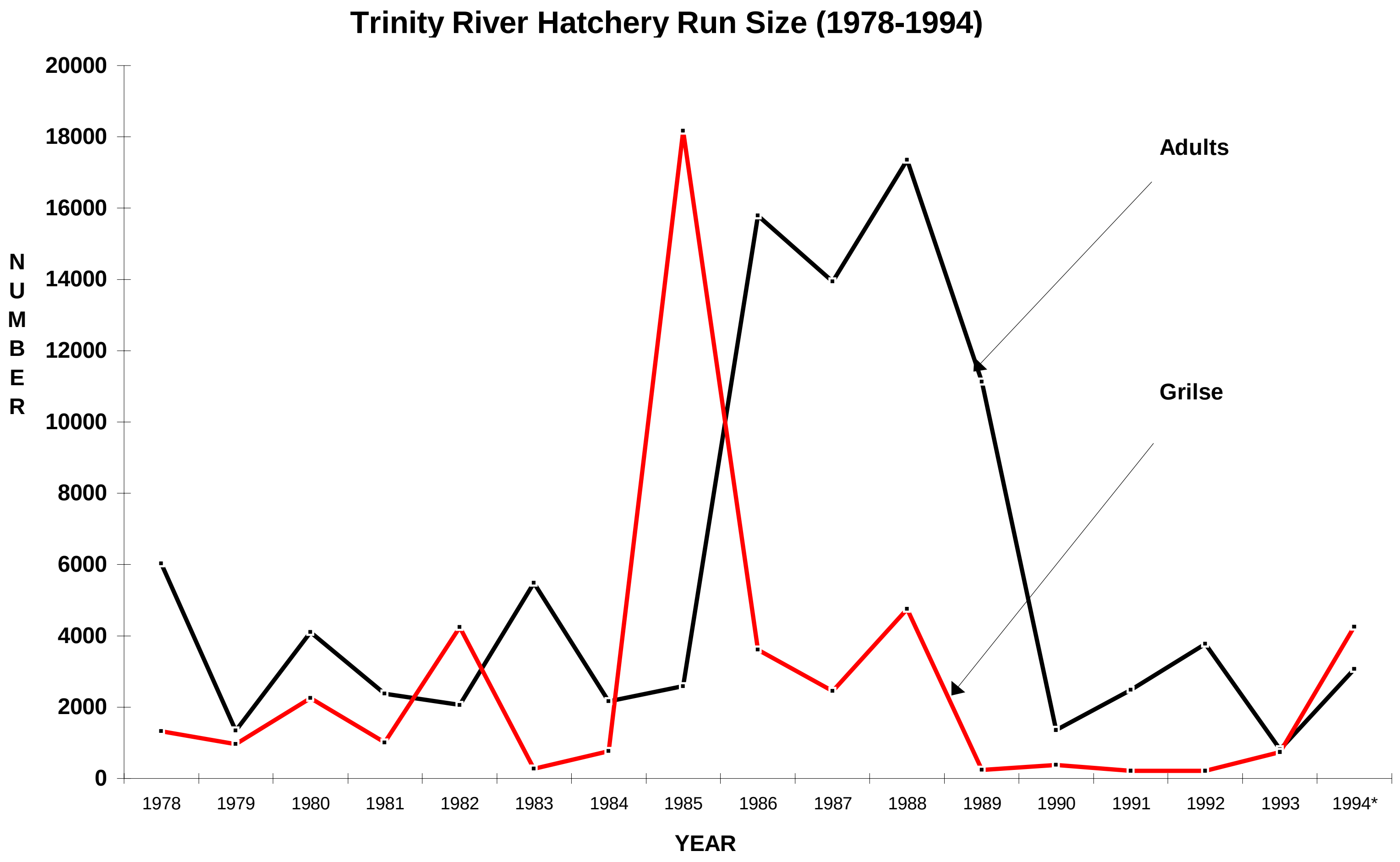

Figure D-2. Trinity River Hatchery Run Size (1978-1994)

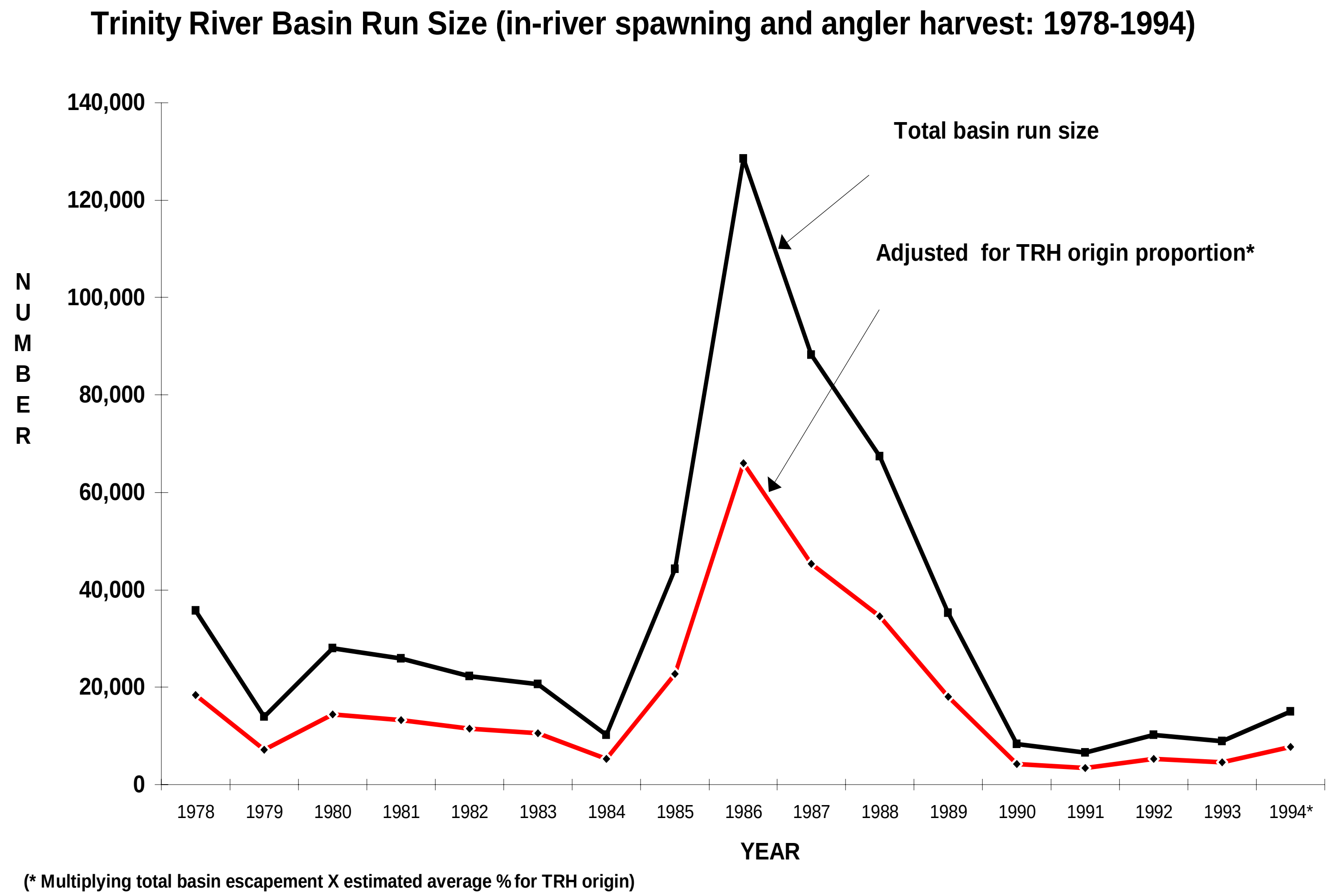

Figure D-3. Trinity River Basin Run Size (in-river spawning and angler harvest: 1978-1994)

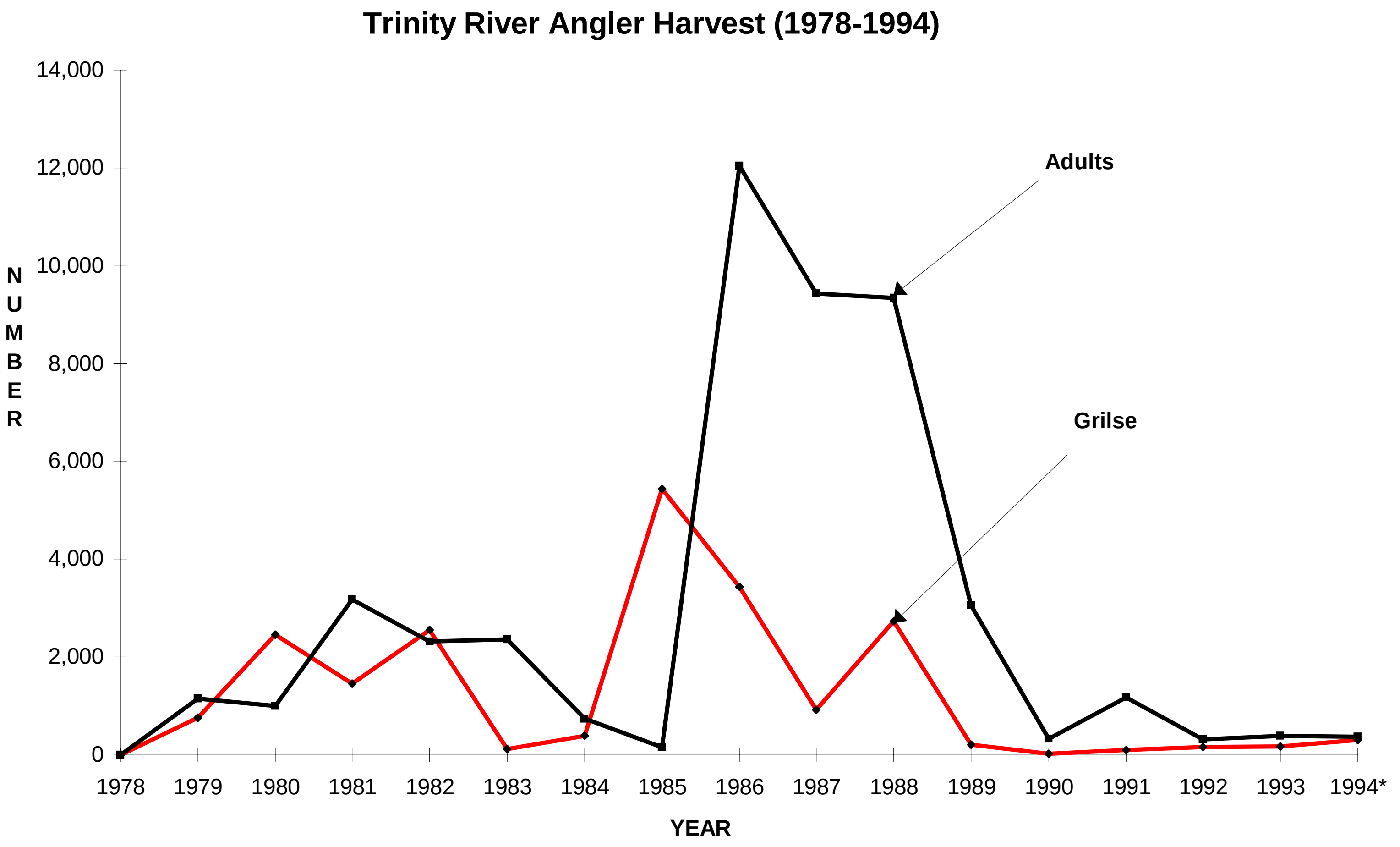

Figure D-4. Trinity River Angler Harvest (1978 - 1994)

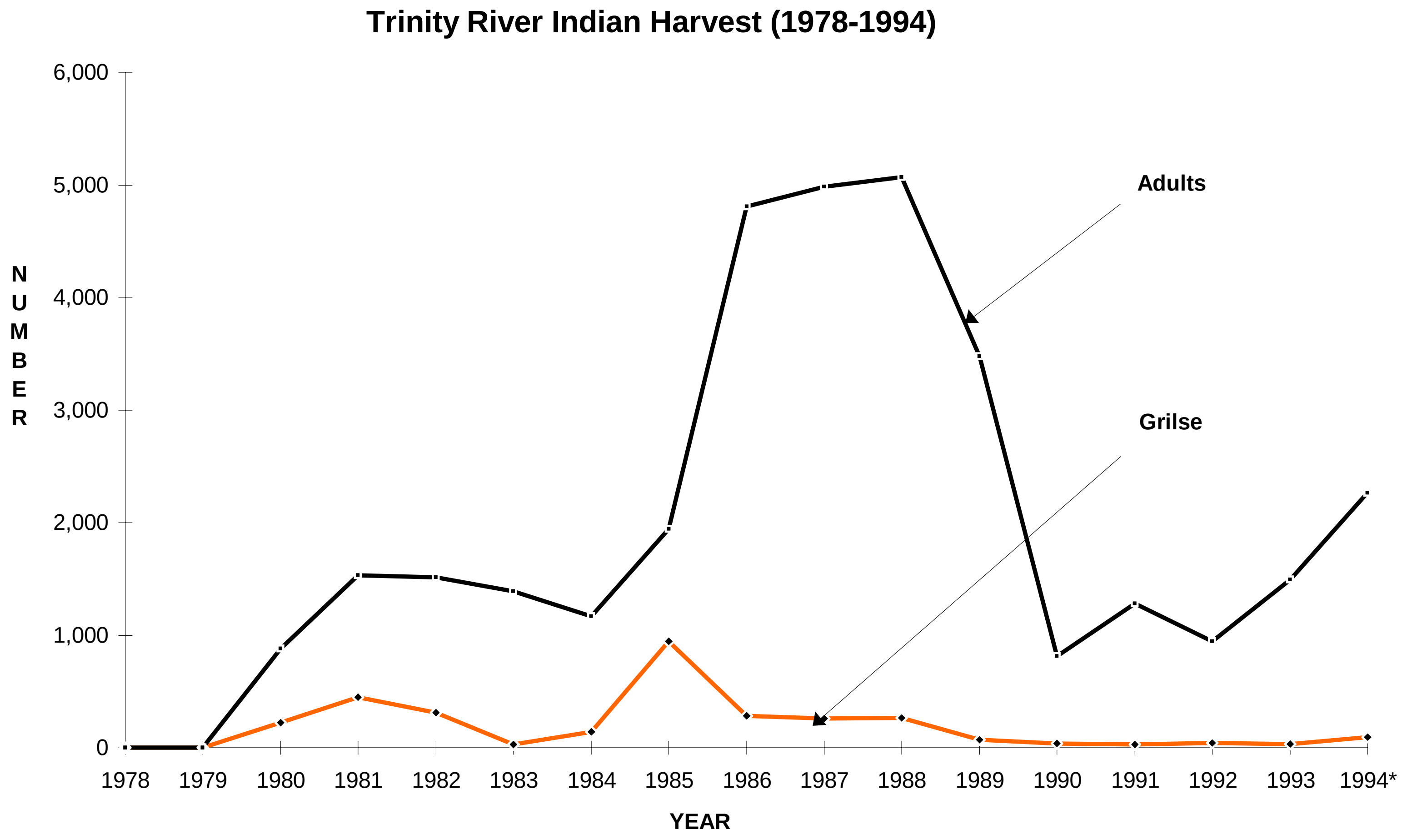

Figure D-5. Trinity River Indian Harvest (1978-1994)

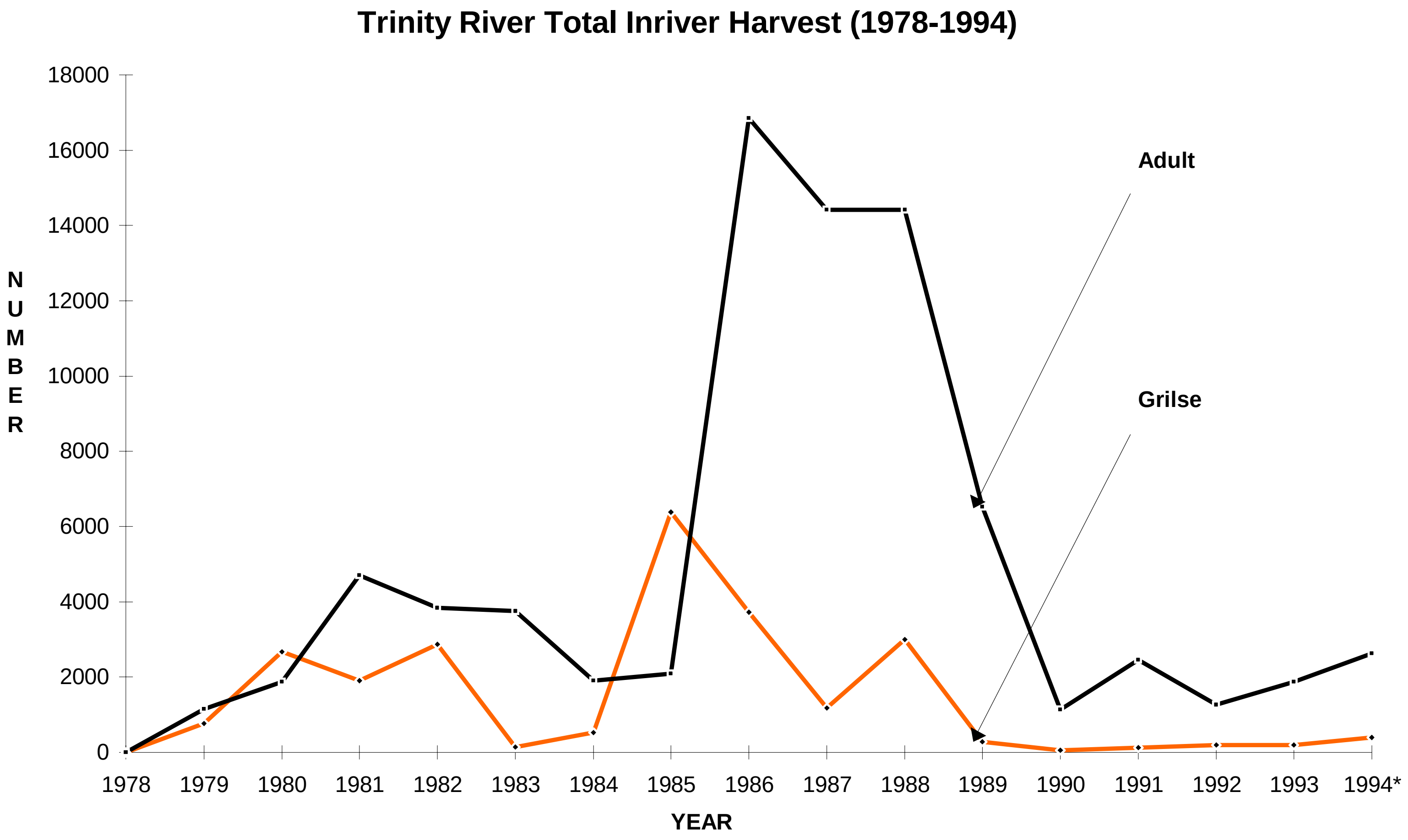

Figure D-6. Trinity River Total Inriver Harvest (1978 - 1994)

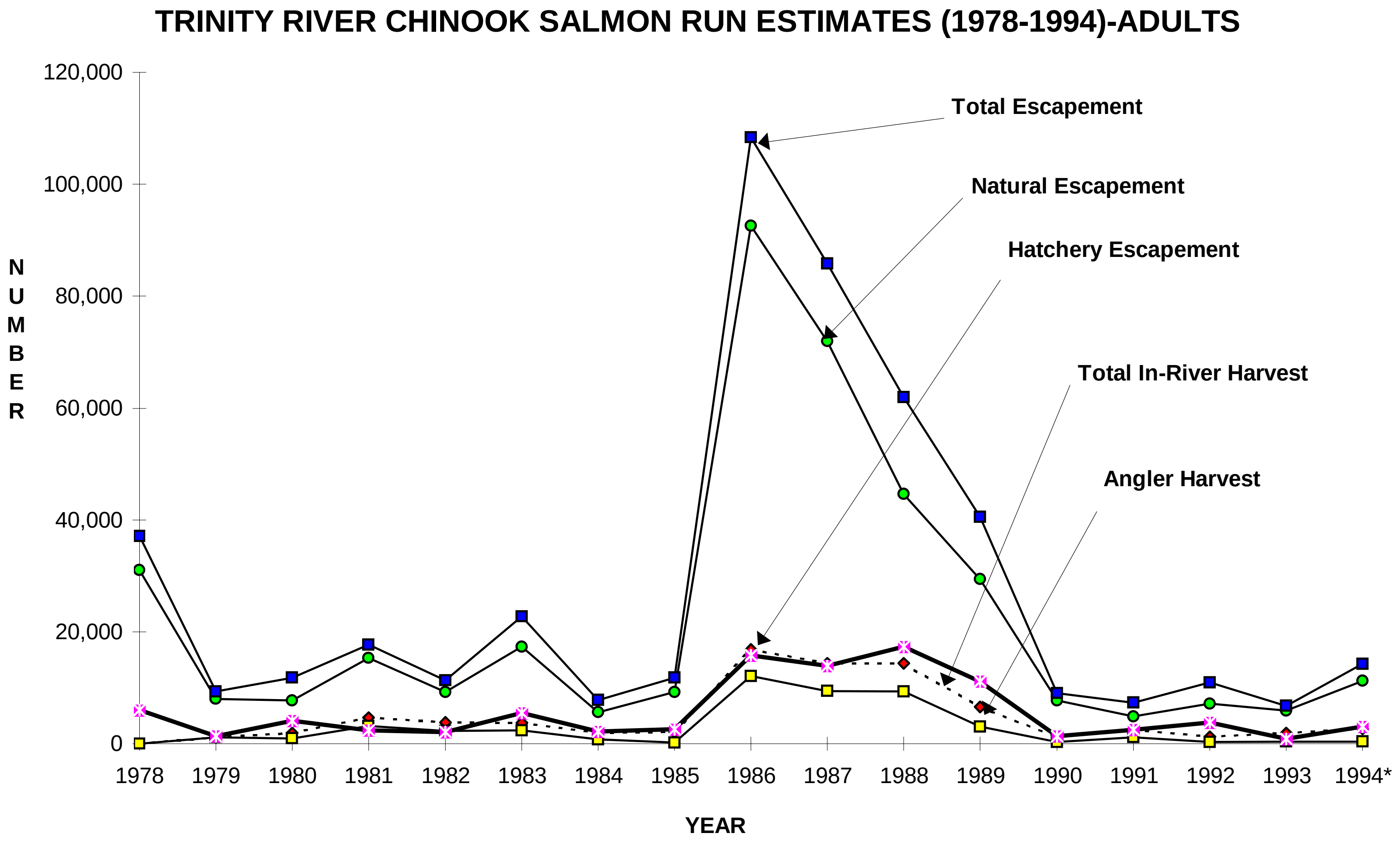

Figure D-7. Trinity River Chinook Salmon Run Estimates (1978- 1994)- Adults

Table D-1. Trinity River Chinook Run Size Estimates (historical) from the Literature

PRE-DAM YEAR(S)	RUN SIZE ESTIMATE	COMMENTS AND SOURCES
1944	27,000	Mean of the estimated range of 18,000 to 36,000, (includs grilse) (Moffet and Smith, 1950; as cited by Leidy and Leidy, 1984)
1944	21,000	Estimated spawning escapement including grilse above Brown's Creek (Moffett and Smith, 1950).
1944	25,600	Total estimated spawning escapement for Upper Trinity above North fork including grilse (Moffet and Smith, 1950)
1944	12,000	Estimated spawning escapement, including grilse, above Lewiston (Moffett and Smith, 1950)
1944	13,500	Estimated spawning escapement, including grilse, below Lewiston (Moffett and Smith, 1950 as cited by Fedriksen Kamine and Assoc., 1980)
1944	12,000	Extrapolated from estimated spawning escapement above Lewiston (including grilse)(USFWS/CDFG ,1956)
1944	25,500	Total spawning escapement for upper Trinity River above North Fork (including grilse) using Gibbs' (1956) distribution and Moffett and Smith's (1950) estimate. (Fredriksen, Kamine & Assoc. 1980)
1944	12,000	Total spawning escapement including grilse above Lewiston.(Moffett and Smith, 1950 as cited by Fredriksen, Kamine & Assoc. 1980)
1944	13,500	Total spawning escapement including grilse below Lewiston using Gibbs' (1956) distribution. (Fredriksen, Kamine & Assoc. 1980)
1945	27,000	Mean of the estimated range of 18,000 to 36,000 (includes grilse) (Moffet and Smith, 1950; as cited by Leidy and Leidy, 1984)
1945	19,000	Total spawning escapement for upper Trinity River above North Fork (including grilse) using Gibbs' (1956) distribution and Moffett and Smith's (1950) estimate. (Fredriksen, Kamine & Assoc. 1980)
1945	9,000	Extrapolated from estimated spawning escapement above Lewiston (includes grilse) (Moffet and Smith, 1950 as cited by USFWS/CDFG ,1956)
1945	9,000	Estimated spawning escapement, including grilse, above Lewiston (Moffett and Smith, 1950)
1945	9,000	Total spawning escapement including grilse above Lewiston.(Moffett and Smith, 1950 as cited by Fredriksen, Kamine & Assoc. 1980)
1945	10,000	Total spawning escapement including grilse below Lewiston using Gibbs' (1956) distribution and Moffett and Smith's (1950) estimate. (Fredriksen, Kamine & Assoc. 1980)
1946	15,000	Estimated above Lewiston (assumed including grilse) (Moffet and Smith, 1950)
Historic	59,000	Estimated from commercial harvest and angler harvest data from landings and average adult weights as calculated by Moffett and Smith, (1950).
1944, 1945	10,000	Estimate of the portion of spawning escapement (including grilse) above the present dam location (Moffet and Smith, 1950 as cited by Wales , 1950).
Historic	84,000	Estimated Klamath system total escapement counts of 168,000; of which 1/2 were Trinity fish, (Coots, 1967 as cited by Leidy and Leidy, 1984)
Historic	66,000	Historic chinook spawning escapements within the Trinity River drainage (Holmberg, 1972 as cited by Leidy and Leidy, 1984).
1955	27,445-50,126	Total estimated spawning escapement including grilse (Gibbs, 1956).
1955	38,786	Mean of the estimated total spawning escapement range of >27,445<50,126 for upper Trinity River river above North Fork (Gibbs, 1956).
1955	35,000	Total escapement including grilse for upper Trinity River (estimated from Gibbs, (1956) by USFWS/CDFG (1956).
1955	40,900	Total mainstem spawning escapement including grilse as estimated by Fredriksen, Kamine & Assoc.(1980) from Gibbs' (1956) data.
1955	25,000	Total spawning escapement including grilse above Lewiston (Fredriksen, Kamine & Assoc., 1980 estimated from Gibbs' (1956) data.
1955	15,600	Total spawning escapement including grilse below Lewiston (Fredriksen, Kamine & Assoc., 1980 estimated from Gibbs' (1956) data.
1955	300	Total spawning escapement including grilse for tributaries below Lewiston (Fredriksen, Kamine & Assoc., 1980 estimated from Gibbs' (1956) data.
1955	24,000	Total Fall run spawning escapement including grilse above Lewiston (USFWS/CDFG ,1956 estimated from Gibbs' (1956) data.

Table D-1. Continued.

PRE-DAM YEAR(S)	RUN SIZE ESTIMATE	COMMENTS AND SOURCES
1955	3,000	Total Spring run spawning escapement including grilse above Lewiston (USFWS/CDFG ,1956 estimated from Gibbs' (1956) data.
1955	8,000	Total Summer run spawning escapement including grilse above Lewiston (USFWS/CDFG ,1956 estimated from Gibbs' (1956) data.
1955	19,245	Total spawning escapement estimate including grilse for the reach above the present dams= 47% X 40,946 (Rogers 1972) modification of Gibbs' (1955) estimate and distribution.
1955	21,701	Total spawning escapement including grilse estimate for the reach below the present dams= 53% X 40,946 (Rogers 1972) modification of Gibbs' (1955) estimate and distributions.
1955	18,500	Mean of the estimated range of total spawning escapement including grilse (13,000-24,000) above Lewiston by (Gibbs , 1956 as cited by USFWS/CDFG , 1956).
1956	55,000	Total estimated spawning escapement including grilse (CDFG , undated as cited by USFWS, 1960) as cited by Leidy and Leidy, 1984.
1956	67,115	Mean estimated total spawning escapement including grilse (95% C.L.= 58,000 to 77,000 (Weber, 1965).
1956	67,200	Total mainstem run including grilse (Weber, 1965 as cited by Fredriksen, Kamine & Assoc. 1980).
1956	36,913	Estimated total spwaning escapement including grilse above Lewiston (using redd counts for distribution: 55.1%) (Weber ,1965).
1956	30,134	Estimated total spawning escapement including grilse below Lewiston using redd counts for distribution: 44.9%) (Weber ,1965).
1956	39,000	Total spawning escapement including grilse above Lewiston as estimated by Weber, 1965 (Fredriksen, Kamine & Assoc. 1980).
1956	28,200	Total spawning escapement including grilse below Lewiston as estimated by Weber, 1965 (as cited by Fredriksen, Kamine & Assoc. 1980).
1956	42,013	Total spawning escapement including grilse above Lewiston (62.6%) as estimated by Weber (1965) and using carcass counts for estimating distribution: 62.6%).
1956	25,110	Total spawning escapement including grilse below Lewiston (37.4%) as estimated by Weber (1965) and using carcass counts for estimating distribution: 37.4%).
1958	3,013	Adults trapped at Lewiston, (from Bedell. 1979 as cited by Fredriksen, Kamine & Assoc. 1980.
1958-1959	3,891	Total trapped including grilse at Lewiston trapping station (Murray, 1960)
1959	4,549	Adults trapped at Lewiston, (from Bedell. 1979 as cited by Fredriksen, Kamine & Assoc. 1980.
1959-1960	7,250	Total trapped including grilse at Lewiston trapping station (Murray, 1960)
1960	2,112	Adults trapped at Lewiston, (from Bedell. 1979 as cited by Fredriksen, Kamine & Assoc. 1980.
1960-1961	2,780	Adults trapped at Lewiston trapping station (Murray, 1960)
1960-1961	6,910	Including grilse at trapping station at Lewiston (Murray, 1962)(note: grilse would be of an age class subsequent to the initiation of trapping activities.
1961	846	Total escapement from mainstem above Lewiston (Fredriksen, Kamine & Assoc. 1980)
1962	1,504	Total escapement from mainstem above Lewiston (Fredriksen, Kamine & Assoc. 1980)
Mean (Total)	**38,154**	**Using total spawning escapements for 1944, 1945, 1955, 1956 for below Lewiston**
Range	**19,000-67,115**	
Mean (above)	**18,432**	**Using total spawning escapements for 1944, 1945, 1946,1955, 1956 for above Lewiston**
Range	**9,000-36,913**	
Mean (below)	**18,834**	**Using total spawning escapements for 1944, 1945, 1955, 1956 for below Lewiston**
Range	**10,000-30,134**	

Table D-2. Post-Dam In River Chinook Salmon Spawning Escapement Only.

POST-DAM YEAR(S)	RUN SIZE ESTIMATE	COMMENTS AND SOURCES
1963	82,342	Estimated spawning escapement after completion of the present dams (Both hatchery and natural) (LaFaunce, 1965).
1963	75,607	Estimated spawning escapement (natural) (LaFaunce, 1965)
1963	72,500	Mainstem below Lewiston (LaFaunce, 1963 as cited by (Fredriksen, Kamine & Assoc. 1980)
1963	3,500	Tributaries below Lewiston (LaFaunce, 1963 as cited by Fredriksen, Kamine & Assoc. 1980)
1968	30,350	Total estimated spawning escapement (both natural and hatchery) (Rogers, 1970)
1968	25,578	Estimated spawning escapement (natural)(Rogers, 1970)
1968	25,500	Mainstem below Lewiston (Rogers, 1968 as cited by Fredriksen, Kamine & Assoc. 1980).
1968	100	Tributaries (Rodgers, 1968 as cited by Fredriksen and Kamine, 1980).
1969	48,479	Total estimated spawning escapement with 95% C.L.= 27,572 to 70,950 (Smith, 1975)
1969	45,900	Mainstem below Lewiston (Smith, 1969 (methods and estimate not agreed upon as cited by Fredriksen, Kamine & Assoc. 1980).
1969	45,893	Estimated spawning escapement (natural)(Smith, 1975)
1970	19,396	Total estimated spawning escapement (both natural and hatchery) (Rogers, 1973)
1970	14,952	Estimated spawning escapement (natural)(Rogers, 1973)
1970	14,900	Mainstem below Lewiston including small males (Rogers, 1970 as cited by Fredriksen, Kamine & Assoc. 1980).
1971	166,510	Total estimated spawning escapement using an estimation method (both natural and hatchery) (Rogers, 1982); This method probably resulted in an estimate which is greater than actual spawning numbers.
1971	161,352	Estimated spawning escapement (natural) (Rogers, 1982)
1971	42,800	Mainstem (Rogers as reported by Hubbell, (1973) as cited by Fredriksen and Kamine, 1980).
1968-1972	30,500	Estimated average spawning escapment below Lewiston Dam (Burton, et al 1977; as cited by Leidy and Leidy, 1984) Including Hatchery?
1972	20,600	Mainstem (Miller as cited by VTN as cited by Fredriksen and Kamine, 1980) (not throught to be a valid estimate, op. sit)
1973	6,200	Mainstem (Burton as cited by Fredriksen and Kamine, 1980).
1974	4,000	Mainstem (Miller as cited by VTN as cited by Fredriksen and Kamine, 1980) (not throught to be a valid estimate, op. sit)
1976	4,000	Mainstem (Miller as cited by VTN as cited by Fredriksen and Kamine, 1980) (not throught to be a valid estimate, op. sit)
1977	4,500	Mainstem (Miller as cited by VTN as cited by Fredriksen and Kamine, 1980) (not throught to be a valid estimate, op. sit)
1978	7,000	Mainstem (Miller as cited by VTN as cited by Fredriksen and Kamine, 1980) (not throught to be a valid estimate, op. sit)
1978	35,764	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1979	11,964	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1980	24,537	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1981	21,246	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1978-1981	38,900	Estimated average total chinook spawning escapment for the Trinity River (USFWS, 1983; as cited by Leidy and Leidy, 1984)? Including Hatchery?

Table D-2. Continued.

POST-DAM YEAR(S)	RUN SIZE ESTIMATE	COMMENTS AND SOURCES
1978-1981	30,200	Estimated average fall run spawning escapment for the Trinity River (USFWS, 1983; as cited by Leidy and Leidy, 1984)? Including Hatchery?
1978-1981	8,700	Estimated average spring run spawning escapment for the Trinity River (USFWS, 1983; as cited by Leidy and Leidy, 1984)? Including Hatchery?
1982	17,423	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1983	18,137	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1984	9,070	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1985	38,671	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1986	113,007	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1987	77,869	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1987	26,857	Mean of the range (24,706 to 29,008) of the estimated fall run spawning escapement using the Schaeffer Method (Stempl, 1988)? Including Hatchery?
1987	15,788	Mean of the range (13,637-17,939) of the estimated spawning escapement using the Schaeffer Method (Stempl, 1988)
1987	42,645	Estimated spawning escapment total for both spring and fall runs using Schaeffer Methods for spawner population estimation (Stempl, 1988).
1988	55,242	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1989	31,988	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1990	7,923	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1991	5,249	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1992	9,702	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1993	8,370	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
1994	14,359	Total spawning escapement including grilse forTrinity River Basin (CDFG, 1994 "Klamath River Basin Fall Chinook Salmon Spawner Escapement above Willow Creek"
Post-dam in river spawning escapement		
Mean	**27,650**	**Using: 1963, 1968, 1969, 1970, 1971, 1973, and 1978 through 1994 estimated in-river spawning escapements**
Range	**5,249-113,007**	
Adjusted Post-dam spawning escapement		
Mean	**13,465**	**Using estimated spawning escapements from above and adjusted for ESTIMATED in-river spawning of Trinity River Hatchery origin fish;**
Range	**2,551-54,921**	**(mean for 1986, 1994, and 1992=48.6% of basin run size and range of 32.8-59%.)**

Table D-3. Estimates of Run Sizes of Coho Salmon and Steelhead before and after contruction of the TRD.

	COHO SALMON	
PRE-DAM YEAR(S)	**RUN SIZE ESTIMATE**	**COMMENTS AND SOURCES**
unknown	8,000	Holmberg, 1972 as cited by Leidy and Leidy, 1984
historic	5,000	Estimate spawning escapment for Trinity above Lewiston (USFWS/CDFG ,1956)
POST-DAM YEAR(S)	**RUN SIZE ESTIMATE**	**COMMENTS AND SOURCES**
1969	3,200	Total escapment estimate (Smith, 1975)
1969	1,996	Hatchery return (Smith, 1975)
1969	1,204	Natural spawning escapment (Smith, 1975)
1970	5,245	Total escapment estimate (Rogers, 1972)
1970	3,147	Hatchery return (Rogers, 1972)
1970	2,098	Natural spawning escapment (Rogers, 1972)
1971	509	Total escapment estimate (Rogers, 1982)
1971	47	Hatchery return (Rogers, 1982)
1971	462	Natural spawning escapment (Rogers, 1982)
1973-1980	3,277	Average hatchery returns 1973-1980 (Leidy and Leidy, 1984).
	STEELHEAD	
PRE-DAM YEAR(S)	**RUN SIZE ESTIMATE**	**COMMENTS AND SOURCES**
Historic	10,000	At least this number (USFWS/CDFG, (1956)
1958-1964	3,034	Average adult counts at Lewiston (Hubbell (1973) as cited by CDFG (1977).
		(all estimates refer to estimates for river below the present dams)
POST-DAM YEAR(S)	**RUN SIZE ESTIMATE**	**COMMENTS AND SOURCES**
1960	2,071	Trinity River Hatchery records (Rogers, 1972)
1961	3,526	Trinity River Hatchery records (Rogers, 1972)
1962	3,243	Trinity River Hatchery records (Rogers, 1972)
1963	1,687	Trinity River Hatchery records (Rogers, 1972)
1964	894	Trinity River Hatchery records (Rogers, 1972)

Table D-3. Continued.

POST-DAM YEAR(S)	RUN SIZE ESTIMATE	COMMENTS AND SOURCES
1964	8,044	Natural escapement: mean of the range of 7,499 to 8,684 as determined by visual survey methods used for estimating spawning escapement (LaFaunce, 1965)
1965	6,941	Trinity River Hatchery records (Rogers, 1972)
1966	992	Trinity River Hatchery records (Rogers, 1972)
1967	135	Trinity River Hatchery records (Rogers, 1972)
1968	232	Trinity River Hatchery records (Rogers, 1972)
1969	554	Trinity River Hatchery records (Rogers, 1972)
1969	*	* no estimate of natural escapement was made due to the lack of significant recoveries at the Trinity River Hatchery but estimated to be greater than the Coho escapement for that year (3200) (Smith, 1975)
1970	241	Trinity River Hatchery records (Rogers, 1972)
1971	67	Trinity River Hatchery records (Rogers, 1972)
1971	*	* no estimate of natural escapement in the mainstem was made due to the lack of significant recoveries at the Trinity River Hatchery (Rogers, 1982)
1971	413	Natural spawning escapement estimate for mainstemTrinity River tributaries, of which 18 were previously surveyed by LaFaunce in 1964 (Rogers, 1972).
1972	242	Trinity River Hatchery records (Rogers, 1973)
1972	1,011	Natural spawning escapement estimate for mainstemTrinity River tributaries, of which 18 were previously surveyed by LaFaunce in 1964 (Rogers, 1973).
1963-1973	249	Average Trinity River Hatchery escapement (CDFG, 1977)
1980-1981	24,000	Average spawning escapement (USFWS ,1983)

Table D-4. Trinity River fall run chinook run size estimates.

YEAR	TRINITY RIVER			ANGLER HARVEST			TOTAL IN-BASIN HARVEST		
	GRILSE	ADULT	TOTAL	ADULT	GRILSE	TOTAL	ADULT	GRILSE	TOTAL
1978	4,712	31,052	35,764	0	0	0	31,052	4,712	35,764
1979	3,936	8,028	11,964	1,157	765	1,922	9,185	4,701	13,886
1980	16,837	7,700	24,537	998	2,456	3,454	8,698	19,293	27,991
1981	5,906	15,340	21,246	3,174	1,456	4,630	18,514	7,362	25,876
1982	8,149	9,274	17,423	2,321	2,554	4,875	11,595	10,703	22,298
1983	853	17,284	18,137	2,360	116	2,476	19,644	969	20,613
1984	3,416	5,654	9,070	736	393	1,129	6,390	3,809	10,199
1985	29,454	9,217	38,671	154	5,442	5,596	9,371	34,896	44,267
1986	20,459	92,548	113,007	12,039	3,438	15,477	104,587	23,897	128,484
1987	5,949	71,920	77,869	9,433	923	10,356	81,353	6,872	88,225
1988	10,626	44,616	55,242	9,341	2,735	12,076	53,957	13,361	67,318
1989	2,543	29,445	31,988	3,054	209	3,263	32,499	2,752	35,251
1990	241	7,682	7,923	328	22	350	8,010	263	8,273
1991	382	4,867	5,249	1,177	94	1,271	6,044	476	6,520
1992	2,563	7,139	9,702	314	158	472	7,453	2,721	10,174
1993	2,465	5,905	8,370	391	172	563	6,296	2,637	8,933
1994*	3,150	11,209	14,359	366	308	674	11,575	3,458	15,033
MEAN	7,155	22,287	29,442	2,959	1,328	4,287	25,246	8,483	33,729

APPENDIX E

Trinity River Natural Salmon and Steelhead Escapement Evaluation

Introduction

Since 1978, the CDFG has operated fish monitoring weirs in the Trinity River (at Junction City for spring-run chinook and at Willow Creek for fall-run chinook, steelhead and coho) to mark salmon for harvest and spawning escapement estimation. The CDFG has also adipose fin-clipped/coded wire tagged chinook and coho salmon and fin-clipped steelhead released from Trinity River Fish Hatchery (TRFH). Data collected from recoveries of marked fish in the fisheries, spawning ground surveys and at the hatchery allow for the evaluation of rearing practices and contributions of hatchery-produced fish to the inriver spawning escapement and harvest. This analysis was conducted to assess the current status of the naturally produced spawning escapement of chinook and coho salmon and steelhead of the Trinity River relative to the escapement goals of the Trinity River Restoration Program. For the purposes of this evaluation, the term "inriver spawners" refers to fish that spawn in the Trinity River and excludes fish that return to the TRFH. "Naturally produced" refers to fish whose parents were inriver spawners; "hatchery-produced" refers to fish whose parents were spawned at TRFH.

Methods

Adipose fin-clip data collected at TRFH and at the two weirs were used to estimate the proportion of the inriver spawning escapement (jacks and adults) that were hatchery-produced and naturally produced. The CDFG assumes that the adipose fin clip rate for salmon observed at TRFH represents a population of 100% hatchery-produced fish (CDFG, 1995). Comparison of the adipose fin-clip ($AD\%_{weir}/AD\%_{hatchery}$) rates between fish recovered at the hatchery and at the two weir sites (Willow Creek and Junction City), yields an estimate of the proportion of hatchery-produced fish in the basin (Zuspan, CDFG, 1996, pers. comm.), and subsequently the proportion of naturally produced fish spawning inriver. When the ad-clip rate at the hatchery was less than the ad-clip rate observed at the weirs, it was assumed that all fish were of hatchery origin. Some naturally produced chinook salmon spawn in the hatchery, and since 1991, some adipose fin-clipped chinook salmon observed at the Willow Creek weir were naturally produced. While both of these factors compromise the accuracy of the proportioning, they are unlikely to have a large effect because these numbers are extremely small in any given year. Fin-clip data prior to 1982 was not used because 1982 was the first year that all age classes were represented by fin-clipped fish.

This analysis does not address the impacts of ocean and inriver fisheries on the fishery resources of the Trinity River because data specific to the harvest of Trinity River naturally produced salmonids is extremely limited.

Results

Chinook Salmon: The current fall-run chinook escapement goal of the Trinity River Fish and Wildlife Program is 62,000 naturally produced adult inriver spawners in the Trinity River Basin. Total inriver spawners (jacks and adults) above Willow Creek ranged from 5,249 in 1991 to 113,007 in 1986, and averaged 28,843 from 1978 to 1995 (Table E-1). Adult inriver spawners have ranged from 4,867 in 1991 to 92,548 in 1986, and averaged 25,359 during this period. Substantial numbers of these inriver spawners were hatchery-produced but were designated as "natural" spawners by CDFG because they spawned in the river. Based on ad-clip rates observed at the TRFH and the Willow Creek weir for the period 1982 to 1995, the proportion of naturally produced inriver spawners (jacks and adults) has ranged from 10% in 1985 to 94% in 1992, and averaged 44%. After the proportion of hatchery-produced fall-run chinook are removed from the number of inriver spawners (jacks and adults), numbers of naturally produced fall-run chinook ranged from 2,354 in 1991 to 41,371 in 1995, and averaged 11,044.

Table E.1. Trinity River fall-run chinook spawning escapement above Willow Creek weir and origin of spawners. TRFH = Trinity River Fish Hatchery, WCW = Willow Creek Weir, %H= % of TOTAL BASIN escapement that were hatchery-produced, %Nat= % of Inriver Spawners that were naturally produced. (CDFG, 1996b).

	Inriver Escapement (WCW to Lewiston Dam)				**Ad-clip Rate**						
Year	**Jacks**	**Adults**	**Returns to TRFH**	**BASIN TOTAL**	**WCW**	**TRFH**	**Basin %H**	**Hatchery Produced**	**Naturally Produced**	**Total Inriver Spawners**	**Inriver %Nat**
	A	B	C	D=A+B+C	E	F	G=E/F	H=G*D	I=D-H	J=A+B	K=I/J
1978	4,712	31,052	7,359	43,123	-	-	-	-	-	35,764	-
1979	3,936	8,028	2,299	14,263	-	-	-	-	-	11,964	-
1980	16,837	7,700	6,255	30,792	-	-	-	-	-	24,537	-
1981	5,906	15,340	3,374	24,620	-	-	-	-	-	21,246	-
1982	8,149	9,274	6,293	23,716	0.161	0.218	73.8%	17,515	6,201	17,423	36%
1983	853	17,284	5,765	23,902	0.128	0.148	86.5%	20,672	3,230	18,137	18%
1984	3,416	5,654	2,932	12,002	0.081	0.129	62.8%	7,536	4,466	9,070	49%
1985	29,454	9,217	20,749	59,420	0.192	0.205	93.7%	55,651	3,768	38,671	10%
1986	20,459	92,548	19,404	132,411	0.216	0.268	80.6%	106,719	25,692	113,007	23%
1987	5,949	71,920	16,387	94,256	0.197	0.221	89.1%	84,020	10,236	77,869	13%
1988	10,626	44,616	22,104	77,346	0.111	0.134	82.8%	64,070	13,275	55,242	24%
1989	2,543	29,445	11,371	43,359	0.068	0.103	66.0%	28,625	14,734	31,988	46%
1990	241	7,682	1,719	9,642	0.060	0.128	46.9%	4,519	5,122	7,923	65%
1991	382	4,867	2,687	7,936	0.083	0.118	70.3%	5,582	2,354	5,249	45%
1992	2,563	7,139	3,990	13,692	0.039	0.118	33.1%	4,525	9,167	9,702	94%
1993	2,465	5,905	1,551	9,921	0.040	0.182	22.0%	2,180	7,741	8,370	92%
1994	2,505	10,906	7,706	21,117	0.084	0.128	65.6%	13,858	7,259	13,411	54%
1995	9,262	77,876	15,254	102,392	0.059	0.099	59.6%	61,021	41,371	87,138	47%
1978-1995											
Avg	7,237	25,359	8,733	41,328	-	-	-	-	-	32,597	-
Min	241	4,867	1,551	7,936	-	-	-	-	-	5,249	-
Max	29,454	92,548	22,104	132,411	-	-	-	-	-	113,007	-
1982-1995											
Avg	7,062	28,167	9,851	45,079	-	-	66.7%	35,231	11,044	35,231	44.0%
Min	241	4,867	1,551	7,936	-	-	22.0%	2,180	2,348	5,249	10.0%
Max	29,454	92,548	22,104	132,411	-	-	93.7%	106,719	41,371	113,007	94.0%

From 1978 to 1994, estimates of spring-run chinook inriver spawners (jacks and adults) above Junction City ranged from 1,360 in 1991 to 39,570 in 1988, and averaged 9,803 (Table E-2). From 1982 to 1994, the proportion of naturally produced inriver spawners (jacks and adults) has ranged from 0 to 100%, and averaged 32%. During this period, naturally produced spring-run chinook salmon ranged from 0 to 6,214 fish, averaging 1,551. Several tributaries to the Trinity River also support populations of spring-run chinook, mainly the South Fork Trinity River, New River, North Fork Trinity River, and Canyon Creek (Table E-3), all of which are below the Junction City Weir. Spawning escapement in the South Fork Trinity River has ranged from 33 to 599 fish. Spawning escapements of spring-run chinook in the Salmon River, a tributary to the Klamath River, have ranged from less than 133 to 1,433. The current escapement goal of the Trinity River Fish and Wildlife Program is 6,000 naturally produced spring-run chinook inriver spawners in the Trinity River Basin.

Coho Salmon: The Trinity River Restoration Program's spawning escapement goal for inriver adult coho salmon in the mainstem Trinity River is 1,400 fish. Since 1978, the estimated spawning escapement of coho salmon (jacks and adults) in the Trinity River above Willow Creek has ranged from 558 to 32,373, averaging 10,192 fish (Table E-4). Data for the proportion of hatchery-produced coho salmon was available from 1991 to 1995. During this period, the proportion of naturally produced fish to inriver escapement ranged from 0% to 14%, and averaged 3%. The annual number of naturally produced inriver spawners averaged 202 fish. Based on these data, the Trinity River coho population is predominately of hatchery origin.

Steelhead: The Restoration Program's goal for steelhead is 40,000 naturally produced spawners. Since 1980, the CDFG produced 12 estimates of steelhead inriver escapement upstream from Willow Creek and estimated the hatchery contribution to the natural escapement in six of these years (Table E-5). Numbers of inriver spawners in the Trinity River Basin above Willow Creek have ranged from 1,977 to 28,933 fish, and averaged 9,160. The percentage of naturally produced fish to the inriver spawners ranged from 59% to 88%, and averaged 70% for the six years for which data were available. During these years, numbers of naturally produced inriver spawners ranged from 1,176 to 14,462, and averaged 4,724. The data collected to generate these estimates only account for the fall-run and the early portion of the winter-run and only provides an assessment for a portion of the Trinity River steelhead population.

Currently there are no mitigation or Trinity River Fish and Wildlife Management restoration goals for summer-run steelhead. The largest populations of summer-run steelhead in the Trinity River Basin are now found in the North Fork Trinity and New River (Table E-6). Canyon Creek and the South Fork Trinity also support small runs of summer-run steelhead, although these populations have undoubtedly declined greatly over the years.

Conclusion

Current populations of naturally produced Trinity River anadromous salmonids are at low levels compared to the escapement goals of the Trinity River Fish and Wildlife Restoration Program. The large spawning escapements that have occurred were typically dominated by TRFH fish that spawned in the natural areas of the Trinity and are not indicative of healthy spawning and rearing conditions in the Trinity River. The high contribution of hatchery-produced fish can be attributed to the increased survival at early life stages that these fish experience while naturally produced fish are exposed to the spawning and rearing conditions that exist in the Trinity River that have been severely degraded by the operation of the TRD.

Table E.2. Trinity River spring chinook spawning escapement above Junction City weir and origin of spawners. TRFH = Trinity River Fish Hatchery, JCW = Junction City Weir, %H= % of TOTAL BASIN escapement that were hatchery-produced, %Nat= % of Inriver Spawners that were naturally produced. (Stemple 1988, Zuspan and Sinnen 1996)

	Ad-Clip Rate			**Total**					**Total**	
Year	**TRFH**	**JCW**	**BASIN %H**	**Inriver Spawners**	**Returns to TRFH**	**BASIN TOTAL**	**Hatchery Produced**	**Naturally Produced**	**Inriver Spawners**	**Inriver %Nat**
	A	B	C=B/A	D	E	F=D+E	G=F*C	H=F-G	I	J=H/I
1978	-	-	-	14,413	3,833	18,246	-	-	14,413	-
1979	-	-	-	5 ,008	1,771	6,779	-	-	5 ,008	-
1980	-	-	-	2,926	900	3,826	-	-	2,926	-
1981	-	-	-	3,604	2,500	6,104	-	-	3,604	-
1982	0.753	0.489	64.9%	4,255	1,376	5,631	3,657	1,974	4,255	46%
1983	-	-	-	-	1,158	-	-	-	-	-
1984	0.319	0.028	8.8%	1,494	812	2,306	202	2,104	1,494	100%
1985	0.240	0.223	92.9%	5,696	3,153	8,849	8,222	627	5,696	11%
1986	0.097	0.174	100%	17,706	8,544	26,250	26,250	0	17,706	0%
1987	0.138	0.135	97.8%	31,660	9,853	41,513	40,611	902	31,660	3%
1988	0.130	0.115	88.5%	39,570	14,282	53,852	47,638	6,214	39,570	16%
1989	0.145	0.131	90.3%	18,676	5,000	23,676	21,390	2,286	18,676	12%
1990	0.149	0.125	83.9%	3,006	2,537	5,543	4,650	893	3,006	30%
1991	0.088	0.061	69.3%	1,360	685	2,045	1,418	627	1,360	46%
1992	0.118	0.069	58.5%	1,886	1,846	3,732	2,182	1,550	1,886	82%
1993	0.083	0.091	100%	2,148	2,661	4,809	4,809	0	2,148	0%
1994	0.220	0.170	77.3%	3,447	2,887	4,894	4,894	1,440	3,447	42%
Average (1978-1994)		-	-	9,803	4,215	14,284	-	-	9,803	-
Min	-	-	-	1,360	685	1,158	-	-	1,360	-
Max	-	-	-	39,570	14,282	53,852	-	-	39,570	-
Average (1984-1994)		-	77.7%	10,909	4,470	15,378	13,827	1,551	10,909	32%
Min	-	-	8.8%	1,360	685	2,045	202	0	1,360	0%
Max	-	-	100%	39,570	14,282	53,852	47,638	6,214	39,570	100%

Table E.3. Spring Chinook Spawning Escapement in Trinity River Tributaries and the Salmon River. NS=No Survey was conducted that year.

Stream	1988	1989	1990	1991	1992	1993	1994	1995
Trinity River Basin								
North Fork	28	NS	6	0	0	14	1	50
Canyon Creek	233	NS	13	3	0	7	5	0
New River	12	17	13	2	18	31	5	21
South Fork	59	33	82	186	259	560	378	599
Klamath River Basin								
Salmon River	1,039	287	148	190	330	1,300	1,249	1,215

Although other factors (oceanic conditions, ocean/inriver harvest) also affect spawning populations, natural production of Trinity River salmonid populations is limited during the freshwater phase of their life cycles. A more obvious indicator of the poor condition of the freshwater habitat of the Trinity River is the status of anadromous salmonids. NMFS listed coho salmon as a threatened under the Endangered Species Act; chinook salmon and steelhead are both candidate species.

Table E.4. Trinity River coho salmon spawning escapement above Willow Creek weir and origin of spawners. TRFH = Trinity River Fish Hatchery, WCW = Willow Creek Weir, %H= % of TOTAL BASIN escapement that were hatchery-produced, %Nat= % of Inriver Spawners that were naturally produced. (Zuspan and Sinnen 1996, 1994 and 1995 data were preliminary from personnel communication with W. Sinnen and subject to revision)

Year	Ad-Clip Rate TRFH	Ad-Clip Rate WCW	BASIN %H	Inriver Spawners	Returns to TRFH	BASIN TOTAL	Origin Hatchery	Origin Naturally	%Nat
	A	B	C=B/A	D	E	F=D+E	G=C*F	H=F-G	I=H/D
1978	-	-	-	5,477	3,655	9,132	-	-	-
1979	-	-	-	7,262	3,535	10,797	-	-	-
1980	-	-	-	2,771	3,323	6,094	-	-	-
1981	-	-	-	5,481	4,523	10,004	-	-	-
1982	-	-	-	6,255	4,798	11,053	-	-	-
1983	-	-	-	1,083	706	1,789	-	-	-
1984	-	-	-	9,159	8,861	18,020	-	-	-
1985	-	-	-	26,384	11,786	38,170	-	-	-
1986	-	-	-	19,281	7,991	27,272	-	-	-
1987	-	-	-	32,373	23,338	55,711	-	-	-
1988	-	-	-	24,127	12,816	36,943	-	-	-
1989	-	-	-	13,482	4,970	18,452	-	-	-
1990	-	-	-	2,215	1,635	3,850	-	-	-
1991	0.003	0.003	100%	6,327	2,688	9,015	9,015	0	0%
1992	0.100	0.091	91%	6,733	3,582	10,315	9,387	928	14%
1993	0.136	0.134	99%	3,440	2,117	5,557	5,475	82	2%
1994	0.061	0.070	100%	558	294	852	852	0	0%
1995	0.097	0.104	100%	11,050	4,767	15,817	15,817	0	0%
Avg (1978-1995)		-	-	10,192	6,454	18,058	-	-	-
Min	-	-	-	558	294	852	-	-	-
Max	-	-	-	32,373	23,338	55,711	-	-	-
Avg(1991-1995)		-	98%	5,622	2,690	8,311	8,109	202	3%
Min	-	-	91%	558	294	852	852	0	0%
Max	-	-	100%	11,050	4,767	15,817	15,817	928	14%

Table E.5. Trinity River fall steelhead natural spawning escapement above Willow Creek weir and origin of spawners (Zuspan and Sinnen 1996). TRFH = Trinity River Fish Hatchery, WCW = Willow Creek Weir, %H= % of TOTAL BASIN escapement that were hatchery-produced, %Nat= % of Inriver Spawners that were naturally produced.

Year	Inriver Spawners above WCW	Origin		%Origin	
		Hatchery Produced	Naturally Produced	%H	%Nat
1980	19,563	5,101	14,462	26%	74%
1981	-	-	-	-	-
1982	7,860	971	6,889	12%	88%
1983	6,661	-	-	-	-
1984	6,430	-	-	-	-
1985	-	-	-	-	-
1986	-	-	-	-	-
1987	-	-	-	-	-
1988	11,926	-	-	-	-
1989	28,933	-	-	-	-
1990	3,188	-	-	-	-
1991	8,631	-	-	-	-
1992	2,299	759	1,540	33%	67%
1993	1,977	801	1,176	41%	59%
1994	3,288	878	2,410	27%	73%
1995	3,291	1,424	1,867	43%	57%
1980-1995					
Avg	8,671	-	-	-	-
Min	1,977	-	-	-	-
Max	28,933	-	-	-	-
1980,1982,1992-1995					
Avg	6,380	1,656	4,724	30%	70%
Min	1,977	759	1,176	12%	57%
Max	19,563	5,101	14,462	43%	88%

Table E.6. Summer steelhead counts and estimates (in parentheses) in the Trinity River Basin provided by CDFG. NS=No Survey was conducted that year.

	Location in Trinity Basin				
Year	**South Fork**	**New River**	**North Fork**	**Canyon Creek**	**Upper Trinity**
1980	NS	320 (355)	456	6	31
1981	NS	236 (250)	219	3	2
1982	26	114 (300)	193 (210)	20	NS
1983	NS	NS	160	3	9
1984	8 (30)	335 (340)	179	20	5
1985	3 (20)	NS	57 (112)	10	9
1986	73 (100)	NS	NS	NS	6
1987	NS	(300)	36 (300)	0	9
1988	30	204 (350)	624	32	16
1989	37	600	347 (600)	NS	8
1990	66	343	554	15	13
1991	9 (43)	500-600	825-1037	3	NS
1992	29	272	369	6	NS
1993	42	368	604	24	NS
1994	22	404	990	45	NS
1995	30	775	828	17	NS

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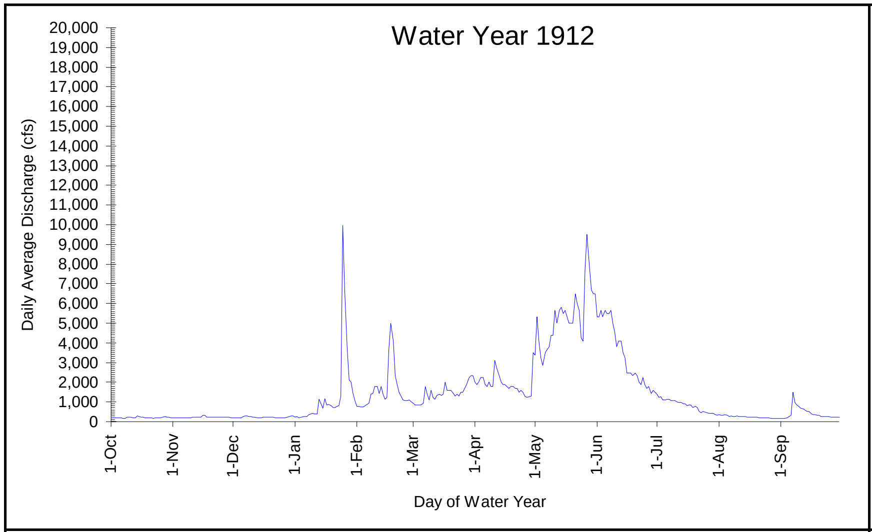
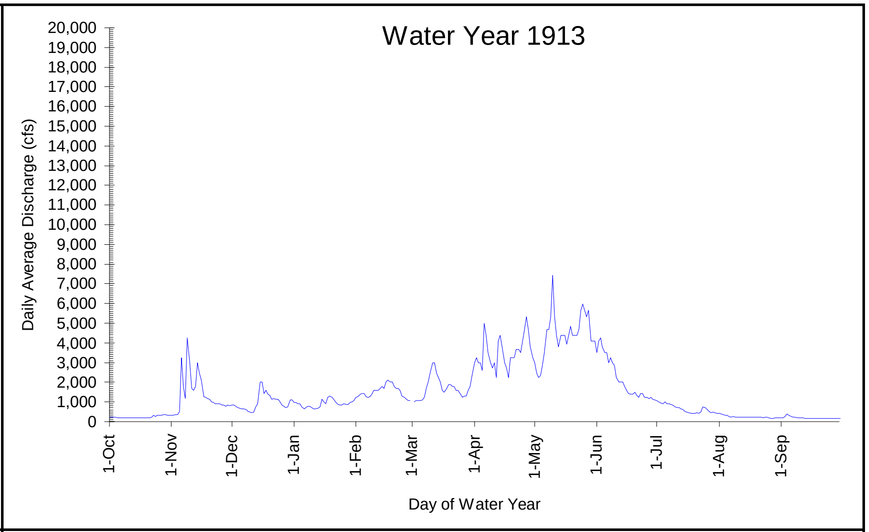
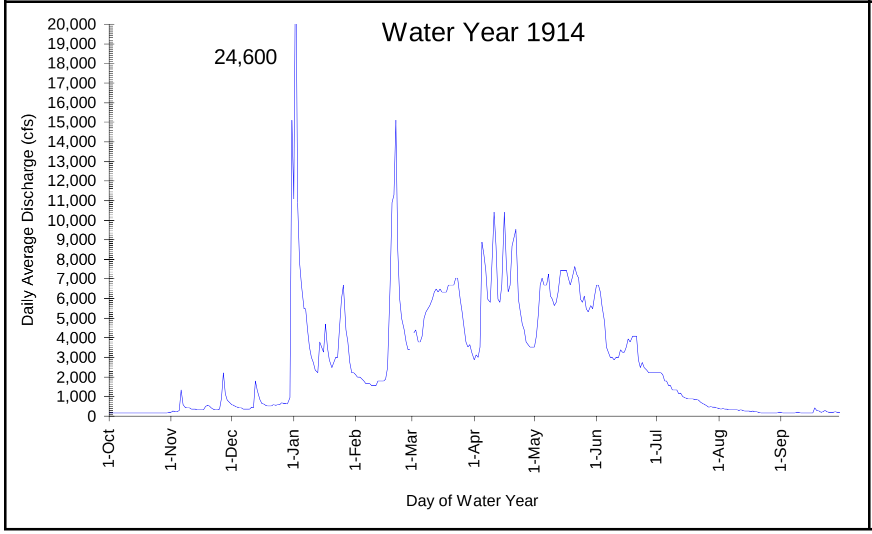
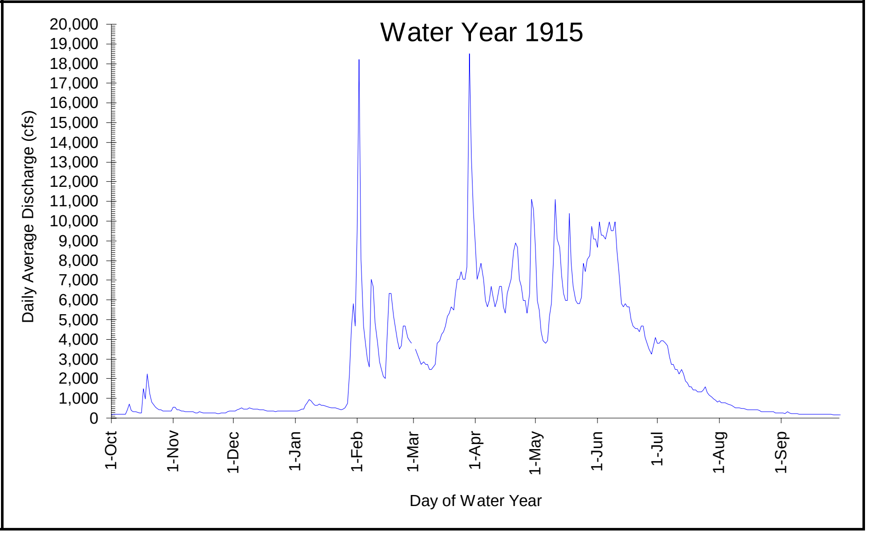
APPENDIX F

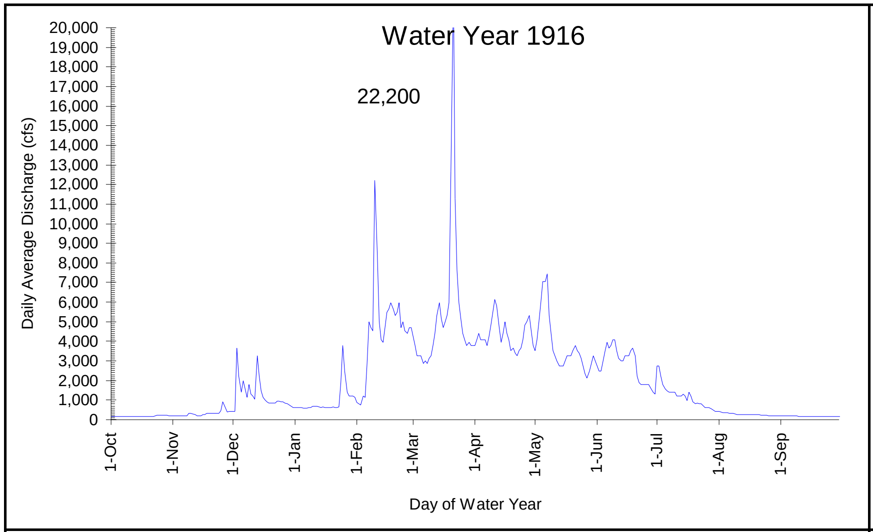
Hydrographs of the Trinity River at Lewiston - 1912 to 1997

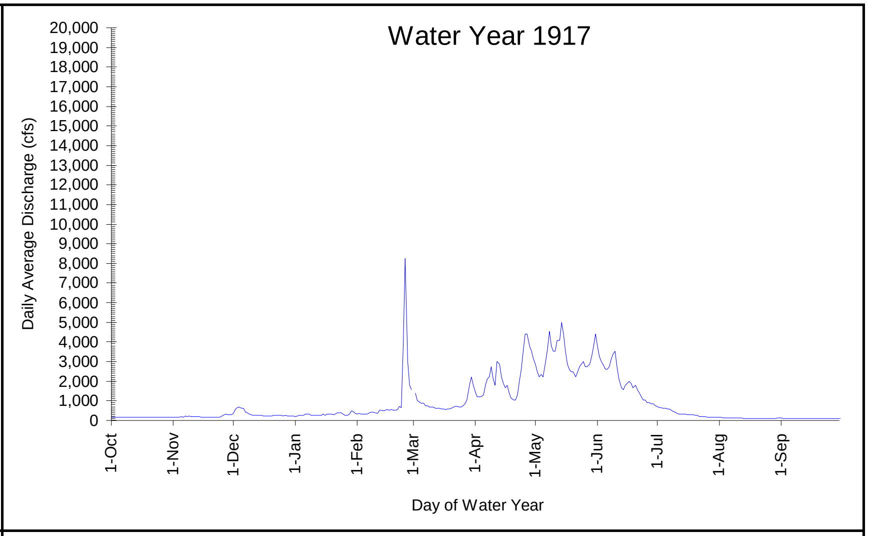

Water Year 1912

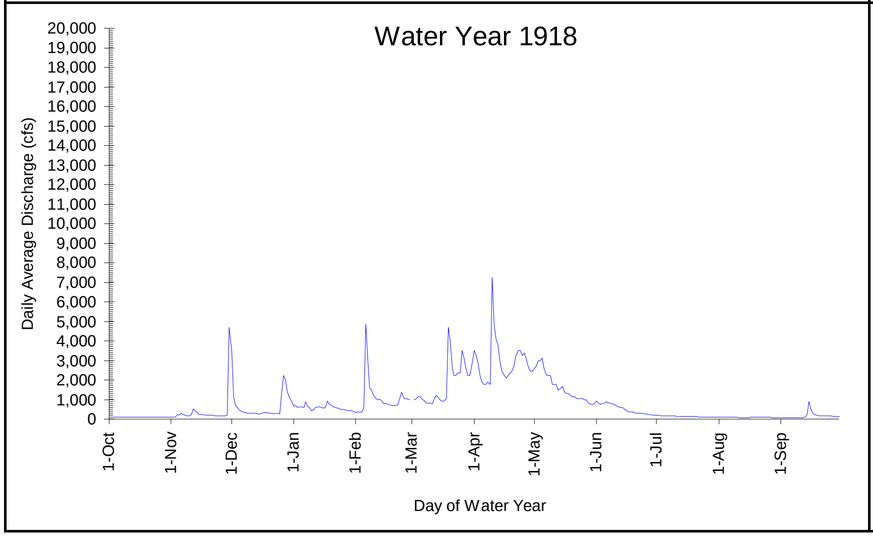

Water Year 1913

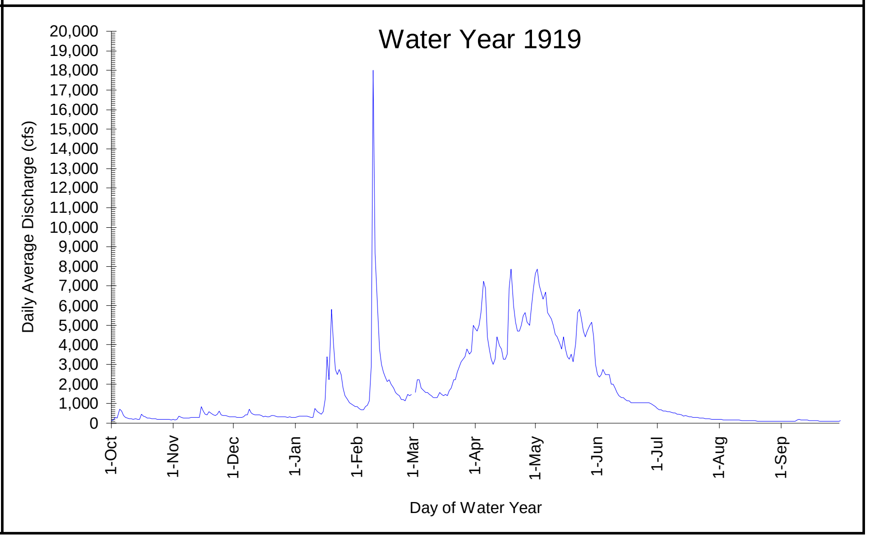

Water Year 1914

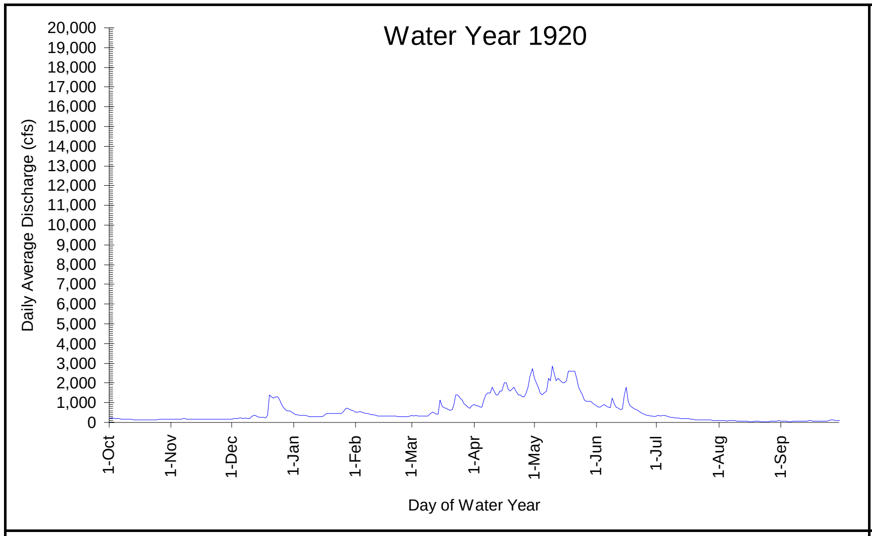

Water Year 1915

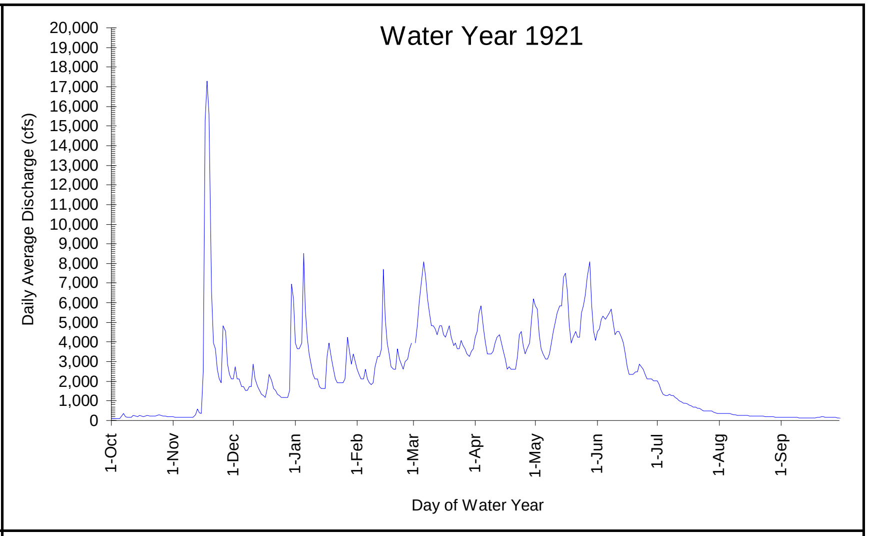

Water Year 1916
22,200
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1917
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1918
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1919
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1920
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1921
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
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1-Feb
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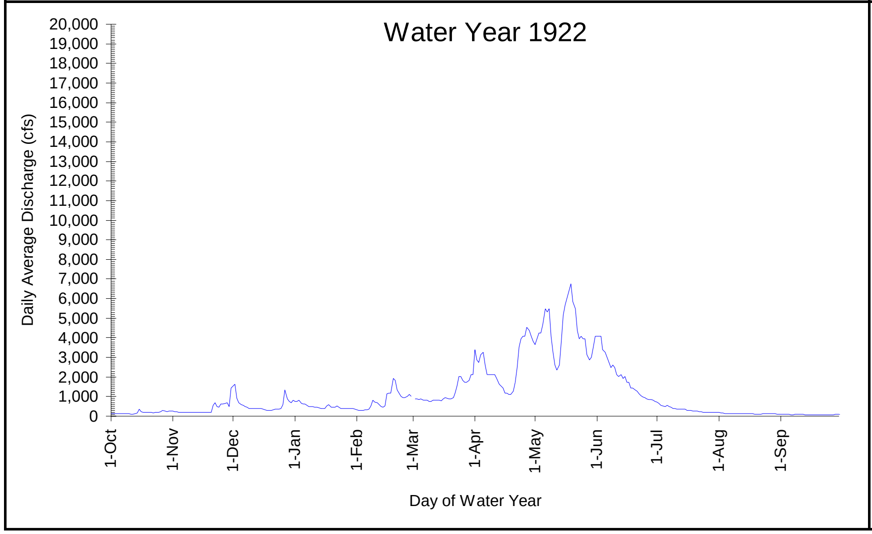
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1922
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
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1-Feb
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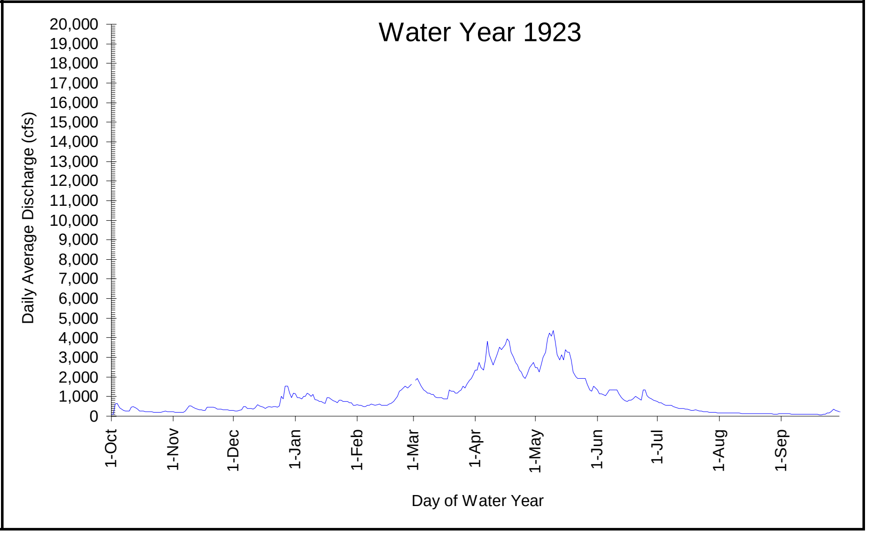
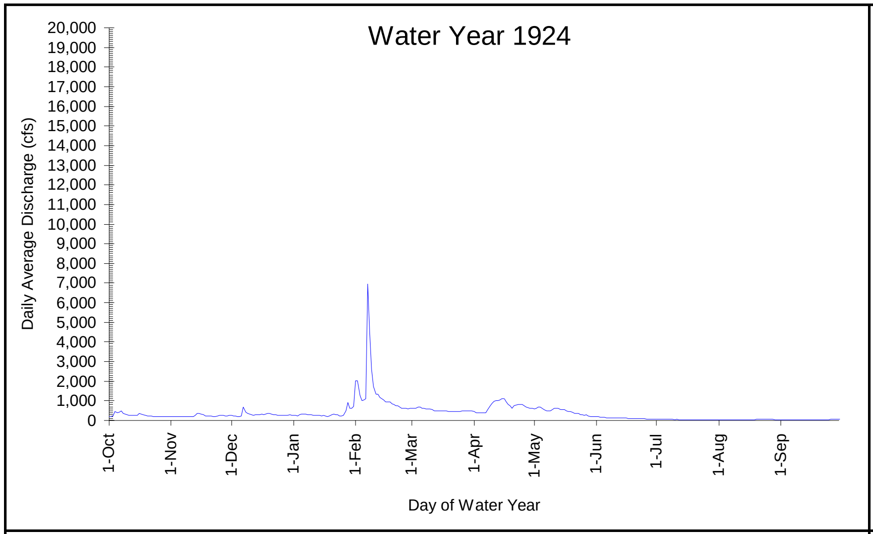
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1923
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1924
Daily Average Discharge (cfs)
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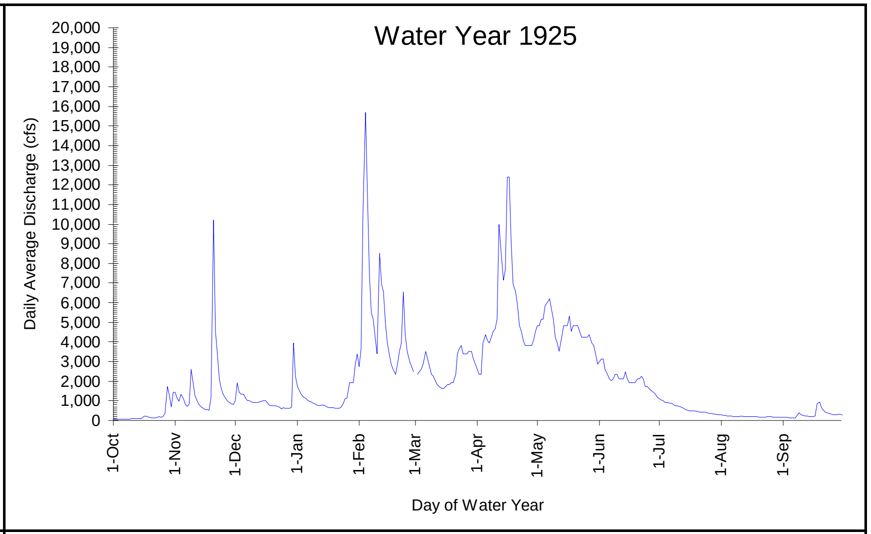
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1925
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
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1-Feb
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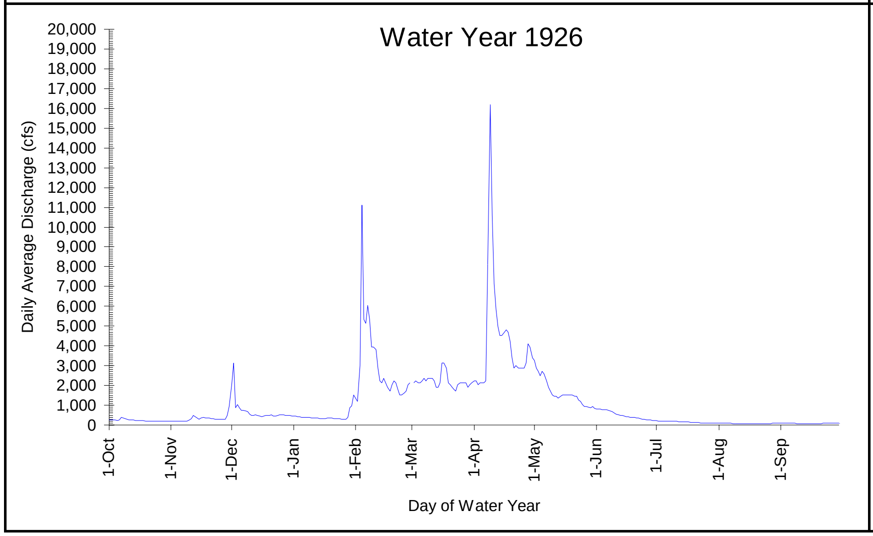
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1926
Daily Average Discharge (cfs)
20,000
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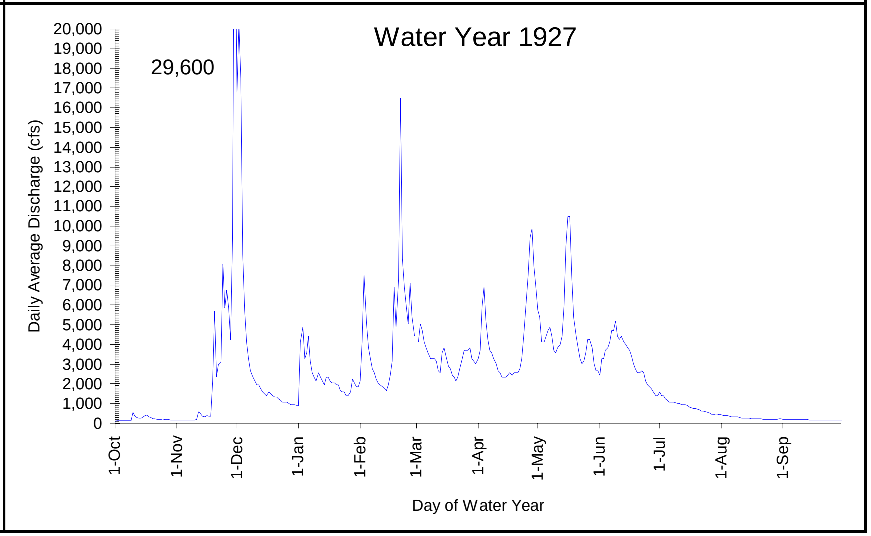
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1927
29,600
Daily Average Discharge (cfs)
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19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
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1-Feb
1-Mar
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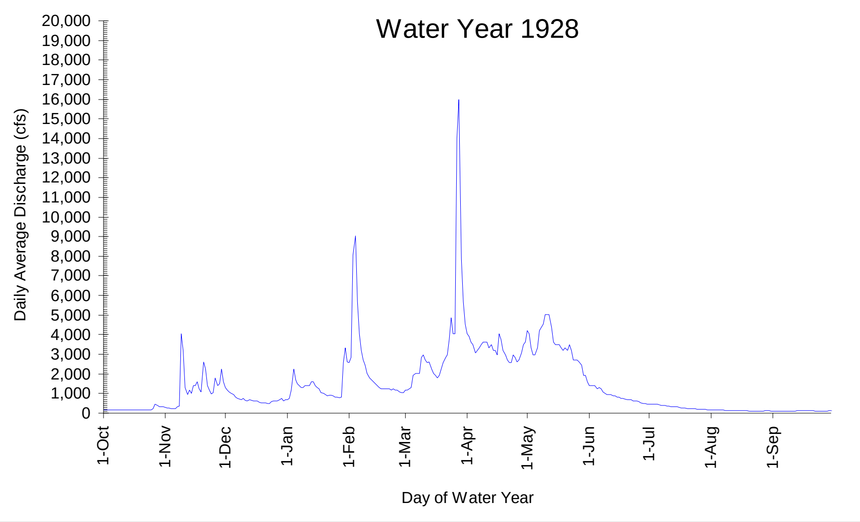
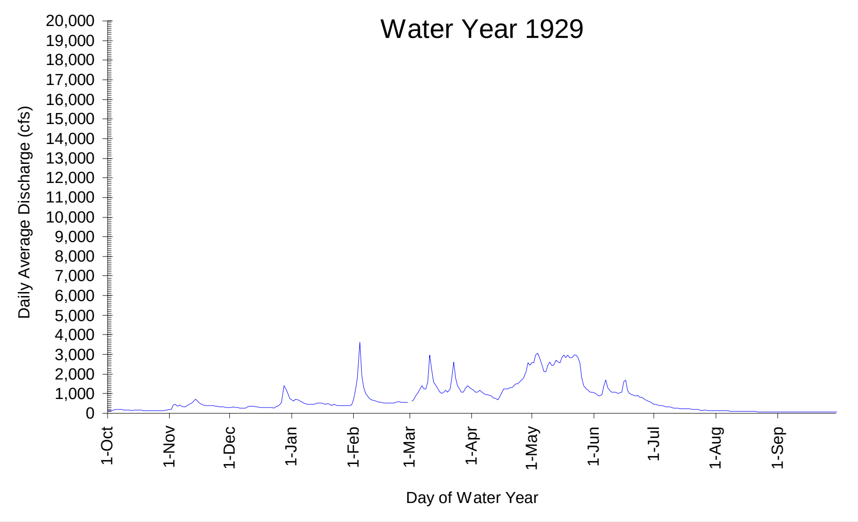
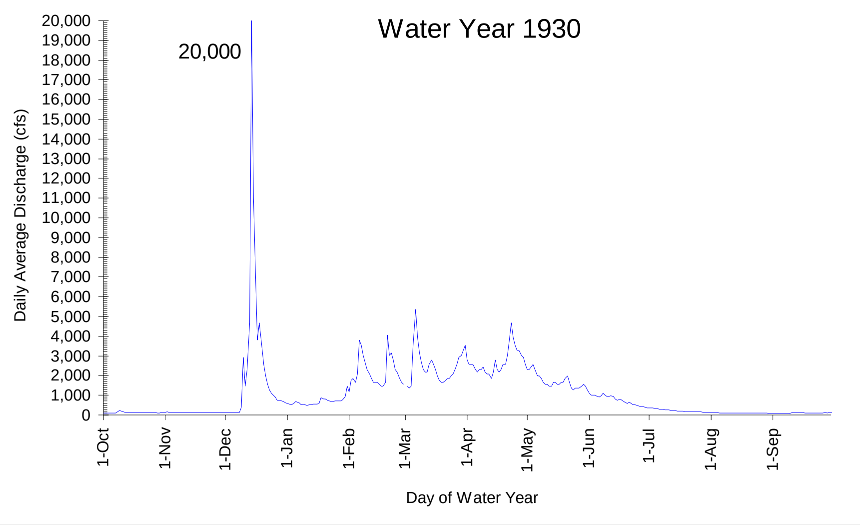
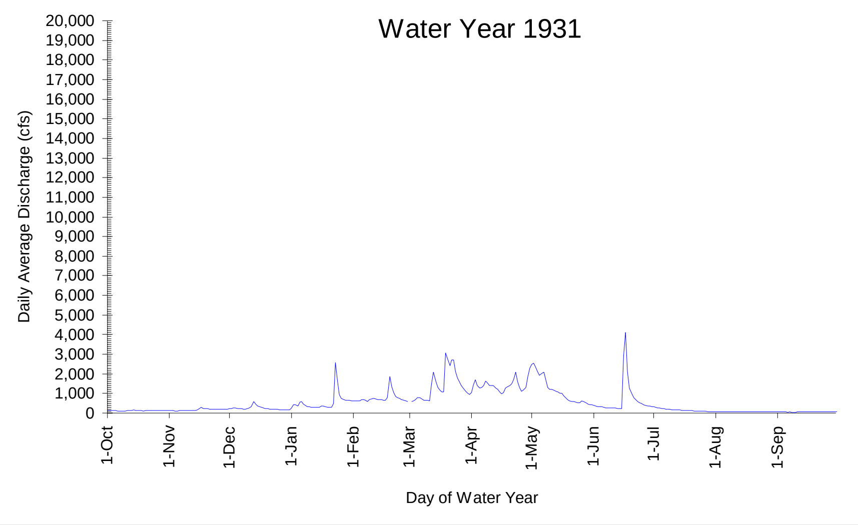
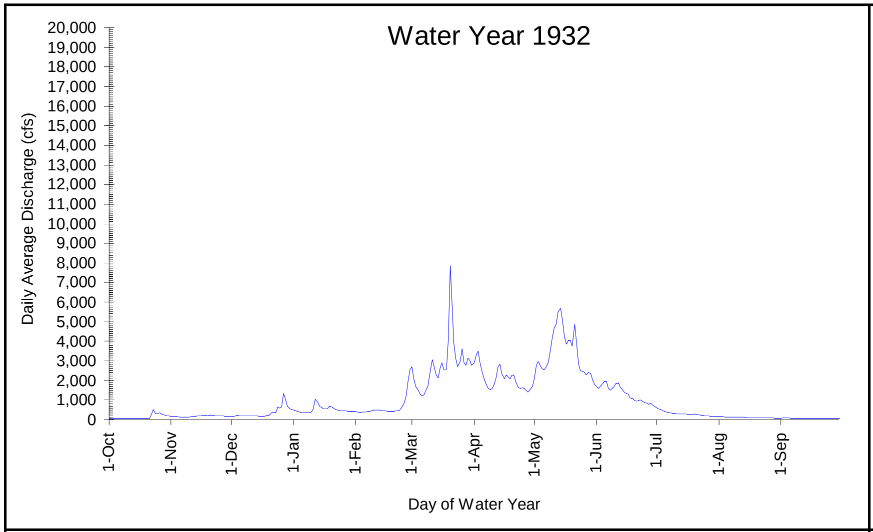
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year

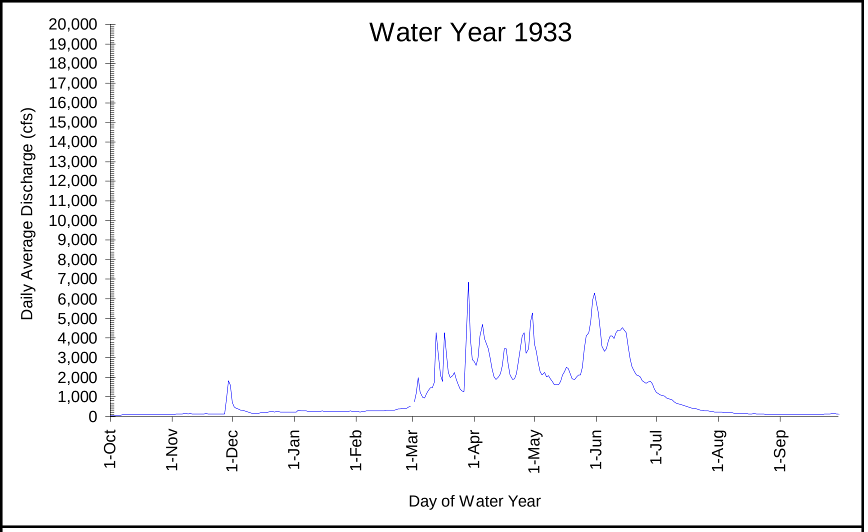

Water Year 1928

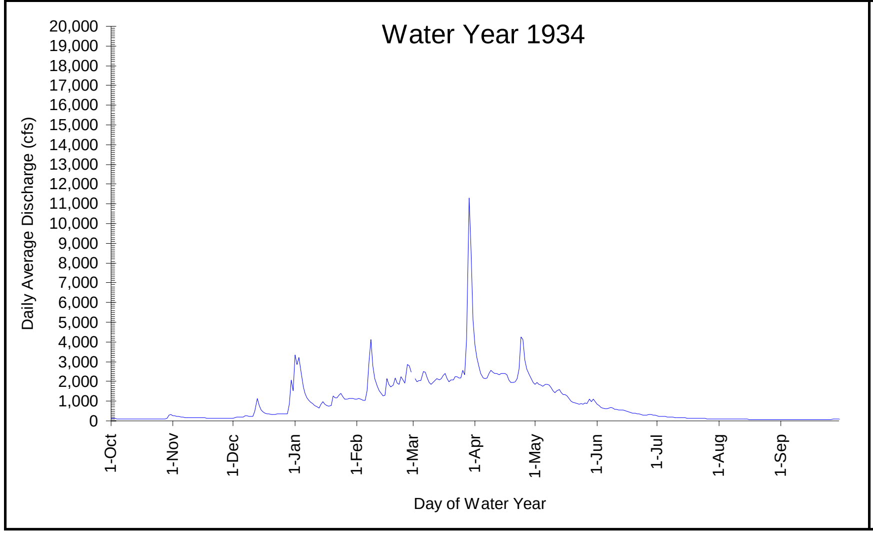

Water Year 1929

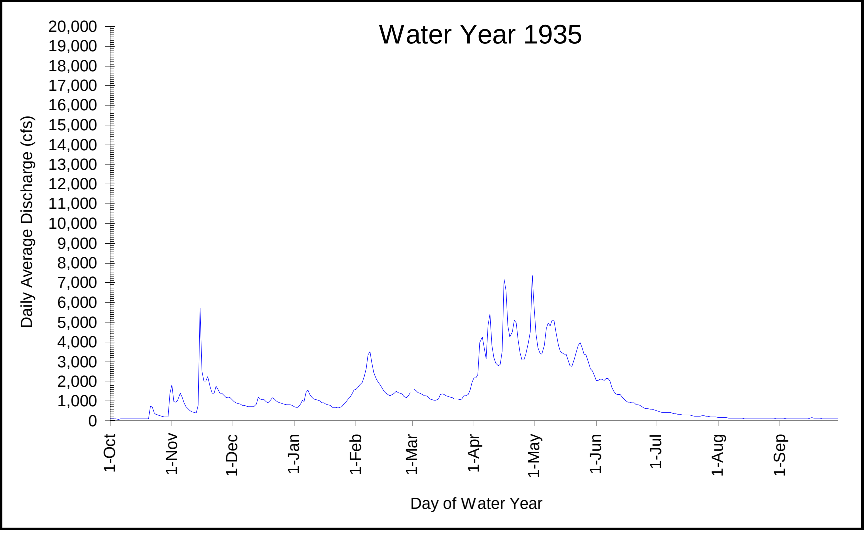

Water Year 1930

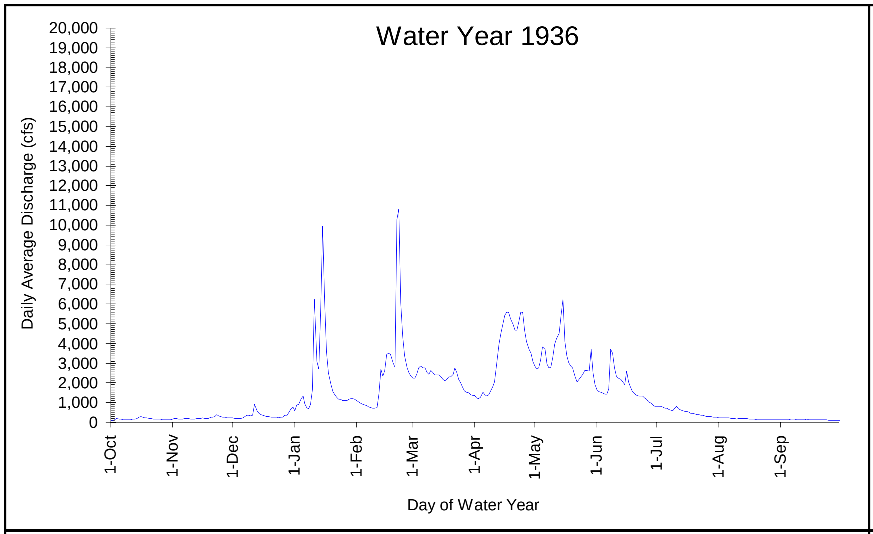

Water Year 1931

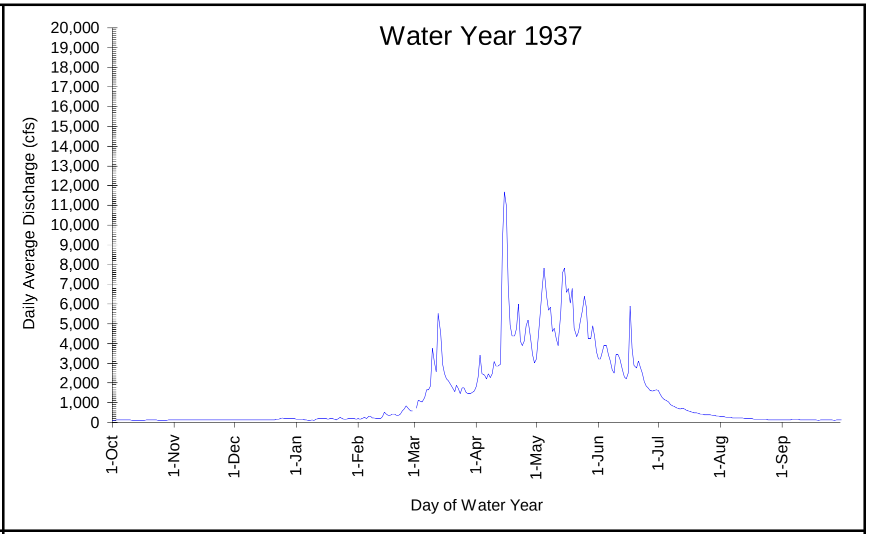

Water Year 1932

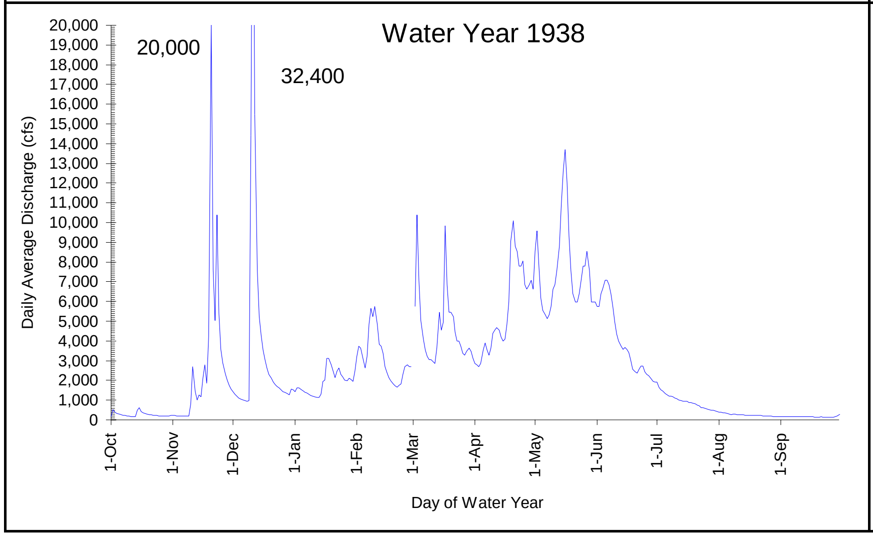

Water Year 1933

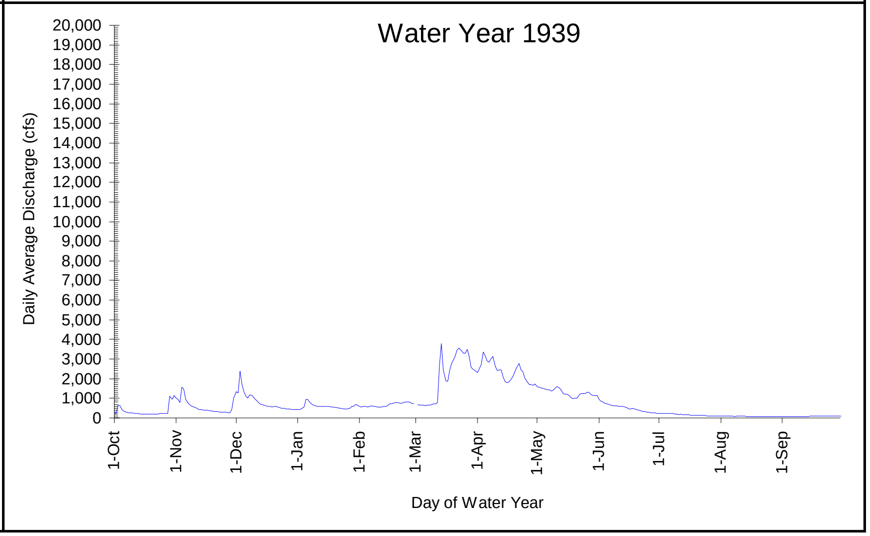

Water Year 1934

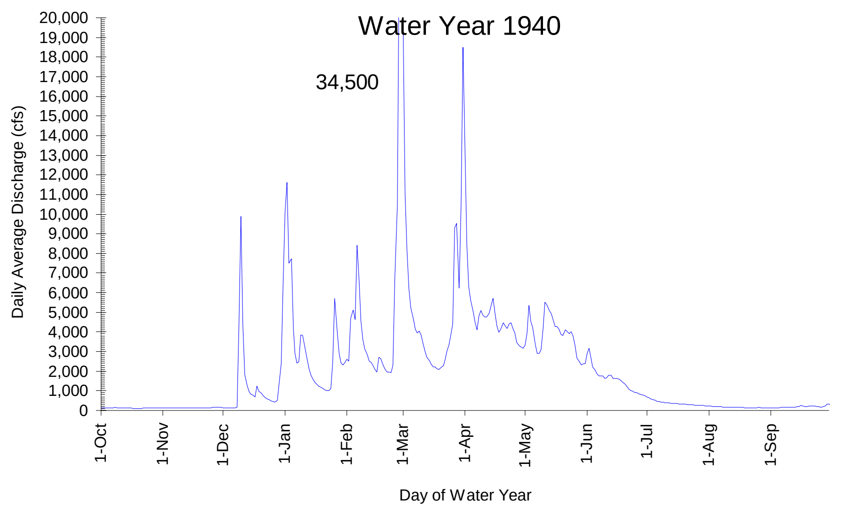

Water Year 1935

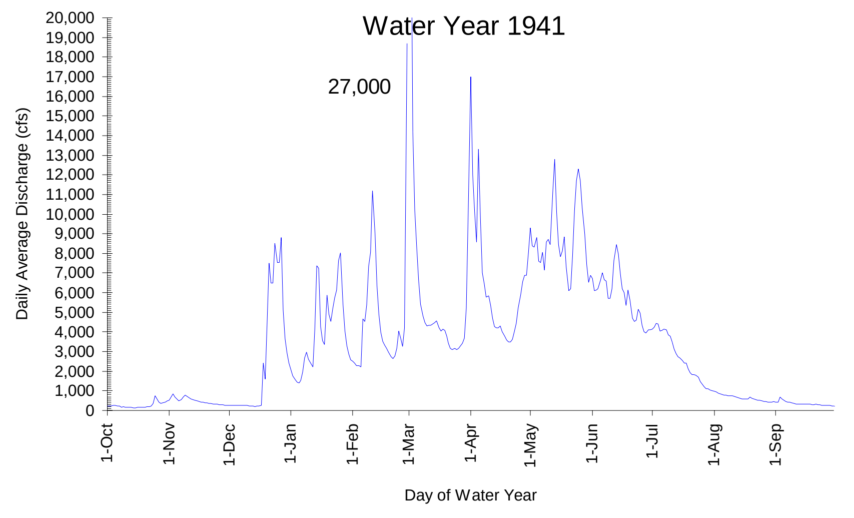

Water Year 1936

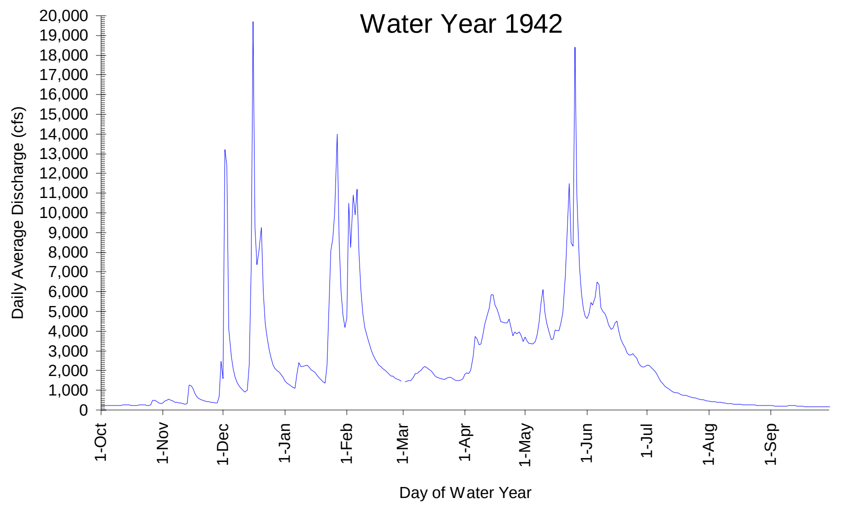

Water Year 1937


Water Year 1938


Water Year 1939


Water Year 1940
34,500
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1941
27,000
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1942
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
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1-Feb
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1-Apr
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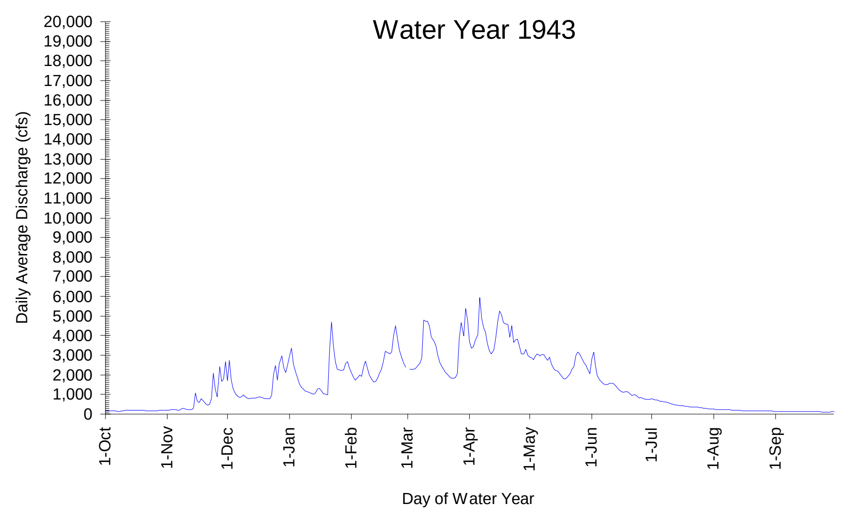
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1943
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
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1-Feb
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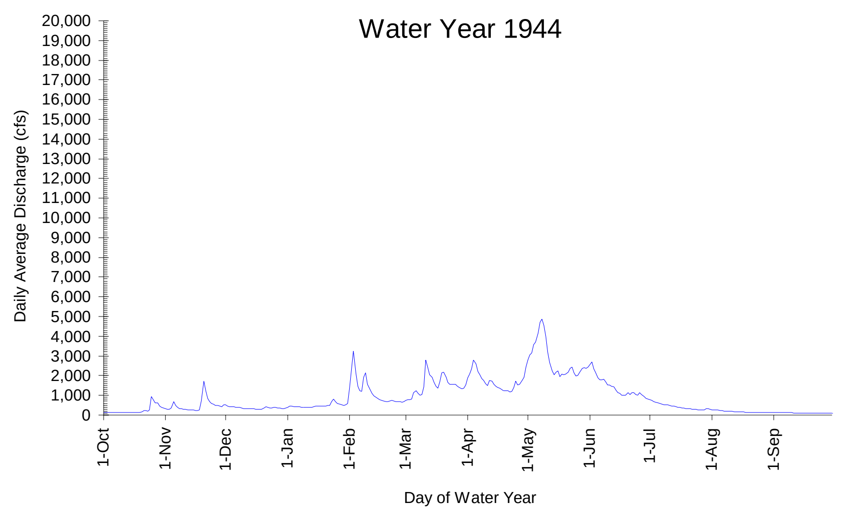
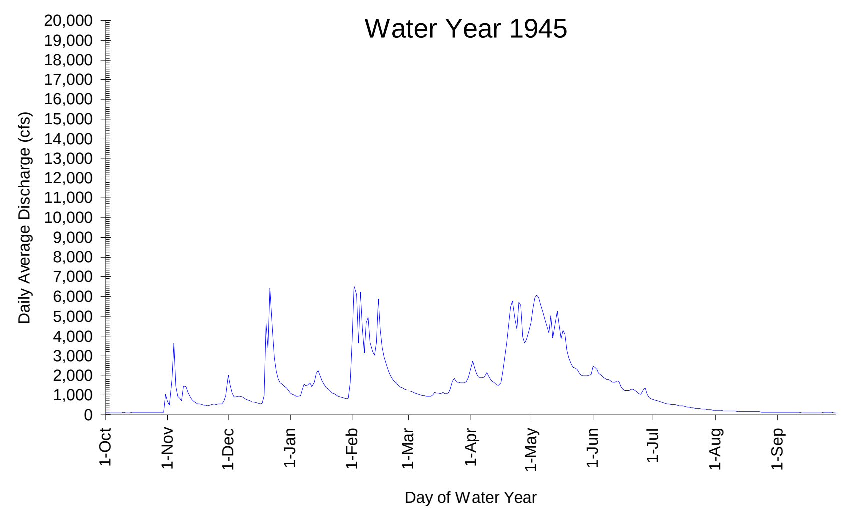
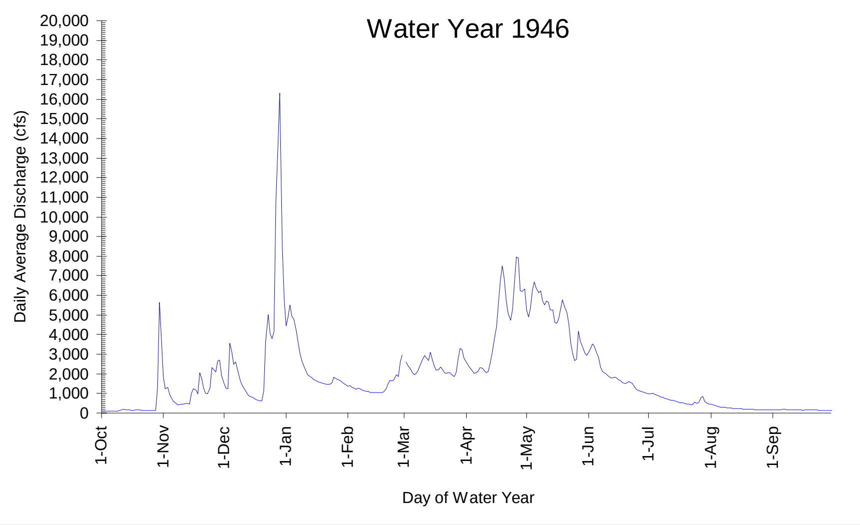
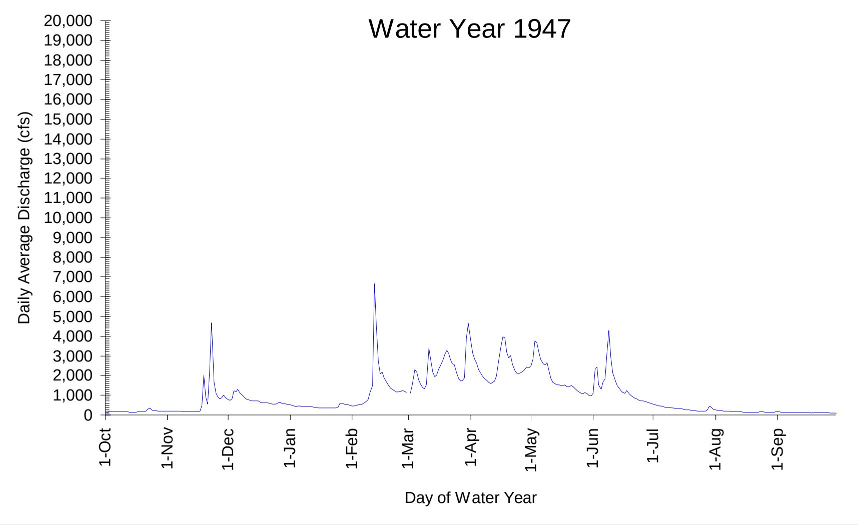
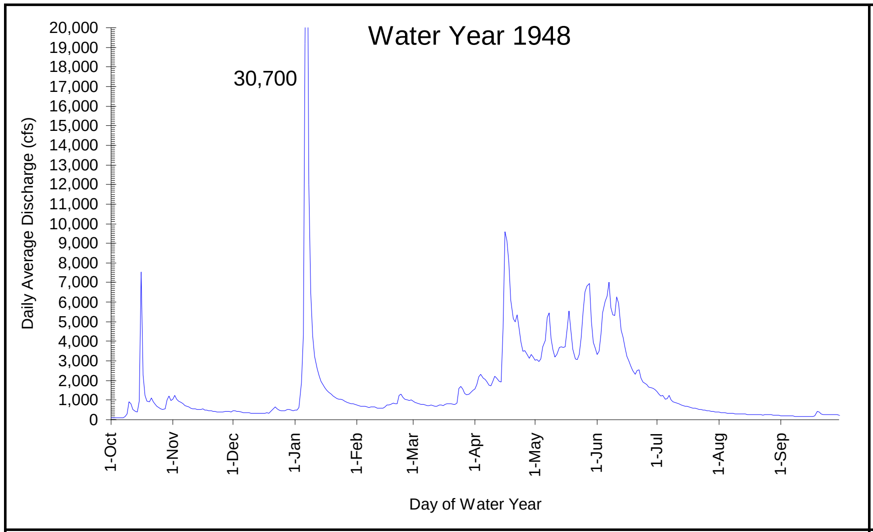
1-Jul
1-Aug
1-Sep
Day of Water Year

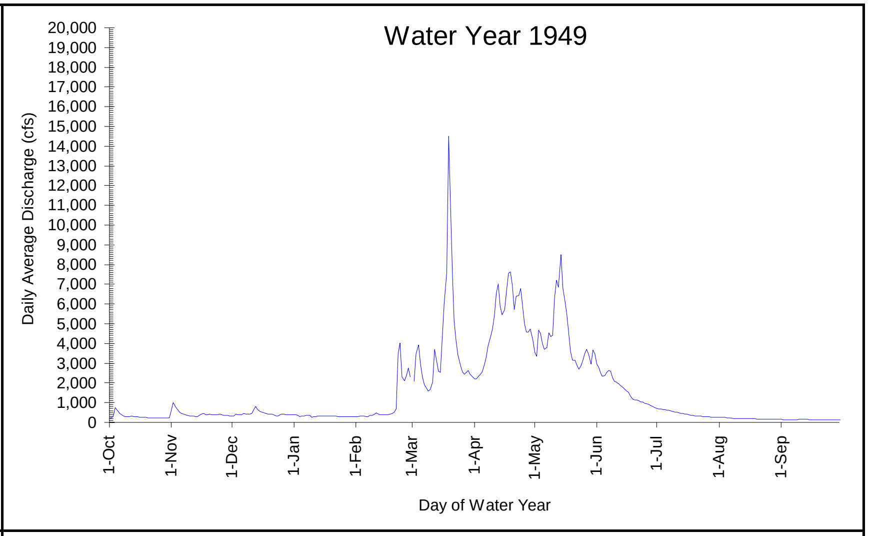

Water Year 1944

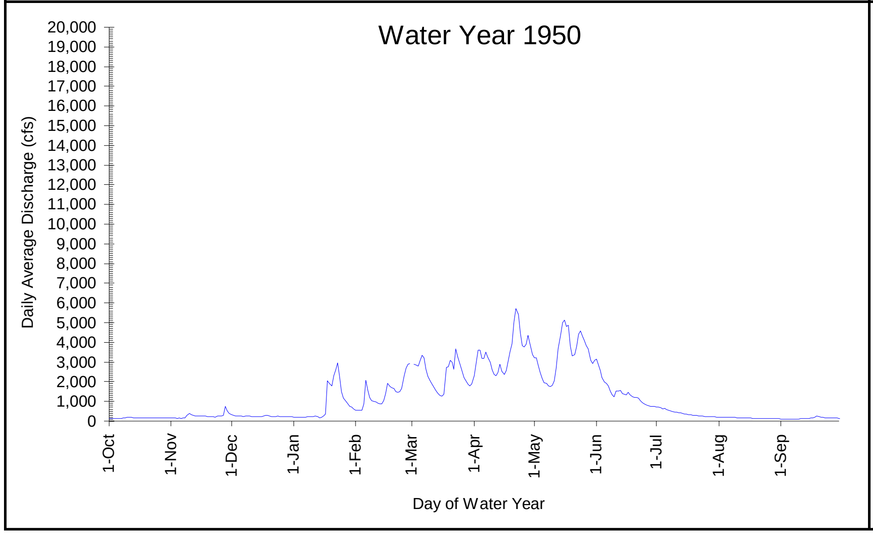

Water Year 1945

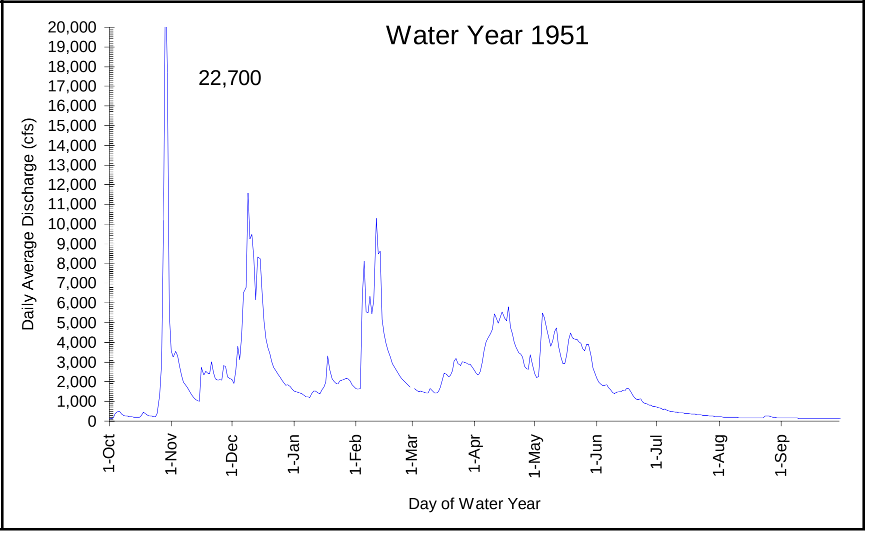

Water Year 1946

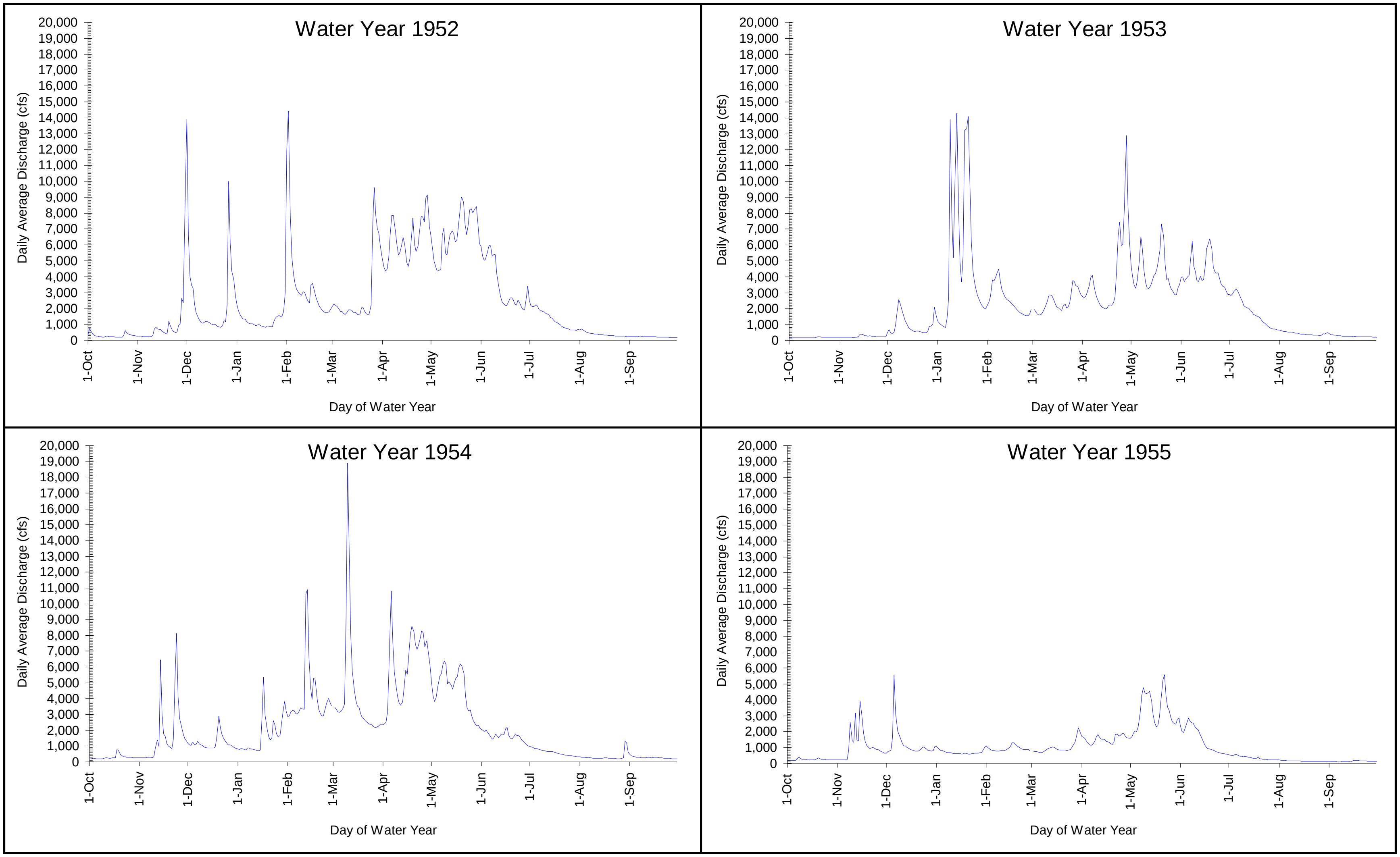

Water Year 1947

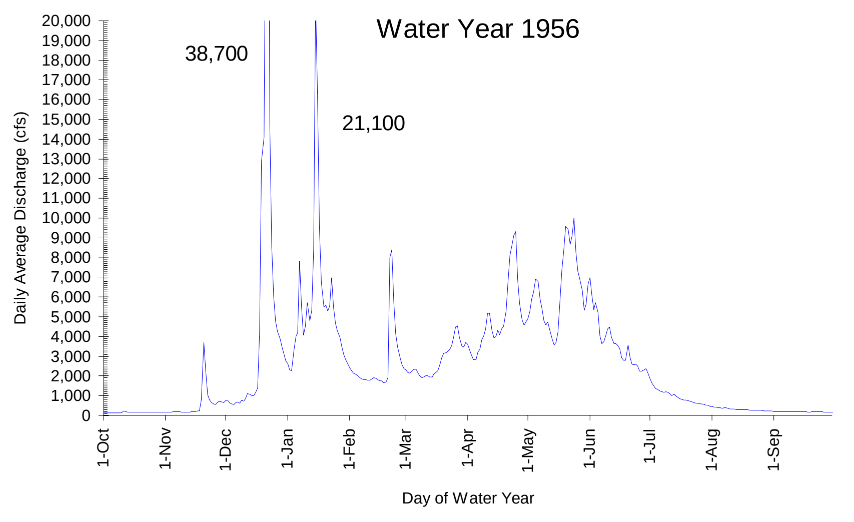

Water Year 1948


Water Year 1949


Water Year 1950


Water Year 1951


Water Year 1952
Water Year 1953
Water Year 1954
Water Year 1955
Daily Average Discharge (cfs)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1956
38,700
21,100
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
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1-Feb
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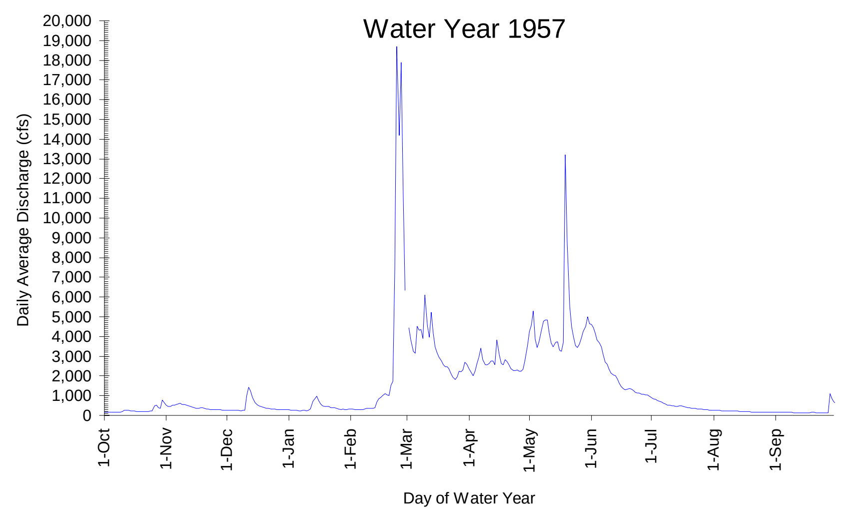
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1957
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
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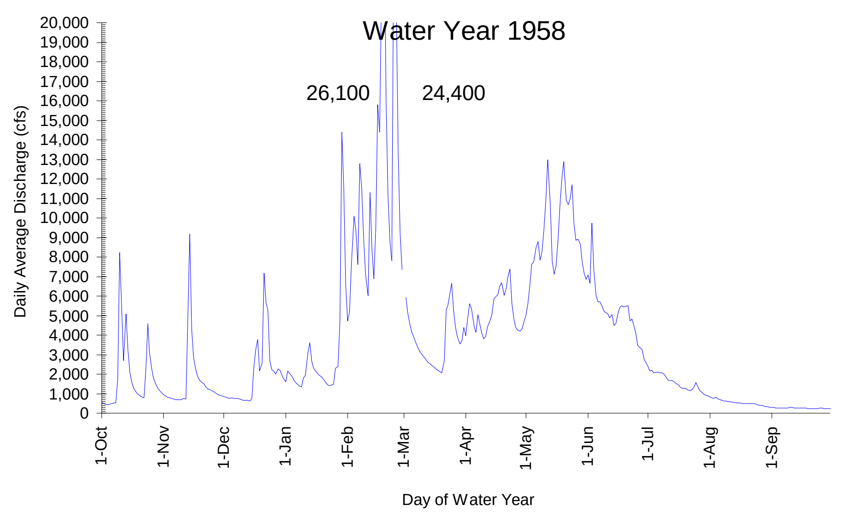
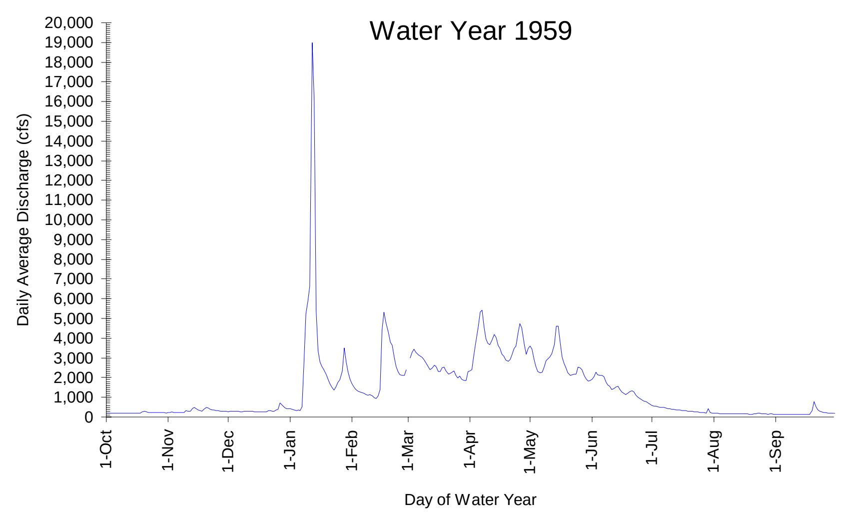
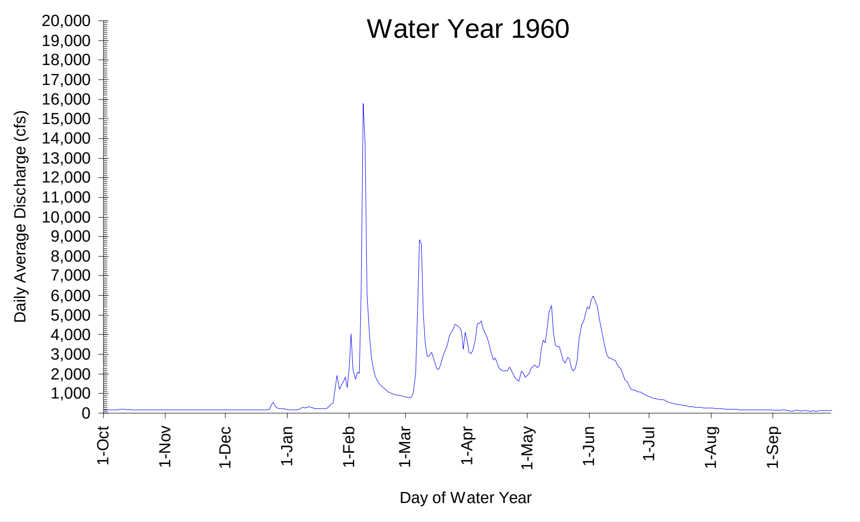
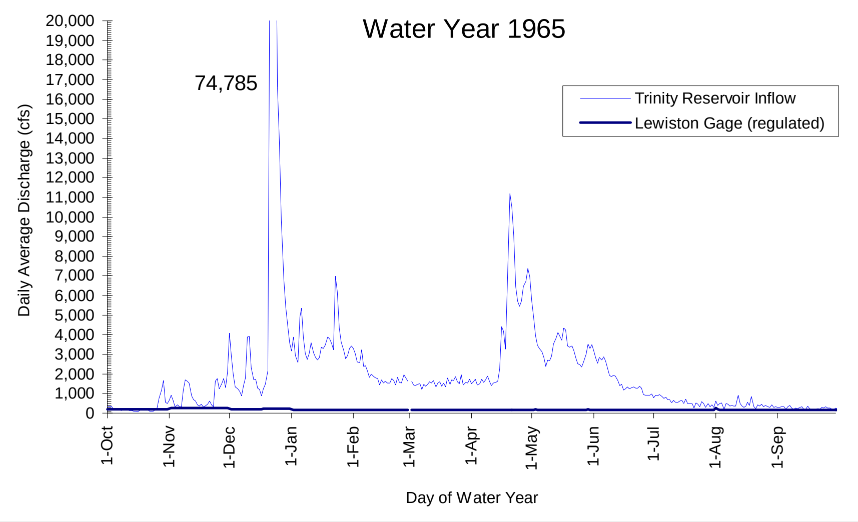
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1958
26,100
24,400
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1959
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1960
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1965
74,785
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
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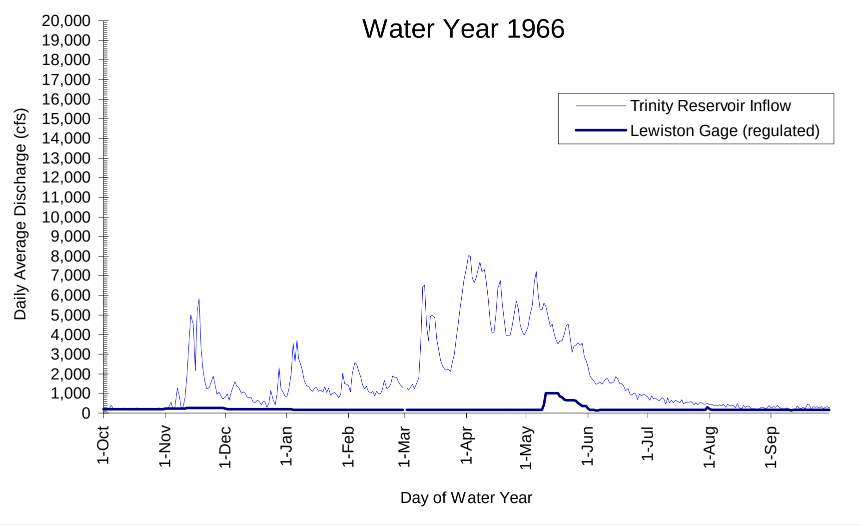
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1966
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
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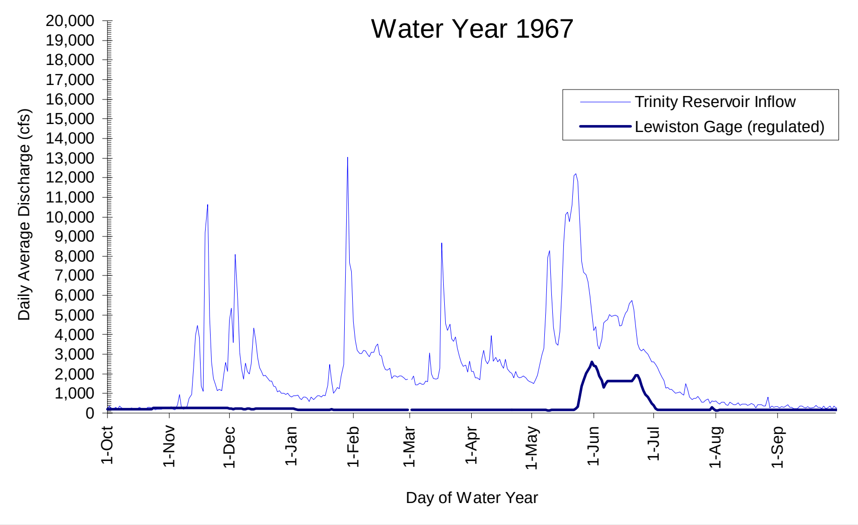
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1967
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
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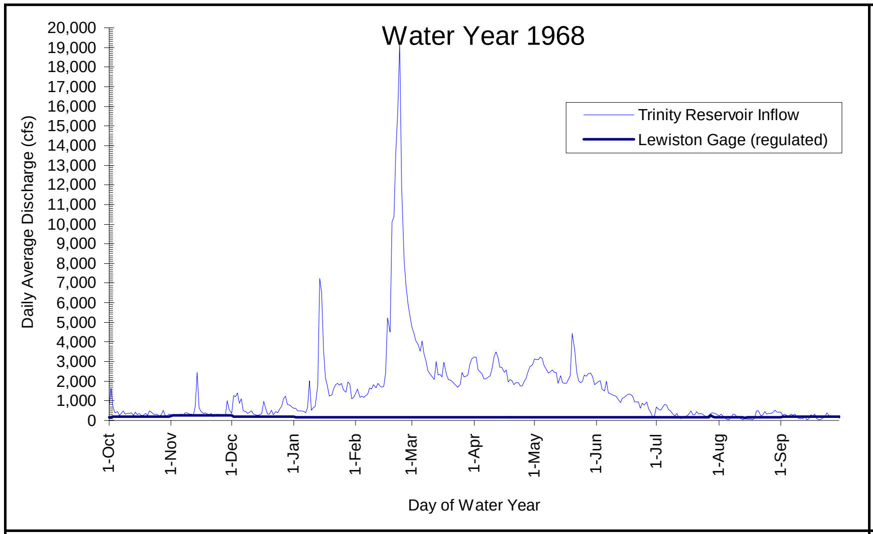
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1968
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
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1,000
2,000
3,000
4,000
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6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
1-Oct
1-Nov
1-Dec
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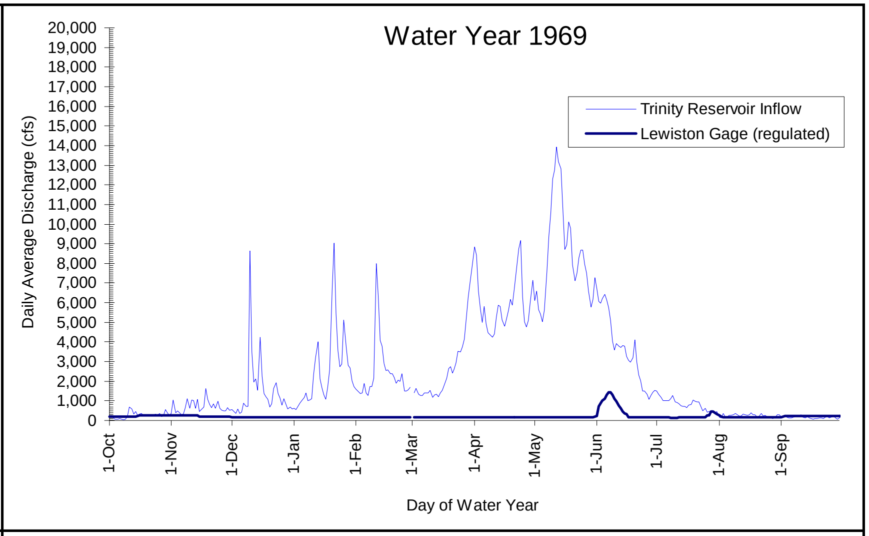
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1969
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
0
1,000
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3,000
4,000
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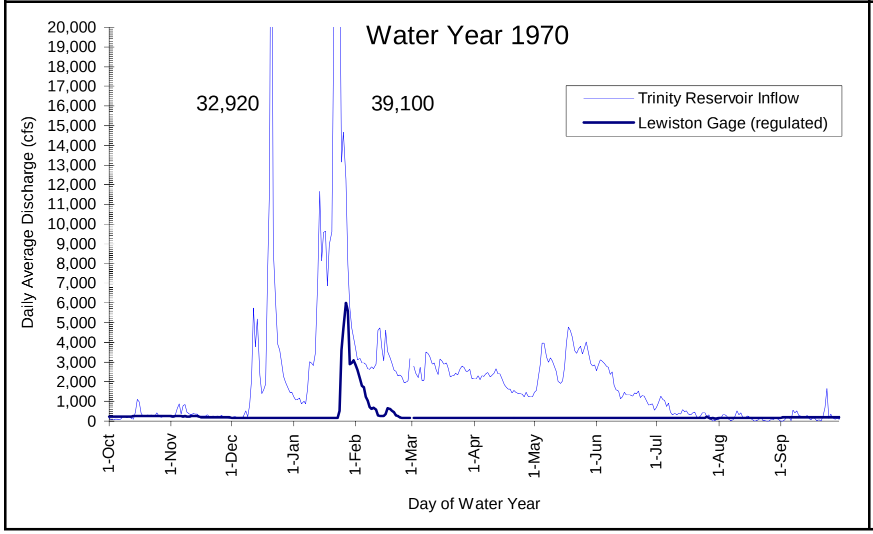
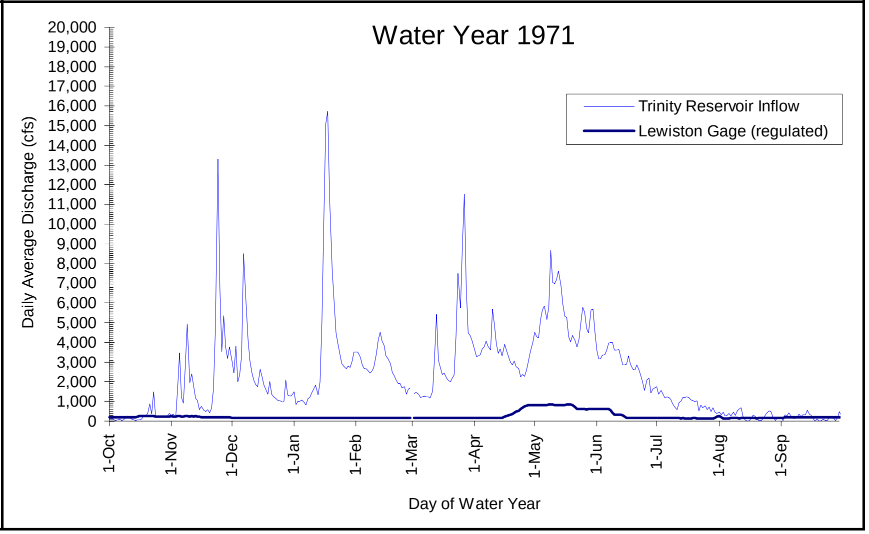
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1970
32,920
39,100
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1971
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Daily Average Discharge (cfs)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
1-Oct
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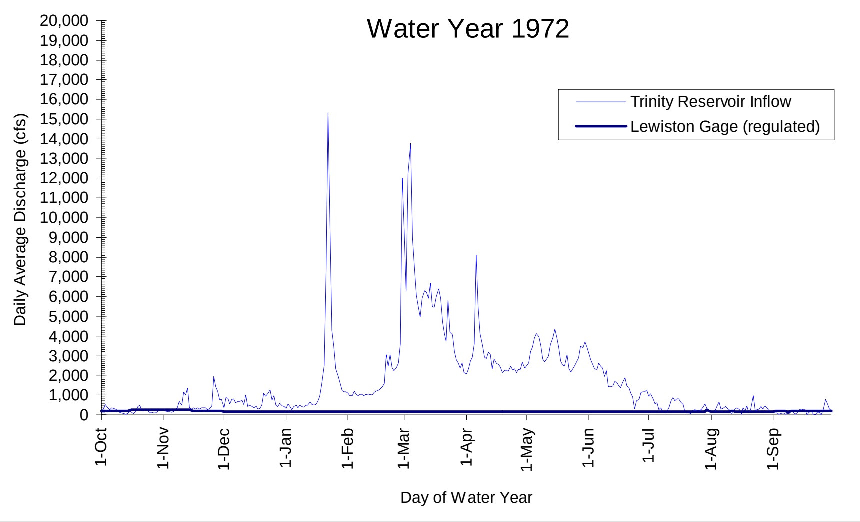
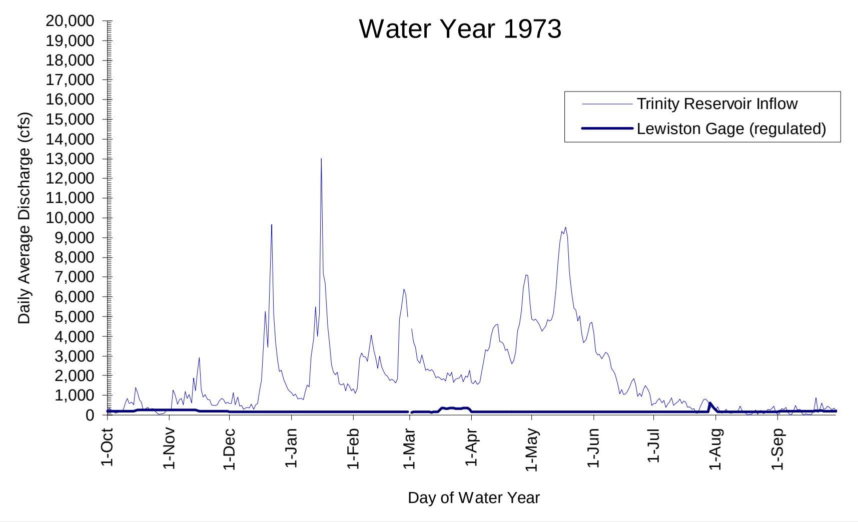
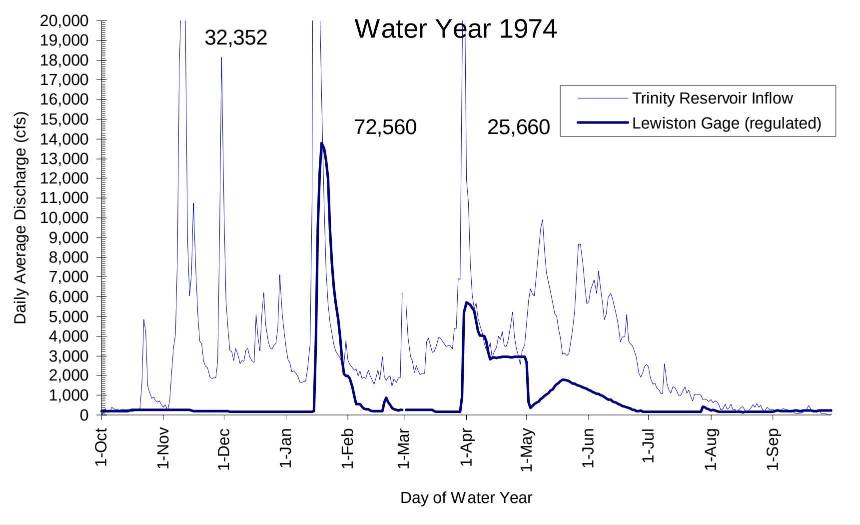
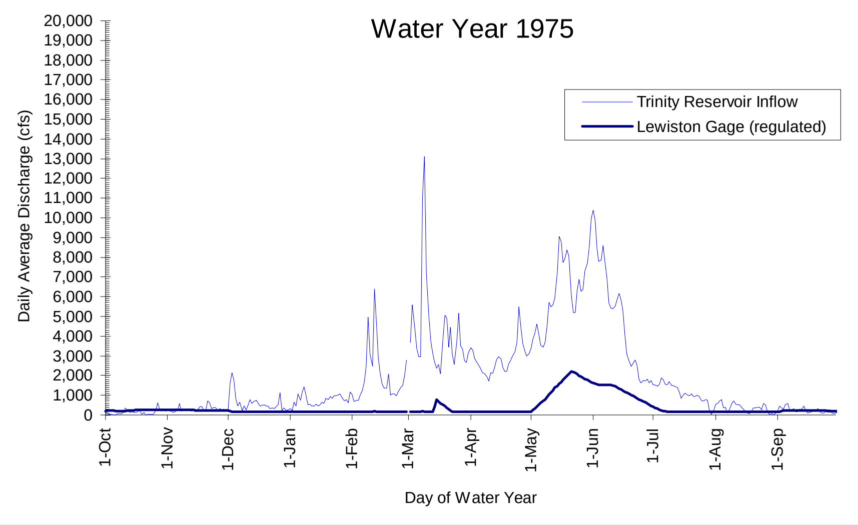
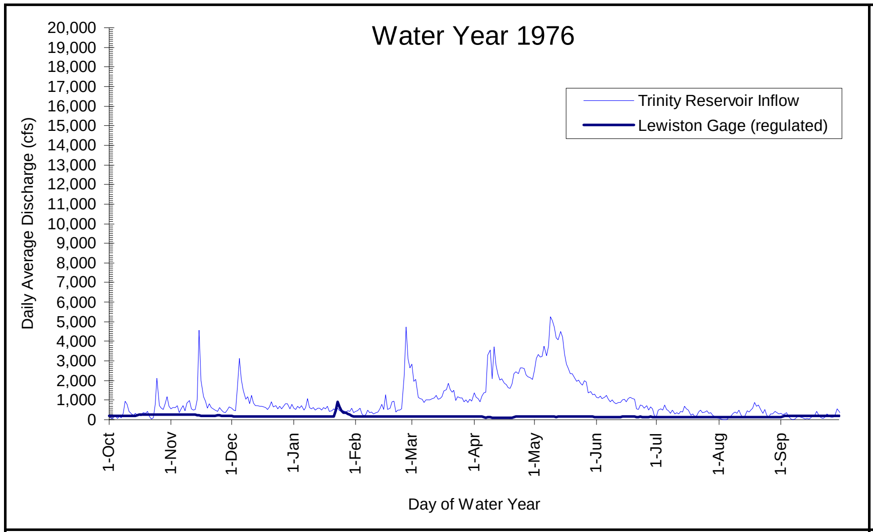
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year

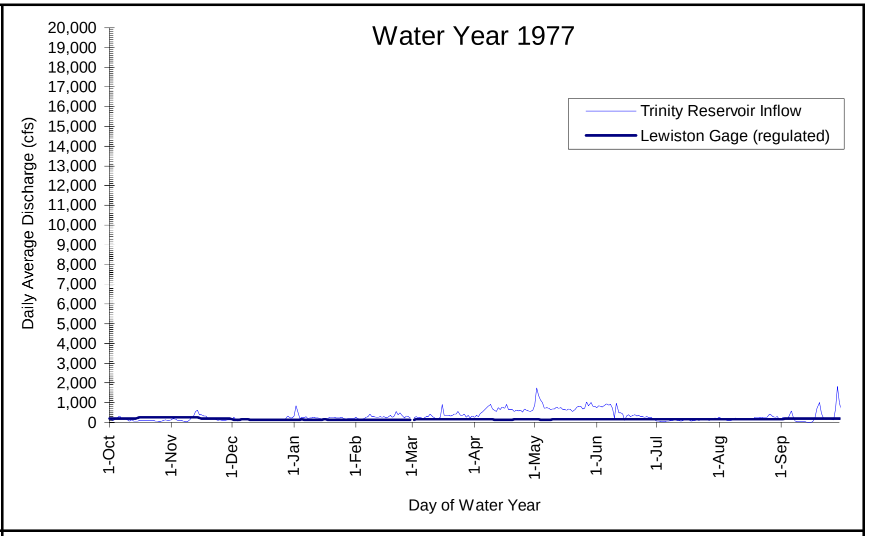

Water Year 1972

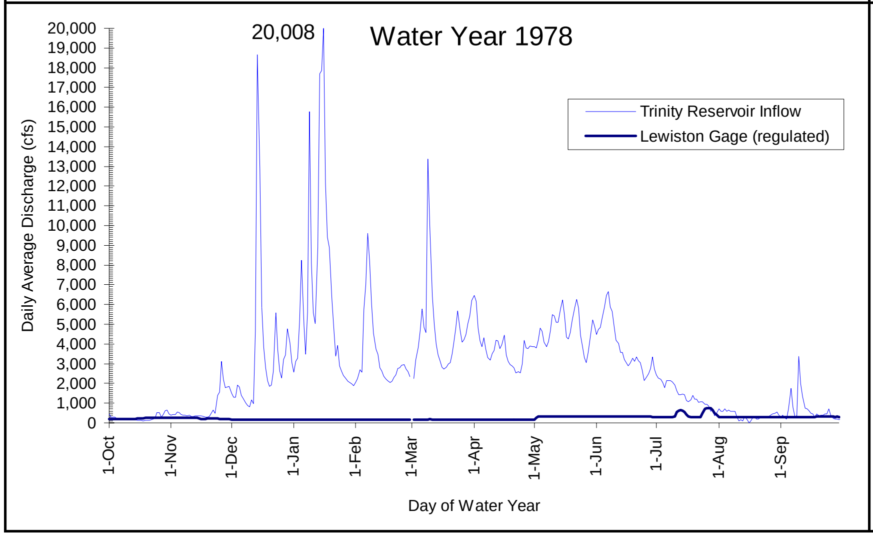

Water Year 1973

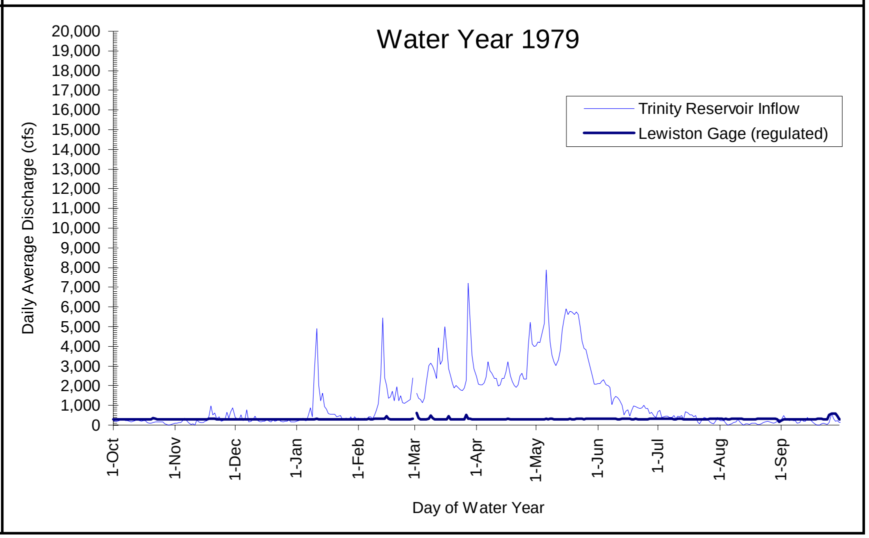

Water Year 1974

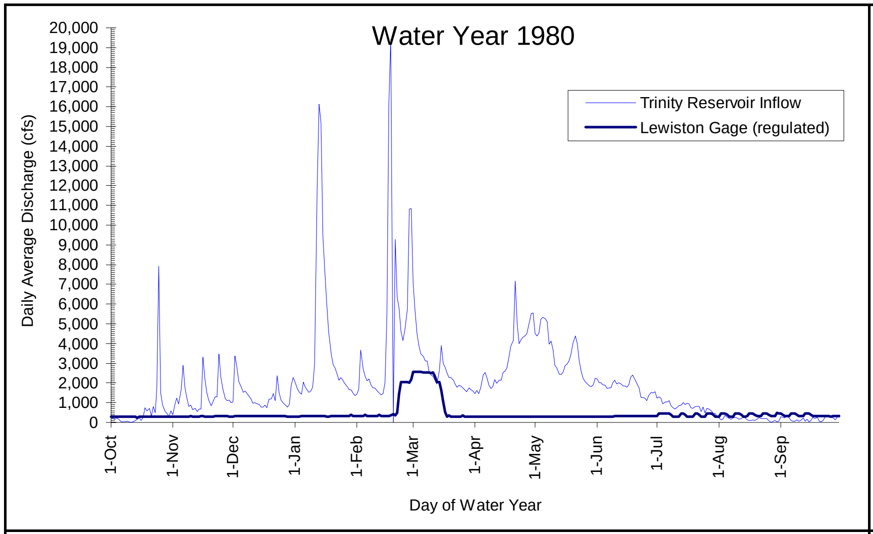

Water Year 1975

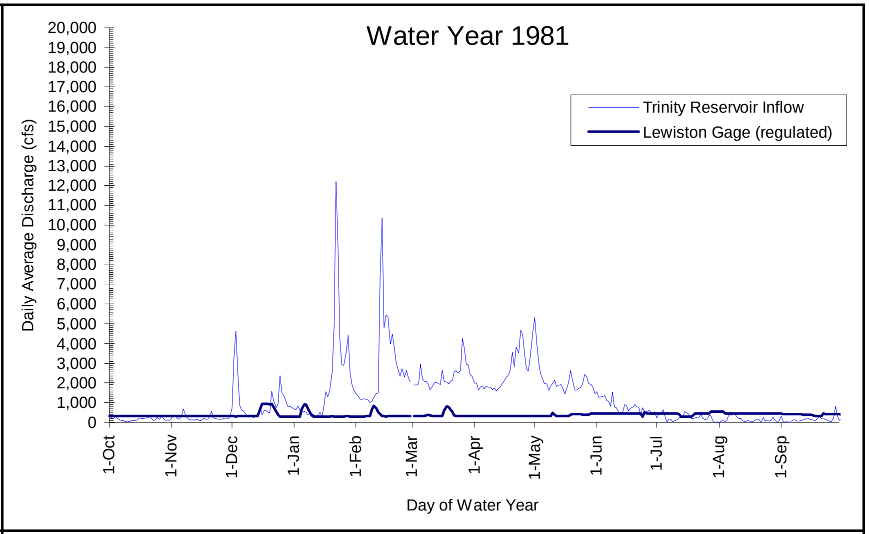

Water Year 1976

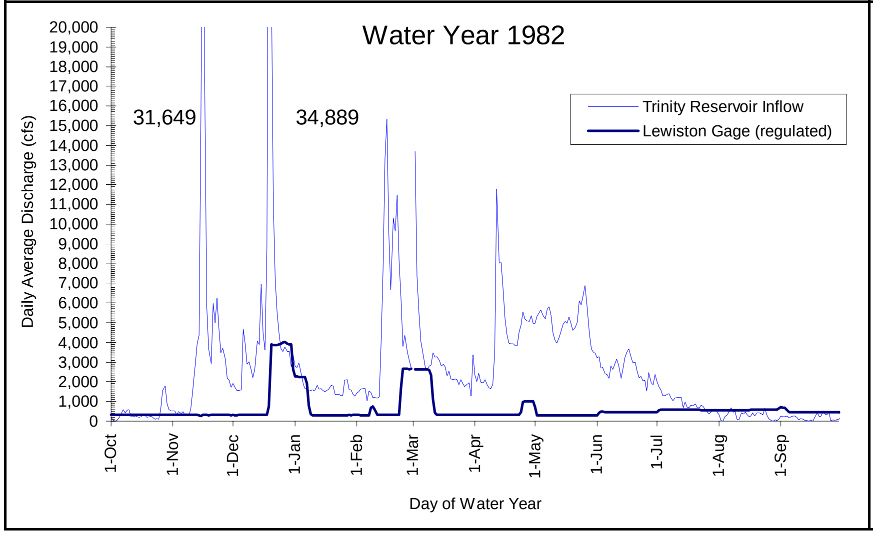

Water Year 1977


Water Year 1978


Water Year 1979


Water Year 1980
Daily Average Discharge (cfs)
0, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000, 10,000, 11,000, 12,000, 13,000, 14,000, 15,000, 16,000, 17,000, 18,000, 19,000, 20,000
1-Oct, 1-Nov, 1-Dec, 1-Jan, 1-Feb, 1-Mar, 1-Apr, 1-May, 1-Jun, 1-Jul, 1-Aug, 1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)


Water Year 1981
Daily Average Discharge (cfs)
0, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000, 10,000, 11,000, 12,000, 13,000, 14,000, 15,000, 16,000, 17,000, 18,000, 19,000, 20,000
1-Oct, 1-Nov, 1-Dec, 1-Jan, 1-Feb, 1-Mar, 1-Apr, 1-May, 1-Jun, 1-Jul, 1-Aug, 1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)


Water Year 1982
31,649
34,889
Daily Average Discharge (cfs)
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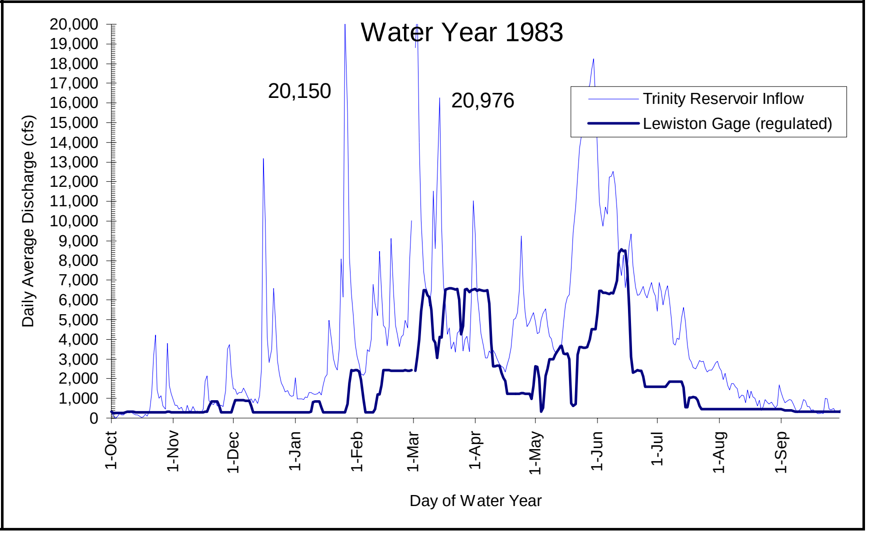
1-Oct, 1-Nov, 1-Dec, 1-Jan, 1-Feb, 1-Mar, 1-Apr, 1-May, 1-Jun, 1-Jul, 1-Aug, 1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)


Water Year 1983
20,150
20,976
Daily Average Discharge (cfs)
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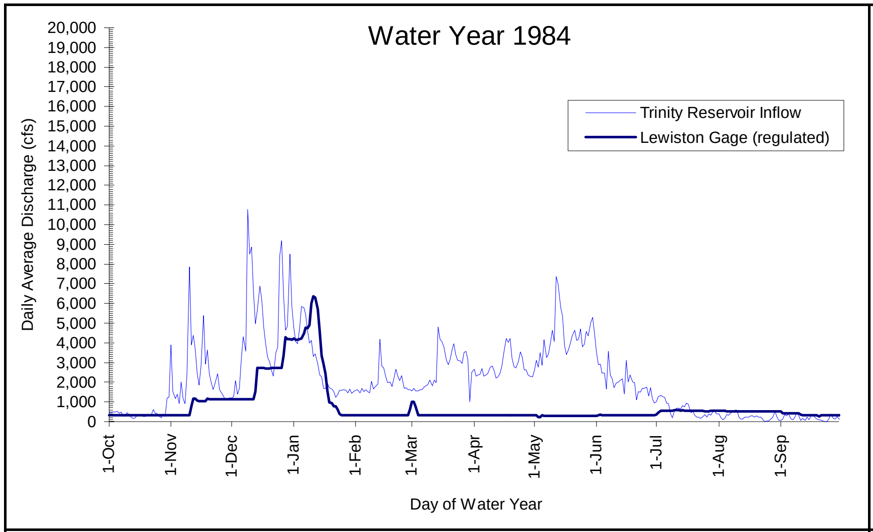
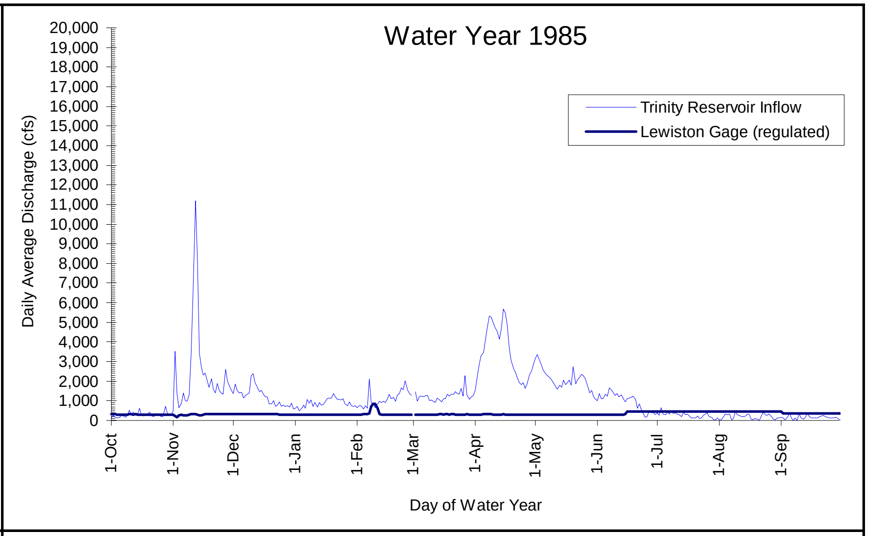
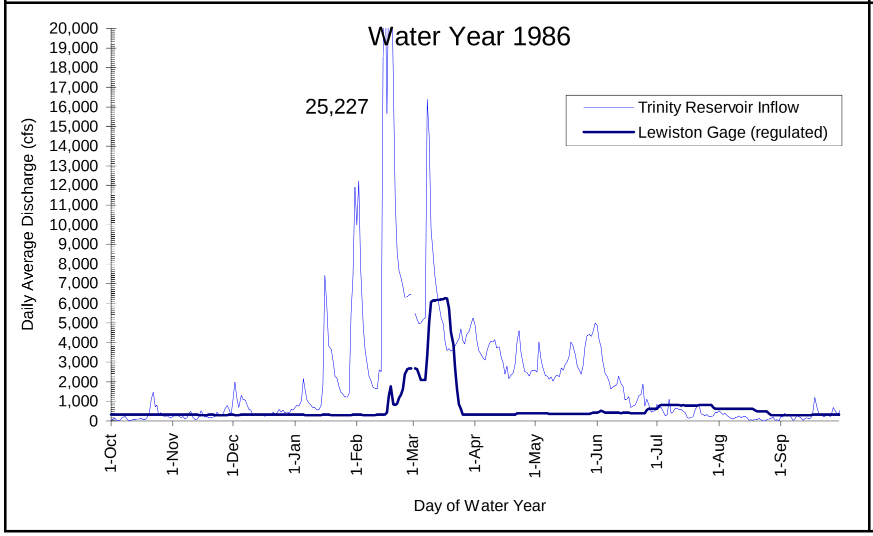
1-Oct, 1-Nov, 1-Dec, 1-Jan, 1-Feb, 1-Mar, 1-Apr, 1-May, 1-Jun, 1-Jul, 1-Aug, 1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)


Water Year 1984
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)


Water Year 1985
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)


Water Year 1986
25,227
Daily Average Discharge (cfs)
20,000
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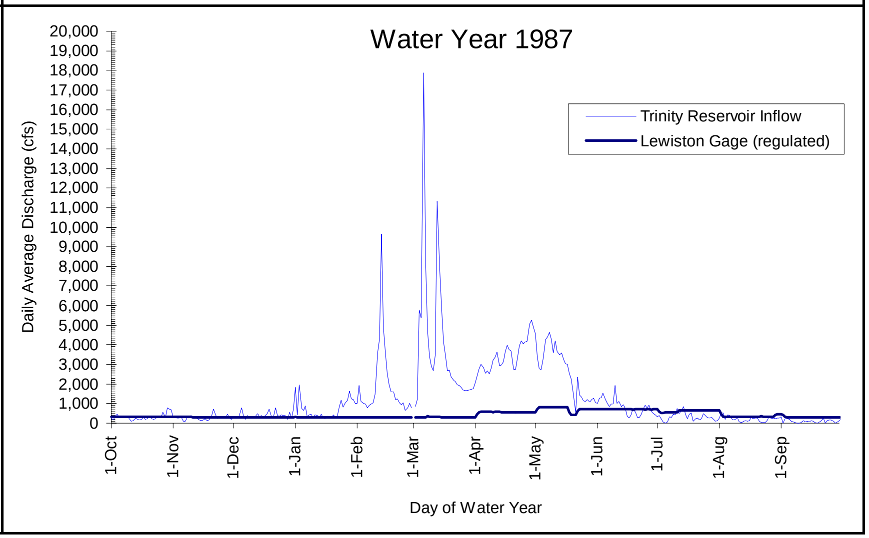
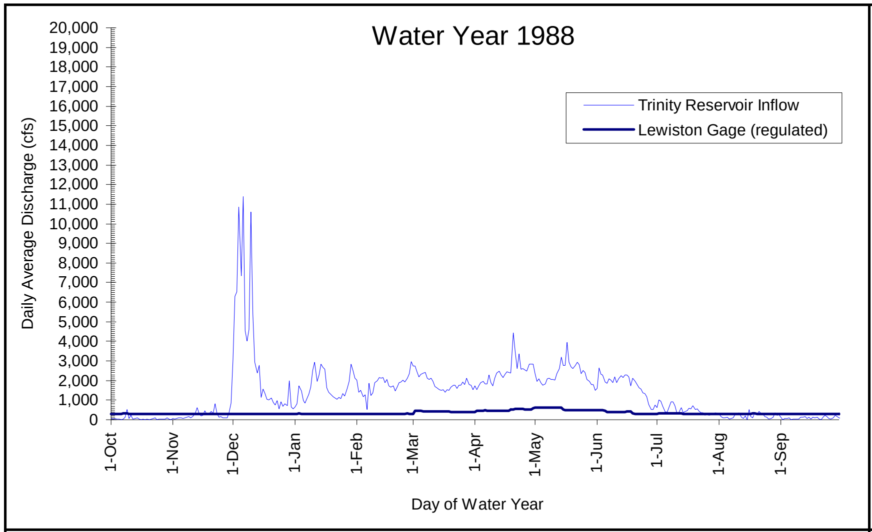
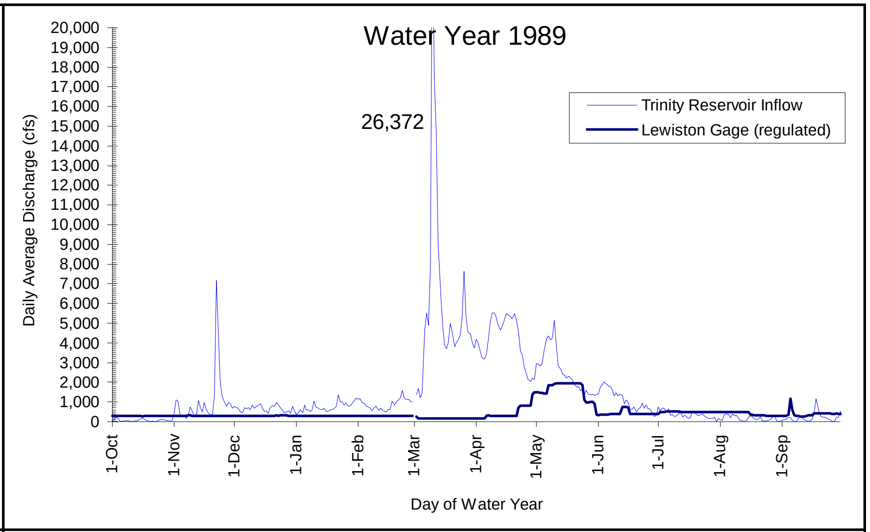
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)

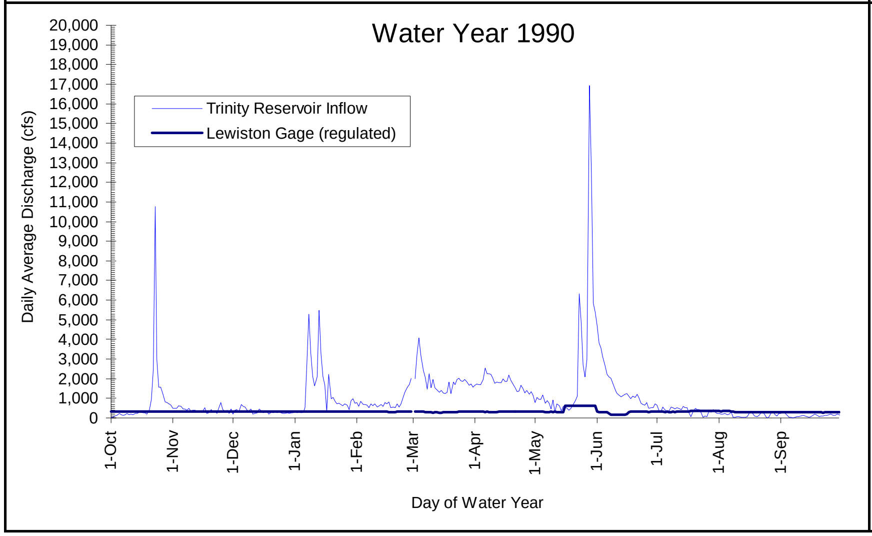

Water Year 1987
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)



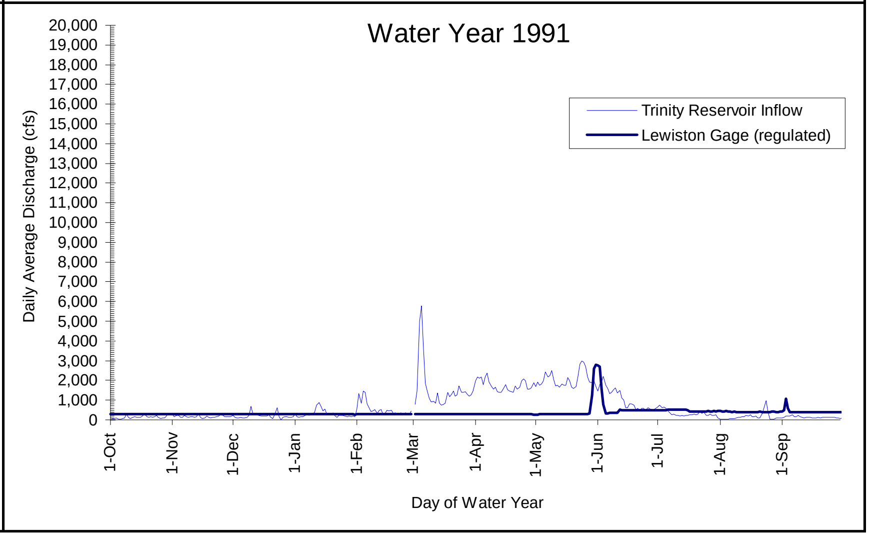
Water Year 1988



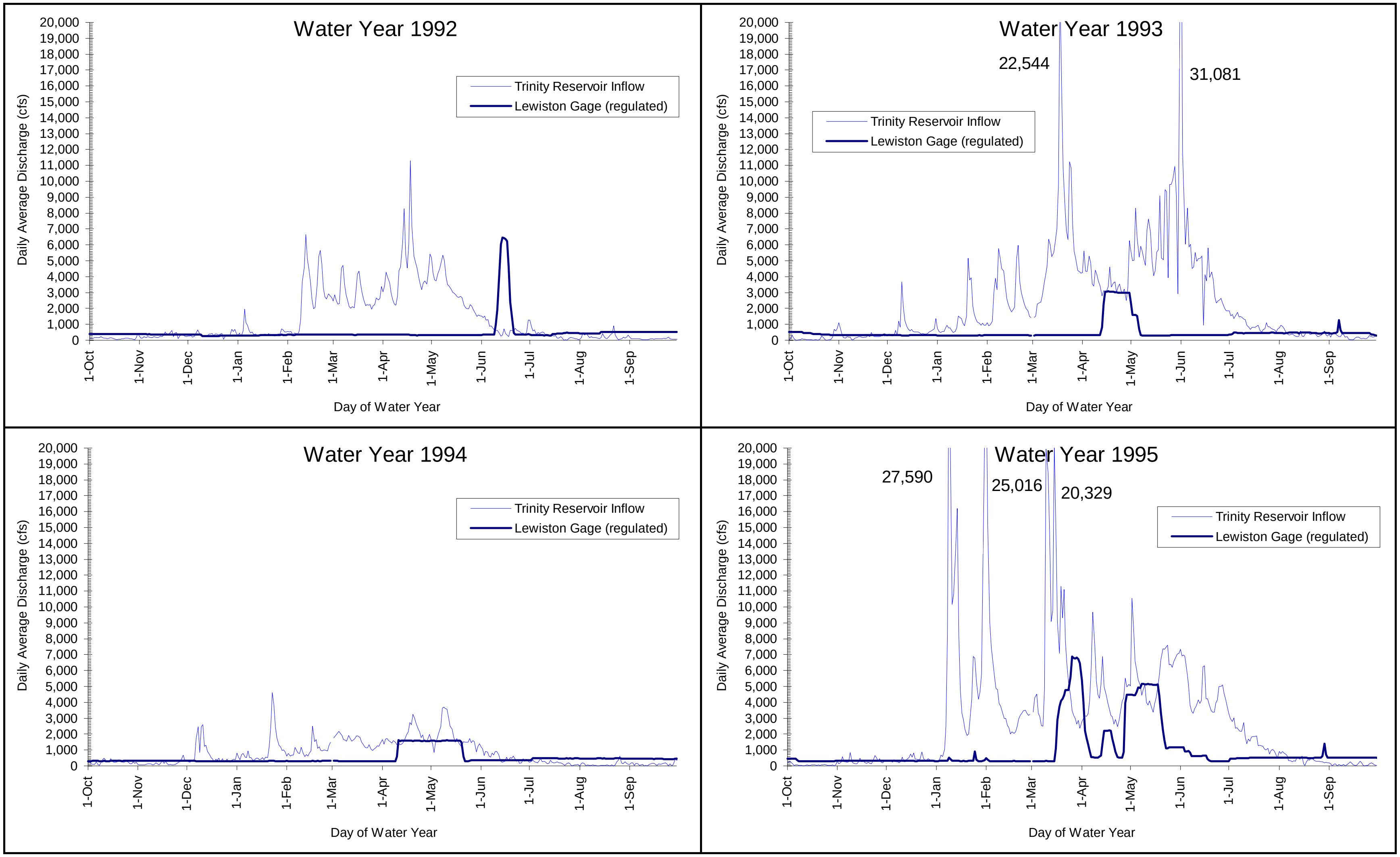
Water Year 1989

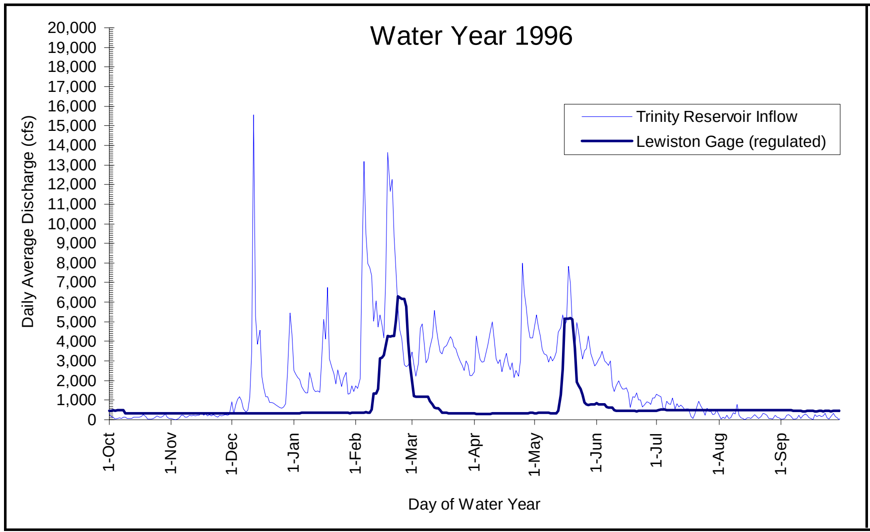


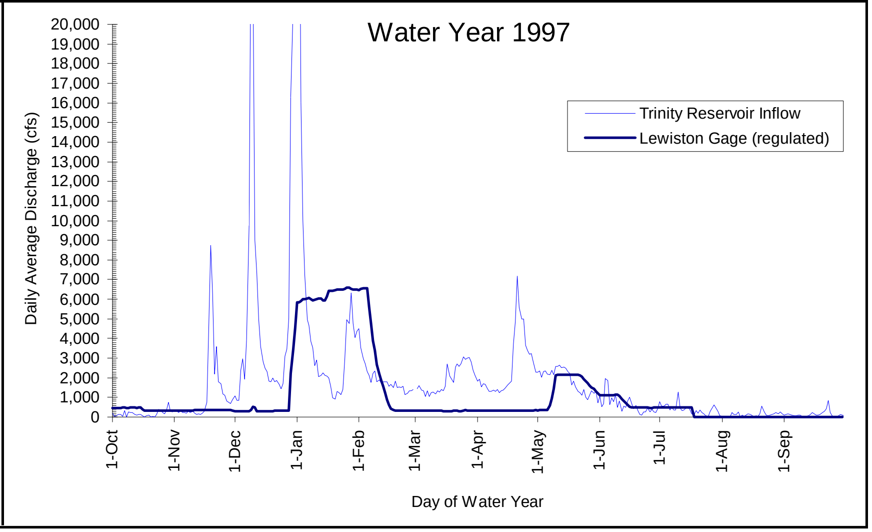
Water Year 1990



Water Year 1991


Water Year 1992
Daily Average Gage Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year
Trinity Reservoir Inflow
Lewiston Gage (regulated)
Water Year 1993
22,544
31,081
Water Year 1994
Water Year 1995
27,590
25,016
20,329


Water Year 1996
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Trinity Reservoir Inflow
Lewiston Gage (regulated)
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year


Water Year 1997
Daily Average Discharge (cfs)
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Trinity Reservoir Inflow
Lewiston Gage (regulated)
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Day of Water Year

APPENDIX G

Rehabilitation Projects

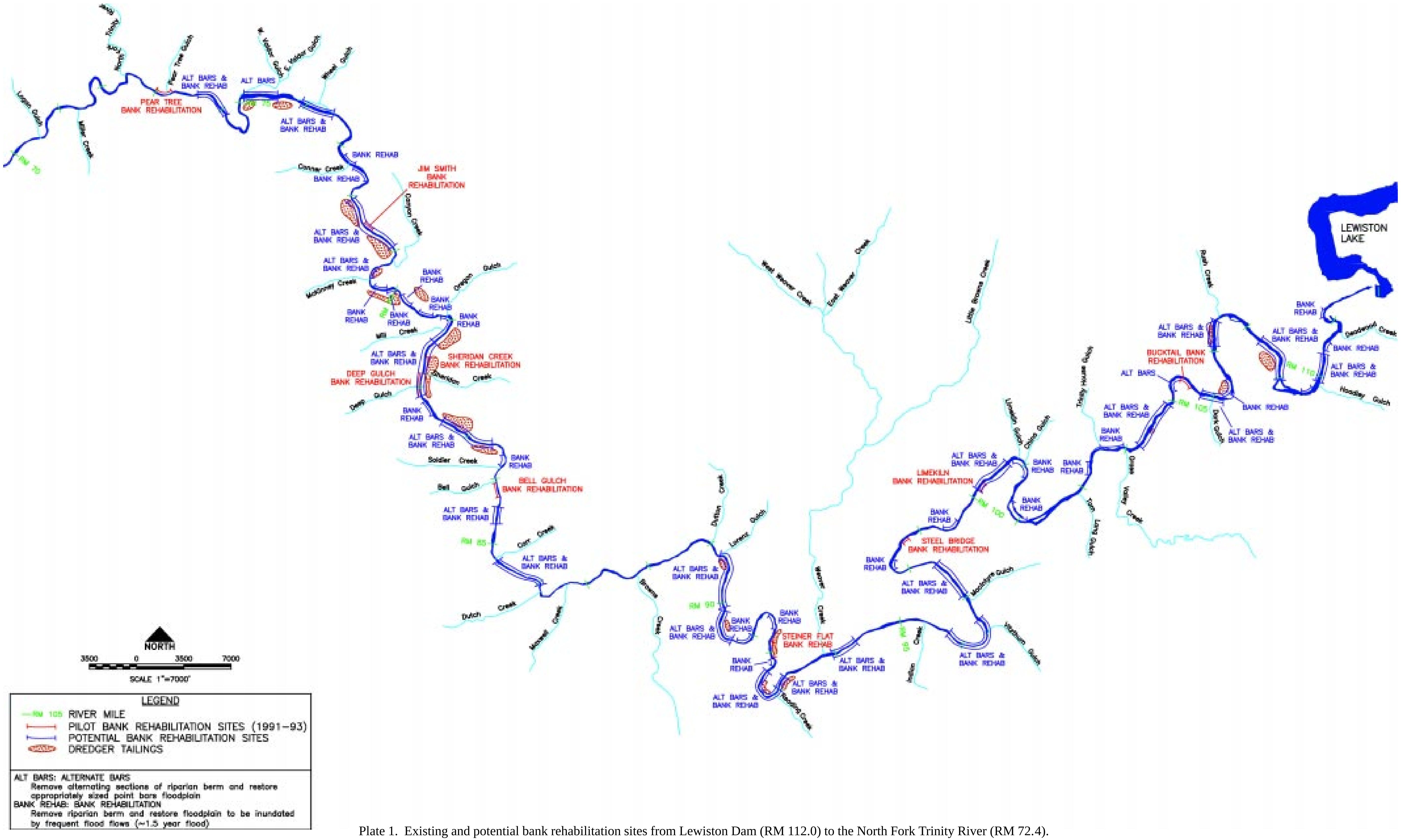


Plate 1. Existing and potential bank rehabilitation sites from Lewiston Dam (RM 112.0) to the North Fork Trinity River (RM 72.4).

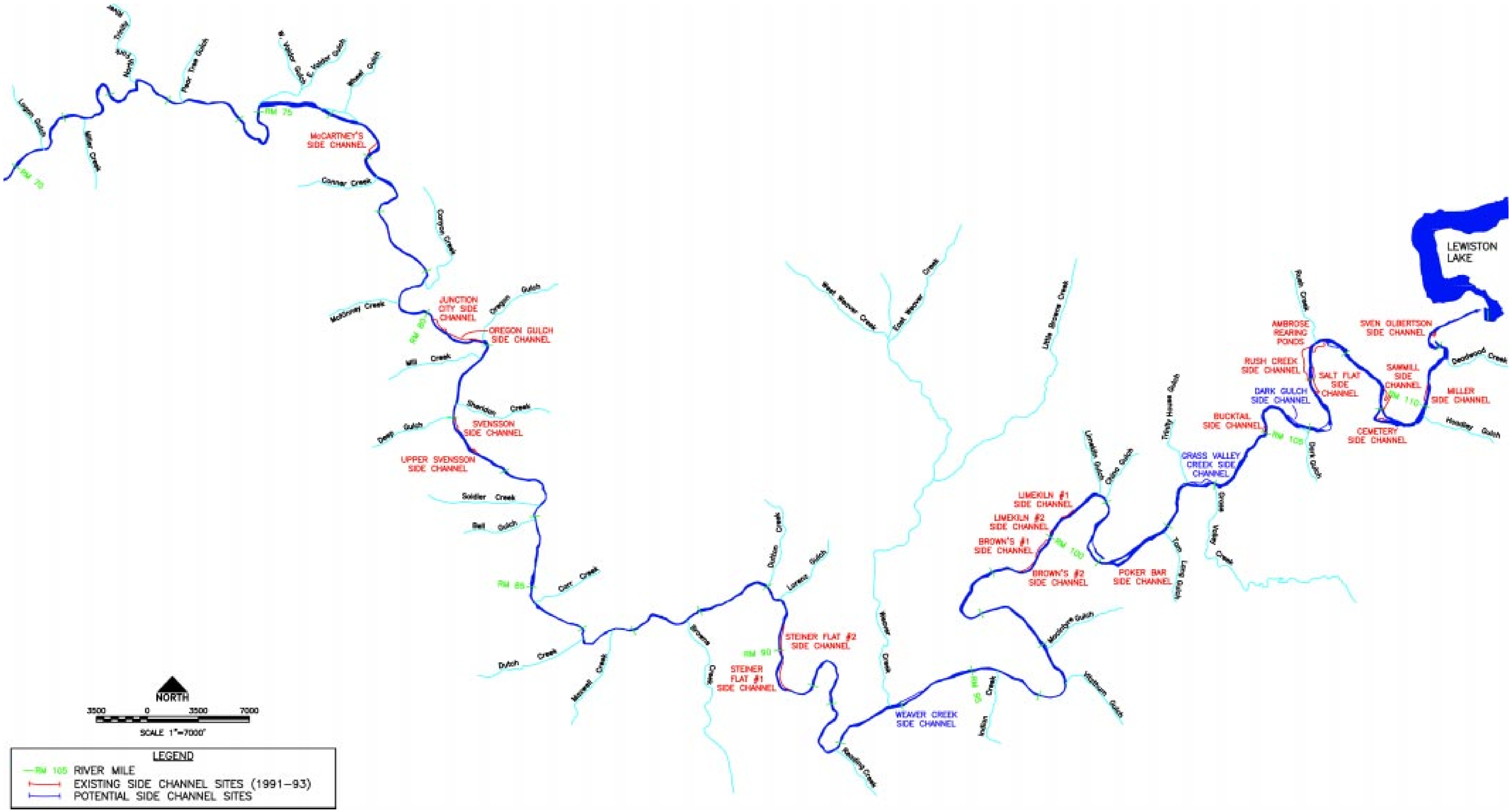


Plate 2. Existing and potential side channel construction sites from Lewiston Dam (RM 112.0) to the North Fork Trinity River (RM 72.4).

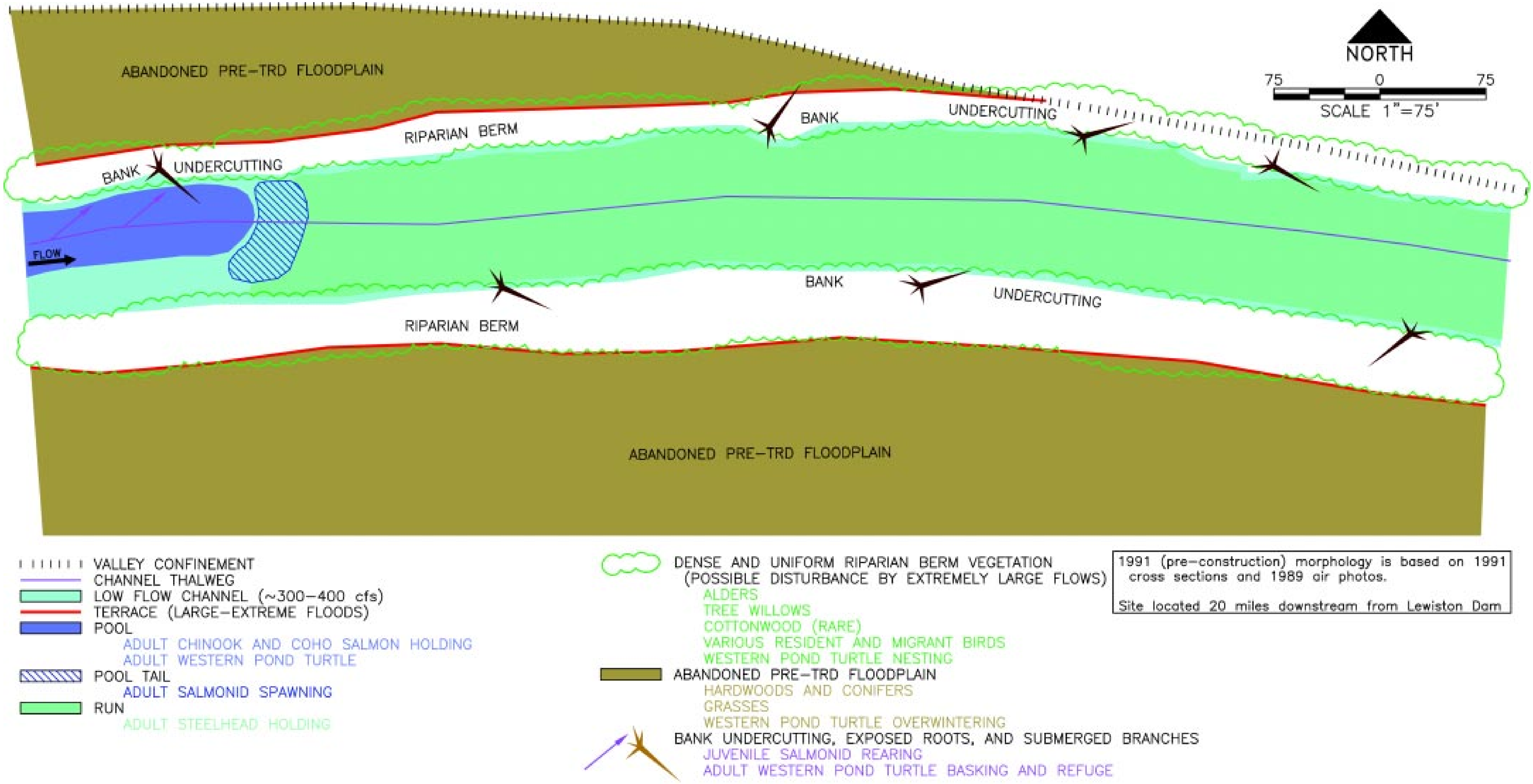


Plate 3. Example of channel morphology with riparian encroachment and low habitat diversity, Steiner Flat study site, 1991.

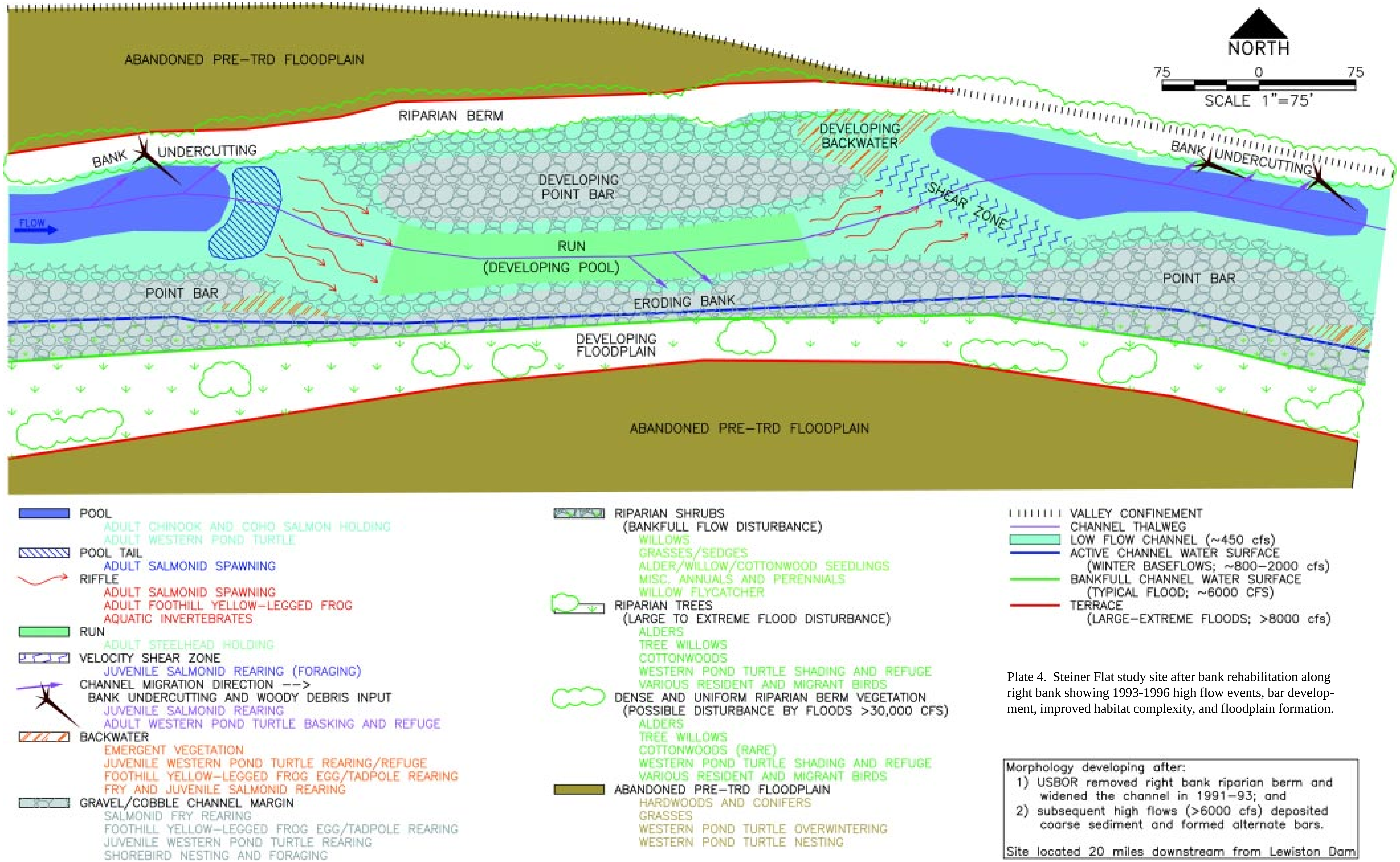


Plate 4. Steiner Flat study site after bank rehabilitation along right bank showing 1993-1996 high flow events, bar development, improved habitat complexity, and floodplain formation.

Morphology developing after:
1) USBOR removed right bank riparian berm and widened the channel in 1991–93; and
2) subsequent high flows (>6000 cfs) deposited coarse sediment and formed alternate bars.

Site located 20 miles downstream from Lewiston Dam

APPENDIX H

Attributes of Alluvial River Ecosystems

Attribute No. 1.
Spatially Complex Channel Morphology

No single segment of channelbed provides habitat for all species, but the sum of all channel segments provides high-quality habitat for native species. A wide range of structurally complex physical environments supports diverse and productive biological communities (Anderson and Nehring, 1985; Sullivan et al., 1987; Bisson et al., 1988; Hill et al., 1991).

***Desired Physical Responses*:**
- An alternate bar morphology extending upstream from the present alluvial transition zone near Indian Creek.
- Development of a functional floodplain, now missing from the post-TRD channel morphology.
- Asymmetrical cross-sections in a meandering channel with a sinuous thalweg pattern.

***Desired Biological Responses (if all annual hydrograph components are provided*)
- Riparian community with all stages of successional development.
- No loss of riparian habitat with channel migration.
- Diverse salmonid habitat available for all life stages over wide-ranging flows, flood and baseflow (Hill et al., 1991; Reeves et al., 1996; *in* Poff et al., 1997).

Attribute No. 2.
Flows and Water Quality Are Predictably Variable

Inter-annual and seasonal flow regimes are broadly predictable, but specific flow magnitudes, timing, duration, and frequencies are unpredictable because of runoff patterns produced by storms and droughts. Seasonal water-quality characteristics, especially water temperature, turbidity, and suspended-sediment concentration, are similar to those of regional unregulated rivers and fluctuate seasonally. This temporal "predictable unpredictability" is a foundation of river ecosystem integrity (Hill et al., 1991; Poff et al., 1997; Richter et al., 1997).

Objectives for Physical Processes:
- Inundate lower alternate bar features during dispersion of riparian plant seeds.
- Provide variable water depths and velocities over spawning gravels during salmonid spawning to spatially distribute redds.
- Inundate broader margins of alternate bars, including backside scour channels, to create shallow slack areas between late winter and snowmelt periods for early life stage of salmonids and amphibians.
- Provide a favorable range of baseflows for maintaining high-quality juvenile salmonid rearing and macroinvertebrate habitat within an alternate bar morphology.
- Provide late-spring outmigrant stimulus flows.
- Rapid post-snowmelt recession stage to strand/desiccate seedlings initiating/establishing on alternate bar surfaces.

Desired Physical Responses:

- Restore physical/riparian processes associated with a snowmelt peak and recession hydrograph components below Lewiston Dam.
- Optimize available physical habitat for anadromous salmonids for all seasons.
- Restore periodic inundation of the floodplain and groundwater dynamics.

Desired Biological Responses (if all annual hydrograph components provided):

- Elimination of most woody riparian cohorts from exposed surfaces of alternate bars.
- Establishment of early-successional riparian communities on floodplains and terraces.
- Improved anadromous salmonid egg survival.
- Natural seasonal timing of hydrograph components to complement life-history requirements of native plants and animals.
- Greater channel complexity, more habitat, and higher water quality for all freshwater life-history stages of salmonids.
- Increased macrobenthic invertebrate productivity.

Attribute No. 3.
Frequently Mobilized Channelbed Surface

Channelbed framework particles of coarse alluvial surfaces are mobilized by the bankfull discharge (Leopold et al., 1964; Richards, 1982; Nelson et al., 1987), which occurs on average every 1 to 2 years.

Objectives (every two of three years as an annual maximum):

- Achieve incipient condition for general channelbed surface.
- Surpass threshold for transporting sand through pools.
- Scour 1- to 2-year-old seedlings on alternate and medial bars.
- Frequently mobilize spawning gravel deposits.

Desired/Diagnostic Physical Responses:

- Mobilize surface rocks (D_{84}) in general channelbed surface and exposed portions of alternate bars.
- Reduce coarseness of surface layer above Indian Creek.
- Reduce sand storage in riffle/run habitat and pools.
- Create local scour depressions around large roughness elements.
- Mobilize spawning gravel deposits several surface layers deep.

Desired Biological Responses (if physical processes achieved):

- Higher survival of eggs and emerging alevins by reducing fines (Tagart, 1984; Sear, 1995; Poff et al., 1997).
- Greater substrate complexity in riffle and run habitats for improved macroinvertebrate production (Boles, 1976; Nelson et al., 1987; Ward, 1998).
- Scour 1-and 2-year-old woody riparian seedlings along margins of alternate bars.

- Greater habitat complexity (micro-habitat features).
- Deeper pool depths/volumes for adult fish cover and holding (Platts et al., 1983; Nelson et al., 1987; Sullivan et al., 1987; Bisson et al., 1988; Barnhart and Hillemeier, 1994).

Attribute No. 4.
Periodic Channelbed Scour and Fill

Alternate bars are scoured deeper than their coarse surface layers by floods exceeding 3- to 5-year annual maximum flood recurrences. This scour is typically accompanied by re-deposition, such that net change in channelbed topography following a scouring flood usually is minimal.

Objectives for Physical Processes:

- Rejuvenate spawning gravel deposits.
- Kill 2- to 4-year-old seedlings establishing on alternate bar surfaces.
- Deposit fine substrate onto upper alternate bar and floodplain surfaces.

Desired Physical Responses:

- Close to dam, reduction in surface-to-subsurface D_{50} and D_{84} particle-size ratios.
- Significant scouring (several surface layers deep) of most alluvial features, including steeper riffles.
- Formation of alternate bar sequences upstream from Indian Creek.
- More alternate bars and developing bar sequences downstream from Douglas City.
- Increased diversity of surface particle-size distributions.
- Greater topographic complexity of side channels associated with alternate bars, especially distal portions.
- Increased pool depths.

Desired Biological Responses (if physical processes achieved):

- Improved anadromous salmonid spawning and rearing habitat (Hill et al., 1991).
- Reestablishment of dynamic riparian plant stands in various stages of succession on higher elevations of alternate bars.
- Mortality of 3- to 4-year-old saplings on alternate bar surfaces to discourage riparian plant encroachment and riparian berm formation.
- Rehabilitation of habitat for riparian-dependent amphibian, bird, and mammal species.

Attribute No. 5.
Balanced Fine and Coarse Sediment Budgets

River reaches export fine and coarse sediment at rates approximately equal to sediment inputs. The amount and mode of sediment storage within a given river reach fluctuates, but channel morphology is sustained in dynamic quasi-equilibrium when averaged over many years (Sear, 1994; Poff et al., 1997).

Objectives for Physical Processes:

- Reduce fine sediment storage in the mainstem.
- Maintain coarse sediment storage in the mainstem.
- Route mobilized D_{84} through alternate bar sequence every two of three years, on average.
- Prevent mainstem accumulation of tributary bed material.
- Eliminate bedload impedance reaches.

Desired Physical Responses:

- D_{84} tracer rocks should negotiate alternate bar sequences; i.e., larger particles from upstream riffles should not accumulate in downstream pools.
- Reduced storage of fine sediment in riparian berms.
- Eliminate aggradation, and encourage slight degradation of bed elevation at tributary deltas (smooth-out longitudinal profile through these reaches).
- Increases pool depths.
- Maintains physical complexity by sustaining alternate bar morphology.

Desired Biological Responses:

- Improves and maintain spawning and rearing habitat quality without reducing quantity (Poff et al., 1997).
- Increases adult salmonid cover and holding (Nelson et al., 1987).
- Reduces riparian berms.

Attribute No. 6.
Periodic Channel Migration

The channel migrates at variable rates and establishes meander wavelengths consistent with regional rivers with similar flow regimes, valley slopes, confinement, sediment supply, and sediment caliber (Williams and Wolman, 1984; Chien, 1985, in Poff et al., 1997; Sullivan et al., 1987; Johnson, 1994).

Objectives for Physical Processes:

- Promote bank erosion in alluvial reaches.
- Floodplain deposition every 3 to 5 years.
- Create channel avulsions every 10 years on average.

- Encourage meander wavelengths 8 to 10 bankfull-widths long.
- Stored sediment in the floodplain is slowly released downstream.

Desired Physical Responses:

- Maintain channel width while channel migrates.
- Create sloughs through infrequent channel avulsions.
- Create side channels through frequent alternate bar reshaping.
- Increase meander amplitude and expression of the thalweg.
- Create water temperature variability within alternate bar sequences.
- Increase input of large woody debris along channel margins.

Desired Biological Responses (if all physical objectives achieved):

- Diverse age class structure in stands of cottonwood and other species dependent on channel migration.
- Full range of seral stages in riparian plant communities.
- Increased habitat quality and quantity for native vertebrate species dependent on early successional riparian forests (Hartman, 1965; Bustard and Narver, 1975; Sullivan, 1987).
- High flow refuge and summer thermal refugia for amphibians and juvenile fish provided in rejuvenated scour channels.
- Increased habitat complexity by input of large woody debris from eroding banks.

Attribute No. 7.
A Functional Floodplain Floodplain

On average, floodplains are inundated once annually by high flows equaling or exceeding bankfull stage. Lower terraces are inundated by less frequent floods, with their expected inundation frequencies dependent on norms exhibited by similar, but unregulated river channels. These floods also deposit finer sediment onto the floodplain and low terraces (Leopold et al., 1964; Sullivan, 1987; Poff et al., 1997; Ward, 1998).

Objectives for Physical Processes:

- Inundate the floodplain on average once annually.
- Encourage local floodplain surface deposition and/or scour by less frequent but higher floods.
- Have floodplain construction keep pace with floodplain loss as the channel migrates across the river corridor.
- Provide sufficient channel confinement to maintain hydraulic processes (Attribute Nos. 3 and 4).

Desired Physical Responses:

- Maintain channel width as river migrates.
- Increase hydraulic roughness and greater flow storage during high-magnitude floods.

Desired Biological Responses (if all physical objectives achieved):

- Increased woody riparian overstory and understory species diversity, compensating for woody riparian stands lost along outside banks of eroding meander bends.
- Keeps physical processes conducive for maintaining early-successional riparian dependent species, especially for birds and amphibians.

Attribute No. 8.
Infrequent Channel-Resetting Floods

Single large floods (e.g., exceeding 10- to 20-year recurrences) cause channel avulsions, widespread rejuvenation of mature riparian stands to early-successional stages, side channel formation and maintenance, and off-channel wetlands (e.g., oxbows). Resetting floods are as critical for creating and maintaining channel complexity as are lesser magnitude floods (Sullivan et al., 1987; Poff et al., 1997; Ward, 1998).

Objectives for Physical Processes:

- Form/Reshape alternate bar surfaces every 10 to 20 years, on average.
- Improve bedload routing by minimizing impedance of bedload transport past tributary deltas.
- Eliminate or minimize extent of mature riparian vegetation stands on alternate bar surfaces and floodplains every 10 to 20 years.
- Deposit fine substrate on lower terrace surfaces once every 10 to 20 years.
- Provide infrequent deep scour high on alternate bars and on the floodplain.
- Construct and maintain (rejuvenate) natural side channels.
- Scour and redeposit entire alternate bar sequences every 10 to 20 years.

Desired Physical Responses:

- Deep scour (several D_{84} surface layers deep) in most alluvial features, including steeper riffles.
- Significant channel migration and infrequent channel avulsion.
- Alternate bar scour and redeposition.
- Extensive removal of saplings and mature trees in riparian stands.
- Increase complexity of natural side channels.

Desired Biological Responses (if physical processes achieved):

- Improve anadromous salmonid spawning and rearing habitats.
- Increase adult fish cover and holding habitat (Nelson et al., 1987).
- Create dynamic riparian stands in various stages of succession on higher elevations of alternate bars.
- Control populations of 3- to 4-year-old saplings on alternate bar surfaces close to channel center, and scour stands of mature riparian vegetation.

Attribute No. 9.
Self-Sustaining Diverse Riparian Plant Communities

Natural woody riparian plant establishment and mortality, based on species life history strategies, culminate in early- and late-successional stand structures and species diversities (canopy and understory) characteristic of self-sustaining riparian communities common to regional unregulated river corridors (Beschta and Platts, 1986; Ligon et al., 1995; Poff et al., 1997).

Objectives for Riparian Processes:

- Prevent woody riparian plant encroachment.
- Maintain early-successional woody riparian communities.
- Remove mature riparian trees established in the riparian berms.
- Eliminate widespread presence of riparian berms.
- Rehabilitate off-channel wetland communities.

Desired Biological Responses (if all physical objectives achieved):

- Floods periodically scour seedlings and saplings.
- Channel migration initiates new riparian cohorts.
- Channel avulsion creates oxbows and off-channel wetland habitats, initiating diverse patches of riparian stands.
- Woody riparian overstory and understory species diversity and age class distribution increases in floodplains.
- Greater habitat availability for wildlife dependent on early seral stages of riparian plant communities.

Attribute No. 10.
Naturally-fluctuating Groundwater Table

Inter-annual and seasonal groundwater fluctuations in floodplains, terraces, sloughs, and adjacent wetlands occur in a manner similar to that in regional unregulated river corridors (Stanford et al., 1996; Ward, 1998).

Objectives for Physical Processes:

- Naturally fluctuating seasonal groundwater elevation and surface-water elevations in scour channels and off-channel wetlands.

Desired Physical Responses:

- Maintenance of off-channel habitats, including overflow channels, oxbow channels, and floodplain wetlands.

Desired Biological Responses (if physical processes achieved):

- High diversity of habitat types within the entire river corridor (Poff et al., 1997; Ward, 1998).

APPENDIX I

Plan of Study for Trinity River Fishery Flow Evaluations

Plan of Study
For Trinity River
Fishery Flow Evaluations

Trinity River, Northwestern California

Lead Agency: U. S. Fish and Wildlife Service
Assisting Agencies: Members of the Trinity River Basin
Fish and Wildlife Task Force

Approved: /sgd/ Ronald Lambertson DEC 8- 1983
Acting Director, U.S. Fish and Wildlife Service Date

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Study Goal: The goal of this study is to monitor the rehabilitation of fishery habitat in the Trinity River below Lewiston Dam in northwestern California. The information from this study together with harvest and escapement information from other ongoing studies will be used to advise the Secretary whether the Department is operating the Trinity River Division consistent with its authorizing provisions for the protection and propagation of fishery resources. This study will meet the intent of the Secretarial decision of January 1981 pertaining to increased flow releases for anadromous fishery protection in the Trinity River downstream of Lewiston Dam - a major feature of the Trinity River Division, Central Valley Project, operated by the U.S. Bureau of Reclamation.

Backqround and Overview: The Trinity River is a major tributary of the Klamath River in northwestern California. The natural resources of the Trinity River Basin sustain many important resource-based social and economic interests. Historically, the Trinity has been recognized as a major producer of chinook and coho salmon and steelhead trout. Indian, sport and commercial salmon fisheries have operated on these runs. Mineral, timber and water resources have also been developed in the Trinity Basin. These developments together with fisheries harvest, are believed to have caused major declines in fall-run chinook and steelhead trout populations over the past two decades. Specific user groups dependent on the fisheries stocks as well as the general northern coastal economics have suffered as a result of the fisheries declines.

These losses are of high concern to this Department for two reasons:
First, the Department has Indian Trust responsibilities which extend to protection of Indian fisheries rights and resources and, second, the act authorizing the construction of the Trinity River Division of the Central Valley Project directs the Secretary to preserve and propagate anadromous fish in the basin.

The Trinity River Division which is the only major water development project in the Trinity River Basin serves to export water from the Trinity River to the Central Valley of California. Since its operation began in 1963, the project has annually exported about 75-90 percent of the runoff at Lewiston Dam. The reminder of flow has been released downstream either for fisheries purposes (about 10 percent annually 1963-73 and somewhat higher in more recent years) or as water surplus to the project's immediate needs.

Coincident with construction and operation of the Trinity River Division, logging accelerated within the Trinity Basin. Higher watershed erosion rates and lowered stream flows downstream of Lewiston Dam resulted in extensive sedimentation of fish habitat. Maintenance of minimum stream-flow releases and construction and operation of a fish hatchery were not sufficient to sustain fisheries populations. Declines in some stocks have exceeded 90 percent of former levels.

In December of 1980, the Fish and Wildlife Service and the Bureau of Reclamation reached an agreement to increase releases to the Trinity River below Lewiston Dam to aid in the rehabilitation of the important and rapidly dwindling anadromous fishery resources. The agreement was approved by the former Secretary Andrus in January 1981 and has been supported by Secretary Watt.

In addition to increasing flow releases for fishery purposes, the agreement also provides for a special study over a 12-year period during which improved releases would be maintained. The Fish and Wildlife Service is to conduct the study in consultation with the Bureau of Reclamation and the California Department of Fish and Game. At the end of the 12-year period, a report will be made to the Secretary describing the effectiveness of the improved flows and any other habitat rehabilitation measures (such as those contained in the proposed Trinity River Basin Fish and Wildlife Management Program) in restoring fishery populations and habitat below Lewiston Dam.

The fishery flow agreement and study are necessary because the congressional authorization for construction and operation of the Trinity River Division provides for the preservation and propagation of the Trinity's indigenous fishery resources by the Secretary and, as previously indicated, these resources are declining.

A number of factors in combination, including overharvest, are thought to be responsible for fishery declines, but not all are within the jurisdiction of the Secretary of the Interior to correct. Habitat losses due to low river flows and sediment accumulation in the main stem Trinity River can be restored in part by increasing flows, trapping sediments, and mechanically rehabilitating spawning and rearing areas, and by reducing erosion through improved watershed management in tributary streams. The Department of the Interior is focusing effort on these tasks.

The Secretary has taken the first step towards rehabilitation of fish runs by improving fishery flow releases (at the expense of other project water uses). A sediment control project (Buckhorn Mtn. Dam-Grass Valley Creek Sediment Control Project) has been authorized by Congress and Interior will likely begin work on the project during Fiscal Year 1984. The Trinity River Basin Fish and Wildlife Task Force - a 13-member group of Government specialists advisory to the Bureau of Reclamation - has developed a comprehensive plan for the rehabilitation and management of fish and wildlife resources throughout the Trinity Basin. With the cooperative assistance of the Bureau of Reclamation and Bureau of Indian Affairs, Fish and Wildlife Service is preparing an Environmental Impact Statement on the Task Force management program. Legislation to authorize and fund the program has been introduced in Congress.

The efforts described above will largely rehabilitate salmon and steelhead habitat in the Trinity River system. Restoration of the fish populations themselves, however, will also be dependent on effective harvest management. This year (1983) the Pacific Fisheries Management Council has adopted a 20-year plan to rebuild salmon runs in the Klamath-Trinity Basin through controlled ocean harvests. Adherence to that plan or even tougher standards, as well as the effective management of Indian and sport fisheries, is vital to the successful replenishment of the anadromous runs.

Although the 12-year study plan presented here addresses habitat restoration, it is clear that consideration will have to be given to the role of harvest management in allowing run goals to be met. It is anticipated that relevant data and evaluations from other monitoring efforts (harvests and escapements) will be considered and included in developing reports and recommendations to the Secretary during this study.

Study Description: The study will span 12 years and consist of 6 major tasks:

1. Study plan review and modification
2. Habitat preference criteria development
3. Habitat availability and need
4. Fish population characteristics and life history relationships
5. Study coordination
6. Reports

The study will require a maximum of 8.8 full-time-equivalent positions depending on work in progress and will require annual funding ranging from $116,431 to $359,273. The study will focus on the main stem Trinity River from Lewiston Dam to its confluence with the Klamath River at Weitchpec. Each study task is described in the following section. Efforts and funding estimates for each task are presented. Effort is shown in biologist days and total staff days (A biologist-day includes biotechnicians). It is assumed that the Fish and Wildlife Service will be the lead agency. There is opportunity for (and interest in) participation by the California Department of Fish and Game and Water Resources and Hoopa Valley Business Council. Their cooperation will be solicited. Interagency participation may alter effort and funding requirements somewhat.

A matrix table showing task schedules and levels of effort throughout the study period is appended. It is intended that this study: 1) Be conducted by utilizing current scientific methodologies; 2) be flexible to meet changing fishery resource conditions; 3) be closely coordinated with other studies and resource management agencies; and 4) be reported on by performing timely data analyses, at regular intervals and at the conclusion of the study.

Consequences of Not Performing Study: Without this study the Department of the Interior will be unable to show how it is meeting its commitments and requirements to maintain and propagate fishery resources in the Trinity River Basin. The Department will continue to be challenged by Indian and other fishery resource management and interest groups and the Trinity River Division will continue to be viewed by these elements as a classic example of the incompatibility of water resource development with fishery maintenance and of the failure of the Federal Government to be responsive to area of origin concerns.

TASK 1. Annual Study Plan Review and Modification

Objective: The objective of TASK 1 is to assure that the study plan reflects current findings and data needs.

Need: As the study progresses certain study elements may require an approach modified from that originally envisioned. Changes will be made based on experience gained from previous efforts.

Methods: Each study year the project leader will review the study efforts and findings with the principal resource management agencies in the Trinity River Basin, including the Trinity River Basin Fish and Wildlife Task Force. Based on these meetings a final study plan for the following year will be prepared.

Effort: Work required to complete TASK 1 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1-11	55 (5/yr)	110 (10/yr)
12	0	0
Total	55 days	110 days

Funding: Funding required to complete TASK 1 is estimated to be:

Study Year(s)	Amount
1	$ 1,590
2- 11	16,630 ($1,663/yr)
12	0
Total	$18,223

TASK 2. Habitat Preference Criteria Development

Objective: The objective of Task 2 is to develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for chinook and coho salmon and steelhead trout spawning, incubation, rearing, holding, and migration. Other factors such as water quality and temperature will also be considered under TASK 3.

Need: Improved preference criteria are needed to use with stream - flow hydraulic data to determine the amount of habitat presently existing for salmon and steelhead, to determine the amount required and types required to achieve target levels of natural fish production, and to monitor increases in habitat gained from flow management and mechanical habitat rehabilitation work.

Methods: Field data will be collected using a variety of techniques. Emphasis will be on visual observations through diving and snorkeling where possible. Other techniques may include electrofishing, seining, redd sampling, and other measures as necessary. Where sufficient data are available, a bivariate analysis will be performed using procedures outlined in Instream Flow Information Paper No. 12 (Bovee, FWS/OBS 82/26, 1982) to develop habitat preference criteria for the following species and life stages:

Species	Race	Life Stage
Chinook salmon	Spring run	Adult holding Spawning Incubation Rearing (fry) Juvenile migration
Chinook salmon	Fall run	Adult holding Spawning Incubation Rearing (fry) Juvenile migration
Coho salmon	Fall run	Adult holding Spawning Rearing (fry) Rearing (yearling) Juvenile migration
Steelhead trout	Summer run (possible)	Adult holding Spawning Rearing (fry) Rearing (yearling) Juvenile migration
Steelhead trout	Winter run	Adult holding Spawning Incubation Rearing (fry) Rearing (yearling) Juvenile migration

Effort: Effort needed to complete TASK 2 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	178	356
2	200	400
3	145	290
4 -11	88 (11 / yr)	176 (22 / yr)
12	0	0
Total	611	1,222

Funding: Funding required to complete TASK 2 is estimated to be:

Study Year(s)	Amount
1	$ 54,604
2	64,532
3	48,236
4-11	29,272 ($3,659/yr)
12	0
Total	$200,646

TASK 3. Determination of Habitat Availability and Needs.

Objectives: There are two objectives for TASK 3. The first is to determine the amount of salmon and steelhead habitat available in the Trinity River downstream of Lewiston Dam under various flow conditions and the various levels of habitat rehabilitation that may be achieved either through the Trinity River Basin Fish and Wildlife Management Program or through other resource management actions. The second objective is to determine the amount of habitat required for each freshwater life stage of salmon and steelhead to sustain those portions of the fish populations in the Trinity Basin that were historically dependent on the Trinity River downstream of Lewiston Dam.

Need: The information from this TASK is needed to evaluate the effectiveness of river flows and other measures in providing adequate amounts and distribution of fish habitat.

Methods: The Incremental Instream Flow Methodology developed by the Fish and Wildlife Service will be utilized as the primary evaluation tool. The methodology and its uses are described in Instream Flow Information Paper No. 12 (Bovee, FWS/OBS 82/26, 1982) and other publications by the Service's Instream Flow and Aquatic Systems Group. The methodology uses hydraulic and biological data to simulate habitat conditions over a range of potential flows. Water temperatures and other water quality data will be collected and incorporated into the habitat evaluations.

Field data will be collected 3 to 4 times over the 12-year study period from representative study reaches between Lewiston and Weitchpec. This will allow a running tally of habitat conditions and make it possible to account for habitat changes due to flows and watershed restoration, as opposed to any instream habitat rehabilitation by mechanical means.

Calculations of available habitat will be based on habitat preference criteria developed under TASK 2. Determination of habitat needs will also consider population use data to be developed under TASK 4. Minor field and laboratory research investigations may be required to test the validity of assumptions on egg and fry survival under various sediment conditions. It is anticipated that this and other specialized work may be undertaken through cooperative arrangements with research institutions.

The major subtasks of TASK 3 are:

1. Selection, establishment and maintenance (minor brush clearing, surveying, etc.) of measurement stations.

2. Hydraulic data collection over a range of flows at each station - repeated 2 - 3 times after initial period depending on streamflows and channel conditions (rehabilitation work).

3. Data analysis and habitat projections assuming various channel and flow conditions, and temperature and other water quality conditions.

The field schedule and effort for each subtask is detailed in the appended table.

Effort: Work required to complete TASK 3 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	444	888
2	390	780
4, 6, 8, 10	1,200 (300/yr)	2,400 (600/yr)
3, 5, 7, 9, 11	1,000 (200/yr)	2,000 (400/yr)
12	0	0
Total	3,034	6,068

Funding: Funding required to complete TASK 3 is estimated to be:

Study Year (s)	Amount
1	$ 141,192
2	129,737
4, 6, 8, 10	399.192 ($99,798/yr)
3, 5, 7, 9, 11	332,660 ($66,532/yr)
12	0
Total	$1,002,781

TASK 4. Determination of Fish Population Characteristics and Life History Relationships.

Objective: The objective of TASK 4 is to determine the relative levels of successful use by fish populations of available habitat in the Trinity River downstream of Lewiston Darn.

Need: Although some information is available on spawning escapements and spawning redd numbers in certain areas, very little is known about the total distribution of fish between Lewiston and Weitchpec or their spawning success and the subsequent survival and growth of juveniles. This type of information is needed to determine which habitat factors may be limiting the restoration of fish population.

Methods: Selected study reaches will be surveyed periodically to develop indices of habitat use, fish distribution, and the survival and growth of juveniles. Survey field methods will include snorkeling, seining, electroshocking, emergent fry trapping, and other techniques found suitable. Survey methods will be refined and standardized based on experimentation during the first year.

Benthic aquatic organisms will also be monitored to determine the overall health and productive capabilities of the Trinity in the established field study reaches. Food habits of juvenile salmonids will be examined to determine utilization of available food supply. Methods for this study element will be patterned after those developed by researchers with the U.S Forest Service and Brigham Young University (Biotic Condition Index: Integrated Biological, Physical and Chemical Stream Parameters for Management. Robert H. Winget and Fred A. Mangum. October 1979. Intermountain Region, Forest Service, U.S. Dept. of Agriculture) and others.

Effort: The effort required to complete TASK 4 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	93	186
2,4,6,8,10,11	2,232 (372/yr)	4,464 (744/yr)
3,5,7,9	3,736 (664/yr)	7,472 (1,361/yr)
12	0	0
Total	6,061	12,122

Funding: Funding required to complete TASK 4 is estimated to be:

Study Year(s)	Amount
1	$ 29,574
2,4,6,8,10,11	742,500 ($123,750/yr)
3,5,7,9	910,158 ($227,539/yr)
12	0
Total	$1,682,230

TASK 5. Study Coordination

Objective: The objective of TASK 5 is to develop and maintain coordination with other study and resource management agencies in the Trinity River Basin to maximize effective use of available information (and to avoid duplication of work).

Need: Presently, the California Department of Fish and Game, Bureau of Indian Affairs, Forest Service, Bureau of Land Management, Hoopa Valley Business Council (Fisheries Department) and the Fish and Wildlife Service have fisheries studies and management programs underway. Additional study efforts will occur under this program and the comprehensive fish and wildlife management program proposed by the Trinity River Basin Fish and Wildlife Task Force. It is essential that studies be coordinated to prevent unintended interference and to make use of study results in planning future work and making management decisions.

Methods: Coordination will be maintained through both formal and informal contacts. Other study leaders and local fishery resource managers will be contacted on at least a bimonthly basis. Formal coordination meetings will, be scheduled twice yearly. Quarterly work progress reports (prepared under TASK 6) and preliminary fisheries reports will be provided to interested agencies.

Effort: The effort required to complete TASK 5 is estimated to be:

Study Year (s)	Biologist Days	Total Staff Days
1 - 11	220 (20/yr)	440 (40/yr)
12	10	20
Total	230	460

Funding: Funding required to complete TASKS is estimated to be:

Study Year (s)	Amount
1	$ 6,360
2 - 11	66,532 ($6,653/yr)
12	3,327
Total	$76,219

TASK 6. Reports (Progress, Findings and Recommendations)

Objective: The objectives of TASK 6 are: 1) To report on the analysis of information developed from field investigations (TASK 2, 3, and 4) and on relevant information from other studies which have a bearing on the levels of fishery resource rehabilitation achieved in the Trinity River between Lewiston and Weitchpec and 2) to develop recommendations to the Secretary and to other resource management agencies concerning future management options and needs.

Need: Fishery rehabilitation efforts achieved through improved flow releases from Lewiston Dam and from mechanical aquatic habitat and watershed rehabilitation should be monitored and critically analyzed.

Methods: Three types of reports will be prepared under TASK 6. The first type will be quarterly progress and planning reports detailing study activities and accomplishments during the past quarter and describing anticipated activities during the current quarter. These will generally be prepared and distributed within 2 weeks of the close of each quarter. The second type will be preliminary findings reports containing field data and analyses for major portions of one or more study elements. As an example, this type of report would be produced following completion of the habitat preference criteria study element (TASK 2) and at the end of each of the 3 to 4 periods of hydraulic streamflow data collection and computer analysis (TASK 3). The preliminary findings reports should be completed after data analysis and during the year following completion of field work. The final type of report will be the concluding report to the Secretary.

The concluding report will summarize the findings of each of the study elements (from various preliminary findings reports), evaluate the results of improved flows and other rehabilitation measures in an overall manner, and convey to the Secretary the Service's recommendations with respect to future management options and needs for the Trinity River downstream of Lewiston Dam.

Effort: Effort needed to complete TASK 6 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	10	20
2	20	40
4,6,8,10	120(30/yr)	240 (60/yr)
3,5,7,9,11	130 (26/yr)	260 (52/yr)
12	340	680
Total	620	1,240

Funding: Funding required to complete TASK 6 is estimated to be:

Study Year(s)	Amount
1	$ 3,180
2	6,653
4,6,8,10	39,921 ($ 9,910/yr)
3,5,7,9,11	43,246 ($ 1,649/yr)
12	113,104
Total	$206,104

Table I-1. Schedule of Activities and Effort (Biologist Days) for Trinity River Fishery Flow Evaluations

Fiscal Year	85	86	87	88	89	90	91	92	93	94	95	96
Study Area	1	2	3	4	5	6	7	8	9	10	11	12
STUDY TASK												
Study Plan Review and Modification	5	5	5	5	5	5	5	5	5	5	5	
Habitat Preference Criteria	178	200	145	11	11	11	11	11	11	11	11	
Habitat Availability and Need	444	390	200	300	200	300	200	300	200	300	200	
Fish Population Characteristics and Relationships	93	372	604	372	684	372	684	372	684	372	372	
Study Coordination	20	20	20	20	20	20	20	20	20	20	20	10
Reports	10	20	26	30	26	30	26	30	26	30	26	340
Total Effort[a]	750	1,007	1,000	738	946	738	946	738	946	738	634	350
Funding	238,500	335,000	359,273	245,503	314,696	245,503	314,696	245,503	314,696	245,503	210,906	116,431
Grand Total	3,186,210											

[a] Effort in Biologist Days (1 Biologist Day = 2 Staff Days)

APPENDIX J

Calculation of the Descending Limb of the Snowmelt Hydrograph

One of the components of an annual hydrograph for the Trinity River is the descending limb of the snowmelt hydrograph. An analysis of Trinity River flow data was conducted to develop predictive equations for this component of the hydrograph.

Methods

Daily flow data for the Trinity River at Lewiston were obtained from USGS records. Annual flow data were stratified according to the water year classification presented in Chapter 4. For each water year class, years were identified in which the descending limb of the snowmelt hydrograph (typically April-June/July, depending on water year class) displayed a relatively smooth decrease throughout this period. Years in which large storm events occurred during the snowmelt period were excluded from analysis because of the disruption of the relation between flow and time due to these events.

Once appropriate water years were identified, flow data for the range of flows of interest for each water year class were obtained. For all water year classes, the lower range of flows was approximately 450 cfs, the flow recommended to meet the summer/fall temperature criteria for the Trinity River. The upper range depended on water year class and was selected to correspond to approximately the peak flow recommended for a specific water year class to achieve fluvial geomorphic objectives. The upper ranges were: 11,000 cfs for Extremely Wet water years, 8,500 cfs for Wet water years, 6,000 cfs for Normal water years, 4,500 for Dry water years, and 1,500 for Critically Dry water years. For individual water years, the flow for each day was coupled with a corresponding day value (i.e.: day corresponding with the first day of the flow range was designated day 1, the second - day 2, etc.).

For each year, flow data were log transformed and regressed on corresponding day data. The slope and intercept parameters were then averaged for each water year class to develop composite predictive equations. After development of the composite equations, the intercept parameter was adjusted so the predicted flow on day 0 would equal the peak flow for that water year class.

Results

Regression statistics for each water year are presented in Table J.1. Parameters for the composite equations are presented in Table J.2. During the hydrograph refinement process, the slope parameters for the Extremely Wet and Wet water years were adjusted to increase the slope of the descending limb. This exercise was conducted to reduce the recommended releases during the descending limb of the hydrograph while still meeting smolt temperature criteria. The water not released during the descending limb of the hydrograph was used to increase recommended releases prior to the fluvial geomorphic peaks to meet smolt temperature criteria. The slope parameter was changed from -0.0176 to -0.0240 for the Extremely Wet water year class from -0.0179 to -0.0291 for the Wet water year class.

Table J-1. Regression statistics for the descending limb of individual water years.

Water Year Class	Year	Slope	Intercept	r^2	n
Critically Dry	1918	-0.0136	3.2614	0.91	39
	1939	-0.0131	3.2614	0.86	40
Dry	1922	-0.0138	3.8781	0.78	73
	1926	-0.0173	3.5262	0.95	49
	1933	-0.0276	3.6190	0.98	36
	1935	-0.0191	3.7203	0.95	53
Normal	1912	-0.0202	3.8252	0.98	58
	1919	-0.0172	3.8665	0.93	69
	1945	-0.0147	3.7649	0.96	74
	1949	-0.0141	3.9081	0.89	82
	1966	-0.0137	3.7343	0.95	88
Wet	1921	-0.0191	3.8789	0.97	63
	1942	-0.0190	3.9518	0.97	67
	1946	-0.0155	3.8834	0.98	77
	1969	-0.0198	3.9623	0.95	67
	1971	-0.0140	3.9316	0.93	87
	1973	-0.0197	3.8390	0.91	63
	1975	-0.0198	3.9000	0.80	74
	1984	-0.0155	3.8239	0.86	70
	1993	-0.0184	3.8040	0.91	63
Extremely Wet	1915	-0.0181	4.1252	0.98	78
	1938	-0.0193	4.0291	0.98	70
	1941	-0.0150	4.0860	0.95	94
	1956	-0.0184	3.9490	0.99	71
	1958	-0.0154	4.0898	0.98	98
	1974	-0.0131	4.0138	0.83	93

Table J-2. Slope, Intercept, number of years (n) and years used to develop flow predictive equations for the descending limb of the snowmelt hydrograph and parameters for the adjusted equations.

Water Year Class		Slope	Intercept	n	Years
Critically Dry	Actual	-0.0133	3.2360	2	1918, 1939
	Adjusted	-0.0133	3.1760		
Dry	Actual	-0.0191	3.7308	4	1922, 1926, 1933, 1935
	Adjusted	-0.0191	3.6532		
Normal	Actual	-0.0160	3.8259	5	1912, 1919, 1945, 1949, 1966
	Adjusted	-0.0160	3.7782		
Wet	Actual	-0.0179	3.8962	9	1921, 1942, 1946, 1969, 1971, 1973, 1975, 1984, 1993
	Adjusted	-0.0179	3.9294		
Extremely Wet	Actual	-0.0176	4.0488	6	1915, 1928, 1941, 1956, 1958, 1974
	Adjusted	-0.0176	4.0414		

APPENDIX K

Temperatures

Temperature Evaluations of the Recommended Spring Hydrographs

This appendix provides detail of how recommended spring hydrographs, composed of dam releases for geomorphic, ramping, and water temperature related needs, are likely to influence water temperatures of the Trinity River. Using methods outlined in Section 5.5.2.2, composite schedules (Table K.1) were modeled in SNTEMP and predicted water temperatures were compared to optimal smolt temperatures (OST), marginal smolt temperatures (MST), and unsuitable smolt temperatures (UST) identified in Section 5.5.

Results

Extremely Wet Years

Simulations of the composite schedules for EXTREMELY WET years (n = 3) show that optimal smolt temperatures (OST) are generally met from April 15 to July 8 (Figures K.1A). While the peak release to meet geomorphic needs decreases water temperatures in the lower river, water temperatures still remain within OST. Ramping down from the peak results in a warming trend while maintaining OST through the week of July 8.

Summary information on longitudinal water temperature profiles indicate that on average the percentage of river meeting OST and MST from April 15 through July 8 would be 99 and 100 %, respectively (Table K.2).

Wet Years

Simulations of the composite schedules for WET years (n = 5) show that optimal smolt temperatures (OST) are generally met from April 15 to July 8 (Figure K.1B). Scheduled releases indicate that 300 cfs is adequate to meet OST on April 15, and that the increased releases that occur from this time until the peak release (May 20) result in OST. Although the peak release does decrease water temperatures, water temperatures still remain within OST. After the peak release, the recommended release pattern provides for a warming trend and meets OST through the week of July 8.

Summary information on longitudinal water temperature profiles indicates that on average the percentage of river meeting OST and MST from April 15 through July 8 would be 97 and 100 %, respectively (Table K.2).

Normal Years

While only one year was simulated with the NORMAL year schedule, results indicate that the recommended release schedule does generally meet the OST (Figure K.2A). Only during the weeks of April 15, June 3 and July 8 were recommended releases (300, 2,300, and 1,543 cfs, respectively) insufficient to meet OST. Similar to the wetter year schedules, the peak release (i.e., 5,683 cfs) decreases water temperatures although they still remain within OST. After the peak release, the recommended release pattern provides a warming trend while meeting OST until the week of July 8 after which water temperatures become marginal.

Summary information on longitudinal water temperature profiles indicates that on average the percentage of river meeting OST and MST from April 15 through July 8 would be 91 and 97 %, respectively (Table K.2).

Table K.1. Average weekly dam releases modeled in SNTEMP.

Week	Average Weekly Recommended Releases (cubic feet/sec)				
	Extremely Wet	**Wet**	**Normal**	**Dry**	**Critically Dry**
15-Apr	300	300	300	300	300
22-Apr	500	500	500	557	1,243
29-Apr	1,500	2,000	2,500	4,071	1,500
06-May	2,000	2,500	5,683	3,788	1,500
13-May	2,000	5,786	5,005	2,783	1,500
20-May	7,786	7,196	3,867	2,045	1,500
27-May	9,807	5,266	2,988	1,503	1,445
03-Jun	6,619	3,329	2,309	1,104	1,104
10-Jun	5,067	2,153	2,000	811	811
17-Jun	3,420	2,000	2,000	596	596
24-Jun	2,313	2,000	2,000	461	461
01-Jul	2,000	2,000	2,000	450	450
08-Jul	1,543	1,543	1,543	450	450

Dry Years

Simulations of the composite schedules for DRY years (n = 8) show that water temperatures can be temporally variable (Figure K.2B). On April 15, a release of 300 cfs results in a wide possible range of temperatures in the lower Trinity River, some of which may become UST. During the peak release (4,071 cfs) river water temperatures become optimal. Ramping down from the peak release provides for a gradual warming trend while providing at least MST until mid-June.

Summary information on longitudinal water temperature profiles indicate that on average the percentage of river meeting OST and MST from April 15 through July 8 would be 73 and 91%, respectively (Table K.2).

Critically Dry Years

Simulations of the composite schedules for CRITICALLY DRY years show that water temperatures also can be temporally variable (Figure K.3). While in some years this schedule could provide OST, there are other years that UST could result. However, the recommended release schedule does provide a warming trend and generally provides at least MST from April to mid-June.

Summary information on longitudinal water temperature profiles indicate that on average the percentage of river meeting OST and MST from April 15 through July 8 would be 63 and 89 %, respectively (Table K.2).

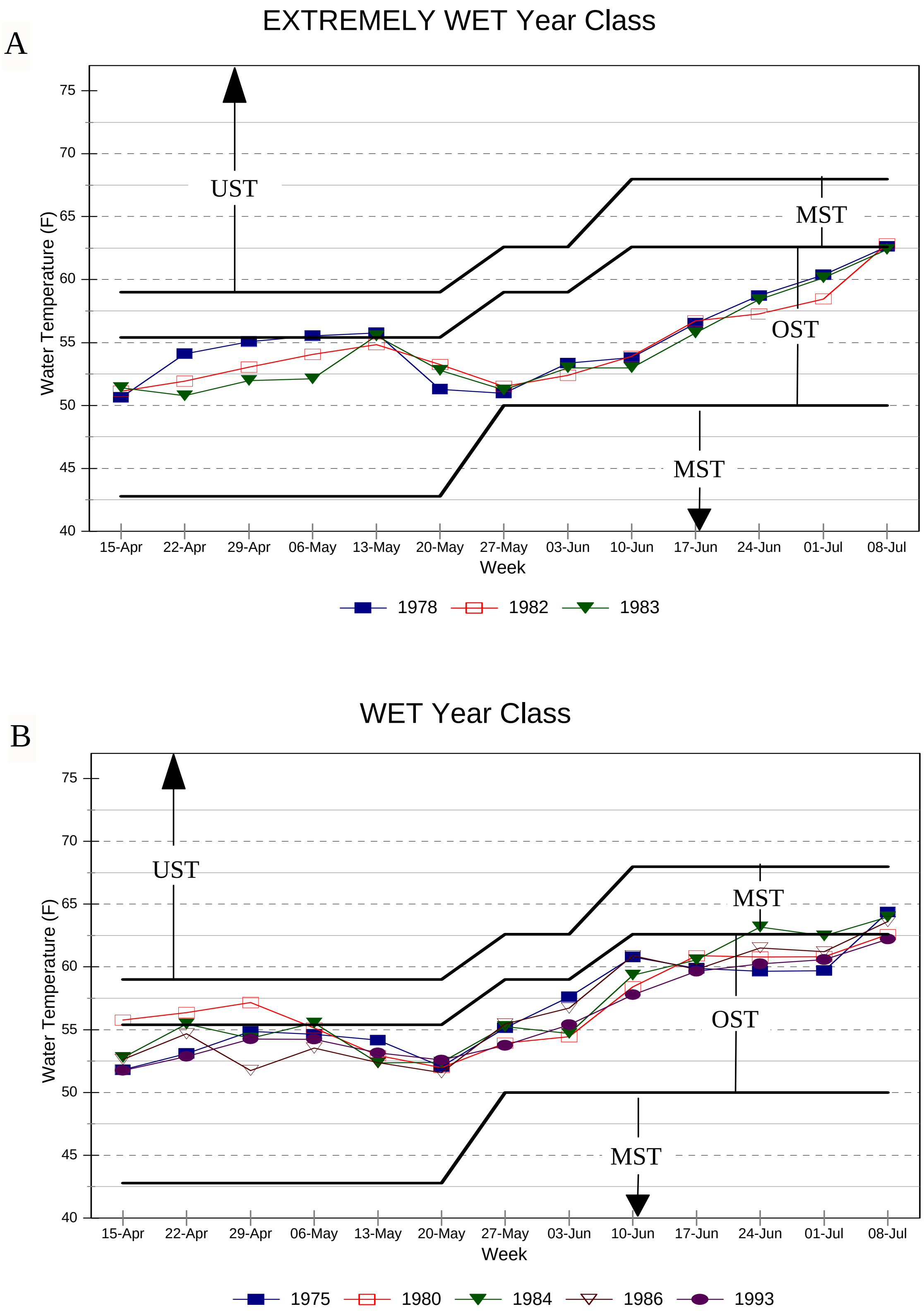

Figure K.1. Predicted water temperatures at Weitchpec (RM 0.0) during spring under EXTREMELY WET (A) and WET (B) water year schedules. UST = Unsuitable Smolt Temperatures, MST = Marginal Smolt Temperatures, and OST = Optimal Smolt Temperatures.

Table K.2. Average percentage of miles of the Trinity River from Lewiston Dam to the confluence of the Klamath River that meet temperature criteria presented in Section 5.5. Temp.--temperature; e.wet--extremely wet water year; wet--wet water year; normal--normal water year; dry--dry water year; c.dry--critically dry water year.

WEEK	TEMP. CRITERIA ^{0}F	AVERAGE PERCENTAGE OF MILES MEETING TEMPERATURE CRITERIA				
		E.WET n = 3	WET n = 5	NORM. n = 1	DRY n = 8	C.DRY n = 3
		Optimal Smolt Temperatures				
15-Apr	42.8 - 55.4	100	92	45	85	80
22-Apr	42.8 - 55.4	100	90	100	83	89
29-Apr	42.8 - 55.4	100	93	100	100	76
06-May	42.8 - 55.4	97	98	100	100	82
13-May	42.8 - 55.4	91	100	100	84	78
20-May	42.8 - 55.4	100	100	100	82	60
27-May	50.0 - 59.0	100	100	100	91	77
03-Jun	50.0 - 59.0	100	100	67	71	63
10-Jun	50.0 - 62.6	100	100	100	82	69
17-Jun	50.0 - 62.6	100	100	100	54	58
24-Jun	50.0 - 62.6	100	98	100	43	35
01-Jul	50.0 - 62.6	100	100	100	42	32
08-Jul	50.0 - 62.6	93	86	67	35	26
AVG		**99**	**97**	**91**	**73**	**63**
		Optimal and Marginal Smolt Temperatures				
15-Apr	42.8 - 59.0	100	100	67	100	89
22-Apr	42.8 - 59.0	100	100	100	96	100
29-Apr	42.8 - 59.0	100	100	100	100	100
06-May	42.8 - 59.0	100	100	100	100	95
13-May	42.8 - 59.0	100	100	100	100	100
20-May	42.8 - 59.0	100	100	100	100	86
27-May	50.0 - 62.6	100	100	100	100	100
03-Jun	50.0 - 62.6	100	100	100	93	100
10-Jun	50.0 - 68.0	100	100	100	100	100
17-Jun	50.0 - 68.0	100	100	100	85	100
24-Jun	50.0 - 68.0	100	100	100	72	76
01-Jul	50.0 - 68.0	100	100	100	78	60
08-Jul	50.0 - 68.0	100	100	100	62	47
AVG		**100**	**100**	**97**	**91**	**89**

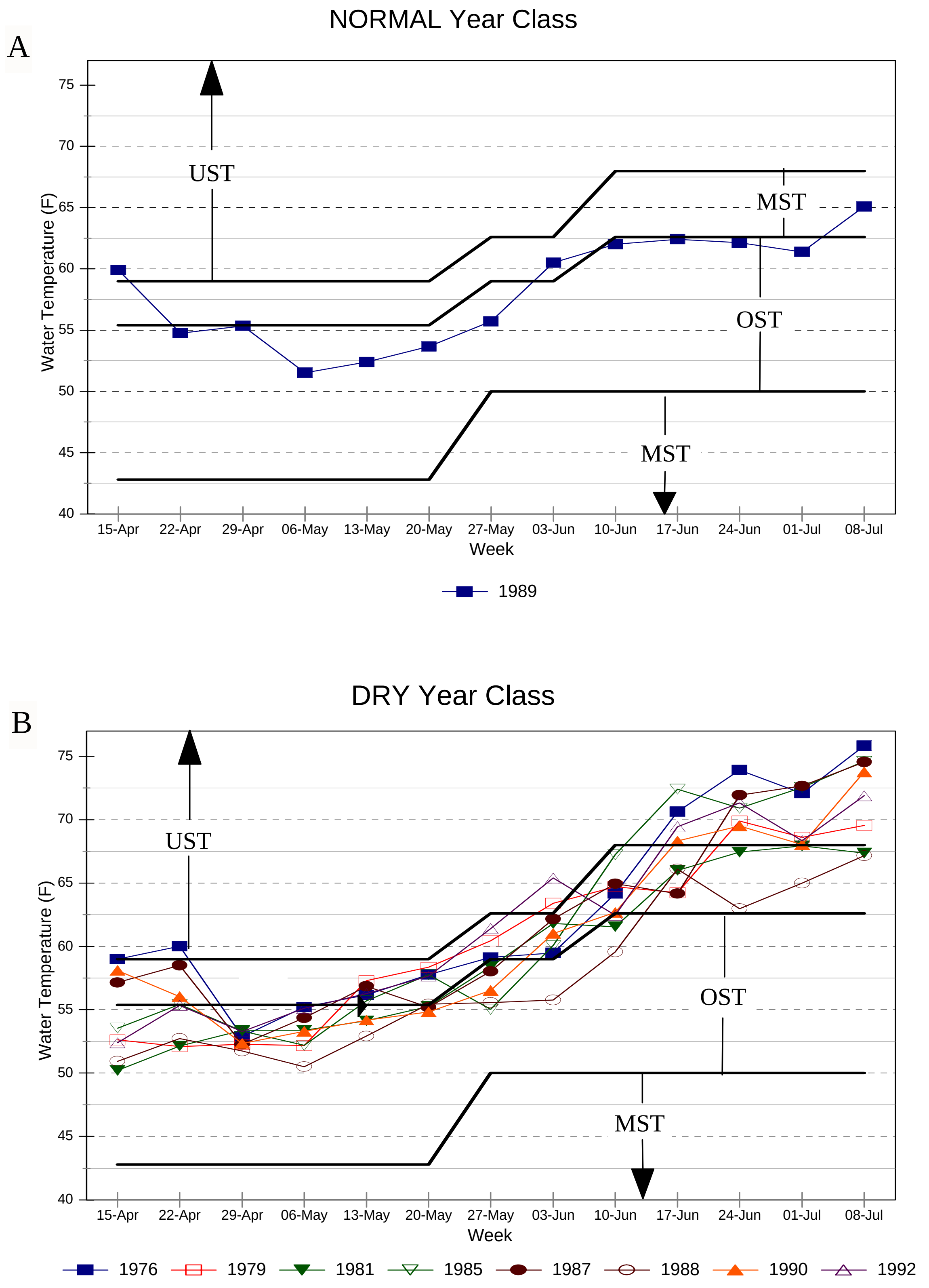

Figure K.2. Predicted water temperatures at Weitchpec (RM 0.0) during spring under NORMAL (A) and DRY (B) water year schedules. UST = Unsuitable Smolt Temperatures, MST = Marginal Smolt Temperatures, and OST = Optimal Smolt Temperatures.

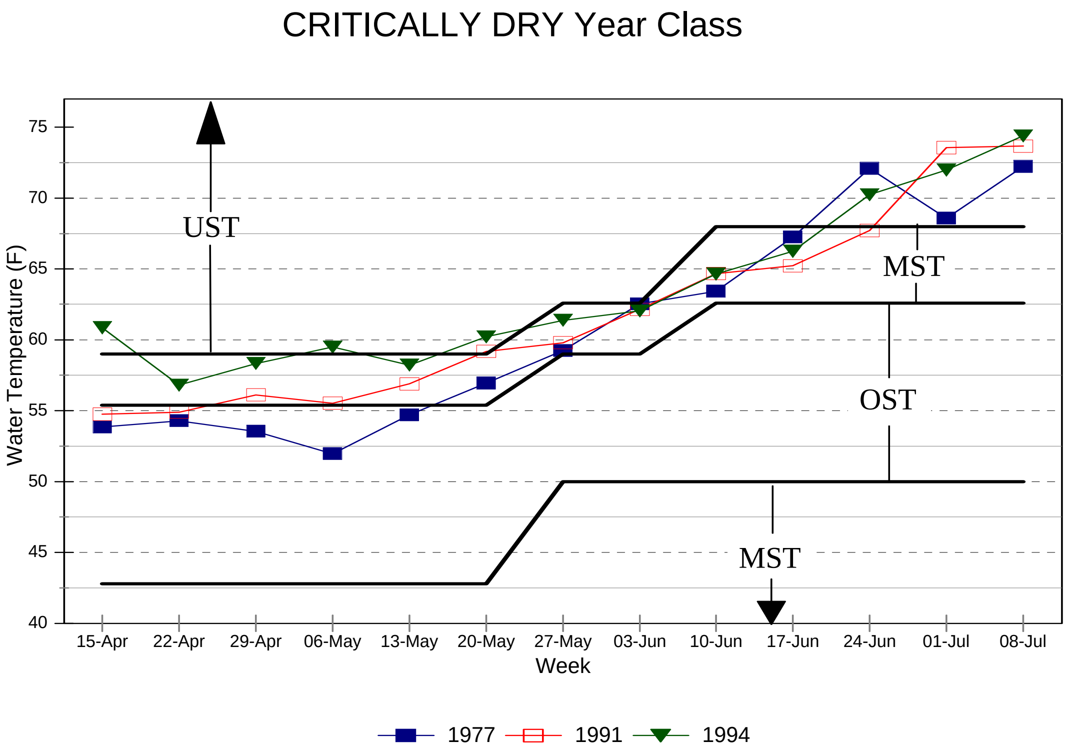

Figure K.3. Predicted water temperatures at Weitchpec (RM 0.0) during spring under the CRITICALLY DRY water year schedule. UST = Unsuitable Smolt Temperatures, MST = Marginal Smolt Temperatures, and OST = Optimal Smolt Temperatures.

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APPENDIX L

Temperature Evaluations at the Trinity River Confluence with the Klamath River

Likely Differences in Water Temperature at the Confluence of the Trinity and Klamath Rivers due to the TRFE flow recommendations.

Introduction

Water temperature is perhaps the single most important variable affecting salmonid survival (Brett, 1952). One life-stage that is of particular concern on the Trinity River is the springtime and early summer outmigration of salmon and steelhead smolts that migrate through the Trinity River and into the Klamath River, and eventually to Pacific Ocean. In the absence of good water quality during this journey, the survival of smolts and parr may be jeopardized (See Section 5.5).

Because Lewiston Dam releases can affect water temperatures in the lower Trinity River during the spring outmigration period (Zedonis, 1997), the differences in water temperature of the Klamath River and the Trinity River at their confluence could be of concern. This analysis evaluated the likely value of these differences in water temperatures as a result of the increased dam releases associated with the TRFE release recommendations. Discussions of the likely effects of altered thermal regimes on salmonids are included.

Methods

Empirical Approach

The first approach to evaluating differences in water temperatures of the Trinity and Klamath Rivers before mixing was to simply compare water temperatures measured on each river just upstream of their confluence. Measurements taken in 1992, 1993, and 1994 were chosen for this evaluation since these years represent a variety of different water year types and complete data sets. Only the weeks from April 29 to July 15 were evaluated as these were the only weeks that large dam releases were recommended.

Water temperature data were taken at Weitchpec Falls (RM 0.7) for the Trinity River and at Big Bar (RM 49.7) on the Klamath River, which is approximately 6 miles upstream of the confluence with the Trinity River located at RM 43.5. Flow data were obtained from the Hoopa gage (RM 12.4) on the Trinity River, and Orleans gage (RM 59.6) on the Klamath River. Although temperature and flow data were not collected at the confluence area, these two variables were assumed to represent conditions at the confluence area.

Model Approach

The second approach was to use the SNTEMP model of the Trinity River (Zedonis, 1997) to predict how the TRFE releases might have altered the thermal regime at the confluence if they occurred during the years of 1992, 1993, and 1994. These three years were chosen because: (1) they were represented by a complete data set at the time of this assessment; and (2) they represent a range of different hydrometeorological conditions, but are representative of the conditions for which the SNTEMP model was calibrated (calibration years are 1991 to 1994). Using inflow volumes into Trinity Lake as an indicator of water year class (See Chapter 3: Background), 1992, 1993, and 1994 were considered dry, wet, and critically dry years, respectively.

Under the model approach, several simulations were performed. For each of the three years (1992, 1993, and 1994), all of the TRFE flow releases were evaluated for water temperature and flow at the mouth of the Trinity River. In addition, simulations were performed for a "baseflow" condition of 300 cfs. For each of the model runs, release water temperatures were set to 48.2° F for each week during the April 29 to July 15 time period. The SNTEMP model was run eighteen times, and flow and predicted water temperatures at the mouth of the Trinity River (RM 0.0) were then compared to actual Klamath River water temperature (RM 49.7) and flow conditions (RM 59.6) to predict what might have happened if the TRFE recommended releases had occurred.

Results

Empirical Approach

Evaluation of water temperatures during 1992, 1993, and 1994 (Figure L-1; Tables L-1, L-2, and L-3) indicates that the thermal regimes of the Klamath and Trinity Rivers at the confluence were generally within 2.0° F between the time period of April 29 to July 15. Exceptions to this did, however, occur. In 1992, Trinity River water temperatures were as much as 7.4° F colder than the Klamath River as a result of increased Lewiston Dam releases (6,000 cfs for 5 days) during the weeks of June 10th and 17th (Table L-1). In contrast, in 1993 Trinity River water temperatures were 3° F warmer than the Klamath River during the week of May 20th when Lewiston Dam releases were 300 cfs.

In 1993, weather patterns differed from those of 1992 and 1994. During this year more precipitation resulted in more flow accretion in the Klamath and Trinity Rivers. During this year, average weekly flow conditions at Weitchpec (RM 0.0) on the Trinity River from April 29 to July 15 ranged from 1,800 to 10,700 cfs. At the Orleans gaging station on the Klamath River, average weekly flows ranged from 2,900 to 21,700 cfs. Larger Klamath River flows typically associated with cooler and wetter conditions resulted in average weekly water temperatures to be 1.0° F colder than the Trinity River (Table L-2). Examination of 1994 water temperatures shows that the Trinity and Klamath River water temperatures were very similar. Water temperatures were always less than 1.0° F different and the average difference was 0.1° F (Table L.3). During this year, flow levels were very low in both the Trinity and Klamath Rivers.

Model Approach

1992

Under 1992 hydrometeorological conditions, the TRFE releases would have resulted in water temperatures in the lower Trinity River becoming much cooler than the Klamath River (Figure L-2, and Tables L-4 to L-9). Under an Extremely Wet schedule, water temperatures in the Trinity River would have become as much as 15° F cooler than the Klamath River. On average, weekly water temperatures would have been 8.8° F cooler.

Under Wet and Normal year release schedules Trinity River water temperatures would have also been considerably cooler than the Klamath River. For the Wet year schedule (Table L-5), water temperatures would have been as much as 12.9° F cooler and on average 8.2° F cooler. For the Normal year release schedule (Table L-6), water temperatures would have been as much as 9.5° F cooler and on average 7.8° F cooler.

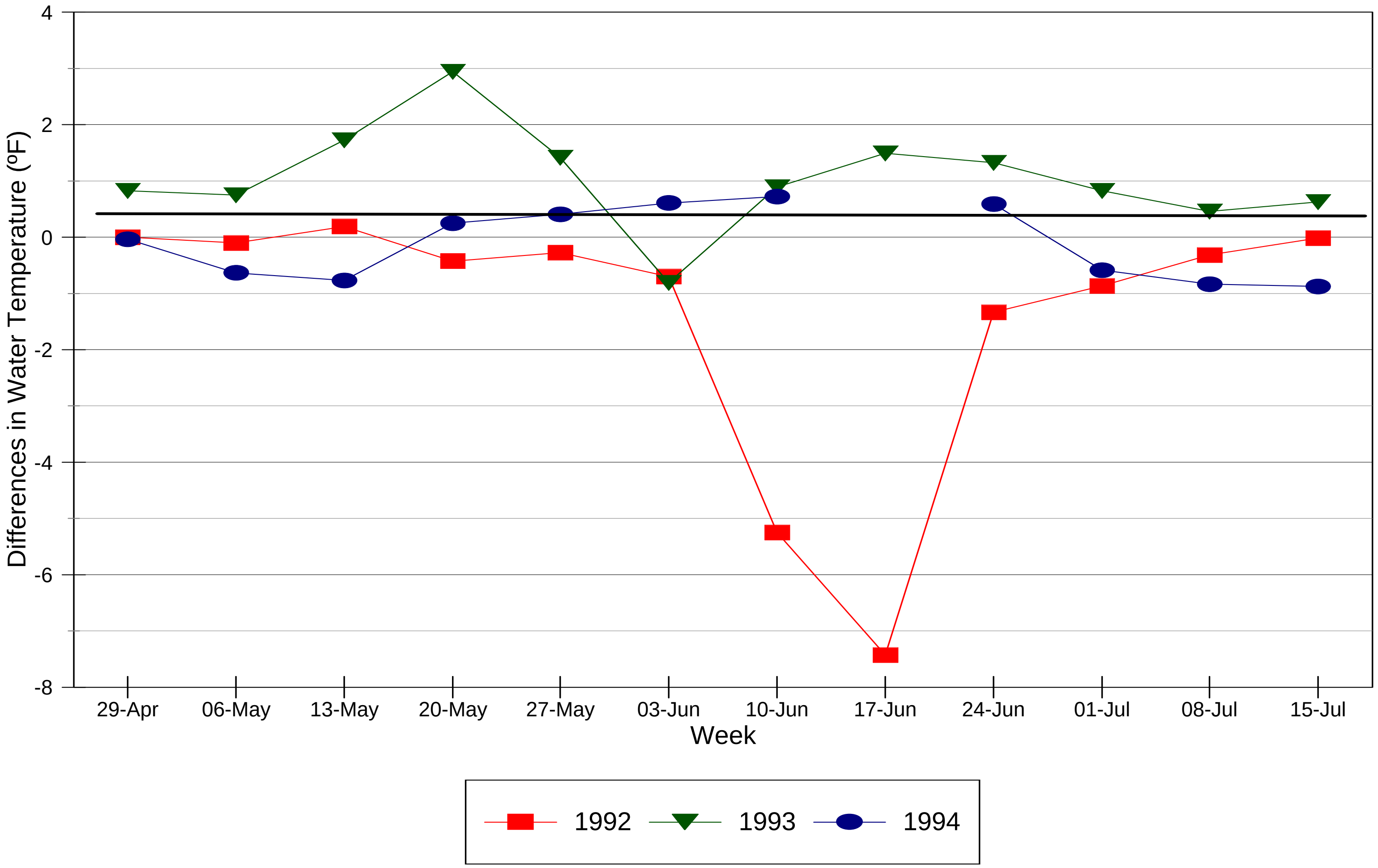

Figure L-1. Water temperature differences at the confluence of the Klamath and Trinity River for 1992, 1993, and 1994. Results are based upon real gage and temperature data. Refer to Tables L.1 - L.3 for information on dam releases, etc. Negative values indicate Trinity River water temperatures are colder than Klamath River water.

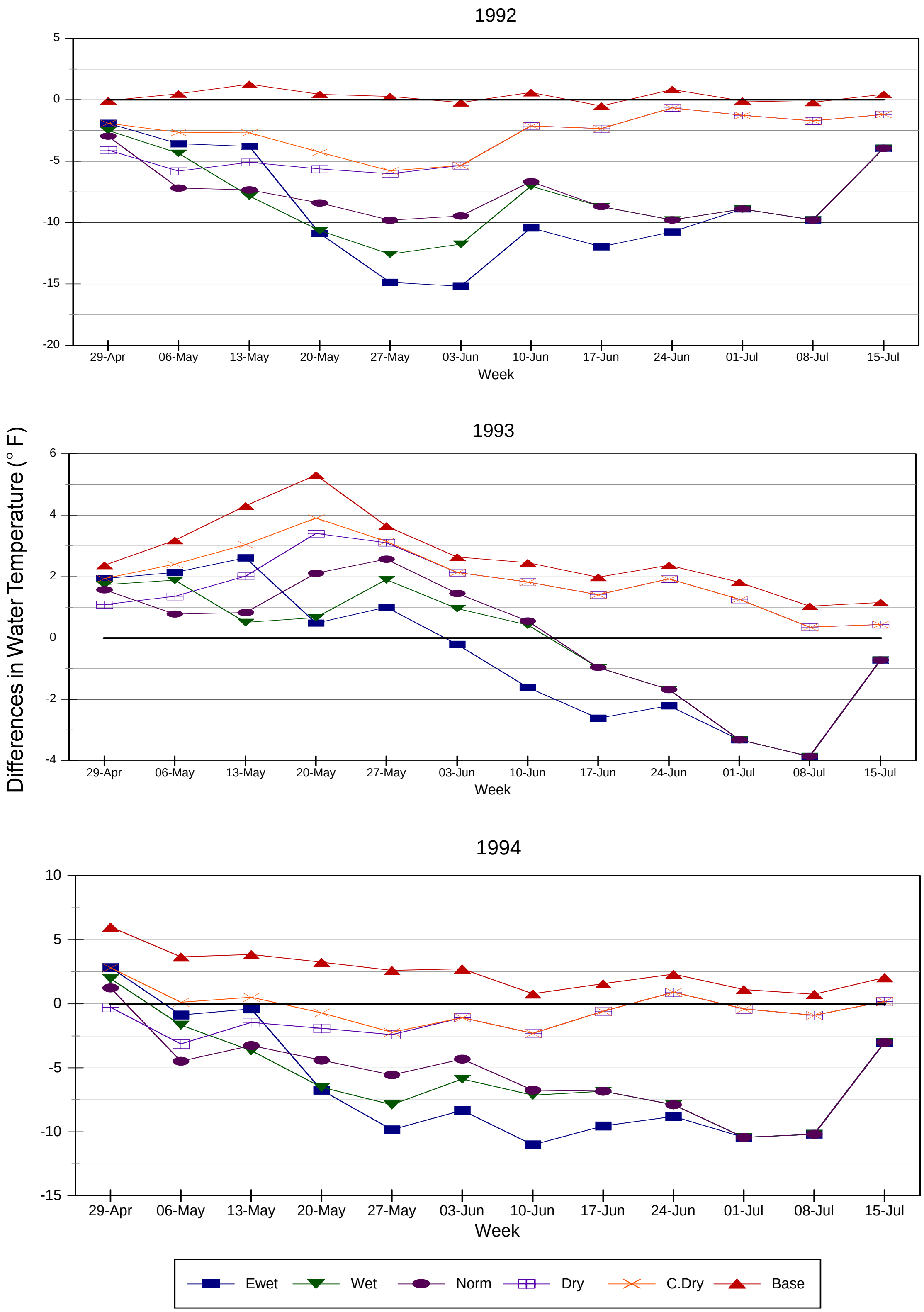

Figure L-2. Predicted water temperature differences at the confluence of the Klamath and Trinity Rivers for three years using five Trinity River Flow Evaluation Recommendation flow schedules. Base-flow conditions are a 300 cfs dam release. Negative values indicate that Trinity River water temperatures are colder.

Table L-1. Results of mixing of actual water temperature and river flows of the Klamath and Trinity Rivers, spring, 1992.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1992	Trinity R. @ Hoopa	Klamath R. @Big Bar	Difference (Trinity -	Trinity Confluence	Lewiston Dam	Klamath @ Orleans	Iron Gate Dam	Flow (cfs)			Water Temperatures (° F)
Week	Avg Week	Avg Week	Klamath)	Avg Week	Release	Avg Week	Release	Combined	%Trinity	%Klamath	Mixed
29-Apr	59.1	59.1	0.0	3231	321	4871	529	8103	40	60	59.1
06-May	62.6	62.7	-0.1	2541	327	3714	518	6256	41	59	62.7
13-May	63.3	63.2	0.2	1944	325	2766	515	4710	41	59	63.2
20-May	64.8	65.2	-0.4	1627	322	2410	503	4037	40	60	65.1
27-May	68.7	69.0	-0.3	1379	334	1987	490	3366	41	59	68.9
03-Jun	70.2	70.9	-0.7	1126	344	1676	486	2801	40	60	70.6
10-Jun	59.8	65.1	-5.2	4521	4549	1596	476	6117	74	26	61.2
17-Jun	64.6	72.0	-7.4	2662	2251	1679	651	4341	61	39	67.5
24-Jun	70.8	72.1	-1.3	961	363	1479	418	2439	39	61	71.6
01-Jul	68.7	69.6	-0.9	1050	322	1576	433	2626	40	60	69.3
08-Jul	73.3	73.7	-0.3	749	307	1337	426	2087	36	64	73.5
15-Jul	75.4	75.5	0.0	751	414	1129	437	1879	40	60	75.4
Average	66.8	68.2	-1.4	1879	848	2185	490	4063	44.5	55.5	67.3

Table L-2. Results of mixing of actual water temperature and river flows of the Klamath and Trinity Rivers, spring, 1993.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1993	Trinity R. @ Hoopa	Klamath R. @Big Bar	Difference (Trinity -	Trinity Confluence	Lewiston Dam	Klamath @ Orleans	Iron Gate Dam	Flow (cfs)			Water Temperatures (° F)
Week	Avg Week	Avg Week	Klamath)	Avg Week	Release	Avg Week	Release	Combined	%Trinity	%Klamath	Mixed
29-Apr	53.6	52.7	0.8	8784	1756	18629	3873	27413	32	68	53.0
06-May	53.6	52.8	0.8	5847	303	18657	4100	24504	24	76	53.0
13-May	55.9	54.2	1.7	4906	301	17029	2499	21934	22	78	54.5
20-May	56.8	53.9	2.9	4989	305	17400	1357	22389	22	78	54.5
27-May	54.1	52.7	1.4	10690	318	21129	1741	31819	34	66	53.2
03-Jun	54.4	55.2	-0.8	8860	336	21729	6023	30589	29	71	55.0
10-Jun	58.9	58.0	0.9	5684	324	12871	1601	18556	31	69	58.3
17-Jun	62.9	61.4	1.5	4336	320	9056	1067	13391	32	68	61.9
24-Jun	63.9	62.6	1.3	3134	324	5637	779	8771	36	64	63.0
01-Jul	65.7	64.9	0.8	2624	436	4127	738	6751	39	61	65.2
08-Jul	67.4	66.9	0.5	2177	447	3303	677	5480	40	60	67.1
15-Jul	66.1	65.4	0.6	1813	460	2867	683	4680	39	61	65.7
Avg	59.4	58.4	1.0	5320	469	12703	2095	18023	31.6	68.4	58.7

Table L-3. Results of mixing of actual water temperature and river flows of the Klamath and Trinity Rivers, spring, 1994. ND--no data.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1994 Week	Trinity R. @ Hoopa Avg Week	Klamath R. @Big Bar Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	55.4	55.4	-0.0	3150	1574	3943	574	7093	44	56	55.4
06-May	59.0	59.6	-0.6	3439	1589	5817	853	9256	37	63	59.4
13-May	57.1	57.8	-0.8	3071	1576	4167	676	7239	42	58	57.5
20-May	61.3	61.1	0.2	1981	358	3399	869	5380	37	63	61.2
27-May	64.0	63.5	0.4	1543	345	2693	585	4236	36	64	63.7
03-Jun	63.2	62.6	0.6	1314	347	2406	854	3720	35	65	62.8
10-Jun	67.3	66.5	0.7	1130	345	2044	609	3174	36	64	66.8
17-Jun	ND	66.5	ND	961	347	1917	823	2879	33	67	44.3
24-Jun	69.6	69.0	0.6	851	357	1606	567	2457	35	65	69.2
01-Jul	71.4	72.0	-0.6	846	468	1454	570	2301	37	63	71.8
08-Jul	74.2	75.0	-0.8	798	483	1329	574	2127	38	62	74.7
15-Jul	75.6	76.5	-0.9	724	466	1236	571	1960	37	63	76.2
Avg	59.8	65.5	-0.1	1651	688	2668	677	4318	37.3	62.7	63.6

Table L-4. Hypothetical flows: Model results: TRFE EXTREMELY WET year flows and 1992 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1992 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	57.1	59.1	-1.9	4407	1500	3943	529	8350	53	47	58.1
06-May	59.1	62.7	-3.6	4212	2000	5817	518	10030	42	58	61.2
13-May	59.4	63.2	-3.8	3623	2000	4167	515	7790	47	53	61.4
20-May	54.3	65.2	-10.9	9082	7786	3399	503	12480	73	27	57.3
27-May	54.1	69.0	-14.9	10844	9807	2693	490	13537	80	20	37.1
03-Jun	55.7	70.9	-15.2	7309	6619	2406	486	9715	75	25	59.4
10-Jun	54.6	65.1	-10.4	5639	5067	2044	476	7683	73	27	57.4
17-Jun	60.0	72.0	-12.0	4675	3420	1917	651	6592	71	29	63.5
24-Jun	61.4	72.1	-10.8	2913	2313	1606	418	4519	64	36	65.2
01-Jul	60.7	69.6	-8.9	2733	2000	1454	433	4187	65	35	63.8
08-Jul	63.9	73.7	-9.8	1977	1543	1329	426	3306	60	40	37.8
15-Jul	71.5	75.5	-4.0	1028	696	1236	437	2263	45	55	73.7
Avg	59.3	68.2	-8.8	4870	3729	2668	490	7538	62.4	37.6	62.2

Table L-5. Hypothetical flows: Model results: TRFE WET year flows and 1992 hydrometeorological conditions.

	Water Temperature (° F)			Flow (cfs)				Combined Rivers			
1992 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	56.6	59.1	-2.5	4908	2000	3943	529	8851	55	45	57.7
06-May	58.4	62.7	-4.4	4710	2500	5817	518	10527	45	55	60.8
13-May	55.3	63.2	-7.8	7405	5786	4167	515	11572	64	36	58.1
20-May	54.6	65.2	-10.7	8492	7196	3399	503	11891	71	29	57.6
27-May	56.4	69.0	-12.6	6306	5266	2693	490	8999	70	30	60.2
03-Jun	59.1	70.9	-11.8	4022	3329	2406	486	6428	63	37	63.5
10-Jun	58.0	65.1	-7.0	2726	2153	2044	476	4770	57	43	61.1
17-Jun	63.3	72.0	-8.7	3256	2000	1917	651	5173	63	37	66.5
24-Jun	62.3	72.1	-9.8	2602	2000	1606	418	4208	62	38	66.1
01-Jul	60.7	69.6	-8.9	2733	2000	1454	433	4187	65	35	63.8
08-Jul	63.9	73.7	-9.8	1977	1543	1329	426	3306	60	40	67.8
15-Jul	71.5	75.5	-4.0	1028	696	1236	437	2263	45	55	73.7
Avg	60.0	68.2	-8.2	4180	3039	2668	490	6848	60.1	39.9	63.1

Table L-6. Hypothetical flows: Model results: TRFE NORMAL year flows and 1992 hydrometeorological conditions.

	Water Temperature (° F)			Flow (cfs)				Combined Rivers			
1992 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	56.1	59.1	-3.0	5406	2500	3943	529	9349	58	42	57.4
06-May	55.5	62.7	-7.2	7892	5683	5817	518	13709	58	42	58.6
13-May	55.8	63.2	-7.3	6624	5005	4167	515	10791	61	39	58.6
20-May	56.8	65.2	-8.4	5166	3867	3399	503	8564	60	40	60.2
27-May	59.2	69.0	-9.8	4032	2988	2693	490	6725	60	40	63.1
03-Jun	61.4	70.9	-9.5	3001	2309	2406	486	5407	56	44	65.6
10-Jun	58.4	65.1	-6.7	2574	2000	2044	476	4618	56	44	61.3
17-Jun	63.3	72.0	-8.7	3256	2000	1917	651	5173	63	37	66.5
24-Jun	62.3	72.1	-9.8	2602	2000	1606	418	4208	62	38	66.1
01-Jul	60.7	69.6	-8.9	2733	2000	1454	433	4187	65	35	63.8
08-Jul	63.9	73.7	-9.8	1977	1543	1329	426	3306	60	40	67.8
15-Jul	71.5	75.5	-4.0	1028	696	1236	437	2263	45	55	73.7
Avg	60.4	68.2	-7.8	3858	2716	2668	490	6525	58.6	41.4	63.6

Table L-7. Hypothetical flows: Model results: TRFE DRY year flows and 1992 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1992 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	55.0	59.1	-4.1	6981	4071	3943	529	10924	64	36	56.4
06-May	56.9	62.7	-5.8	6003	3789	5817	518	11820	51	49	59.8
13-May	58.0	63.2	-5.1	4407	2782	4167	515	8574	51	49	60.5
20-May	59.6	65.2	-5.6	3347	2044	3399	503	6746	50	50	62.4
27-May	63.0	69.0	-6.0	2549	1504	2693	490	5242	49	51	66.1
03-Jun	65.5	70.9	-5.4	2060	1105	2406	486	4466	46	54	68.4
10-Jun	62.9	65.1	-2.1	1767	812	2044	476	3811	46	54	64.1
17-Jun	69.7	72.0	-2.4	1829	597	1917	651	3746	49	51	70.9
24-Jun	71.5	72.1	-0.7	1063	459	1606	418	2669	40	60	71.9
01-Jul	68.3	69.6	-1.3	1183	448	1454	433	2637	45	55	69.0
08-Jul	71.9	73.7	-1.7	883	448	1329	426	2211	40	60	73.0
15-Jul	74.2	75.5	-1.2	780	448	1236	437	2016	39	61	75.0
Avg	64.7	68.2	-3.4	2738	1542	2668	490	5405	47.4	52.6	66.5

Table L-8. Hypothetical flows: Model results: TRFE CRITICALLY DRY year flows and 1992 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1992 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	57.1	59.1	-1.9	4410	1501	3943	529	8353	53	47	58.1
06-May	60.1	62.7	-2.7	3715	1501	5817	518	8532	39	61	61.7
13-May	60.5	63.2	-2.7	3125	1501	4167	515	7292	43	57	62.0
20-May	60.9	65.2	-4.3	2804	1501	3399	503	6202	45	55	63.3
27-May	63.2	69.0	-5.8	2489	1444	2693	490	5182	48	52	66.2
03-Jun	65.5	70.9	-5.4	2060	1105	2406	486	4466	46	54	68.4
10-Jun	62.9	65.1	-2.1	1767	812	2044	476	3811	46	54	64.1
17-Jun	69.7	72.0	-2.4	1829	597	1917	651	3746	49	51	70.9
24-Jun	71.5	72.1	-0.7	1063	459	1606	418	2669	40	60	71.9
01-Jul	68.3	69.6	-1.3	1183	448	1454	433	2637	45	55	69.0
08-Jul	71.9	73.7	-1.7	883	448	1329	426	2211	40	60	73.0
15-Jul	74.2	75.5	-1.2	780	448	1236	437	2016	39	61	75.0
Avg	65.5	68.2	-2.7	2176	980	2668	490	4643	44.4	55.6	67.0

Table L-9. Hypothetical flows: Model results: BASE FLOW conditions of 300 cfs and 1992 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1992 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	59.0	59.1	-0.1	3210	300	3943	529	7153	45	55	59.0
06-May	63.2	62.7	0.5	2514	300	5817	518	8331	30	70	62.9
13-May	64.4	63.2	1.2	1924	300	4167	515	6092	32	68	63.5
20-May	65.7	65.2	0.5	1603	300	3399	503	5002	32	68	65.4
27-May	69.3	69.0	0.2	1345	300	2693	490	4038	33	67	69.1
03-Jun	70.6	70.9	-0.2	1255	300	2406	486	3661	34	66	70.8
10-Jun	65.7	65.1	0.6	1255	300	2044	476	3299	38	62	65.3
17-Jun	71.5	72.0	-0.5	1532	300	1917	651	3450	44	56	71.8
24-Jun	73.0	72.1	0.8	904	300	1606	418	2510	36	64	72.4
01-Jul	69.5	69.6	-0.1	1035	300	1454	433	2489	42	58	69.6
08-Jul	73.4	73.7	-0.2	734	300	1329	426	2063	36	64	73.6
15-Jul	75.9	75.5	0.5	632	300	1236	437	1868	34	66	75.6
Avg	68.4	68.2	0.3	1495	300	2668	490	4163	36.3	63.7	68.2

Dry and Critically Dry release schedules result in smaller differences in water temperatures than the Extremely Wet, Wet and Normal schedules (Tables L-7 and L-8). Using a Dry release schedule results in water temperatures that are as much as 6.0° F cooler than the Klamath River, but on average 3.4° F cooler. Using the Critically Dry release schedule results in water temperatures that are as much as 5.8° F different, but on average 2.7° F cooler.

Under baseflow conditions (a 300 cfs release from April 29 to July 15), the Trinity River water temperatures would have been very similar to the Klamath River water temperatures (Table L-9). Water temperatures would have only differed by as much as 0.8° F and on average would have been 0.3° F warmer than the Klamath River.

1993

Under an Extremely Wet release schedule, Trinity River water temperatures during the spring would have initially been warmer than the Klamath River, then colder later (Figure L-2, Table L-10). During the peak Lewiston Dam release of 9,807 cfs (week of May 27th), water temperatures of the Trinity River would have been about 1.0° F warmer than the Klamath. By early July water temperatures of the Trinity River would have become up to 3.9° F cooler than the Klamath River. On average, Trinity River water temperatures would have only been only 0.5° F cooler than the Klamath River.

Results of simulations under Wet and Normal release schedules are similar to that of the Extremely Wet release schedule. The only differences that occur between these releases are subtle changes in flows and thus water temperatures. On average, the Wet and Normal release schedules resulted in water temperatures that were 0.2° F (Table L-11) and 0.1° F (Table L-12) cooler than the Klamath River. In both of these years, Trinity River water temperatures would have been colder during the months of June and July.

Results of simulations using Dry and Critically Dry and base flow schedules (Tables L-13 and L-14) indicated that water temperatures of the Trinity River would have been warmer than the Klamath River. The Dry release schedule would have resulted in water temperatures that were as much as 3.4° F warmer and on average 1.7° F warmer than the Klamath River. The Critically Dry release schedule would have resulted in water temperatures that were as much as 3.9° F warmer and on average 2.0° F warmer than Klamath River water temperatures. Under baseflow conditions, water temperatures would have risen further, as much as 5.3° F warmer and on average 2.7° F warmer than the Klamath River (Table L-15).

1994

Simulation results for this year were fairly similar to those of 1992. Simulations for Extremely Wet, Wet, and Normal release schedules indicate that the high flows associated with these year types would result in Trinity River temperatures being considerably colder than the Klamath River (Figure L-2; Tables L-16 to L-18).

Dry and Critically Dry release schedules, however, would have resulted in water temperatures fairly similar to those in the Klamath River. A Dry release schedule would have resulted in water temperatures as much as 3.1° F colder, but on average 1.1° F colder than the Klamath River (Table L-19). A Critically Dry release schedule would have resulted in water temperatures less than 2.8° F colder and on average 0.3° F colder than the Klamath River (Table L-20).

Table L-10. Hypothetical flows: Model results: TRFE EXTREMELY WET year flows and 1993 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1993 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	54.7	52.7	1.9	8538	1500	18629	3873	27167	31	69	53.3
06-May	55.0	52.8	2.1	7549	2000	18657	4100	26206	29	71	53.5
13-May	56.8	54.2	2.6	6607	2000	17029	2499	23635	28	72	54.9
20-May	54.4	53.9	0.5	12464	7786	17400	1357	29864	42	58	54.1
27-May	53.7	52.7	1.0	20180	9807	21129	1741	41308	49	51	53.2
03-Jun	55.0	55.2	-0.2	15144	6619	21729	6023	36873	41	59	55.2
10-Jun	56.4	58.0	-1.6	10434	5067	12871	1601	23306	45	55	57.3
17-Jun	58.8	61.4	-2.6	7436	3420	9056	1067	16492	45	55	60.2
24-Jun	60.4	62.6	-2.2	5123	2313	5637	779	10761	48	52	61.5
01-Jul	61.6	64.9	-3.3	4188	2000	4127	738	8315	50	50	63.2
08-Jul	63.1	66.9	-3.9	3270	1543	3303	677	6573	50	50	65.0
15-Jul	64.7	65.4	-0.7	2048	696	2867	683	4915	42	58	65.1
Avg	57.9	58.4	-0.5	8582	3729	12703	2095	21285	41.6	58.4	58.0

Table L-11. Hypothetical flows: Model results: TRFE WET year flows and 1993 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1993 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	54.5	52.7	1.7	9039	2000	18629	3873	27668	33	67	53.3
06-May	54.7	52.8	1.9	8047	2500	18657	4100	26704	30	70	53.4
13-May	54.7	54.2	0.5	10388	5786	17029	2499	27417	38	62	54.3
20-May	54.6	53.9	0.7	11875	7196	17400	1357	29275	41	59	54.2
27-May	54.6	52.7	1.9	15642	5266	21129	1741	36771	43	57	53.5
03-Jun	56.2	55.2	1.0	11857	3329	21729	6023	33586	35	65	55.6
10-Jun	58.5	58.0	0.4	7521	2153	12871	1601	20392	37	63	58.2
17-Jun	60.4	61.4	-1.0	6017	2000	9056	1067	15073	40	60	61.0
24-Jun	60.9	62.6	-1.7	4813	2000	5637	779	10450	46	54	61.8
01-Jul	61.6	64.9	-3.3	4188	2000	4127	738	8315	50	50	63.2
08-Jul	63.1	66.9	-3.9	3270	1543	3303	677	6573	50	50	65.0
15-Jul	64.7	65.4	-0.7	2048	696	2867	683	4915	42	58	65.1
Avg	58.2	58.4	-0.2	7892	3039	12703	2095	20595	40.3	59.7	58.2

Table L-12. Hypothetical flows: Model results: TRFE NORMAL year flows and 1993 hydrometeorological conditions.

	Water Temperature (° F)			Flow (cfs)				Combined Rivers			
1993 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs) Combined	%Trinity	%Klamath	Water Temperatures (° F) Mixed
29-Apr	54.3	52.7	1.6	9537	2500	18629	3873	28166	34	66	53.3
06-May	53.6	52.8	0.8	11229	5683	18657	4100	29886	38	62	53.1
13-May	55.0	54.2	0.8	9608	5005	17029	2499	26636	36	64	54.5
20-May	56.0	53.9	2.1	8549	3867	17400	1357	25949	33	67	54.6
27-May	55.3	52.7	2.6	13368	2988	21129	1741	34497	39	61	53.7
03-Jun	56.7	55.2	1.5	10837	2309	21729	6023	32565	33	67	55.7
10-Jun	58.6	58.0	0.5	7369	2000	12871	1601	20241	36	64	58.2
17-Jun	60.4	61.4	-1.0	6017	2000	9056	1067	15073	40	60	61.0
24-Jun	60.9	62.6	-1.7	4813	2000	5637	779	10450	46	54	61.8
01-Jul	61.6	64.9	-3.3	4188	2000	4127	738	8315	50	50	63.2
08-Jul	63.1	66.9	-3.9	3270	1543	3303	677	6573	50	50	65.0
15-Jul	64.7	65.4	-0.7	2048	696	2867	683	4915	42	58	65.1
Avg	58.3	58.4	-0.1	7569	2716	12703	2095	20272	39.7	60.3	58.3

Table L-13. Hypothetical flows: Model results: TRFE DRY year flows and 1993 hydrometeorological conditions.

	Water Temperature (° F)			Flow (cfs)				Combined Rivers			
1993 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs) Combined	%Trinity	%Klamath	Water Temperatures (° F) Mixed
29-Apr	53.8	52.7	1.1	11112	4071	18629	3873	29741	37	63	53.1
06-May	54.2	52.8	1.4	9339	3789	18657	4100	27997	33	67	53.3
13-May	56.2	54.2	2.0	7390	2782	17029	2499	24419	30	70	54.8
20-May	57.3	53.9	3.4	6730	2044	17400	1357	24130	28	72	54.8
27-May	55.8	52.7	3.1	11885	1504	21129	1741	33014	36	64	53.8
03-Jun	57.4	55.2	2.1	9636	1105	21729	6023	31365	31	69	55.9
10-Jun	59.9	58.0	1.8	6183	812	12871	1601	19054	32	68	58.6
17-Jun	62.8	61.4	1.4	4615	597	9056	1067	13671	34	66	61.9
24-Jun	64.5	62.6	1.9	3273	459	5637	779	8910	37	63	63.3
01-Jul	66.1	64.9	1.3	2638	448	4127	738	6765	39	61	65.4
08-Jul	67.3	66.9	0.3	2175	448	3303	677	5478	40	60	67.1
15-Jul	65.9	65.4	0.4	1801	448	2867	683	4668	39	61	65.6
Avg	60.1	58.4	1.7	6398	1542	12703	2095	19101	34.7	65.3	59.0

Table L-14. Hypothetical flows: Model results: TRFE CRITICALLY DRY year flows and 1993 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1993	Trinity R. @ Hoopa[a]	Klamath R. @Big Bar [b]	Difference (Trinity -	Trinity Confluence	Lewiston Dam	Klamath @ Orleans	Iron Gate Dam	Flow (cfs)			Water Temperatures (° F)
Week	Avg Week	Avg Week	Klamath)	Avg Week	Release	Avg Week	Release	Combined	%Trinity	%Klamath	Mixed
29-Apr	54.7	52.7	1.9	8541	1501	18629	3873	27170	31	69	53.3
06-May	55.2	52.8	2.4	7051	1501	18657	4100	25709	27	73	53.5
13-May	57.2	54.2	3.0	6109	1501	17029	2499	23137	26	74	55.0
20-May	57.8	53.9	3.9	6186	1501	17400	1357	23586	26	74	54.9
27-May	55.9	52.7	3.1	11825	1444	21129	1741	32954	36	64	53.9
03-Jun	57.4	55.2	2.1	9636	1105	21729	6023	31365	31	69	55.9
10-Jun	59.9	58.0	1.8	6183	812	12871	1601	19054	32	68	58.6
17-Jun	62.8	61.4	1.4	4615	597	9056	1067	13671	34	66	61.9
24-Jun	64.5	62.6	1.9	3273	456	5637	779	8910	37	63	63.3
01-Jul	66.1	64.9	1.3	2638	448	4127	738	6765	39	61	65.4
08-Jul	67.3	66.9	0.3	2175	448	3303	677	5478	40	60	67.1
15-Jul	65.9	65.4	0.4	1801	448	2867	683	4668	39	61	65.6
Avg	60.4	58.4	2.0	5836	980	12703	2095	18539	33.2	66.8	59.0

Table L-15. Hypothetical flows: Model results: BASE FLOW CONDITIONS of 300 cfs and 1993 hydrometeorological conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1993	Trinity R. @ Hoopa[a]	Klamath R. @Big Bar [b]	Difference (Trinity -	Trinity Confluence	Lewiston Dam	Klamath @ Orleans	Iron Gate Dam	Flow (cfs)			Water Temperatures (° F)
Week	Avg Week	Avg Week	Klamath)	Avg Week	Release	Avg Week	Release	Combined	%Trinity	%Klamath	Mixed
29-Apr	55.1	52.7	2.4	3150	300	18629	3873	21779	14	86	53.1
06-May	56.0	52.8	3.2	3439	300	18657	4100	22096	16	84	53.3
13-May	58.5	54.2	4.3	3071	300	17029	2499	20100	15	85	54.8
20-May	59.2	53.9	5.3	1981	300	17400	1357	19381	10	90	54.4
27-May	56.4	52.7	3.6	1543	300	21129	1741	22671	7	93	53.0
03-Jun	57.9	55.2	2.6	1314	300	21729	6023	23043	6	94	55.4
10-Jun	60.5	58.0	2.5	1130	300	12871	1601	14001	8	92	58.2
17-Jun	63.4	61.4	2.0	961	300	9056	1067	10017	10	90	61.6
24-Jun	64.9	62.6	2.4	851	300	5637	779	6488	13	87	62.9
01-Jul	66.7	64.9	1.8	846	300	4127	738	4974	17	83	65.2
08-Jul	67.9	66.9	1.0	798	300	3303	677	4101	19	81	67.1
15-Jul	66.6	65.4	1.2	724	300	2867	683	3591	20	80	65.7
Avg	61.1	58.4	2.7	1651	300	12703	2095	14354	13.0	87.0	58.7

Table L-16. Hypothetical flows: Model results: TRFE EXTREMELY WET year flows and 1994 hydrometeorlogical conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1994 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	58.3	55.4	2.8	3076	1500	3943	574	7018	44	56	56.7
06-May	58.7	59.6	-0.9	3849	2000	5817	853	9666	40	60	59.3
13-May	57.4	57.8	-0.4	6496	2000	4167	676	7663	46	54	57.6
20-May	54.3	61.1	-6.8	9407	7786	3399	869	12805	73	27	56.1
27-May	53.7	63.5	-9.9	10996	9807	2693	585	13688	80	20	55.6
03-Jun	54.3	62.6	-8.3	7585	6619	2406	854	9990	76	24	56.3
10-Jun	55.5	66.5	-11.0	5851	5067	2044	609	7895	74	26	58.4
17-Jun	57.0	66.5	-9.5	4032	3420	1917	823	5950	68	32	60.0
24-Jun	60.2	69.0	-8.8	2807	2313	1606	567	4413	64	36	63.4
01-Jul	61.6	72.0	-10.4	2373	2000	1454	570	3827	62	38	65.5
08-Jul	64.8	75.0	-10.2	1857	1543	1329	574	3186	58	42	69.1
15-Jul	73.5	76.5	-3.0	953	696	1236	571	2189	44	56	75.2
Avg	59.1	65.5	-6.4	4690	3729	2668	677	7358	60.7	39.3	61.1

Table L-17. Hypothetical flows: Model results: TRFE WET year flows and 1994 hydrometeorlogical conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1994 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	57.4	55.4	2.0	3577	2000	3943	574	7520	48	52	56.4
06-May	58.0	59.6	-1.7	4347	2500	5817	853	10164	43	57	58.9
13-May	54.2	57.8	-3.6	7277	5786	4167	676	11445	64	36	55.5
20-May	54.5	61.1	-6.5	8817	7196	3399	869	12215	72	28	56.4
27-May	55.7	63.5	-7.9	6458	5266	2693	585	9151	71	29	58.0
03-Jun	56.7	62.6	-5.9	4297	3329	2406	854	6703	64	36	58.8
10-Jun	59.4	66.5	-7.1	2938	2153	2044	609	4982	59	41	62.3
17-Jun	59.7	66.5	-6.8	2613	2000	1917	823	4530	58	42	62.6
24-Jun	61.1	69.0	-7.9	2696	2000	1606	567	4102	61	39	64.2
01-Jul	61.6	72.0	-10.4	2373	2000	1454	570	3827	62	38	65.5
08-Jul	64.8	75.0	-10.2	1857	1543	1329	574	3186	58	42	69.1
15-Jul	73.5	76.5	-3.0	953	696	1236	571	2189	44	56	75.2
Avg	59.7	65.5	-5.8	4000	3039	2668	677	6668	58.5	41.5	61.9

Table L-18. Hypothetical flows: Model results: TRFE NORMAL year flows and 1994 hydrometeorlogical conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1994 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	56.7	55.4	1.2	4075	2500	3943	574	8018	51	49	56.1
06-May	55.1	59.6	-4.5	7528	5683	5817	853	13345	56	44	57.1
13-May	54.6	57.8	-3.3	6497	5005	4167	676	10664	61	39	55.8
20-May	56.7	61.1	-4.4	5491	3867	3399	869	8889	62	38	58.3
27-May	58.0	63.5	-5.5	4184	2988	2693	585	6877	61	39	60.2
03-Jun	58.3	62.6	-4.3	3277	2309	2406	854	5682	58	42	60.1
10-Jun	59.8	66.5	-6.8	2786	2000	2044	609	4830	58	42	62.6
17-Jun	59.7	66.5	-6.8	2613	2000	1917	823	4530	58	42	62.6
24-Jun	61.1	69.0	-7.9	2496	2000	1606	567	4102	61	39	64.2
01-Jul	61.6	72.0	-10.4	2373	2000	1454	570	3827	62	38	65.5
08-Jul	64.8	75.0	-10.2	1857	1543	1329	574	3186	58	42	69.1
15-Jul	73.5	76.5	-3.0	953	696	1236	571	2189	44	56	75.2
Avg	60.0	65.5	-5.5	3678	2716	2668	677	6345	57.4	42.6	62.2

Table L-19. Hypothetical flows: Model results: TRFE DRY year flows and 1994 hydrometeorlogical conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
1994 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (° F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	55.2	55.4	-0.3	5650	4071	3943	574	9592	59	41	55.3
06-May	56.5	59.6	-3.1	5639	3789	5817	853	11456	49	51	58.1
13-May	56.4	57.8	-1.5	4280	2782	4167	676	8447	51	49	57.1
20-May	59.2	61.1	-1.9	3672	2044	3399	869	7071	52	48	60.1
27-May	61.1	63.5	-2.4	2701	1504	2693	585	5394	50	50	62.3
03-Jun	61.5	62.6	-1.1	2076	1105	2406	854	4482	46	54	62.1
10-Jun	64.2	66.5	-2.3	1600	812	2044	609	3644	44	56	65.5
17-Jun	65.9	66.5	-0.6	1211	597	1917	823	3128	39	61	66.3
24-Jun	69.9	69.0	0.9	957	459	1606	567	2563	37	63	69.3
01-Jul	71.6	72.0	-0.4	823	448	1454	570	2277	36	64	71.9
08-Jul	74.1	75.0	-0.9	763	448	1329	574	2091	36	64	74.7
15-Jul	76.7	76.5	0.2	706	448	1236	571	1942	36	64	76.5
Avg	64.4	65.5	-1.1	2506	1542	2668	677	5174	44.7	55.3	64.9

Table L-20. Hypothetical flows: Model results: TRFE CRITICALLY DRY year flows and 1994 hydrometeorlogical conditions.

Water Temperature (° F)				Flow (cfs)				Combined Rivers			
								Flow (cfs)			Water Temperatures (º F)
1994 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Combined	%Trinity	%Klamath	Mixed
29-Apr	58.3	55.4	2.8	3079	1501	3943	574	7022	44	56	56.7
06-May	59.7	59.6	0.1	3351	1501	5817	853	9168	37	63	59.7
13-May	58.3	57.8	0.5	2998	1501	4167	676	7165	42	58	58.0
20-May	60.4	61.1	-0.7	3128	1501	3399	869	6527	48	52	60.7
27-May	61.3	63.5	-2.2	2641	1444	2693	585	5334	50	50	62.4
03-Jun	61.5	62.6	-1.1	2076	1105	2406	854	4482	46	54	62.1
10-Jun	64.2	66.5	-2.3	1600	812	2044	609	3644	44	56	65.5
17-Jun	65.9	66.5	-0.6	1211	597	1917	823	3128	39	61	66.3
24-Jun	69.9	69.0	0.9	957	459	1606	567	2563	37	63	69.3
01-Jul	71.6	72.0	-0.4	823	448	1454	570	2277	36	64	71.9
08-Jul	74.1	75.0	-0.9	763	448	1329	574	2091	36	64	74.7
15-Jul	76.7	76.5	0.2	706	448	1236	571	1942	36	64	76.5
Avg	65.2	65.5	-0.3	1944	980	2668	677	4612	41.2	58.8	65.3

Baseflow conditions would have resulted in water temperatures that were considerably warmer than the Klamath River (Table L-21). Under this scenario, water temperatures would have been as much as 6.0 °F warmer than the Klamath River and on average 2.6 °F warmer.

Discussion

Water Temperature Differences

These analyses have provided information that betters our understanding of the differences in Trinity and Klamath River water temperature regimes that have occurred in 1992, 1993, and 1994, and of those that might occur under the Trinity River Flow Recommendations. While this analysis does not evaluate a large number of years, the three years chosen represented a wide range of hydrologic conditions, from Wet (1993) to Dry (1992) and Critically Dry (1994).

Comparison of real data indicated that the thermal differences of the Trinity and Klamath Rivers were very small except when Lewiston Dam releases were large, (i.e., a 6,000 cfs release during June 1992) (Table L-1)relative to flows in the Klamath River, that resulted in a 7.4° F temperature differential. Because this year was a Dry year, flow accretion in the Trinity River below Lewiston Dam during the time of the 6,000 cfs release was less than 400 cfs. Similarly, flow accretion in the Klamath River between Iron Gate Dam (Klamath River Mile 190.1) and the Orleans gage (Klamath River Mile 59.2) was approximately 1,000 cfs. In contrast to the effects of this high flow, simulations with a base release of 300 cfs on May 20, 1993, indicate that Trinity River water temperatures could have been 2.9° F warmer than the Klamath River.

Model simulations using the Trinity River Flow Evaluation Recommendations also provide interesting information about what could be expected under a variety of flow schedules and different water year types. These analyses indicated that the temperature differential between the Klamath River and the Trinity River lessens when year types are matched with the corresponding TRFE release schedules. For example, if in the years 1992, 1993, and 1994, flows were based upon the TRFE recommendations, temperature differences would have been on average 3.4°, 0.2°, and 0.3° F cooler, respectively. Conversely, the differential becomes greatest when the extremes are mismatched (e.g., using an Extremely Wet year schedule in a Critically Dry year, which may result in water temperatures being as great as 11° F cooler: Table L-16). Again, because the TRFE recommendations are based upon hydrologic conditions, water temperature differentials should be small.

Water Temperature Differences and Salmonids

Although the recommendations are matched to year types that lessen temperature differentials between the Trinity and the Klamath Rivers, the innate error in predicting runoff patterns that largely influence water temperature dictates that there will be times that flow patterns will result in temperature differences. Although matching the recommendations to year types will lessen temperature differentials between the Trinity and the Klamath River, runoff patterns largely influence water temperature and are innately difficult to predict. However, the following generalities about the salmonid thermal requirements and the nature of stream dynamics do provide enough information to conclude that the TRFE recommendations will likely not result in any adverse conditions for salmonids. First, water temperature differences of less than 10° F (e.g., 55° to 65° F) are considered safe to stock chinook salmon juveniles (K. Rushton, Iron Gate Hatchery Manager, pers. comm). Stocking of salmon from one location to the other often leads to an

Table L-21. Hypothetical flows: Model results: BASE FLOW CONDITIONS of 300 cfs and 1994 hydrometeorlogical conditions.

Water Temperature (˚ F)				Flow (cfs)				Combined Rivers			
1994 Week	Trinity R. @ Hoopa[a] Avg Week	Klamath R. @Big Bar [b] Avg Week	Difference (Trinity - Klamath)	Trinity Confluence Avg Week	Lewiston Dam Release	Klamath @ Orleans Avg Week	Iron Gate Dam Release	Flow (cfs)			Water Temperatures (º F)
								Combined	%Trinity	%Klamath	Mixed
29-Apr	61.4	55.4	6.0	1878	300	3943	574	5821	32	68	57.4
06-May	63.3	59.6	3.7	2150	300	5817	853	7968	27	73	60.6
13-May	61.7	57.8	3.8	1797	300	4167	676	5964	30	70	59.0
20-May	64.3	61.1	3.2	1928	300	3399	869	5326	36	64	62.2
27-May	66.1	63.5	2.6	1497	300	2693	585	4190	36	64	64.5
03-Jun	65.3	62.6	2.7	1271	300	2406	854	3677	35	65	63.6
10-Jun	67.3	66.5	0.8	1088	300	2044	609	3132	35	65	66.8
17-Jun	68.1	66.5	1.6	915	300	1917	823	2832	32	68	67.0
24-Jun	71.3	69.0	2.3	798	300	1606	567	2404	33	67	69.7
01-Jul	73.1	72.0	1.1	674	300	1454	570	2129	32	68	72.4
08-Jul	75.7	75.0	0.7	614	300	1329	574	1943	32	68	75.2
15-Jul	78.5	76.5	2.1	558	300	1236	571	1794	31	69	77.1
Avg	68.0	65.5	2.6	1264	300	2668	677	3932	32.5	67.5	66.3

abrupt immersion into a completely different environment and therefore probably represents a worse case scenario. Boyd (1990) recommends that transfer of fish between waters occur only when water temperatures are less than 5.4° to 7.2° F, and that a rate of change of 0.4° F per minute can be tolerated.

Salmonids in a stream system generally do not experience abrupt changes in water temperatures like those that hatchery planted fish might experience. Rather, fish traveling downstream are apt to be slowly exposed to warming or cooling conditions. At the confluence of the Trinity and Klamath Rivers, thermal differences would vary over space and time. Fish traveling down the Trinity River into the Klamath River may experience slightly warmer water temperatures. At the confluence, it is expected that when differences do occur that fish will be able to move in and out of the gradients at will until they have acclimated to the new thermal regime or moved to more desirable locations.

While it appears that there is little chance of having large temperature differences at the confluence area, the Adaptive Environmental Assessment and Management Program (AEAMP) should evaluate the influences of dam releases on water temperatures and salmonids encountering these conditions. Modified operation scenarios could include the construction of a multilevel outlet works on Trinity Dam, altered diversion patterns, and the modified use of the water temperature curtain in Lewiston Reservoir. Through these modifications more variable release temperatures could be attained. As previously mentioned, however, perhaps there are benefits in providing cooler water to the Klamath River. Only by exploring these conditions through the AEAMP will we better understand the consequences of our actions.

APPENDIX M

Recommended Daily Releases from Lewiston Dam

Table M1. Recommended daily releases (cfs) from Lewiston Dam

Date	Extremely Wet	Wet	Normal	Dry	Critically Dry
01-Oct to 15 Oct	450	450	450	450	450
16-Oct to 21-Apr	300	300	300	300	300
22-Apr	500	500	500	300	300
23-Apr	500	500	500	300	900
24-Apr	500	500	500	300	1,500
25-Apr	500	500	500	300	1,500
26-Apr	500	500	500	300	1,500
27-Apr	500	500	500	900	1,500
28-Apr	500	500	500	1,500	1,500
29-Apr	1,500	2,000	2,500	2,500	1,500
30-Apr	1,500	2,000	2,500	3,500	1,500
01-May	1,500	2,000	2,500	4,500	1,500
02-May	1,500	2,000	2,500	4,500	1,500
03-May	1,500	2,000	2,500	4,500	1,500
04-May	1,500	2,000	2,500	4,500	1,500
05-May	1,500	2,000	2,500	4,500	1,500
06-May	2,000	2,500	4,000	4,306	1,500
07-May	2,000	2,500	6,000	4,121	1,500
08-May	2,000	2,500	6,000	3,943	1,500
09-May	2,000	2,500	6,000	3,773	1,500
10-May	2,000	2,500	6,000	3,611	1,500
11-May	2,000	2,500	6,000	3,455	1,500
12-May	2,000	2,500	5,784	3,307	1,500
13-May	2,000	2,500	5,574	3,164	1,500
14-May	2,000	3,000	5,373	3,028	1,500
15-May	2,000	4,000	5,178	2,897	1,500
16-May	2,000	6,000	4,991	2,773	1,500
17-May	2,000	8,500	4,811	2,653	1,500
18-May	2,000	8,500	4,637	2,539	1,500
19-May	2,000	8,500	4,469	2,430	1,500
20-May	3,000	8,500	4,307	2,325	1,500
21-May	4,000	8,500	4,151	2,225	1,500
22-May	6,000	7,666	4,001	2,129	1,500
23-May	8,500	6,833	3,857	2,037	1,500
24-May	11,000	6,000	3,717	1,950	1,500
25-May	11,000	6,000	3,583	1,866	1,500
26-May	11,000	6,000	3,453	1,785	1,500
27-May	11,000	6,000	3,328	1,708	1,500
28-May	11,000	6,000	3,208	1,635	1,500
29-May	10,444	5,690	3,092	1,564	1,500
30-May	9,889	5,322	2,980	1,497	1,497
31-May	9,333	4,977	2,872	1,433	1,433
01-Jun	8,778	4,655	2,768	1,371	1,371
02-Jun	8,222	4,354	2,668	1,312	1,312
03-Jun	7,667	4,072	2,572	1,255	1,255
04-Jun	7,111	3,809	2,479	1,201	1,201
05-Jun	6,556	3,562	2,389	1,150	1,150
06-Jun	6,000	3,332	2,303	1,100	1,100

Table M1. continued.

Date	Extremely Wet	Wet	Normal	Dry	Critically Dry
07-Jun	6,000	3,116	2,219	1,053	1,053
08-Jun	6,000	2,915	2,139	1,007	1,007
09-Jun	6,000	2,726	2,062	964	964
10-Jun	6,000	2,550	2,000	922	922
11-Jun	5,664	2,385	2,000	883	883
12-Jun	5,359	2,230	2,000	845	845
13-Jun	5,071	2,086	2,000	808	808
14-Jun	4,798	2,000	2,000	774	774
15-Jun	4,540	2,000	2,000	740	740
16-Jun	4,295	2,000	2,000	708	708
17-Jun	4,064	2,000	2,000	678	678
18-Jun	3,845	2,000	2,000	649	649
19-Jun	3,638	2,000	2,000	621	621
20-Jun	3,443	2,000	2,000	594	594
21-Jun	3,257	2,000	2,000	568	568
22-Jun	3,082	2,000	2,000	544	544
23-Jun	2,916	2,000	2,000	521	521
24-Jun	2,759	2,000	2,000	498	498
25-Jun	2,611	2,000	2,000	477	477
26-Jun	2,470	2,000	2,000	450	450
27-Jun	2,337	2,000	2,000	450	450
28-Jun	2,212	2,000	2,000	450	450
29-Jun	2,093	2,000	2,000	450	450
30-Jun	2,000	2,000	2,000	450	450
01-Jul	2,000	2,000	2,000	450	450
02-Jul	2,000	2,000	2,000	450	450
03-Jul	2,000	2,000	2,000	450	450
04-Jul	2,000	2,000	2,000	450	450
05-Jul	2,000	2,000	2,000	450	450
06-Jul	2,000	2,000	2,000	450	450
07-Jul	2,000	2,000	2,000	450	450
08-Jul	2,000	2,000	2,000	450	450
09-Jul	2,000	2,000	2,000	450	450
10-Jul	1,700	1,700	1,700	450	450
11-Jul	1,500	1,500	1,500	450	450
12-Jul	1,350	1,350	1,350	450	450
13-Jul	1,200	1,200	1,200	450	450
14-Jul	1,050	1,050	1,050	450	450
15-Jul	950	950	950	450	450
16-Jul	850	850	850	450	450
17-Jul	750	750	750	450	450
18-Jul	675	675	675	450	450
19-Jul	600	600	600	450	450
20-Jul	550	550	550	450	450
21-Jul	500	500	500	450	450
22-Jul to 30 Sep	450	450	450	450	450

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APPENDIX N

Adaptive Environmental Assessment and Management

What is AEAM?

Adaptive Environmental Assessment and Management (AEAM) is a formal, systematic, and rigorous program of learning from the outcomes of management actions, accommodating change, and improving management (Holling, 1978). Such a program combines assessment and management. Most agency and task force structures do not allow both to go on simultaneously (International Institute for Applied Systems Analysis, 1979). The basis of adaptive environmental assessment and management is the need to learn from past experience, data analysis, and experimentation. AEAM combines experience with operational flexibility to respond to future monitoring and research findings and varying resource and environmental conditions. AEAM uses conceptual and numerical models and the scientific method to develop and test management choices. Decision makers use the results of the AEAM process to manage environments characterized by complexity, shifting conditions, and uncertainty about key system component relations (Haley, 1990; McLain and Lee, 1996).

The AEAM approach to management relies on teams of scientists, managers, and policymakers to jointly identify and bound management problems in quantifiable terms (Holling, 1978; Walters, 1986). In addition, the adaptive approach to management "recognizes that the information we base our decisions on is almost always incomplete" (Lestelle et al., 1996). This recognition encourages managers to treat management actions as experiments, whose results can better guide future decisions. AEAM must not only monitor changes in the ecosystem, but also must develop and test hypotheses of the causes of those changes to promote desired outcomes. The results are informed decisions and increasing certainty within the management process.

Modern management strategies must have explicit and measurable outcomes. There are not many unambiguous clear-cut answers to complex hydraulic, channel-structure, and water-quality changes, but the AEAM process allows managers to adjust management practices (such as reservoir operations) and integrate information relating to the riverine habitats and the system response as new information becomes available.

Alluvial river systems are complex and dynamic. Our understanding of these systems and our predictive capabilities are limited. Together with changing social values, these knowledge gaps lead to uncertainty over how to best implement habitat maintenance or restoration efforts on regulated rivers. Resource managers must make decisions and implement plans despite these uncertainties. AEAM promotes responsible progress in the face of uncertainty. AEAM provides a sound alternative to either "charging ahead blindly" or being "paralyzed by indecision". Holling (1978) states that, "AEAM avoids the pitfall of requiring the costly amassing of more descriptive data before proceeding with policy initiatives. Instead, strategies are adopted as learning experiments in a fluid feedback structure that mandates vigorous self-critiquing and peer review at every stage, such that evaluation and corrective information is disclosed quickly and strategies modified or discontinued accordingly."

A well-designed AEAM program (1) defines goals and objectives in measurable terms; (2) develops hypotheses, builds models, compares alternatives, and designs system manipulations and monitoring programs for promising alternatives; (3) proposes modifications to operations that protect, conserve and enhance the resources; and (4) implements monitoring and research programs to examine how selected management actions meet resource management objectives. The intention of the AEAM program is to provide a process for cooperative integration of water- control operations, resource protection, monitoring, management, and research.

AEAM is Linked with Appropriate Assessment

AEAM assesses the results and effects of reservoir operations and instream flow regimes on biotic resources. The results of the assessments sustain or modify future operations. Outlined in Figure N.1 is a generalized 10-step AEAM process applicable to any management situation. The remainder of this Appendix is a brief description of each step in the process.

Determine Ecosystem Goals and Objectives

Resource agencies and stakeholders form the ecosystem restoration goals through a watershed-planning process. A key to successful watershed planning and ecosystem restoration is a combination of democratic stakeholder processes, technical input, and leadership. It is an error to assume that people will protect a stream if "educated". Management should work toward creating common ground where there are win/win outcomes; consider competitiveness, environmental soundness, and social/political issues; clarify areas of conflict and view conflict as an opportunity to learn; maintain a policy-evaluation framework that assumes, and is adaptable to, changing objectives; and address clearly stated conflicting alternatives, not a single, presumed true social goal (Holling, 1977).

Once goals for restoring or sustaining the ecosystem are firmly in view, the technical processes may begin. The first step quantifies past trends and the current status of the ecosystem and watershed. Scientists must then translate the goals into a set of measurable end points (objectives for ecosystem response).

Determine the Ecosystem Baseline

The ecosystem baseline includes all relative data, past and present, describing physical, chemical, and biological features of the river system. This will become the reference condition from which progress toward the management goals is measured.

Hypothesize Biological/Physical System Behavior/Response

Develop hypotheses of system behavior and responses of the biological, chemical, and physical components of the river ecosystem to directed management actions.

Select Future Management Actions

Based upon past and current conditions of the ecosystem, and armed with hypotheses about the consequences of management actions, the adaptive philosophy applies two processes for changing management activities. The first is to identify alternative management procedures to achieve the stated habitat and biota response objectives, and the second is to compare and select from the alternatives those that appear to move the system toward management objectives. For regulated rivers this should be an annual process along with a review of current system operating criteria and procedures. If alternative actions are proposed to achieve the same response, then designed experiments compare the alternatives (perhaps in consecutive years) leading to selection of the action that most efficiently achieves the measurable objective(s).

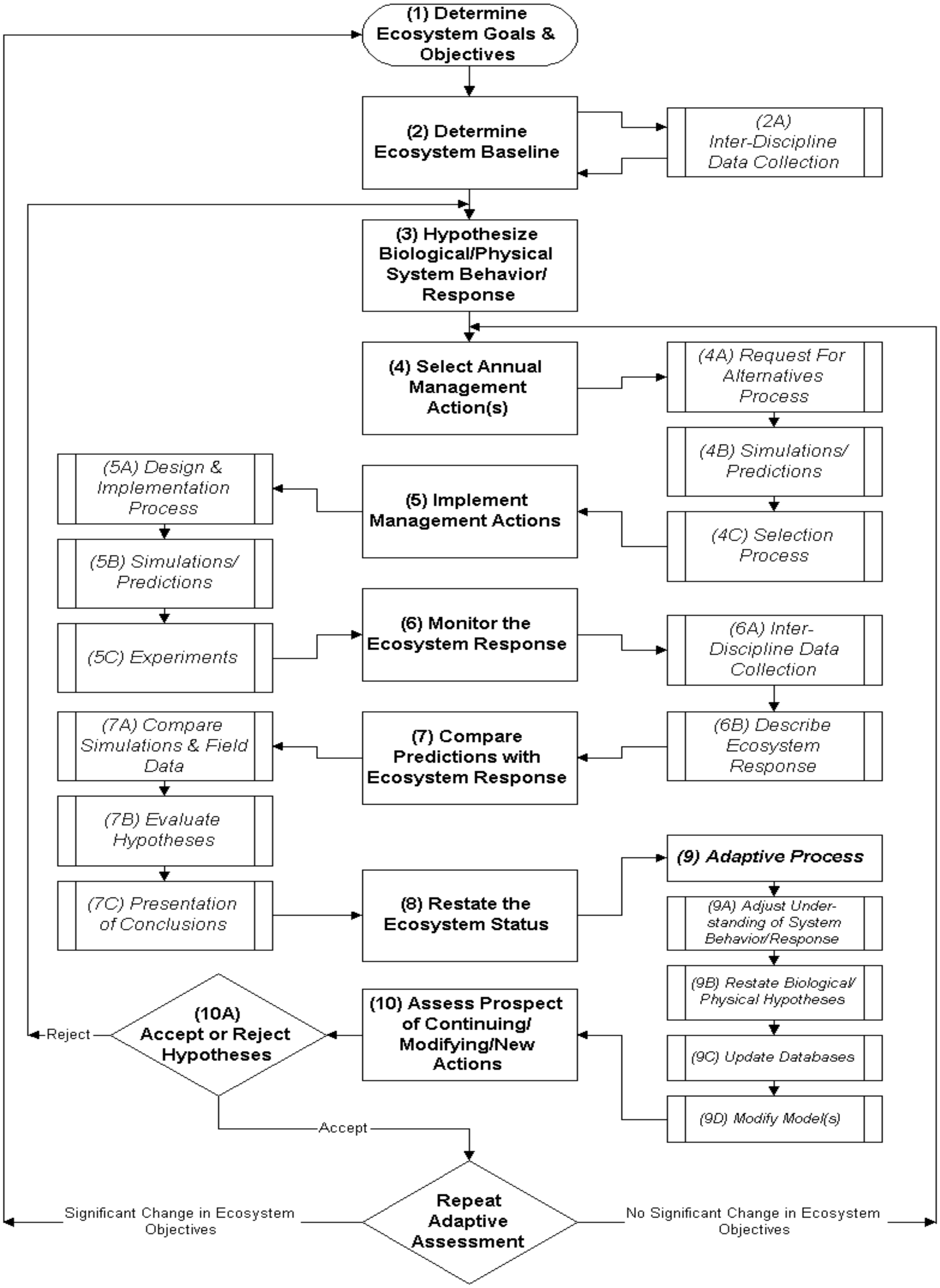

Figure N.1. Adaptive Environmental Assessment and Management process.

Simulations/Predictions - Using state-of-the-art models, the inter-disciplinary scientists simulate and predict the outcomes of the proposed management action alternatives. The results of the simulations and predictions form the basis for selecting the best management alternative.

Selection Process - Examine water-supply forecasts, status of the biota, and anticipated life-history needs of keystone species. The selection process must be a rational, well-regulated process, open to review and control by the management authority. The alternative selected should have the highest probability for successful implementation and achieve the annual management objectives based upon the water supply (e.g., water year type) and hypotheses for the system response.

Implement Management Actions

Design and Implementation - The inter-disciplinary scientists and management collectively are responsible for the design of the operating criteria and procedures for implementing the management actions prescribed by the selection process.

Simulations/Predictions - Experts at modeling, simulating, experimental design, and predicting the outcome of management actions will endeavor to forecast seasonal responses to the selected annual operating criteria and procedures. The task is to expertly simulate and predict measurable physical, chemical, and biological responses of the river ecosystem to the selected management actions. Rigorous application of the scientific method tests each iteration (annual forecasts/predictions) of simulation models through post-audit comparisons of observed versus expected results.

Experiments - Management must support short-term and long-term scientific experiments as part of an operations post-audit evaluation program. Experiments may be necessary to compare alternative hypotheses or alternative operating protocols that advocates present to achieve identical (or very similar) measurable objectives. When uncertainty in system response leads to differing scientific opinions, experiments are set up as alternative management actions compared between years.

Monitoring the Ecosystem Response

Data Collection - The purpose of the data is to continue adding to the understanding of the ecosystem and its current status.

Database Updates - Annual monitoring data are summarized and incorporated into an open and shared database.

Experimental Design - Annual monitoring programs designed to test results of annual operating procedures are essential to establish scientific validity of the management actions taken.

Description of Ecosystem Responses - Data collected during the monitoring process are used to describe the response of the ecosystem to imposed management actions. The purpose is to establish scientific validity for the management program, gain management control over the causal processes, understand how management actions cause changes in the ecosystem, support or refute ecosystem-response hypotheses, and improve model predictions.

Compare Predictions with Ecosystem Response

Post-Audit Comparison of Simulations and Field Data - Comparisons of model predictions with field observations are made, and recommendations are given for model improvement, changes to the operating criteria and procedures, and monitoring program as appropriate. Replace model validation with invalidation - the process of establishing a degree of belief for each of a set of alternative model simulations (Holling, 1978). The scientific objective is to offer opinions on an annual basis of acceptance or rejection of the system-response hypotheses and to continually improve predictive capability.

Presentation of Conclusions - Sharing the conclusions in an open atmosphere will encourage participation and input from stakeholders. When scientific debate challenges management actions, stakeholders with differing opinions on operating criteria and procedures are requested to offer testable alternative hypotheses rather than simply argue to discredit the selected management procedures.

Restate the Ecosystem Status

After the implementation of specific operating criteria and procedures, the status of the ecosystem is reassessed and described. The new state is compared to the baseline state in order to measure progress toward ecosystem objectives. This should be done in winter just prior to the annual February to May water-supply forecasting period.

Adaptive Process

The adaptive component of the management process is the learning and evolution of understanding. This process encourages stakeholders to gain an understanding of the ecosystem, its behavior and response to management actions, and the potential for achieving stated objectives.

Adjust Understanding of Ecosystem Behavior/Response - The most difficult part of the AEAM process is for individual stakeholders to adjust their understanding to a different point of view concerning how the ecosystem functions. To accomplish this, assessment must be viewed as an ongoing process and not as a one-time screening prior to a resource development decision (Holling, 1978). Given each annual water-supply forecast, the suite of models is utilized to predict physical, chemical, and biological responses under the annual operating criteria and procedures, or designed experimental releases, as appropriate. The adjustment takes honest examination of the data and scientific analyses following careful, deliberate management actions.

Modify Model(s) - Based upon the degree of congruence between model predictions and post- audit observations certain models may be recalibrated, modified by reformulating certain relations, or, if necessary, replaced with new models. Following the annual updating of the suite of models, the next round of management actions can commence. Models are simply recalibrated or slightly modified to increase predictive ability as long as data support model projections.

Assess Prospect of Continuing/Modifying/New Actions

Restate Biological/Physical Hypotheses - An ongoing element of the process is to constantly challenge the stated system hypotheses and improve the ability to predict the behavior and response of the ecosystem so that progress toward the management objective is rapid. If certain hypotheses of system response are not supported, then new hypotheses must be proposed, modeled, and in turn tested.

The scientists must offer an annual statement of the system hypotheses presenting evidence in support or rejection of tested hypotheses.

Recycle Through Adaptive Processes - Design annual management actions (operating criteria and procedures). If system hypotheses are supported (not rejected), then recycle through the process by going back to step 4 and selecting annual operating criteria and procedures for the forecasted water supply (water year class).

If system hypotheses are rejected, recycle through the process by going back to step 3, stating alternative hypotheses to achieve the same management goals.

Redefine Ecosystem Goals when Appropriate - On occasions such as natural disasters, toxic spills, or major legislative actions, the ecosystem management (social) goals may change. In such events, recycle through the adaptive process by going back to step 1. Restate the system goals, perhaps requiring a different or modified baseline and certainly the generation of new hypotheses of system response translated to new measurable system objectives.

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APPENDIX O

AEAM Tasks for Improving Understanding of the Alluvial River Attributes and Biological Responses in the Trinity River

Introduction

Considerable effort was put forth by the authors of this Trinity River Flow Evaluation Report. This involved searching the scientific literature, examining the completed Trinity River studies, compiling data, and conducting additional analyses specifically for this report.

The recommendations for the initial reservoir release schedules and river corridor management actions were built upon a series of workshop discussions. This led to a listing of hypotheses about how the Trinity system had responded since the construction and operation of the TRD and what would be required to reverse these trends and rehabilitate the habitats. This appendix summarizes many of the hypotheses, potential competing hypotheses, management objectives, what is known specifically about the Trinity River, and the major unknown or unquantified issues that need to be addressed. This listing is organized by season of year and is directed to the appropriate hydrograph component (release schedule) as is presented in Tables 8.5 to 8.9 in the chapter on recommendations. This listing is not meant to be exhaustive but to provide a summary of the major issues discussed during the evolution of the recommended Trinity River flow management strategy. The logic and initial recommendations represented here are a foundation upon which the Adaptive Management Team can further improve understanding of the system, accomplish validation of management models, and increase the overall certainty of management decisions.

Summer/Fall Baseflow

All water years - June 26 to October 15

Hypothesis:

- If water temperatures are less than 60° F degrees downstream to Douglas City (through June 26-Oct 15), then no temperature-related mortality will occur to adult spring chinook salmon, and impacts to spring chinook salmon eggs developing *in vivo* will be negligible.
- If water temperatures are near optimal, then juvenile coho salmon and steelhead growth rates and size at age will increase, increasing smolt-to-adult success.
- Lewiston releases of 450 cfs for temperature needs provide a greater benefit to adult spring chinook salmon, juvenile coho salmon, and juvenile steelhead, than the benefits associated with releases of 300 cfs. Releases of 450 cfs would provide additional spring chinook salmon spawning habitat, juvenile coho salmon rearing habitat, and juvenile steelhead rearing habitat.

Potential competing hypotheses:

- Reducing Lewiston releases below summer low flows will cause pools to stratify, providing optimal water temperatures in bottoms of deep pools.
- Spring chinook salmon habitat (thus production) can be increased, and redd dewatering can be decreased, by releasing 300 cfs from mid-September through early April.

Objectives:

- Provide near-optimal water temperatures from Lewiston Dam to Douglas City.

What we know:

- Studies of the survival of Sacramento River chinook salmon eggs developing *in vivo* as a function of temperature showed that temperatures between 38° F and 60° F are needed (Boles, 1988).
- Spring chinook salmon over-summering distribution is most concentrated from Lewiston to Douglas City (USFWS, 1988).
- Lewiston release of 450 cfs achieves temperature targets at Douglas City and North Fork, the basis of empirical evidence (Zedonis, pers. comm.).
- Microhabitat-to-flow relations within the riparian berms of the existing channel indicate relatively low levels of suitable habitat for young-of-year anadromous salmonids. The habitat quality generally declines at flows approaching the top of the bank (berms) owing to increasing velocities.

What we don't know:

- What temperatures are necessary for protection of Trinity River adult spring-run chinook salmon as well as their eggs developing *in vivo*?
- What temperatures are necessary for protection of various life stages of Trinity River anadromous fishes, including chinook salmon, coho salmon, steelhead, green sturgeon, and lamprey.
- What were summer temperatures at locations used by holding spring chinook salmon prior to the construction of the dam?
- What Lewiston releases (if any) would lead to thermal stratification of pools above the North Fork?
- How will spring-through-fall temperatures provided by the recommendations impact amphibians?
- How will these temperatures impact other aquatic vertebrates?
- What will the habitat—discharge relation be in the rehabilitated mainstem channel?

Potential Management Actions

- Monitor temperatures at downstream control points (Douglas City, North Fork, Weitchpec), and manage Lewiston releases to provide appropriate downstream temperatures if temperature thresholds are approached.
- Develop and test criteria specific to Trinity River adult chinook salmon, coho salmon, and steelhead physiology.
- Evaluate growth rates for juvenile coho salmon and steelhead as a function of summer/fall water temperatures.

- Monitor adult spring chinook salmon distributions under stratified and unstratified conditions in pools of the mainstem Trinity and/or the South Fork Trinity River to document carrying capacity as a function of pool volume and water near optimal temperatures.
- Monitor juvenile coho salmon and steelhead density under pool stratified and unstratified conditions in pools of the mainstem Trinity and/or the South Fork Trinity River to document carrying capacity as a function of pool volume and water temperatures.
- Monitor adult spring chinook salmon distributions during holding and spawning periods.
- Evaluate competing hypotheses regarding water-temperature management (e.g., can we achieve fish production objectives if pools are allowed to stratify?; can Trinity River fish thrive at temperatures other than those now thought necessary?).
- Conduct real-time temperature modeling/monitoring to evaluate whether flows can be reduced from 450 cfs to 300 cfs in early/mid-September, which may increase the hydraulic suitability of microhabitat in the rehabilitated channel.

Winter Baseflow

- All water years - October 16 to April 22-May 17

Hypotheses:

- By maximizing suitable spawning habitat area for chinook salmon, coho salmon, and steelhead, we are increasing spawning success and fry production.
- By maximizing suitable rearing habitat area for chinook salmon, coho salmon, and steelhead, we are increasing growth rates, size at age, and production.
- By increasing the availability of high-quality over-winter habitat for steelhead and coho salmon (by increasing the availability of large interstitial spaces within the streambed), survival to age one-plus will increase, and smolt production will increase.
- Real-time flow management will allow optimization of Lewiston releases to maximize production within a given year (emergence timing, number and distribution of redds, spatial differences in discharge versus habitat area).

Competing hypotheses:

- Gradually increasing Lewiston releases from September to December will better distribute salmonid spawners, increasing spawning success.
- Broader distribution of redds will decrease risk of cohort loss from redd scour during tributary-generated flooding.
- Pulse flows can be effective in assisting adult salmon migrations into tributaries.

Objectives:

- Maximize suitable habitat area for chinook salmon, coho salmon, and steelhead spawning.
- Maximize habitat area for coho salmon and steelhead rearing and over-wintering habitat.
- Improve migration access into tributaries.

What we know:

- Flow-to-habitat relations within existing bermed channel morphology.
- Rearing habitat for fry chinook salmon is a primary limiting factor within the existing channel morphology.
- Over-winter habitat for juvenile steelhead and coho salmon is a primary limiting factor within the existing channel.
- Spawning habitat can soon become limiting within the existing channel morphology if escapement increases.
- Given the temperature regime, we can estimate the time of emergence for each species and race of anadromous salmonid.
- Optimal and marginal ranges of temperature for incubation and rearing, obtained from the literature, can be achieved with recommended flow releases.
- Distribution of chinook salmon spawners is well known from CDFG carcass counts.

What we don't know:

- Flow-to-habitat relations with a new channel morphology.
- Contribution of tributaries to basin-wide anadromous salmonid production, particularly upstream from the North Fork Trinity River.
- Whether access to tributaries is a problem as a result of delta aggradation, etc.
- Where do salmon spawn within channel morphology? How does this spatial distribution change with discharge within reaches?
- Relationship of redd scour and dewatering to releases.
- How tributary flow accretion impacts downstream habitat availability relationships in real-time.

Potential Management Actions

- Establish network of telemetered temperature and streamflow gages so that we can perform real-time habitat and temperature modeling to optimize incubation success (redd scouring, redd dewatering, egg survival, time of sac-fry emergence) and manage rearing habitat in synchronization with tributary accretions.

- Re-evaluate flow-to-habitat relations to refine microhabitat responses to flow releases.
- Utilize stratified sampling to allow for extrapolation to entire 40-mile reach of upper Trinity River.
- Annually update flow-to-habitat relations to improve management of releases for provision of microhabitat.
- Implement data-gathering between October and April 1 (sediment transport, redd counts and distribution, juvenile growth rates, habitat data, etc.).
- Recalibrate and update all predictive models for the antecedent conditions prior to April 1, to prepare and evaluate release schedule for the snowmelt peak and snowmelt runoff period based on these conditions.

Fall/Winter Flood Flows

Potential management Actions

- All water years - November to late February
- No high-flow releases are planned, but sychronization of peak releases with stormflows should be evaluated through the adaptive management program to assess opportunities to maximize benefits of high-flow releases while conserving water.

Hypotheses:

- A single high-flow release each year will accomplish necessary geomorphic work (sediment transport, fine sediment deposition on floodplains, channel migration, bed mobility and scour, riparian vegetation scour, etc.).
- Preventing fall/winter peak flows in reaches nearest to Lewiston will reduce egg/embryo mortality associated with redd scour.
- Peak flow releases redistribute juvenile salmonids throughout the mainstem, minimizing competition for habitat and food.
- Peak flow releases encourage outmigration of hatchery-released salmonids, minimizing competitive interactions with non-hatchery steelhead and coho salmon.
- Management objectives will be met without need to synchronize releases with tributary stormflows.
- Gravel introductions near Lewiston during peak flow releases will improve spawning and rearing habitat, leading to increased production.
- Fine sediment control efforts such as trapping at Hamilton Ponds will continue to be necessary.

Competing hypotheses:

- Synchronizing peak Lewiston releases with fall/winter peak flows in tributaries will transport fine sediment delivered by tributaries in suspension, deposit the fine sediment on floodplains, and will be less likely to reduce infiltration of mainstem alluvial deposits by fines.

- Synchronizing peak Lewiston releases with tributary flood events increases downstream coarse sediment transport capacity, which allows us to better balance reach-wide coarse sediment budgets.
- Synchronizing peak releases with tributary stormflows would increase the magnitude and frequency of scour events, increasing riparian vegetation mortality and improving success with rehabilitation of riparian plant community diversity.

What we know:

- Peak releases near 6,000 cfs are adequate to initiate scour and transport of channelbed sediment at many locations.
- Peak discharges in tributaries downstream from Lewiston Dam are driven predominantly by rainfall, rather than snowmelt events.
- Tributary-generated floods are large enough below Douglas City to mobilize the bed surface with regularity.
- Large flood events occurring during egg incubation cause scour-induced mortality.

What we don't know:

- Hydrology in several significant tributaries downstream from Indian Creek.
- Redd scour and egg mortality as a function of discharge and location in the mainstem channel.
- Distribution of salmon spawning within existing or rehabilitated channel morphology. How does this spatial distribution change with discharge within a reach?
- How much real-time modeling and monitoring could yield information that would reduce constraints/restraints to flow management.

Management Actions

- The network of telemetered streamflow- and temperature-monitoring stations needs to be expanded.
- Flood-routing models must be used to evaluate impacts/opportunities for synchronizing Lewiston releases with tributary stormflows for management of microhabitat, geomorphic processes, and water temperatures.

Ascending Limb of Snowmelt Peak

- April 22-May 24 depending on water year

Hypotheses:

- There are no substantial negative biological impacts to rapid up-ramping rates.
- There are no substantial negative biological impacts associated with timing of annual peak releases.
- Timing of ascending-limb releases is optimal for anadromous fish species.

Competing Hypotheses:

- Timing and rate of Lewiston release up-ramp will substantially impact early life stage of anadromous salmonids (eggs, sac fry, fry), as well as amphibians and other wildlife species.

What we know:

- Natural up-ramping rates during historical rainfall events was very rapid.
- Natural up-ramping rates during snowmelt runoff events was rapid, but not as rapid as during rainfall events.
- Timing of peak flows was highly variable prior to dam construction.

What we don't know:

- Impacts of rapid up-ramping to salmonids, yellow legged frogs, turtles.
- Biological impact of having peak flows (in the reach nearest the dam) at virtually the same time each year, rather than over a 6 month period as observed in the hydrological record.

Potential management Actions

- Monitor impact of release increases in real time, adjusting to limit hazards to early life stage of anadromous salmonids, amphibians, and other riparian/aquatic organisms.

Snowmelt Peak Flow

- All Water Years - April 24 - May 29

Hypotheses:

- A single snowmelt peak is sufficient to accomplish desired geomorphic work (sediment transport, fine sediment deposition on floodplains, channel migration, bed mobility and scour, riparian scour, etc.).
- Peak releases of 11,000 cfs will cause bed scour to a depth greater than two D_{84} on exposed alluvial surfaces, scouring and killing woody riparian vegetation up to two and a half years old (the previous 3 year's cohorts).
- Peak releases of 8,500 cfs will cause bed scour to a depth greater than one D_{84} on exposed alluvial surfaces, scouring and killing woody riparian vegetation up to one and a half years old (the previous 2 year's cohorts).
- Peak releases of greater than 6,000 cfs will cause bed mobilization of the D_{84} size class on exposed alluvial surfaces, scouring and removing woody riparian vegetation that established the previous year (the previous year's cohort).
- Peak flow releases greater than 6,000 cfs will access floodplains, depositing fine sediment on floodplain surfaces and improving natural riparian regeneration.

- Peak flow releases greater than 3,000 cfs will begin to move the most mobile of coarse alluvial deposits within the active channel (e.g., in locations such as pool tails, median bars).
- Recommended durations of peak releases will transport coarse sediment supplied by tributaries downstream through the mainstem. Routing coarse sediment downstream will replenish alluvial deposits, creating and maintaining spawning and rearing habitat, and increasing salmonid production.
- Bed scour to a depth greater than 2 D_{84}, combined with reduced fine sediment supply to the mainstem, will improve spawning and rearing habitat quality; improved spawning and rearing habitat will improve egg emergence and fry rearing success, increasing salmonid production.
- Peak releases greater than 6,000 cfs, combined with physical channel alteration, will encourage channel migration. Channel migration will assist in the creation of new floodplain surfaces, improve particle-sorting processes within the active channel, and recruit large woody debris into the channel. As a result, channel complexity will increase, juvenile rearing habitat will be enhanced, and salmonid productivity will increase.
- Scheduling peak releases from April 24 to May 29 reduces mortality of juvenile outmigrants by increasing turbidity, decreasing travel time, and reducing juvenile salmonid density (fish/yd^3 of water)
- Scheduling peak releases from April 24 to May 29 minimizes risk of scour mortality on incubating salmonid eggs, increasing fry production.
- Salmonid fry are more susceptible to stranding than are juveniles or smolts, and because most salmonids are juveniles and smolts in April through June, scheduling peak releases from April 24 to May 29 minimizes vulnerability of early life stages to stranding, increasing salmonid production.
- Staggering of peak releases will afford advantages to certain species if necessary. For example, in drier years, yellow-legged frog egg masses may have greater hatching success than in wetter years (instead of all years being poor or good).
- Existing fine sediment control efforts (Buckhorn Dam, Hamilton Ponds, and watershed-rehabilitation projects), combined with recommended releases, will transport fine sediment at a rate greater than input, decreasing fine sediment storage in the mainstem. Reduced storage of fine sediment in the mainstem will increase adult holding habitat (number and depth of pools), improve rearing habitat (lower embeddedness along channel margins and in riffles; increased availability of substrate interstices used for over-wintering), and improve spawning habitat (decreased fine sediment in spawning gravel).
- By inundating a bar during riparian seed-release period, establishment of riparian plants cannot occur.

Competing hypotheses:

- By failing to synchronize peak flow releases with tributary floods, fine sediment delivered by tributaries will be more likely to infiltrate mainstem alluvial deposits rather than depositing on floodplain surfaces.
- Pool dredging will be required to push the fine sediment budget into a deficit, because releases will be insufficient in many years to transport fine sediment volumes yielded to the mainstem.

- Transport during the peak flow will be insufficient to export fine sediment at a rate greater than input. An extended-duration medium-magnitude release will be required following annual peak releases.

What we know:

- Sediment inputs have been quantified for Deadwood Creek, Rush Creek, Grass Valley Creek, and Indian Creek for water years 1997 and 1998. Sediment transport has been quantified for the Trinity River at Lewiston and Limekiln Gulch gaging stations for water years 1997 and 1998.
- Streamflows have been quantified at above-mentioned sediment-monitoring sites.
- Bed-mobility thresholds have been quantified for most of existing channelbed between Lewiston Dam and the North Fork Trinity. Thresholds are reached at flows between 5,000 and 6,000 cfs.
- Bed-mobility thresholds for mobile deposits within the active channel between Lewiston Dam and the North Fork Trinity have been quantified. These occur at or above 3,000 cfs.
- Bed-mobility thresholds for the channelbed at evolving channel-rehabilitation sites have been quantified. These thresholds occur between 5,000 and 6,000 cfs.
- Yearly peak releases since 1995 (6,000 to 30,000 cfs) have prevented riparian re-encroachment on evolving bank-rehabilitation sites.
- Individual, short-duration peak flows less than 30,000 cfs do not appreciably disturb the existing riparian berms above the North Fork Trinity.

What we don't know:

- Whether recommended high-flow releases and existing fine sediment control efforts will significantly decrease fine sediment storage in the mainstem channel.
- Whether recommended high-flow releases in concert with a coarse sediment management program will provide for adequate distribution and amounts of coarse sediment in reaches near Lewiston.
- We are uncertain of specific requirements for durations of peak (sediment-transporting) flows because volumes of tributary-derived sediment will vary substantially from year to year. Yearly monitoring of tributary sediment delivery, combined with sediment transport and routing modeling (e.g., HEC-6), will be required to fine-tune yearly duration of flows on an annual basis.
- Will sequences of Critically Dry water years lead to encroachment by riparian vegetation?

Magnitude objectives:

- **Extremely Wet water years**–Cause bed scour to a depth greater than 2 D_{84} on newly formed alternate bar faces to discourage/prohibit encroachment by riparian vegetation. Empirical plots of discharge versus relative scour depth (D_{sc}/D_{84}) have variable results, with D_{sc}/D_{84} values of 2 ranging from 8,000 to 16,000 cfs. 11,000 cfs was chosen as the first discharge to be evaluated in the adaptive management program.

- **Wet water years-**- Cause bed scour to a depth greater than 1 D_{84} on newly formed alternate bar faces to discourage/prohibit encroachment of riparian vegetation. Empirical plots of discharge versus relative scour depth (D_{sc}/D_{84}) have variable results, with D_{sc}/D_{84} values of 1 ranging from 6,000 to 8,500 cfs. 8,500 cfs was chosen as a conservative estimate of releases to be evaluated in adaptive management program.

- **Normal water years-**- Cause general bed mobilization on most alluvial deposits within channel, particularly on alternate bar faces to discourage/prohibit encroachment of riparian vegetation. Experiments by Wilcock et al. (1995) on non-rehabilitated sites suggest that discharges between 5,000 cfs and 6,000 cfs accomplish this objective, and results from McBain and Trush (1997) on rehabilitated alternate bar surfaces were in general agreement. Therefore, 6,000 cfs was chosen as the release to be evaluated in the adaptive management program.

- **Dry water years-**- Cause bed mobilization of alluvial deposits within channel, such as pool tails, median bars, and lower portions of alternate bar faces. Results from McBain and Trush (1997) suggest that flows exceeding 2,700 cfs begin to mobilize these deposits. A release of 4,500 cfs was chosen as the initial release to be evaluated in adaptive management program.

- **Critically Dry water years-**- Inundate point bar surfaces of rehabilitated alternate bar sequences to preclude germination of seeds on exposed gravel/cobble surfaces. There is considerable concern that this approach will prevent formation of a riparian berm along the low water channel, but may result in the formation of a new riparian berm higher on the bank. Discharges that inundate newly formed point bars range from 1,300 to 3,300 cfs, with the variability caused by differing construction techniques, differing obstruction angles, and other factors. A release of 1,500 cfs was chosen as a first estimate to be evaluated in the adaptive management program.

Duration objectives (for all water years)

- Transport coarse sediment delivered to mainstem Trinity River from Deadwood Creek and Rush Creek at a rate equal to input for respective water years. Duration of the peak flow event is the most uncertain portion of the channel-forming flow recommendation because the volume of coarse sediment delivered to the mainstem Trinity River varies tremendously from year to year. An initial duration recommendation of 5 days is based on extrapolating two years of coarse sediment budget data to a longer term average for Extremely Wet years. However, the uncertainty associated with this estimate is large.

- Transport fine sediment (<5/16 inch) delivered to mainstem Trinity River from Deadwood Creek, Rush Creek, Grass Valley Creek, and others at a rate equal to or greater than input for respective water years, such that instream fine sediment storage decreases over time.

Management Actions

- Establish HEC-6 modeling reaches immediately downstream from tributary deltas (and Lewiston Dam).

- Establish network of flow gages sufficient for management of releases in synchronization with tributary stormflows.

- Establish index reaches to monitor fine sediment storage in channel (both surface and subsurface)

- Monitor/model rehabilitation sites to ensure that bed-mobility and bed-scour thresholds (and associated responses of riparian vegetation) achieve desired objectives.
- Continue Buckhorn Dam and Hamilton Pond fine sediment control efforts on Grass Valley Creek.
- Calculate, on an annual basis, the input of fine and coarse sediment from significant tributaries between Lewiston Dam and the North Fork Trinity. Apply estimates in scheduling of peak flow durations.

Descending Limb of Snowmelt Peak

All water years - May 5 to July 22

Hypotheses:

- Releases during this period can be used to control water temperatures between Lewiston Dam and Weitchpec within limits optimal for anadromous salmonids. Maintaining water temperatures near optimal levels will increase juvenile salmonid growth rates, increasing survival and production. Also, optimal water temperatures for outmigrating smolts will significantly increase total habitat for juvenile steelhead and coho salmon rearing in habitats throughout the mainstem.
- Gradually decreasing flow releases, timed with increasing ambient air temperatures, causes mainstem water temperatures to rise gradually throughout this period, initiating smolting. Gradually increasing water temperatures also encourages yellow-legged frogs to lay eggs, and increases tadpole growth rates.
- Gradually decreasing releases, timed with increasing ambient air temperatures, allows mainstem water temperatures to rise gradually throughout this period, encouraging upstream migration of adult spring chinook salmon.
- Ongoing fine sediment control efforts (Buckhorn Dam, Hamilton Ponds, and watershed rehabilitation), combined with recommended releases and duration during peak flow periods, will transport fine sediment at a rate greater than input, decreasing fine sediment storage in the mainstem, leading to substantial habitat improvements.
- Fine sediment transport accompanying peak releases will be sufficient. No additional flow releases will be needed to accomplish management goal (substantial decrease in fine sediment storage).
- Gradually decreasing releases will minimize salmonid stranding mortality, supporting increased production of anadromous fishes.
- A gradually receding snowmelt hydrograph will lead to germination of riparian plant species across large areas within the high-flow channel. Peak flow releases in subsequent years will be sufficient to limit success of newly established plants.
- Submerging point bars and other alluvial features during the seed-release periods will prevent seedling initiation/establishment along the low-water channel.
- Recommended ramping rates will minimize stranding-related mortality during the snowmelt runoff period.

- Recommended ramping rates will minimize desiccation mortality to yellow-legged frog egg masses during the snowmelt runoff period.
- Timing of peak flow releases minimizes impacts to fry life stage of salmonids. Peak flows occurring at recommended times will strand only insignificant numbers of anadromous salmonid fry.

Competing hypotheses:

- Smolt outmigration can be stimulated by one or more pulse flows that simulate freshets.
- Smolt outmigration is independent of flow and ramping rates.
- Fine sediment transport during the peak flow will be insufficient, requiring an extended flow at or above 5,000 to 6,000 cfs on the receding limb of the annual peak release during Normal-or-wetter water years.

What we know:

- Marginal and optimal water temperatures for anadromous salmonid life stages from other watersheds, as cited in scientific literature.
- Marginal and optimal water temperatures for maintaining juvenile salmonid growth rates from other watersheds, as cited in scientific literature.
- Smolt outmigration timing on the Trinity River.
- Inundation of the surface of alluvial features (e.g., gravel bars) during the seed-release periods will prevent germination of riparian plant species on these bars.
- Yellow-legged frogs lay eggs along margins of exposed cobble/gravel bars. To remain viable, frog egg masses must remain submerged throughout incubation period.
- Inundation/rapid stage change causes mortality to frog eggs.
- Pre-dam snowmelt hydrology provided conditions which allowed yellow-legged frogs to reproduce in mainstem habitats below Lewiston.
- Warming water temperatures improve egg mass survival and improve tadpole growth rates.
- In the existing channel between Lewiston and the North Fork Trinity, stranding of salmonid fry life stage is most likely when flows decline from 6,000 cfs to less than 2,000 cfs (dropping through berm elevation). As the channel in this reach evolves in response to rehabilitation projects, stranding of fry is likely to become insignificant.

What we don't know:

- Marginal and optimal water temperatures for life stage specific to Trinity River anadromous fishes, including salmonids.
- Adequacy of recommended flows in terms of transporting volumes of fine sediment that will be yielded to the mainstem during wetter water years.

- Will gradually descending flows on descending limb of annual peak releases lead to establishment of riparian plant species across entire bar surfaces? Would rapid decreases in releases at this time of year be a more effective tool?
- What rate of change in stage height causes biologically significant mortality of frog egg masses.
- Potential for stranding of salmonid fry life stage in rehabilitated channel morphology.

Management Actions

- Real-time temperature monitoring through a network of gaging stations at mainstem Trinity and tributary sites downstream to Weitchpec.
- Assessment of fish growth and survival as a function of water temperatures.
- Assessment of primary factors that influence smolting and outmigration (pulse flows, degree-days, water temperature), and evaluation of whether management actions can improve outmigration success.
- Incorporate fine sediment transport measurements during peak flows in order to assess additional transport during snowmelt recession limb.
- Assess basin-wide management strategies for yellow-legged frogs and western pond turtles.

Other Issues

- A potentially much longer list of hypotheses will be fully considered by the AEAM team as they consider the full range of objectives to be addressed. Hypothesis testing will be implemented with a view to those particular issues in which limits to knowledge are pertinent to management of the Trinity River Division as well as the Trinity ecosystem. Following is a list of assumptions made by the team in developing the recommendations for this report. These must be addressed by means of hypothesis testing under the AEAM program as required.
- Smolt survival in the Trinity and lower Klamath Rivers will increase as a result of better temperature conditions that promote smoltification.
- Test: On a short time scale, assess the abundance and health (size, growth, diseases, ATPase activity) of smolts utilizing cooler water-temperature conditions. Using rotary screw-traps placed at key locations (upper Trinity River, lower Trinity River and near the estuary), fish samples could be taken and evaluated. On a longer time scale, use adult returns as a measure of success.
- Smolt survival in the Trinity River and lower Klamath River is increased owing to reduced travel time associated with higher flows.
- Test: Tagging studies using natural and hatchery fish under varied flow patterns. A smolt production model for coho salmon needs to be developed and applied along with the chinook salmon model. Perhaps a model for steelhead as well.
- Recommendations that satisfy habitat needs of anadromous salmonids will also provide for adequate primary and secondary production (will support an adequate food base for anadromous fish species).

- Recommendations that satisfy needs of anadromous salmonids will satisfy needs of other fish species native to the Trinity River.
- Recommendations that satisfy needs of anadromous salmonids will provide for other species including riparian-dependent wildlife and organisms living in hyporheic zones.
- Sediment transport provided by release schedules will preclude the need for pool dredging.
- Temperatures provided throughout the River will be appropriate for locally adapted fish stocks.
- Temperature-control release requirements would not be appreciably different with temperature-control devices installed at Trinity Dam (i.e., a multi-level outlet structure).
- What are the thermal tolerances of Trinity River smolts? Test: Under controlled and natural setting, examine how water temperature affects smoltification of Trinity River parr and smolts. There could also be a need to examine the effects of low dissolved oxygen concentrations on parr and smolts.
- How does Trinity River water affect water quality of the Klamath River? There is evidence that water-quality conditions in the Klamath River may get really poor. Does this occur during spring outmigration, especially in Dry water years? If so, how is this affecting smolt survival? What about other life stages?
- The water-temperature model of the Trinity River must be refined and extended through its confluence with Klamath River.

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