



Science Plan

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Cover photo caption: This image shows the Bucktail channel rehabilitation site in April 2019, three years after construction. The Bucktail channel rehabilitation site was designed to build and sustain dynamic mainstem bar (point, medial) and riffle morphology, and off-channel rearing areas designed to increase and sustain the availability, quantity, and quality of anadromous fish habitat between 300 cfs and 2,000 cfs for all life stages. This image illustrates a pond with a beaver dam analogue in the location of a former gravel quarry that is connected to the river by a perennial side channel (lower right), a main channel that reoccupied a channel that filled in after Trinity Dam was completed (top of photo), and an alcove with perennial flow (second channel from top). The variety of water depths, velocities, and temperatures resulting from the project are intended to provide good rearing conditions for all anadromous fish species that may use the site. *Photo by A. Martin, Yurok Tribal Fisheries Dept., 2019.*

*Edits made to the originally published document to fix two minor typos pg9 & pg40. Original publication November 21, 2022.



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1.0 Introduction

1.1. Purpose

The purpose of this plan is to provide guidance on how the Trinity River Restoration Program (TRRP or Program) should conduct science to reduce critical management uncertainties and support the successful implementation of the Program strategies to achieve Program goals.

The long-term **goals** of the Program are to: 1) restore the form and function of the Trinity River; 2) restore and sustain natural production of anadromous fish populations in the Trinity River to pre-dam levels; and 3) to facilitate full participation by dependent tribal, commercial, and sport fisheries through enhanced harvest opportunities. The TRRP **strategy** for accomplishing these goals is to restore the processes that produce a healthy alluvial river through a combination of five management actions mandated by the 2000 Trinity River Record of Decision (ROD): flow management; habitat rehabilitation; sediment management, watershed rehabilitation, and infrastructure improvements. The ROD also specifies implementation of an Adaptive Environmental Assessment and Management program (AEAM; now commonly referred to as “adaptive management” or “AM”) to ensure the implementation of each of the five management actions listed above is based on the best available scientific information and analyses.

This plan was collaboratively developed with technical representatives from Program partners including the: United States Bureau of Reclamation (USBR), State of California, Hoopa Valley Tribe, National Marine Fisheries Service, Trinity County, United States Fish and Wildlife Service (USFWS), and Yurok Tribe; The United States Forest Service opted out. Significant forward progress was achieved in documenting learning to date and articulating remaining uncertainties. The Science Plan Drafting Committee identified science priorities, a combination of key uncertainties and core activities, which directly address the Program goals and provide focus for Phase 3. Technical details are included in appendices or referenced for brevity.

1.2. Background

Lewiston Dam, part of the Central Valley Project (CVP), was constructed in 1963 near Lewiston, California and is now the upper limit of anadromous fish migration on the Trinity River. At times, up to 90 percent of annual runoff into the Trinity River basin was diverted to the Sacramento River basin, contributing to the decline of Chinook salmon and Coho salmon. These water withdrawals also degraded fish habitat in the Trinity River (USFWS and HVT 1999). In December 2000, the Department of the Interior (DOI) Secretary Bruce Babbitt signed the Record of Decision (ROD; DOI 2000) for the Trinity River Mainstem Fishery Restoration Environmental Impact Statement and Environmental Impact Report (EIS/EIR; DOI 2000 and USFWS *et al.* 2000). The ROD adopted the preferred alternative, a suite of actions that included a variable annual flow regime, mechanical channel rehabilitation, sediment management, watershed restoration, and adaptive management.

1.3. Scope

1.3.1. Spatial Scope

The Program goals are basin wide, i.e., they include all adult returns above the confluence with the Klamath River, including the South Fork Trinity River. The ROD-prescribed management actions have a



variety of spatial scales but are largely focused on the mainstem Trinity River below Lewiston dam (i.e., the restoration reach: RM 112.2 to RM 72.5, Figure 1). Watershed restoration is the only TRRP action that has been employed at the basin scale. The Science Plan provides the following clarifications on spatial scope: (1) watershed restoration should continue to be employed at the basin scale¹; (2) the first mile of the river downstream of the hatchery should be considered 'in scope' for management actions given that the progeny of hatchery fish that spawn in the first mile are considered 'natural origin' (i.e., contribute to Program goals); and (3) Lewiston Dam and Trinity River Dam should be considered 'in scope' for implementation given the importance of the Trinity Reservoir on flows and temperature in the mainstem Trinity River.

1.3.2. Temporal Scope

The Program Document describes the temporal bounds of each phase of the Program: Phase 1 (signing of the ROD in 2000-2010), Phase 2 (2011-2022), Phase 3 (2023-2034), and finally through phase 4 (2034-TBD). Program strategies have evolved and are expected to continue to change over time leveraging new insights provided by the implementation of science activities.

1.3.3. Factors Currently Outside of TRRP Control

There are additional factors that are not directly² within the Program's control and yet influence the Program's ability to achieve its goals. Some of these factors may have been less relevant at the time of the ROD (Section 2.3), or their effects may have been underestimated. These include but are not limited to the following effects:

- Climate change
- Drought
- Poor ocean conditions
- Legal water withdrawals and illegal water withdrawals (e.g., illegal cannabis cultivation)
- Lower Klamath River disease and water quality
- Hatchery operations³
- Harvest management of combined Klamath/Trinity fish stocks
- Unutilized habitat above Lewiston dam

While these factors are out of scope for Phase 3, they are still important to understand. If any of these factors are determined to be critically important, the Program could either (a) determine how to best manage to mitigate these factors (e.g., manage for climate change and associated extreme weather events by proactively taking advantage of floods or protecting from droughts); or (b) consider expanding the nature or scope of restoration actions employed by the Program.

2.0 Looking Back - The First Two Decades of the Program

The ROD was signed in late 2000 and implementation planning began immediately. The TRRP office was established in 2002. The ROD was subsequently challenged and the US District Court issued an injunction on the flow aspects of the ROD. The appeals court reversed district court injunction in 2004 allowing flows to proceed. Program partners and local stakeholders are heavily invested in the Program

¹ This is consistent with the description in the preferred alternative (ROD, page 14).

² The Program may have indirect influence over disease issues in the Lower Klamath and Klamath harvest decisions.

³ A solicitor opinion (signed by Dan Shillito, Pacific Southwest solicitor's office; March 12, 2008) resulted in separation of hatchery management from TRRP focus.



and there has been understandable frustration on all sides in the perceived lack of response by salmonid populations. However, the Program has accomplished a substantial amount since the ROD and there have been many on the ground changes as well as a significant advance in the state of knowledge. This section of the Science Plan describes what has been done, what has been learned, and what has changed since the ROD. It culminates in an updated more holistic conceptual model of the Trinity River.

2.1. What Have We Done?

Flow management. Elevated releases in accordance with the ROD began in 2001 but were limited by court order until the first full ROD volumes were released in 2005. Since that time, actual restoration releases have been within 1% of the allocated volume in all but 5 years and have not exceeded a difference of 3% (Buxton 2021a). Each year the TRRP Flow Work Group develops hydrographs, models the performance of candidate hydrographs, and provides a recommendation to the Trinity Management Council (TMC) for approval and subsequent implementation by USBR Central Valley Operations.

Channel rehabilitation sites. The first channel rehabilitation site, Hocker Flat, was constructed in 2005. As of spring 2022, 40 out of 47 originally proposed rehabilitation sites have been constructed on the mainstem Trinity River below Lewiston Dam (Figure 1).

Gravel augmentation. Gravel augmentation is the oldest post-dam restoration activity and was implemented frequently in the decades before the ROD. Since the ROD, it has been implemented nearly annually and is conducted at both low and high flow. Augmentation has taken place at 5 locations above Grass Valley Creek (GVC) and as part of numerous channel rehabilitation projects. Approximately 62,000 cubic yards of gravel has been introduced to the Trinity River between 2000 and 2021.

Watershed actions to reduce fine sediment inputs.

There were 87 watershed restoration projects identified in the Restoration Action Database⁴ between 2003 and 2018. Some of these were planning projects as opposed to implementation. Projects include settling ponds, road maintenance and decommissioning, barrier removal, channel rehabilitation and instream flow projects. Watershed restoration projects funded by the Program are often carried out by other organizations.

Infrastructure changes. Modification of three bridges on the upper Trinity River so that they could physically pass the higher peak flows envisioned by the ROD was a top priority in the early years of the TRRP. Using hydrologic studies, engineering designs and specifications, and environmental documents completed in 2003, the TRRP awarded two construction contracts totaling six million dollars. Cost sharing funds of two million dollars were acquired from the state to assist with the projects that were completed at or under engineering cost estimates. All three bridges⁵ were completed by 2006, which allowed the ROD flows to be implemented in future years. Other infrastructure improvements included paying landowners along the Trinity River to upgrade their seep wells or river pumps, moving a small house that was in the Trinity River floodplain, and raising the roads in the Poker Bar subdivision so that they would not be flooded during the high flow releases.

⁴ <https://www.trrp.net/dataport/rad/?what=table-trrpwatershed>

⁵ The three bridges were Biggers Road, Poker Bar, and Salt Flat.



The Program has also implemented a range of **science activities** (e.g., monitoring, modeling, analysis), which inform the ongoing implementation of actions. In addition to annual reporting, numerous synthesis reports⁶ have been completed or are underway which compile and evaluate data across years and disciplines. The Program developed and implemented aspects of an AEAM plan otherwise known as the Integrated Assessment Plan (IAP) (TRRP and ESSA 2009). The Phase 1 review (Buffington et al. 2014) and the Refinements exercise (Headwaters 2018) represent Program level examples of ‘evaluation’, a key step in adaptive management (Section 3.1.1), completed to date. Other examples of implementation of adaptive management include the adjustment of gravel augmentation volumes to better match newly calculated transport rates over those from the ROD, and changes in channel rehabilitation site design techniques to yield larger and more immediate benefits to fish habitat than techniques used in the beginning of the Program (Section 2.2.2).

⁶ <https://www.trrp.net/restoration/adaptive-management/synthesis-reports/>

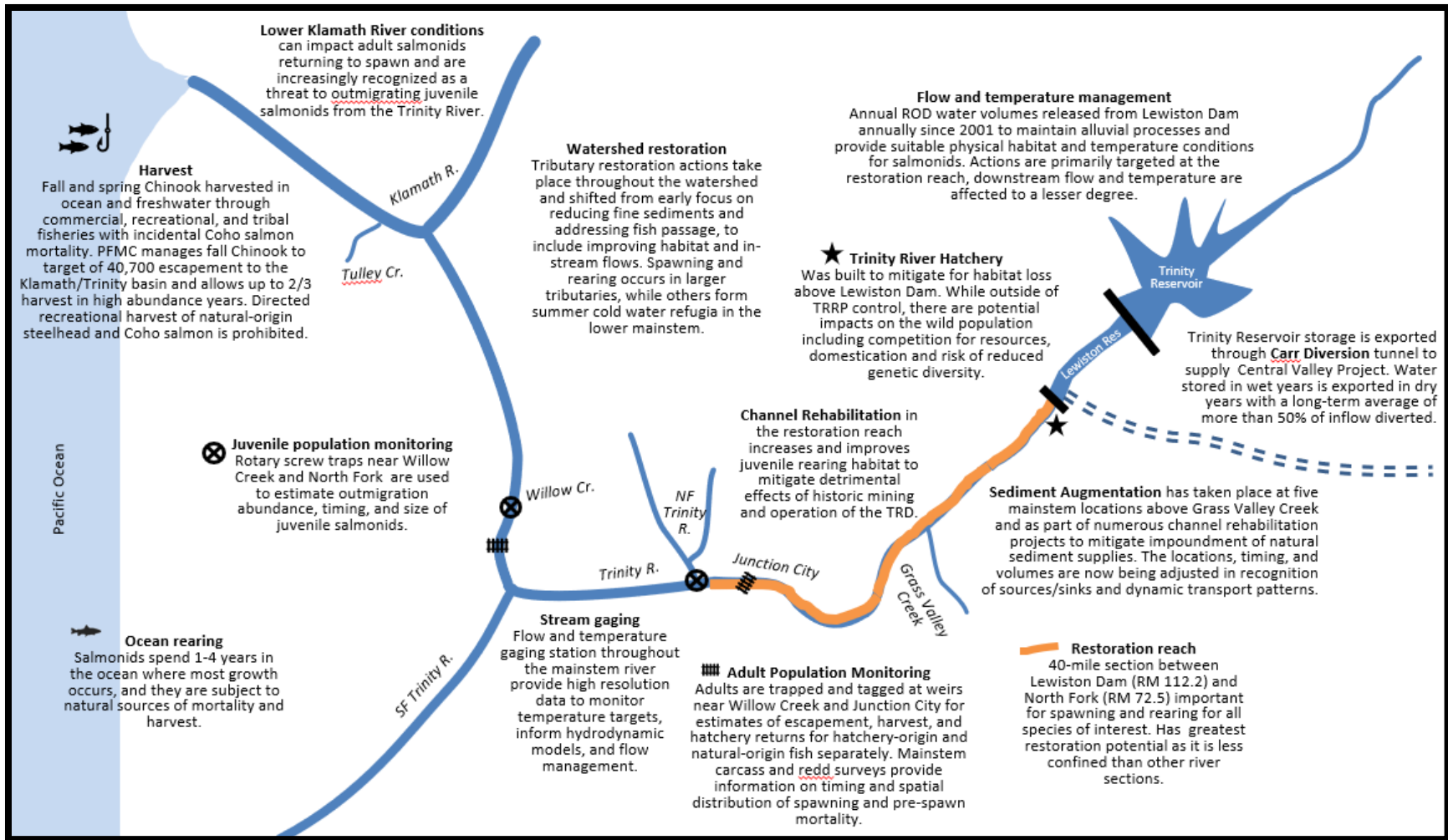


Figure 1. provides a conceptual illustration (not to scale) of the location of Program management actions and associated monitoring sites as well as key features within and outside of TRRP control. Figure adapted from Asarian et al. in press.



2.2. What Have We Learned?

The analysis contained in the Trinity River Flow Evaluation (TRFE) (USFWS and HVT 1999) and underpinning the ROD, was the best available Program science⁷ at the time. Numerous studies were conducted to develop recommendations for flow and sediment management, physical habitat restoration, and watershed restoration. While some findings and analysis contained in the TRFE remain relevant, significant advancements in science and understanding of ecological and riverine processes have occurred in the last 20 years. The ROD recognized that restoration of the Trinity River would require adaptive management to ensure that the Program was informed by the latest science, that assumptions and hypotheses were challenged, and that insights arising from implementation of actions were embraced to inform new actions. It is inevitable that some hypotheses will be wrong, and some actions won't work as expected, which only indicates failure if learned lessons aren't carried forward. The following two sections *briefly* summarize the learning to date associated with the TRFE central hypotheses and management actions. More detail for each can be found in *Appendix A* and *Appendix B* as well as the numerous Program synthesis reports.

2.2.1. Evaluation of the TRFE Central Hypotheses

The three central hypotheses in the TRFE are listed below along with a brief summary of the findings to date. It should be noted that many more hypotheses have been generated by the Program⁸ over the years. Many of these informed the latest effort to document Program objectives and targets (TRRP 2022; *Appendix C*). The Science Plan Drafting Committee chose to take a reductionist approach and focus on the three central hypotheses from the TRFE given the mandate to provide focus.

- 1) *"Habitat diversity in the upper Trinity 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."*
 - Redundant with second hypothesis, refer to next bullet.

- 2) *"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."*
 - Actions to date have increased quantity and quality of physical habitat but not at the scale desired (i.e., not a doubling of fry-rearing habitat).
 - Physical habitat creation has been limited to channel rehabilitation sites, and downstream unraveling (i.e., berm removal and habitat creation beyond the footprint of the restoration sites) did not occur as expected.
 - Physical habitat increases have not been linked to increased number of juvenile salmonid outmigrants, which could indicate underperformance of physical habitat projects, physical habitat is not limiting production, or that habitat increases have provided a compensatory benefit against observed negative population pressures. It is also possible that the potential

⁷ The program document (2022) clarifies that 'Program science' includes the best available scientific information and analysis collaboratively reviewed and interpreted by Program scientists to inform Program learning and management decisions.

⁸ TRFE Appendix O; Conceptual Models and Hypotheses for the TRRP (TRRP 2009).



benefits of physical habitat gains have not been realized due to insufficient flows at the times when juvenile salmonids are present.

- Habitat diversity and dynamism have not been adequately assessed.
- Physical habitat metrics (i.e., depth and velocity) may not sufficiently describe quality of habitat.

3) *“Salmonid smolt survival will improve as a result of better [colder] temperature conditions that increase growth and promote smoltification and reduced travel time associated with emigration.”*

- The opposite is true: colder temperatures due to elevated releases in the spring during the period of thermal stratification in Trinity Reservoir have limited juvenile salmonid growth and caused a reduction in Chinook salmon smolt size at outmigration, which is expected to negatively impact survival (Gast 2021).

2.2.2. Management Actions

The management actions prescribed by the TRFE, and adopted by the ROD, were designed to address fish production bottlenecks as they were understood using the best science available at the time.

Channel Rehabilitation

Designs of physical channel rehabilitation have evolved over the years as scientists and restoration practitioners have learned new techniques to improve the effectiveness of channel rehabilitation designs. In the first few years of physical habitat restoration following implementation of the ROD, an emphasis was placed on removing the riparian berms and lowering the floodplain to create open gravel bars and leverage natural processes to create more habitat and ‘unravel the river.’ However, there was quick recognition that this created poor juvenile rearing habitat because it lacked cover, a critical component of juvenile salmonid rearing habitat. It soon became evident that a heavier hand (i.e., more mechanical intervention) was required to scale the river to the available flows. Sites increased in scale and more large woody debris, beaver dam analogs, and off-channel ponds and alcoves were incorporated into designs to provide both immediate and lasting habitat benefits to rearing juvenile salmonids. The evolution in channel rehabilitation designs is an example of the adaptive management feedback loop functioning within the TRRP over the last two decades. There remain uncertainties around how channel rehabilitation sites interact with flow and how effective they are in producing a measurable benefit to salmonid populations.

Flow

The research and work of USFWS and HVT (1999), the Mainstem Trinity River Fishery Restoration Environmental Impact Statement (USFWS, BOR, HVT, and Trinity County 2000), signing of the ROD in 2000 and subsequent implementation in 2005 lead to significant improvement to both the quantity of water and changes to the simplistic and low volume flow regime released from Lewiston dam to the Trinity River. In combination with other management actions, flows have essentially eliminated the fine sediment impairment that existed upstream of Douglas City, increased coarse sediment transport, improved temperature conditions for holding adult spring Chinook salmon, and likely helped increase juvenile salmon production.

However, the resulting daily dam release schedules recommended in the ROD still resulted in a simplified flow regime, compared to that of the pre-dam natural flow regime (Abel et al., 2022). For example, the ROD dam release strategy contains one peak flow in the spring, and a baseflow of 300 cfs for approximately seven months of the year, from October to April when streams in the region



experience their largest and most variable flow events. The constant flows of 450 cfs in the summer months are also known to create ecological problems such as poor amphibian habitat and a fixed and hardened riparian/river interface (HVTF and McBain Associates 2021) and prevention of thermal stratification in deep pools (Buxton et al. in press).

A multitude of peer-reviewed literature concurrent with or following implementation of the studies in the TRFE highlight the ecological benefits of more natural flow regimes in managed river systems (e.g., Poff et al. 1997; Arthington et al. 2006; Davies et al. 2013). Several recent studies specific to the Trinity River have shown similar results, in which the flow patterns implemented as a result of the ROD suppress water temperatures in the spring and fail to mimic natural flow patterns that have ecological benefits (e.g., Ashton et al 2015; Wheeler et al 2014; Abel et al., 2022). Monitoring of ecological responses to flow releases, including fish production, riparian plant recruitment, and sediment movement, resulted in recommended changes to flow management. This culminated in a recent proposal to shift water releases earlier in the year (Abel et al. 2022) - before most juvenile salmon have emigrated to the ocean, and when tributaries are normally flowing higher. Although this proposal has yet to be implemented, flow management remains one of the most important adaptive management tools available to sustain and restore ecosystem function and fishery populations in the Trinity River (Section 3.1.4).

Habitat Estimation methods

While not a management action per se, Instream Flow Incremental Methodology combined with Physical Habitat Simulation System (PHABSIM) were used to develop the flow recommendations of USFWS and HVT (1999). However, recent publications have shown that habitat suitability-based models like PHABSIM may systematically overestimate low-flow productive capacity for species that prefer low velocities found in pools but are dependent on energy fluxes generated in higher velocity habitats such as riffles (Rosenfeld and Ptolemy 2012; Rosenfeld et al 2016; Rosenfeld and Naman 2021). Standard applications of PHABSIM systematically underestimate the effects of declining discharge on pool-rearing juvenile Coho salmon in small streams by inflating habitat quality at low flows (Rosenfeld and Ptolemy 2012). Mechanistic bioenergetics-based models appear to provide more rigorous estimates of habitat suitability for drift-feeding stream fishes (Railsback 2016; Naman et al. 2019; Naman et al. 2020) than applications such as PHABSIM. The application of PHABSIM in USFWS and HVT (1999) likely resulted in an overestimate of the availability of habitat in the Trinity River to support rearing juveniles at low flows.

Water Temperature

For juvenile water temperatures, the TRFE focused on keeping water temperatures below certain thresholds. However, no concerns were raised that hypolimnetic releases from Trinity Reservoir in the spring would be cold enough to suppress growth of juveniles when the snowmelt portion of the hydrograph was released from Lewiston Dam. However, as detailed in Abel et al. (2022), water temperatures from Lewiston Dam in the spring are nearly always less than the optimal growth range for juvenile salmonids, which reduces metabolism and growth for these ectothermic animals. New objectives for water temperatures in the spring that optimize salmonid growth have been developed by TRRP (TRRP 2022). However, due to lack of a temperature control device in Trinity Reservoir, implementation of these recommendations must be done through improvements to flow management, which has not occurred.



The adult salmonid temperature objectives recommended by USFWS and HVT (1999) and later adopted in the ROD were developed for Chinook Salmon in California's Central Valley. These temperature objectives were thought to be sufficient for all species at the time. However, as reviewed by Carter (2005), water temperatures that are protective of Coho salmon spawning and incubation are less than the adult salmonid water temperature objectives recommended by USFWS and HVT (1999). In years of low Trinity Reservoir storage, water releases from Lewiston Dam in the autumn and early winter are much warmer than thresholds recommended by Carter (2005) for Coho salmon spawning and incubation, even if they are less than the adult salmonid temperature objectives recommended by USFWS and HVT (1999). While new adult salmonid temperature objectives have been developed by TRRP to protect spawning and incubation for Coho salmon, the current regulatory requirements established for the protection of adult salmonids in the Trinity River appear insufficient to protect Coho salmon, particularly when Trinity Reservoir storage is low.

Gravel Augmentation

The TRFE conceptual model suggested the river would transport augmented gravel throughout the system resulting in a balanced sediment budget (i.e., "the conveyor belt"). However, monitoring has shown that flow releases have less capacity to transport gravel than previously estimated and hence water year specific annual high flow augmentation volumes prescribed by the ROD have been reduced (Gaeuman 2014; Gaeuman and Stewart 2017). Instead, it appears that there are both sources (tributary deltas, abandon floodplain terraces, mine tailings, bars) and sinks (scoured channel bed, low floodplains, wide channels), that interrupt coarse sediment transport and result in variable storage lengths and transport rates in different stream reaches (Gaeuman et al. 2017). Increases in habitat and channel complexity after gravel augmentation have been documented (e.g., Lowden Ranch), but so have reductions in habitat and complexity if augmentation continues at the same location after any deficit has been corrected (Gaeuman et al. 2019). Program scientists have updated their conceptual model of sediment transport in the Trinity River and have used this information to inform ongoing management decisions.

Watershed Projects

Flow regulation beginning in the 1960s caused the impairment of river ecological function by reducing fine sediment transport rates. Excessive input from tributary watersheds, combined with the reduced ability of low mainstem flows to export that fine sediment, led the Environmental Protection Agency to place the Trinity River on the 303(d) list of impaired waters. Prior to the ROD, restoration projects were implemented to address fine sediment in Grass Valley Creek (i.e., Buckthorn Dam and Hamilton Ponds). Since the ROD, annual high flow releases from Lewiston Dam, coupled with watershed projects to reduce fine sediment input from tributaries, have led to a considerable reduction in the Trinity River's fine sediment impairment. Indeed, Buxton (2021) concluded that after nearly 20 years of restoration flows, fine sediments have been greatly reduced in the upper river and are now actually in a *deficit* from Lewiston Dam (RM 112.2) to at least Rush Creek (RM 107.8). This deficit may now be impairing ecological function in the upper river such that augmentation of fine sediments in this reach is now being considered *Appendix B*.

Given that fine sediment concerns in the Trinity River have largely been addressed through Program actions, watershed restoration priorities have shifted. Ground water recharge and storage and forbearance for water users have risen in importance to address concerns during the ongoing multiyear droughts California is experiencing (Section 2.3.1). Habitat connectivity and fish passage have also been



identified as priorities. The Integrated Fisheries Restoration Monitoring Plan⁹ for the Klamath Basin, has identified a variety of potential watershed restoration projects in the Trinity River and South Fork Trinity River.

2.3. What Has Changed?

2.3.1. Climate Change

Drought and climate change have gripped the Trinity River basin and the western United States in recent decades. Though there have been several wet and even a few extremely wet years in the past 20 years in the Trinity River basin, 2000 to 2021 was the driest 22-year period since at least the year 800 (Williams et al. 2022). Prior to the three consecutive critically dry years 2020-2022, there were never two consecutive critically dry years recorded in the Trinity River basin since record keeping began in 1912. The predictions of more wet and more dry years and less normal years has been well established in the peer-reviewed literature but was not well understood at the time USFWS and HVT (1999) was published. Climate change effects are expected to continue to reduce snowpack, reduce streamflow, increase stream temperature, and lead to reductions in supply of water to reservoirs (Vicuna et al 2007), such as Trinity Reservoir. Increased atmospheric evaporative demand since 1980 has caused the loss of approximately 50 to 100 mm of water in California, regardless of declines in precipitation (Albano et al 2022). Climate change is expected to continue to reduce the quality of salmonid habitat (McCarthy et al 2009), increase wildfire risk and severity (Schoennagel et al. 2017), increase tree mortality (Madakumbura et al 2020), and make recovery of salmonids more difficult (Isaak et al 2012). In the Trinity River basin, these changes are likely to continue to reduce the quantity and quality of salmonid habitat over time by contributing to reductions in the amount of water in tributaries and the main stem river, as well as warming water temperatures. Though outside of the control of TRRP, climate change has dramatic implications for the recovery of salmonid populations and changes the calculus of the effectiveness of restoration actions, such as the return interval of certain flow levels needed to scour riparian vegetation.

2.3.2. Ocean Conditions

Marine survival is known to have a strong effect on salmonid populations (Beamish et al. 2000). In the northeast Pacific Ocean, upwelling is the primary driver of ocean productivity for salmonids. In years of weak upwelling, production of salmonids off California and Oregon tends to be negatively affected due to a lower quantity and quality of prey items. A marine heat wave beginning in 2014 and continuing to at least 2016, with resurgence in 2019, severely reduced the quality of marine habitat for salmon in the northeast Pacific Ocean (Amaya et al. 2020), contributing to low returns of salmon (Jacox et al. 2018). There is substantial evidence that even prior to these marine heat waves, body size of salmonids throughout the Northeast Pacific Ocean has declined over time, possibly due to size selective harvest, and/or poor ocean productivity (Lewis et al. 2015; Ohlberger et al. 2018). Size of females is directly related to fecundity, which is an important driver of salmonid production (Quinn et al. 2004). As size of females declines, so does the number of eggs, and the total egg mass per female (Quinn and Bloomberg 1992; Ohlberger et al. 2020). Data from Trinity River Hatchery and Iron Gate Hatchery indicate that fecundity of some species was significantly reduced during the marine heat waves from 2014 to 2016 (CDFW unpublished data). Thiamine deficiency in anadromous salmonids throughout California caused

⁹ <https://kbifrm.psmfc.org/>



by a diet high in prey containing the enzyme thiaminase (such as anchovies) should continue to be monitored. Thiamine deficiency results in weakened offspring of salmonids, which may contribute to population declines in the future if the phenomenon continues. Future changes in the marine environment, such as greater frequency of marine heat waves or reduced seasonal upwelling, could limit the potential for TRRP to improve salmonid populations through restoring freshwater habitat.

2.3.3. Fish Disease

Prior to publication of USFWS and HVT (1999), fish disease in the Klamath River was not a focus of fish management agencies. Since 1999, *Ceratonova shasta* has been identified as a major contributor to juvenile salmonid mortality in the Klamath River. In some years, monitoring on the Klamath River at Tulley Creek (RM 38.5 on Klamath River, i.e., 38.5 miles upstream from the Pacific Ocean), downstream of the confluence with the Trinity River, indicated juveniles emigrating through the lower Klamath River are exposed to levels of *C. shasta* spore concentrations that could create significant mortality risk (Bartholomew et al. 2020). In years when spore concentration data in the Klamath River is not collected downstream of the Trinity River confluence, spore concentrations can be high in the reach immediately upstream of the confluence (Voss et al. 2020), indicating that the lower Klamath River spore concentrations are likely at levels that could create mortality risk for juvenile salmonids. In September 2002, a significant fish kill occurred in the lower Klamath River. Though estimates vary, the US Fish and Wildlife Service reported that a minimum of 34,000 adult fish died, which were primarily fall-run Chinook salmon (Guillen 2003). Though a similar large scale adult salmonid fish kill has not occurred since, elevated flows from Lewiston Dam in the late summer and fall have been used to prevent adult fish kills from occurring. These releases are outside of the ROD flow volumes but affect the ecology of the Trinity River in ways not envisioned by USFWS and HVT (1999).

2.3.4. Cannabis Cultivation

Cannabis is a multi-billion-dollar industry which has rapidly increased in prevalence since California Proposition 64 (2016) legalized recreational cannabis use (Bustic and Brenner 2016; Parker et al. 2021; Wartenberg et al. 2021). There has been wide-spread and largely unregulated cultivation in Northern California since the mid-90s (Bauer et al. 2015; Parker et al. 2022). Trinity County along with Humboldt and Mendocino counties are known as the top three producing counties in California (Bauer et al. 2015). There is concern over the environmental impacts of this large-scale production pressure but relatively little empirical evidence. Wartenberg et al. (2021) identified six potential pathways in a recent review of the literature: air pollution, energy use, land cover change, pesticide use, water pollution, and water use. Water use and impacts to stream flow, particularly in low-flow periods which coincide with the growing season (June-Oct) are of relevance to the TRRP. Bustic and Brenner (2016) used satellite imagery to estimate the scale and distribution of cannabis cultivation in Humboldt County and found that the distribution was extensive and patchy in nature, with some clusters exceeding 10,000 plants in a single watershed. This clustering could result in concentration of impacts (e.g., fragmentation, erosion, landslides, stream flow) that could cause extreme local impacts (Bustic and Brenner 2016). Bauer et al. (2014) estimated water usage based on the total number of plants and assumptions around how much water each plant requires (22.7 liters per plant per day) and found that water demands during low-flow periods can exceed the streamflow and completely dewater streams. This is consistent with anecdotal evidence of changes in tributary flows in Trinity County in recent years (Liam Gogan, pers. comm.). Reductions in tributary streamflow can have direct lethal or sub-lethal impacts on species of interest to the Program (e.g., Coho, steelhead, spring Chinook, amphibians). Commercial cannabis growers must



obtain permits through the California Water Board (https://www.waterboards.ca.gov/water_issues/programs/cannabis/cannabis_water_rights) if they divert surface-water or pump groundwater from areas near streams; however, this does not address impacts from illegal operators. There is an urgent need to understand the environmental impacts of both legal and illegal cannabis cultivation in Northern California, and in the context of the TRRP to understand to what extent these impacts are limiting the success of the program.

2.3.5. Wildfire

Before European colonization of the Klamath Mountains, wildfires occurred frequently, with median fire return intervals in mixed conifer forests estimated around 7 to 17 years (Skinner and Chang 1996; Agee 1991; Agee 1993; Skinner 1994). By the mid-1930s, the policy of most forest management agencies was to quickly suppress fires (Loveridge 1944). It is now understood that suppressing the natural fire regime led to the accumulation of forest fuels, which in turn led to more intense contemporary fires that are more difficult to extinguish (Miller 2012) and cause more severe damage to the landscape.

Whether from high fuel loadings, more frequent fire weather¹⁰, changing land management and firefighting policies, or a combination of these, wildfires have increased in frequency, intensity, size, and duration since the 2000 ROD was signed. For example, a large fire in the 1960s was the Hayfork Summit Burn, at 19,000 acres. In the 1980s, a large complex of fires, started by lightning, was 67,000 acres. In 2001, less than a year after the ROD was signed, a relatively small wildfire (1,675 acres) near Weaverville was featured on the cover of the New York Times and was considered newsworthy because it burnt 13 homes. By contrast, recent fires in the hundreds of thousands of acres have become common. The 2021 Monument Fire (223,124 acres), the 2020 August Complex (1,032,648 acres), the 2020 Red Salmon Complex (144,698 acres), the 2018 Carr Fire (229,651 acres), the 2017 Helena Fire (21,846 acres along the TRRP Restoration Reach), and the 2015 River Complex (77,081) are examples of fires that have burned portions of the Trinity River watershed (Calfire 2022) in the last decade. These fires generally began in July and were not extinguished until the rain came in October or November.

Fire effects on streams such as increased sedimentation and water temperatures, and changes in nutrients and allochthonous material inputs (e.g., Gresswell 1999; Neary et al. 2005; Bixby et al. 2015; Jager et al. 2021) have been discussed as ecosystem stressors. For example, after the 2018 Carr Fire, a fine sediment plume from the Deadwood Creek sub-watershed (which burned severely) was deposited in the mainstem Trinity River during a mid-winter storm, covering many salmon redds. The channelbed remained covered by fine sediment until the Spring 2019 ROD flow mobilized it. A similar phenomenon occurred during Summer 2022 from a 2021 fire that impacted the Dutch Creek watershed. However, there may also be benefits from fire to aquatic systems. As fires remove or thin vegetation, evapotranspiration is reduced, and this can result in elevated streamflows (Williams et al. 2022, Collar et al. 2022). Smoke from wildfires covers large areas and reduces the amount of solar radiation exposure to land and water, wildlife, which can encourage the cooling of streams during a season when warm water is a threat to many fish species (David et al. 2018, Asarian et al. 2020). Many of the effects of fire can be mitigated or enhanced through flow releases and channel rehabilitation. As fires change, and our knowledge of fire ecology increases, our strategy for responding to them should change as well.

¹⁰ E.g., warm, dry, and windy conditions, sometimes associated with thunderstorms, during years of below-normal precipitation that stresses vegetation and leads to fuel desiccation.

2.4. Conceptual Model

A driving assumption of the TRFE was that lack of juvenile salmonid rearing habitat was limiting smolt production. Riparian berms and mine tailings had encroached into the floodplain, thereby reducing the amount of rearing habitat at a range of flows. This idea was illustrated through a series of conceptual models showing, pre-TRD, then-current, and desired future conditions (Figure 2) and was the primary focus of mainstem restoration efforts. The depiction of the desired physical form (Figure 2 - panel C) decreased the low flow channel width and low flow physical habitat. The active channel stayed roughly the same size with more emergent bars, but decreased the area of abandoned floodplains created at higher elevation during pre-dam hydrology, in favor of contemporary floodplains engaged and maintained by restoration flows. This shift from perennially wetted habitats to seasonally wetted habitat supports an assemblage of plant species that they support (e.g., willow, alter, cottonwood, sedge etc.) which provide high quality habitat for fish when inundated. Simply put, the objective was to create a scaled-down naturally functioning river with juvenile rearing habitat available across a range of flows, unlike the pre-ROD 'U' shaped channel.

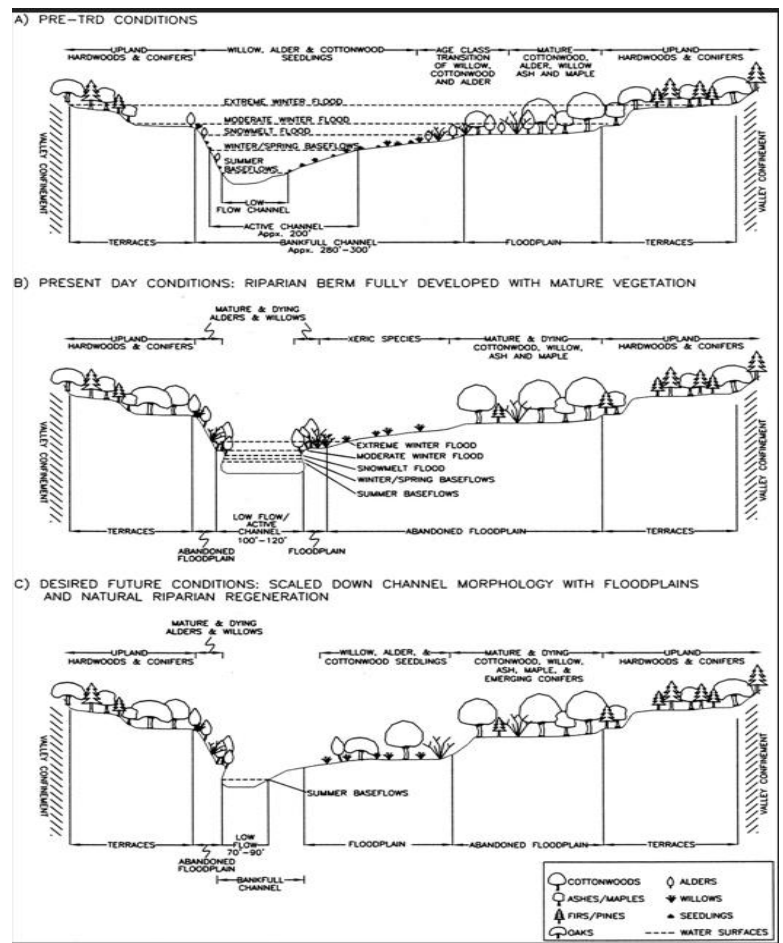


Figure 2. Replicated from Trush et al. 2000, illustrates (A) pre-Trinity River Dam conditions, (B) present day [2000] conditions, and (C) desired future conditions.

Reflections on the original model:

- An increase in emergent bars and floodplain implies that there was an inherent understanding that these seasonally inundated habitats were the missing element impairing channel function and limiting juvenile rearing. This would also imply that flows interacting with these surfaces would be important for their formation and maintenance, but also for seasonal functionality. However, no depiction of seasonal flows other than summer baseflow are provided in the illustration of desired future condition in the original conceptual model. This may indicate that there was disagreement or uncertainty among the authors on how to portray other seasonal flow patterns, such as winter flows.
- The desired condition described by Trush et al. (2000) has not expanded beyond the footprint of restoration sites as envisioned (Section 2.2.2 and *Appendix B*). The desired condition was likely not realistic without incredible amounts of sediment addition that would change the floodway dynamics. Instead, the active channel must increase in width to be able to maintain emergent bars and contemporary floodplains via lowering of the abandoned floodplain.
- Large contiguous areas of low velocity were overvalued by the physical habitat estimation techniques, which were then used to develop the current baseflow recommendations. Similarly,



temperature management neglected thermal diversity in the lateral and vertical dimensions, which would provide for the diverse temperature needs of co-occurring salmonid life stages and other species.

- As the channel form shortcomings are addressed through mechanical restoration, the hydrograph (i.e., reservoir flow releases to the Trinity River) should be re-evaluated to better suit the channel that exists today, or to better meet the biological needs of fish and wildlife for the desired form presented in the TRFE.

Seasonal flood patterns shift dominance of terrestrial and aquatic species assemblages throughout the year (Bayley 1995). Winter is dominated by the aquatic system as many terrestrial species go dormant or migrate to overwintering areas (Gasith and Resh 1999). Variable peak flows expand across the valley bottom recruiting allochthonous materials, while robust base flows inundate areas through spring, increasing autochthonous resource production (Tockner et al. 2000). Conversely, terrestrial and non-obligate aquatic species dominate summer months when the aquatic system is contracted, and the valley bottom is relatively desiccated (Gasith and Resh 1999). Shoulder seasons are transitional periods where both aquatic and terrestrial systems occupy the mainstem valley migrating to it from over-summering or over-wintering refuge (Gasith and Resh 1999). The aquatic system accesses this space in the fall primarily through peak flow variability while baseflows gradually increase until they promote extended access to the valley bottom through robust sustained baseflows in the spring (Trush et al. 2000). During these transitional seasons, many species take advantage of less extreme conditions to migrate, reproduce, and rear offspring in both environments. The phenology of species requires that all ecological services are timed to reproductive and migratory cycles developed over evolutionary time (Ward and Stanford 1995).

The TRFE and ROD attempted to restore some of these ecological services through a truncated seasonal flood and reliance on tributary accretions downstream. This was successful at meeting some objectives identified at the time and was protective of not exceeding ROD flow release allocations. The updated conceptual model emphasizes scaling of the entire hydrograph in a way that would align dam releases with tributary runoff and the phenology of fish and wildlife of the Trinity River. A percent-inflow alternative was considered in the analysis that preceded the ROD but was dismissed due to deficiencies in water year forecasting and muted peak flows due to averaging flows over weekly time periods. New objectives and new forecasting tools now allow for more refined water management on a daily or sub-daily scale over the entire water year. This ability to manage water during times of year previously not exploited will allow the Program to target additional benefits to fish and wildlife preservation and propagation in the Trinity River, while pursuing new lines of scientific inquiry to further refine management actions.

The updated conceptual model (Figure 3) builds on the earlier work (Trush et al. 2000) and incorporates new Program science (Section 2.2). It recognizes the importance of biological and physical processes across seasons and in particular the need for a more natural hydrograph (i.e., timing and variability) to support the entire riparian and aquatic species assemblage. While increasing physical juvenile salmonid rearing habitat is still considered important, the preferred strategy for restoration looks more closely at how the suite of management actions available to TRRP interact to affect rearing habitat (e.g., food availability and temperature) and ecosystem productivity to support salmon and other aquatic species (Figure 3).

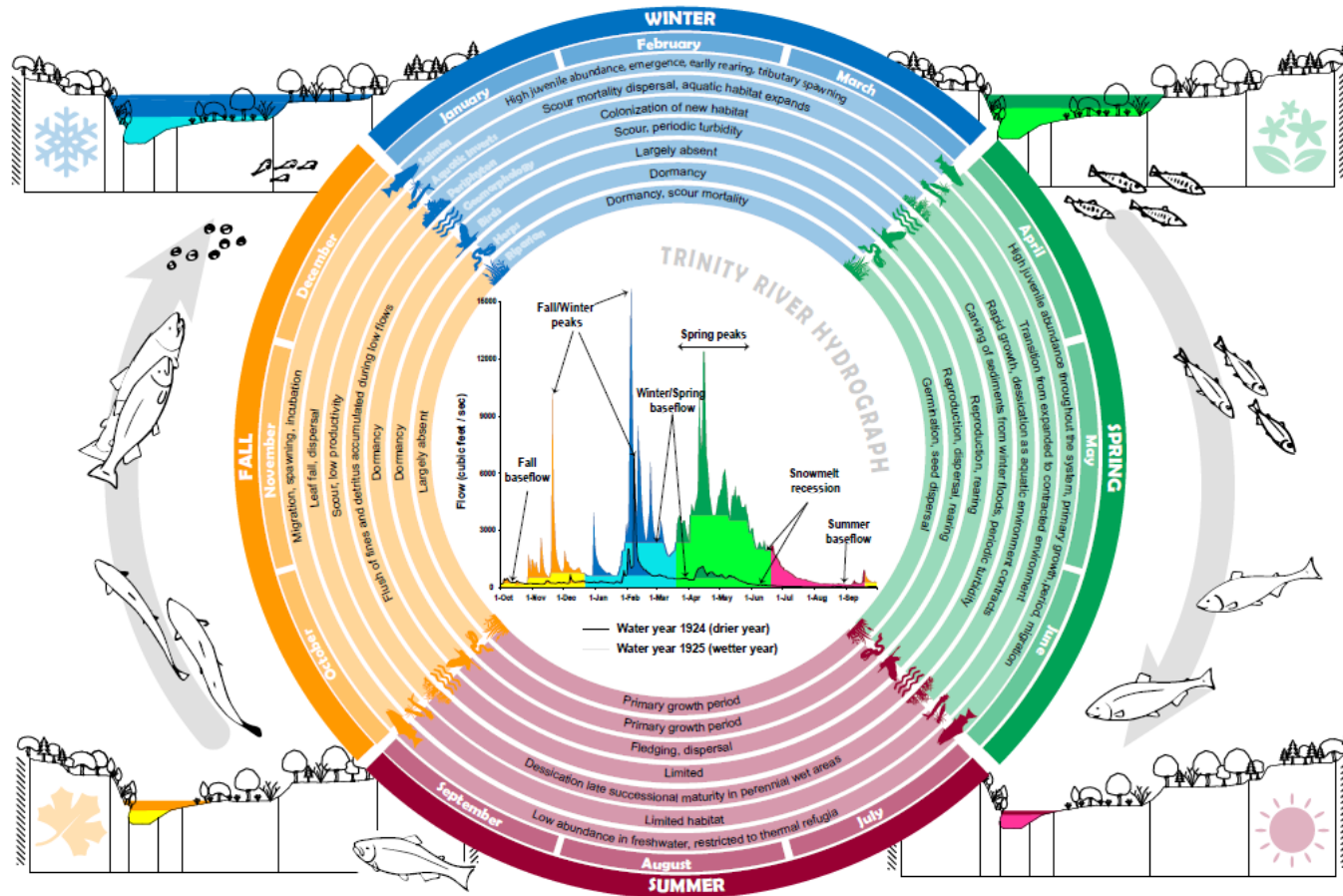


Figure 3. The updated conceptual model shows how the natural hydrograph historically interacted with different aspects (i.e., fish, invertebrates, periphyton, geomorphology, birds, herps, and riparian vegetation) of the ecosystem across seasons. The seasons are illustrated by different colors, with ecosystem services (e.g., scour) shown in the concentric circles. The four images in the corner have been modified from Trush et al. (2000) to show how a more natural hydrograph would interact with the channel (e.g., the darker blue in the winter represents the variability that no longer exists in the managed hydrograph, while the lighter blue represents the baseflows which determine the extent of the aquatic system). Salmonid life cycle artwork provided by Derek Rupert.



3.0 Looking Forward – The Plan

This section of the report builds on what we have learned so far and provides guidance on where the Program should go next. It includes three sub-sections. The first sub-section provides a brief overview of adaptive management as well as TRRP-specific challenges to implementation, opportunities, and roles and responsibilities for successful implementation. The next sub-section identifies the Science Priorities intended to provide focus for Phase 3 of the Program. The final sub-section provides an Information Road Map describing the full suite of science activities, the process for translating data to decisions, and a description of the new annual science planning process.

3.1. Adaptive Management

Adaptive management was top of mind for Program scientists and managers leading up to the ROD and was described in foundational documents such as the TRFE and the Integrated Assessment Plan (TRRP and ESSA 2009). However, the Program has faced criticism on its implementation of science and adaptive management, which was part of the impetus for the recent refinements process (Headwaters 2018). The refinements process found that the Program lacks: an agreed upon definition of adaptive management, an effective adaptive management plan, clarity in terms of goals and objectives, questions and hypotheses of interest, and how to synthesize information into decisions. The refinements report then went on to recommend development and implementation of an adaptive management plan. It also noted the importance of having such a plan supported by decision makers, who play a key role in the adaptive management loop, as described below. Many of these concerns have been addressed in other sections of this report or the Program Document (e.g., goals and objectives). This section focuses on adaptive management and provides concise guidance to support implementation of effective adaptive management on the Trinity River.

3.1.1. What is Adaptive Management?

There are dozens of definitions of adaptive management in the literature. The ROD and TRFE employ one of the earliest definitions:

“AEAM is a formal, systematic, and rigorous process of learning from the outcomes of management actions, accommodating change, and improving management (Holling, 1978).”

This definition still applies in the TRRP. More recent definitions range from extremely long and complex to very simple, but in general they include the following concepts: rigorous or systematic; management uncertainty; learning by doing; improving management outcomes.

Adaptive management is most useful when there is high management uncertainty and an associated management lever (Figure 4) (e.g., flow management on the Trinity). If there is no uncertainty, then decision makers can simply implement the management levers they know to work. If there is high uncertainty, but no available action (e.g., extreme weather events due to climate change), then the focus should be on scenario planning and mitigation.

Adaptive management is often categorized as either 'Active' or 'Passive'. **Active adaptive management** is when plausible alternatives are compared by designing multiple management interventions as experiments. This form of adaptive management is particularly useful when there is high uncertainty but is difficult to implement in practice. Stakeholders and decision makers often resist testing a range of options rather than trying to implement the best approach based on current science. It can also be difficult, but not impossible to use experimental design principles (particularly in river restoration) where sites can't be manipulated in isolation. **Passive adaptive management** involves implementation and evaluation of the expected best management alternative; this approach is more common in practice but is expected to have a lower rate of learning.

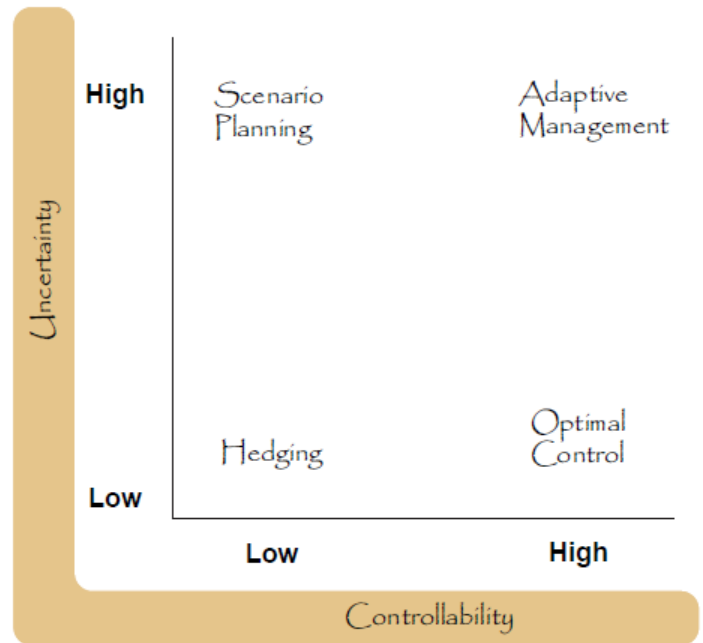


Figure 4. Replicated from DOI 2009, this figure shows how the approach used depends on the degree of 'uncertainty' and 'controllability'.

The DOI Technical Guide on Adaptive Management (DOI 2009) provides a simple nine question key for determining if adaptive management is appropriate (*Appendix D*). In addition to questions about uncertainty and management control, it requires stakeholder engagement, management objectives, modeling of resource relationships and management impacts, ability to monitor, a commitment to adjust in response to learning, and an appropriate legal framework. Greig et al. (2013) summarize 24 enabling factors for effective adaptive management from a practitioner's perspective. Of 24, only about eight of the factors were technical in nature, most of the factors were related to how people work together. Enabling factors included: leadership and strong executive commitment, organizational structure, community involvement, clear problem definition, management relevance, and effective communication.

Adaptive management involves several, purposeful, linked phases, steps, and elements (Murray et al. 2015):

- **PLAN** (Assess & Design): Frame problem, assess, and design actions from view of critical management uncertainties;
- **DO** (Implement & Monitor): Implement learning strategies and monitor actions using hypothesis testing and principles of experimental design;
- **LEARN** (Evaluate & Adjust): Evaluate data to learn about effectiveness of actions and adjust management.



3.1.2. Challenges

As noted in Section 2.0 of this document, the Program has implemented many of the planned management actions and substantial learning has occurred. However, there have also been challenges to effective adaptive management in the Program.

- Failure to adopt the Integrated Assessment Plan, which was intended as an adaptive management plan.
- Adaptive management has largely been done through ‘passive adaptive management’ which results in slower learning. This is at least in part due to the difficulty of having true replicates in a river context. It is also a result of the desire to do what is best for fish now and fear of negative impacts that might result from experimentation with a range of alternatives.
- The TRFE proposed a suite of management actions that are expected to work in combination to achieve goals. However, it is difficult to disentangle findings and determine which individual action or combination of actions is working or not working.
- Factors outside of the Program control (Section 1.3.3) influence Program outcomes.
- The Program has not adjusted for human and environmental changes that have occurred since the TRFE (Section 2.3).
- The ‘adjust’ step has been difficult to implement in practice given ROD limitations (real or perceived).
- Lack of clarity on the legally allowable adjustments to management actions under the AEAM framework of the ROD.
- Implementation has also been hampered by failed motions on agenda items related to adaptive management components. Successful adaptive management cannot occur without commitment from both the scientists (to ensure science is rigorous and decision relevant) and management to ‘close the loop’ at the adjust stage.
- The link back to decision making has been flawed. The Program was described as ‘data rich and information poor’ (Headwaters 2018).
 - The recent effort to draft cross-cutting, multi-year synthesis reports has greatly improved the move from data to information relevant to decision makers.
 - However, synthesis reports are about three years behind data collection and would be more useful if they could be accelerated.
 - The lag in synthesis reporting is likely in part related to the lack of capacity as well as clarity in roles for Program staff and Program funded partner staff (i.e., where do synthesis reports fit on the ‘to-do’ list).
- Insufficient stakeholder input up front. Stakeholder and/or Partner concerns are not tabled early enough and have not been addressed with the same level of rigor as the scientific inputs. This may inadvertently create the situation where decision makers have to make a decision using inputs on the ecological aspects supported by science and inputs on the socio-economic side without supporting evidence either for or against the stated concern (e.g., reductions to fishing). Lack of evidence tends to result in decision makers reverting to risk adverse positions, which will differ depending on their priorities. As noted below, earlier input from stakeholders and/or Partners would mean that the Program can investigate their concerns more fully and provide decision makers with the information they need to make an informed decision.



3.1.3. Roles and Responsibilities

As noted above, lack of clarity in roles has been a major challenge for the Program to date. Figure 5 summarizes each of the six AM steps and uses a RASCI (responsible, accountable, support, consulted, informed) matrix to clarify who needs to be involved at which stages to ensure effective adaptive management. This figure strictly refers to the adaptive management process and does not supersede formal roles and responsibilities as defined in the Program Document.

AM Step	Description	TMC	Program Scientists	TSAC
1-Assess	Define Management goals	Accountable Responsible	Informed	Consulted
	Define specific objectives	Accountable	Responsible	Consulted
	Define targets for objectives; Identify key uncertainties, possible management actions, and stakeholder concerns; Develop models to characterize assumptions/hypotheses about system.	Informed	Accountable Responsible	Consulted
2-Design	Explicit description of proposed action(s) including contrasts and replicates where active AM is possible; Develop associated monitoring plan and data management strategy.	Consulted	Accountable Responsible	Informed
	Determine acceptable level of investment; Agree on proposed action and next steps for alternative outcomes.	Accountable Responsible	Support	Informed
3-Implement	Implement proposed action(s).	Accountable	Responsible	Informed
4-Monitor	Implement monitoring plan.	Accountable	Responsible	Informed
5-Evaluate	Compare monitoring results against objectives and model predictions. Document reductions in uncertainties, evaluate and update hypotheses.	Informed	Accountable Responsible	Informed
6-Adjust	Update the proposed management action alternatives based on learning.	Consulted	Accountable Responsible	Consulted
	Determine acceptable level of investment; Agree on proposed action and next steps for alternative outcomes.	Accountable Responsible	Support	Consulted

Figure 5. RASCI matrix to explicitly identify roles for successful implementation of AM in the Program.¹¹ Responsible: those who do the work to complete the task; Accountable: those who have ultimate control over the task; Support: those who aid responsible team members; Consulted: those whose opinions are sought, 2-way communication; Informed: those who are kept up to date on progress, 1-way communication.

3.1.4. Opportunities

Three scales of adaptive management were identified for Phase 3 of the TRRP. The **first** considers each of the individual management actions (Table 1). As described in the Introduction, there are 5 approved management actions for Phase 3. Each of these is described in more depth in *Appendix B*, including a description of the learning that has happened to date, and any remaining uncertainties. Some actions lend themselves to learning through the adaptive management process better than others. The **second** considers interactions of a combination of management actions. The TRFE strategy was to improve juvenile salmonid habitat through a combination of actions, not individual actions acting in isolation.

¹¹ TMC refers to the Trinity Management Council. Program Scientists¹¹ refers to scientists completing Program work under the TMC direction including the Executive Director’s Office, Partner staff, InterDisciplinary Team (IDT), and supported by technical workgroups, Science Advisory Board (SAB), and contractors. TSAC refers to the proposed TRRP Stakeholder Advisory Committee.



This is an area where more effort could be invested to better understand the interaction of actions (e.g., how physical habitat interacts with flows – Key Uncertainty #1). The **third** and largest scale considers the Program effectiveness at the end of Phase 3 and evaluates whether the current ROD approved strategy is sufficient to achieve Program goals given what we know now (Key Uncertainty #5).

Table 1. This table summarizes the adaptive management potential (Low, Moderate, High) and type (Active, Passive) for individual management actions.

Management action	Potential (AM type)	Rationale
Channel rehabilitation	Moderate (Passive)	As described in <i>Appendix B</i> , there has been a substantial amount of learning to date about how to create the desired physical changes through channel rehabilitation; however, the Program has not yet been able to attribute population responses to the channel rehabilitation sites (<i>Appendix A</i>). The lack of a biological response has led to questions around how the channel rehabilitation sites interact with flows (see Key Uncertainty #1). The design of Phase 3 sites and maintenance of old sites should be informed by a formal review of Phase 2 designs and a commitment to continue to document and incorporate learning about site design and maintenance effectiveness.
Flow management	High (Active)	This action is a good candidate for active adaptive management. There are numerous uncertainties (<i>Appendix B</i>), a high degree of control, existing models, and there is potential for replication and implementation of multiple treatments. In addition, this management action relates to Key Uncertainties #1, 3, and 4 (Error! Reference source not found.).
Gravel	Low – moderate (Active)	This action is a low-moderate candidate for Active adaptive management. Like flows, there is a high degree of control, existing models, potential for replication and implementation of multiple treatments. Much has been learned about how this action is implemented and there are current recommendations on how it should change moving forward. The uncertainties remaining are associated with the natural dynamics of sediment in the Trinity River and the effect to biology of deficit, surplus, and transport. However, the uncertainties (<i>Appendix B</i>) are not currently identified as priorities (Section 3.2.1) and resolving the uncertainties is expected to have less benefit to the TRRP goals.
Watershed restoration	NA	While the Program provides financial support to watershed restoration, the planning and implementation is not a Program-directed activity. Prioritization of watershed restoration in the Trinity is informed by the Integrated Fisheries Restoration and Monitoring Program ¹² and watershed restoration projects are put out to bid and guided by watershed specialists.
Infrastructure	NA currently	There are limited remaining infrastructure actions identified for Phase 3. Most of the infrastructure activities in previous phases have focused on removing barriers (e.g., bridges or homes) to restoration as opposed to being part of the restoration itself. As such the uncertainties as they relate to the Program goals are relatively low. A possible exception is the more recently identified need for improved temperature control at Trinity and Lewiston dams which could be established through installation of a temperature control device to allow selective withdrawal and development of a new conveyance system for Lewiston Reservoir to minimize warming in the reservoir when flow releases are low and air temperature is high (Asarian et al., 2021; Naman 2021). If these recommendations were implemented, in future phases they would provide additional management levers which could be evaluated through active adaptive management.

¹² The Integrated Fisheries Restoration and Monitoring Program guides watershed restoration throughout the Klamath River Basin, of which the Trinity River and South Fork Trinity River are just 2 of 13 sub-basins. (<https://kbifrm.psmfc.org>).



3.2. Science Priorities

The Program goal statement conveys conviction to restore three main attributes of the Trinity River that have been and continue to be harmed by the construction and operation of the Trinity River Division of the Central Valley project. These attributes are defined as follows:

1. The fluvial landscape of the Trinity River Valley and its distribution of alluvial sediments and vegetation, referred to as '**Form**'. (Refer to Goal Statement 1)
2. The flux of energy, wood, water, and sediment which interact with the form of the Trinity River providing conditions for reproduction and maturation of fish and wildlife, referred to as '**Function**'. (Refer to Goal Statement 1)
3. Naturally produced populations of anadromous fish and lawful harvest by fisheries which they support, referred to as '**Fish**'. (Refer to Goal Statements 2 and 3)

These three attributes span disciplines (e.g., physical, fish, wildlife) and leverage commonalities as identified in the updated *Conceptual Model*. In other words, all subject specific objectives can be tied to one or more of these three attributes and therefore one or more of the goal statements. Specific objectives and targets were defined by the Inter-disciplinary Team (IDT) and subject-specific workgroups (*Appendix C*; TRRP 2022) and these provide important Program guidance (e.g., temperature targets by species and life-stage). The objectives and targets should not be prioritized, rather the full list should be used as appropriate to address the key uncertainties related to the three multi-disciplinary attributes (form, function, and fish).

Science priorities include a combination of **key uncertainties** and **core activities** related to each of these attributes. This section defines these terms, identifies the key uncertainties and core activities, and proposes a path forward for Phase 3 implementation.

3.2.1. Key Uncertainties

Key uncertainties associated with the ability to achieve Program goals through management actions provide the framework for adaptive management experimentation, modeling, and learning during Phase 3. Monitoring, modeling, and reporting funded to address key uncertainties will be revisited on an annual cycle as described in the annual science planning process (Section 3.3.3).

The key uncertainties identified for Phase 3 are listed below along with an initial implementation plan. Rationale for each of the key uncertainties is provided in *Appendix E*.¹³

- 1) [Wetted width¹⁴](#) – *Can adjusting site rehabilitation and flow management strategies result in increased rates of wetted width expansion over a range of discharges? [GOAL 1: Form]*

¹³ Key uncertainties are numbered to make it easier to cross reference them later. The numbers are not intended to imply relative importance. Loosely speaking they follow the same sequence as the Program Goal Statements.

¹⁴ Wetted width refers to the interaction of flows with channel form to provide seasonally appropriate habitat.



- 2) Nutrient flux – *Can changing management actions result in greater transfer of energy through trophic levels? [GOAL 1: Function]*
- 3) Temperature regime – *Can we manage temperatures to benefit multiple life stages of salmonids while meeting other species needs? [GOAL 1: Function]*
- 4) Fish production – *At what life stage and/or what habitat resource do bottlenecks to production occur? [GOALS 2 & 3: Fish]*
- 5) ROD effectiveness - *Can we achieve the Program goals with the tools and decision space provided by the ROD? [GOAL 1 Form and function; GOALS 2 & 3: Fish]*

3.2.2. Core Activities

Core activities include monitoring, modeling, or analysis activities that are required (1) for direct assessment of progress towards the goal of the Program, (2) to inform ongoing management decisions, or (3) to support evaluation of the key uncertainties. The list (Table 2) represents a critical set of activities which should be funded throughout Phase 3¹⁵. Other monitoring or investigations may occur as needed, but they should be vetted through the annual science planning process (Section 3.3.3).

Table 2. Core activities are provided along with a brief rationale describing why they are important.

	Core Activities	Rationale
Form	<ul style="list-style-type: none"> • 5-year physical assessment of the 40-mile reach • Aerial imagery – annual • As built surveys – post construction 	<ul style="list-style-type: none"> • Informs Key Uncertainties 1, 4, 5 • Informs progress towards Goal 1
Function	<ul style="list-style-type: none"> • Maintain gage data (i.e., flow and temperature) – annual • Large wood surveys - annual 	<ul style="list-style-type: none"> • Informs annual flow management decisions • Informs Key Uncertainties 2, 3, 4, 5
Fish	<ul style="list-style-type: none"> • Adult and juvenile Chinook salmon population monitoring - annual 	<ul style="list-style-type: none"> • Informs Key Uncertainties 4, 5 • Informs progress towards Goal 2 & 3

3.2.3. Path Forward

This section briefly describes the proposed path forward and expected timelines (Figure 6) to address key uncertainties for Phase 3. Additional detail is provided in *Appendix E*.

Implement active adaptive management of flows (Key Uncertainty: #1-3)

Flow is the best opportunity for Phase 3 active adaptive management (Table 1) and is directly relevant to Key Uncertainties 1, 2, and 3. This means that with one management experiment, at least part of three key uncertainties can be addressed. Appendix E provides an initial adaptive management plan for flow management which should be implemented at the beginning of Phase 3. As noted in Section 3.1.3,

¹⁵ While these activities are expected to remain constant through Phase 3, the specific approaches or level of effort may be revisited at the Program scientist’s discretion as new information or technologies emerge.



this preliminary plan needs to be further developed and vetted with both stakeholders and decision makers. **[Timing: 3-5 years minimum, more likely to continue throughout Phase 3]**

Complete a limiting factors assessment (Key Uncertainty #4)

A limiting factors analysis should be conducted at the beginning of Phase 3 to re-examine the original assumption of limited physical juvenile rearing habitat in the upper Trinity River as being the bottleneck to production. Not only have the analysis tools, models and state of science changed in the last two decades, new factors have emerged that are thought to be causing mortality or otherwise limiting production that were either unknown or not present at the time USFWS and HVT (1999) completed their analysis. **[Timing: 3 years, should be prioritized given the potential for informing other uncertainties]**

Implement core activities (monitoring, modeling, analysis) (Key Uncertainty: #1-5)

These activities provide the fundamental knowledge base for assessing effectiveness of management actions individually and collectively, and long-term consistent funding is critical to maximizing the power of the data to inform management actions and reduce uncertainties. **[Timing: throughout Phase 3]**

Complete a review of Phase 2 channel rehabilitation sites (Key Uncertainty #1)

The Program's treatment of channel rehabilitation sites is an example of passive adaptive management. While substantial learning has been documented, there remains some disagreement about the approach to rehabilitation sites which this review will help to resolve. Such a review could also provide guidance in terms of what site maintenance is required and where / when it should occur. The Program should use the results of this review to develop a river corridor plan. **[Timing: one-off exercise, scheduled for Fiscal Year 2023]**

Review of long-term monitoring activities (Key Uncertainty:1-5)

Numerous long-term, annual or semiannual activities are currently implemented that provide a knowledge base to assess effectiveness of management at achieving programmatic objectives and/or provide data for models (e.g., S3) or efforts (e.g., site restoration design). Many of these activities have been ongoing for many years, decades in some cases. While there is value in data collected during all these activities, a formal assessment of the relative importance and need for each activity toward informing programmatic objectives or other needs has not been conducted. We recommend a thorough evaluation of all long-term monitoring activities for their relevance to management, with particular attention to methods employed, frequency of surveys, and spatial scope. It is important for the Program to find and maintain an appropriate balance between "need to know" and "nice to know" long-term data streams and research to address key uncertainties given available funding for science activities.

Complete a Phase 3 review to determine whether ROD actions are sufficient to achieve goals (Key Uncertainty #5).

The Program will be over 30 years old at the end of Phase 3. Much has been learned since 2000, from Program experience as well as the broader scientific community. The context has also changed substantially with climate change and related factors being more prevalent. The ROD actions themselves should be evaluated at the end of Phase 3 to determine whether they are sufficient to achieve Program goals. This exercise involves a combination of data analysis (using core activities) to determine whether actions are leading to positive changes as predicted and modeling to assess the likelihood of future gains (e.g., maximum habitat possible with footprint of channel rehabilitation sites). If at the end of Phase 3 the data demonstrate that the TRRP is unlikely to achieve Program goals through tools and decision



space provided by the ROD, then ROD actions should be revisited accounting for the current context (Section 2.3) and factors currently outside of TRRP control (Section 1.3.3). Active adaptive management is not possible for this management action as there is no replicate for the TRRP. **[Timing: within the last 3 years of Phase 3]**

Timing and sequencing

The five key uncertainties described above are all considered priorities. However, the timing, duration, and sequencing of related investigations may differ (Figure 6). Active adaptive management of flows (which relates to Key Uncertainties #1, 2, and 3) should be initiated as soon as possible to help achieve Program goals by leveraging the learning to date as well as maximizing the learning potential over Phase 3. The limiting factors analysis (Key Uncertainty #4) should also be fast-tracked to inform the relative necessity and priority order of other key uncertainties. The Phase 3 review (Key Uncertainty #5) can't happen until the end of Phase 3. Some of the investigations will be ongoing (e.g., implementation of core activities), while others have a fixed duration (e.g., Phase 2 channel rehabilitation site review).

Figure 6. Sequencing and expected duration of tasks to resolve key uncertainties. The darker shade of grey indicates greater uncertainty.

Task	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Implement Active AM of flows	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey	Dark Grey
Limiting factors assessment				Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey
Implement core activities (monitoring, modeling, analysis)	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey
Review of Phase 2 channel rehabilitation sites			Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey
Review of long-term monitoring activities	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey
New tasks emerging from SP process		Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey	Light Grey
Program review to determine whether ROD actions are sufficient to achieve goals									Light Grey	Light Grey	Light Grey

3.3. Information Road Map

The Program has struggled to effectively action learning (Headwaters 2018; Section 3.1.2). This section of the plan provides a summary of the types of science activities, the synthesis and process by which science within the Program or external to the Program gets assimilated into the ‘best available Program science’, and finally, an improved annual science planning process.

3.3.1. Science Activities

There are several possible categories of science activities which inform learning within the Program.

Evaluation Tools. These are not investigations in and of themselves but can be used for investigations or experiments (e.g., 40-mile hydraulic model, Stream Salmonid Simulator).

Long Term Monitoring. Science programs that track some aspect of the state of the ecosystem through time. In the short term the results provide the status or a snapshot in time, and over multiple years the



results provide information on trends and variability (e.g., rotary screw traps for juvenile fish population, estimates of adult fish escapement, or stream gages).

Short Term Investigations. Scientific studies that try to fill knowledge gaps identified by the Program (e.g., invertebrate drift study, lamprey spawning survey) or improve evaluation tools.

Learning from Literature. Learning from other systems can be brought into the Program in three ways: the information is incorporated into our understanding of the Trinity Basin without in-basin validation, we replicate the experiment to see if it is applicable in the Trinity Basin, or we assume the study is correct and hypothesize how a change to a management action would affect the system and then test that prediction.

Hypothesis Testing in an Adaptive Management Framework. Ultimately all Program management actions are intended to increase salmon production. However, the mechanism is often indirect, and it is important to understand the hypothesized mechanism behind the management action and salmon populations to evaluate their effectiveness. Ideally, we would be able to simply monitor adult returns and assess progress towards Program goals, but we need to show that the changes we make are or are not affecting the mechanism as predicted. That finding will determine if a change in management is warranted.

3.3.2. Science to Decisions

Any document that the TRRP produces has the potential to affect Trinity River restoration. Many documents that are published in the primary literature, even if they do not specifically refer to the Trinity River or its native salmonids, also have the potential to affect Trinity River restoration. This section describes the process to ensure that new information is adequately reviewed, considered for use in making management decisions, and assimilated into the Program. This is for documents that have already been peer-reviewed and either submitted to the Program or published elsewhere and are relevant to the Program.

The process is a routing and accounting system to ensure that documents are sufficiently considered in the context of adaptive management. The decision to change a management action (e.g., changing the frequency, timing, or duration of floodplain inundation based on the growth rates, survival, or feeding rates of juvenile salmonids) shall be formally documented in the subsequent TRRP annual report. This information is then used to inform annual work plans and plan implementation (e.g., define hydrographs, plan sediment augmentation and channel rehabilitation projects, and prioritize funding of watershed projects). Periodic symposia provide forums for Program scientists to discuss how new information can or should affect the Program.

Three broad categories of documents are considered here, and each has a slightly different path to assimilation:

TRRP-produced scientific reports These reports are funded, at least partially, by TRRP and focus on organisms, processes, or resources of direct interest to the Program. Because they are funded by TRRP, the IDT participates in their scoping, are aware of their finalization, and have advance knowledge of how they might affect future decision-making.



Process:

- 1) Author submits final product to the TRRP Data Steward.
- 2) TRRP Data Steward documents the submittal in the TRRP document tracking spreadsheet and notifies Science Coordinator.
- 3) Science Coordinator forwards document to IDT and schedules a presentation from a co-author. The presentation can be at a workgroup (including IDT), a TMC meeting (if requested by ED), or science symposium. Presentations should focus on the findings and recommendations of the report.
- 4) The IDT determines which workgroup(s) should review the report.
- 5) Workgroup(s) review the report (see review instructions in next section).
- 6) Workgroup submits recommendation to IDT.
- 7) IDT determines if report justifies change(s) to management actions and, if so, makes recommendation to TMC.
- 8) If the document influences a change within the program, the science coordinator publishes the adaptive management decision in TRRP's annual report

TRRP-produced environmental documents These reports are generally authored by contractors so that permits or permission are granted for TRRP projects. Examples include project specific Environmental Assessments under the National Environmental Policy Act and Surface Water Pollution Prevention Plans under the California Clean Water Enforcement and Pollution Prevention Act. These documents generally do not contain new scientific information, but they often describe constraints or make commitments (e.g., temporal work windows, water temperature targets, 1:1 replacement of riparian vegetation) that Program scientists need to know about and affect the level of flexibility of management decisions.

Process:

- 1) Author submits final product to the TRRP Environmental Specialist
- 2) Environmental Specialist documents the submittal in the Project Folder on the TRRP network and notifies Implementation Branch Chief
- 3) Environmental Specialist and Implementation Branch Chief determine whether any new operational constraints or commitments are specified in the document.
- 4) Implementation Branch Chief forwards document to IDT and schedules a presentation from a co-author. The presentation can be at a workgroup (including IDT), a TMC meeting (if requested by ED), or project meeting. Presentations should focus on the permitting requirements identified in the report.
- 5) The IDT determines which workgroup(s) should review the report, and this is based on the management action that is affected by the new constraint or commitment.
- 6) Workgroup(s) review the report (see review instructions in next section)
- 7) Workgroup submits recommendation to IDT
- 8) Science coordinator documents decision in the TRRP document tracking spreadsheet
- 9) If the document influences a change within the program, the science coordinator publishes the adaptive management decision in TRRP's annual report.

Externally produced scientific reports These are generally published in the primary literature but can also be gray-literature reports produced by other entities. Program scientists, on a continual basis, regularly review publications and bring important publications to the attention of workgroups or IDT



representatives on their own initiative. Scientific findings that are consistent with broader knowledge of the Trinity River may influence Program decision-making.

Process:

- 1) Any partner, including members of a TRRP stakeholder advisory group, who finds an external report of interest to them may forward it to their workgroup coordinator and agency IDT representative for consideration of how it may affect the Program. If either their workgroup coordinator or agency IDT representative concurs that it may have potential value, it is submitted to the Science Coordinator or Implementation Branch Chief.
- 2) The Science Coordinator or Branch Chief forwards the document to IDT
- 3) The IDT determines which workgroup(s) should review the report.
- 4) The workgroup(s) review the report (see review instructions in next section).
- 5) The workgroup(s) submits recommendation to IDT for consideration.
- 6) The IDT reviews the recommendation and if they agree, the Science Coordinator documents the decision in the TRRP document tracking spreadsheet.
- 7) If the document influences a change within the Program, the Science Coordinator publishes the adaptive management decision in TRRP's annual report.

Workgroup Review Instructions:

The workgroup coordinator completes a report based on input from the workgroup. The report template describes the major findings of the report, hypotheses that were tested, what management actions the report relates to, what opportunistic learning ideas arose that the authors may not have highlighted and makes recommendations to change (or not) the management action based on the findings of the report. The purpose of this review is to determine what the document 'means' to the program and enshrine that as 'best available Program science'. It is important that reviewers recognize that progress based on reductionist science is usually incremental and based on many contributions over time, so it is reasonable to conclude the report is inconclusive if more research is needed to affirm or change a management action.

3.3.3. Annual Science Planning Process

Given that the 'best available Program science' is constantly evolving in unpredictable ways, it is important to have an agreed upon and formalized process by which annual science decisions can be made as new information arises. This will improve transparency and consistency of decisions as well as improving the efficiency and effectiveness of Program science. The process must ensure the Program benefits from external expertise where necessary while being guided by the extensive history and understanding of Program scientists and partners. This section provides a formalized but flexible process for how key uncertainties are reviewed, prioritized, and actioned. The primary difference in the new process described here is to enable Program scientists to play a stronger role in identifying science needs and guiding science related activities. It also clarifies the roles and responsibilities of different parties to support annual science planning, including the Science Advisory Board (SAB). The process is summarized in Table 3, with more detail provided below.



Table 3. This table provides a summary of the steps, timing, and responsibilities involved in the annual science planning process. IDT = Inter Disciplinary Team, SAB= Science Advisory Board, EDO=Executive Director’s office, TMC= Trinity Management Council.

Step #	Description	Whom	When
1	Confirm Key Uncertainties and determine focus for upcoming funding cycle	IDT	July (of previous fiscal year)
2	Develop specific research questions	IDT with input from SAB	Sept - Oct
3	Develop RFP	EDO supported by IDT + workgroups as needed	Nov - Dec
4	Post RFP	EDO	Jan 1 – Feb 28
5	Evaluation of individual project proposals	Workgroups + SAB	March - April
6	Develop science proposal (i.e., portfolio of projects to fund)	IDT	May
7	Presentation of science proposal	IDT	May
8	Funding decision	TMC	June
9	Contracting	EDO	Oct

Step 1: Confirm key uncertainties and determine focus for upcoming funding cycle (July)

The IDT will confirm the list of key uncertainties is still appropriate. The key uncertainties are not expected to change frequently, but the process must be agile enough to respond to unexpected changes. If a new key uncertainty is identified, it will be discussed and vetted by the IDT using the following questions to guide the discussion:

- Is the new uncertainty nested within an existing key uncertainty? If so, consider adding to the research question parking lot.
- Will assessing this key uncertainty result in revised management actions via AM? Which Actions?
- Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal (i.e., form, function, fish)?
- What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?
- Is there a sequential nature required to resolve key uncertainties? If so, where in the sequence is this key uncertainty?

It will not be possible to resolve all key uncertainties in one year. An initial multi-year plan or path forward is described in Section 3.2.3 and Figure 6. However, the IDT shall update the plan and determine the focus of the upcoming funding cycle annually. The IDT will consider what has been learned to date, budget, and context (e.g., drought conditions). In some years the IDT may choose to focus on a single key uncertainty. In other years the IDT may choose to spread effort across multiple key uncertainties simultaneously.

Step 2: Develop specific research questions (Sept - Oct)

The desired outcome of this step is a short list of the most important and time sensitive research questions to address the focal key uncertainties identified in Step 1. These research questions will form



the basis for specific 'Requests For Proposals' (RFPs) – Step 3. The research questions must be specific enough to ensure the proposals address the identified Program need but should not prescribe the approach or methods, so that the Program is able to benefit from external expertise. A parking lot of potential research questions will be cataloged and maintained to capture good ideas that are not selected for a given year.

Process:

- Research questions may be suggested at any time by Program scientists and recorded in the research question parking lot.
- The IDT will meet and identify a draft list of the most important / time sensitive of the potential research questions and document any supporting information. The key uncertainties and annual focus identified in Step 1 provide the bounds of the IDT discussion.
- The IDT and SAB will meet to discuss the draft list of potential research questions, evaluate trade-offs, and finalize the list which is moved to Step 3. Involving the SAB early in the annual science planning process will provide an independent check on Program direction. Direct interactions among the IDT and SAB will optimize the Program's benefit from SAB expertise.

Step 3: Develop RFP(s) (Nov – Dec)

The RFP(s) is/are developed by the EDO with support from the IDT and workgroups as necessary.

The number of RFPs will vary between years depending on the nature of the research questions and the desired skill sets. The budget may be pre-determined (e.g., 20% for RFP A and 80% for RFP B) or may be open (i.e., one pot to be split among the projects depending on the submissions) and criteria for prioritizing allocations in an open setting will be done prior to issuance of RFPs.

The RFP should include these elements at a minimum:

- Specific research questions (Step 2)
- A description of how the research question(s) is/are expected to help reduce the Key Uncertainties (Step 1)
- A description of how the project is expected to influence management decisions
- A description of how the project will help to build Program capacity (e.g., describe knowledge transfer requirements)
- The nature of the project (e.g., literature review, modeling, data collection, field study)
- Desired skill set
- Deliverables and schedule
- Budget information (may be RFP specific or not, as described above)
- Explicitly stated proposal evaluation rubric with definitions

Step 4: Post RFP (Jan 1-Feb 28)

The EDO is responsible for administering the RFP. The goal is to have a consistent funding cycle, so proponents are prepared to respond each year, resulting in greater likelihood of receiving high quality proposals.



Step 5: Evaluation of Proposals (March – May)

Proposals are expected to respond directly to the specific research questions outlined in Step 2. The process for evaluating and prioritizing proposals is as follows:

- If the proposal does not address the questions and content noted in the RFP, it is dismissed outright by the EDO.
- Proposals are assigned to the appropriate workgroup(s) depending on the research question(s) by the IDT.
- Workgroups use a standardized form based on the evaluation rubric included in the RFP to evaluate, independently, the technical merit of each proposal. Workgroup members will not review proposals where they have a conflict of interest (i.e., member is part of the proposal team or works for an organization on the proposal team). The workgroups screen out any proposals which do not meet the minimum technical requirements.
- The SAB reviews the short list provided by the workgroups and ranks the proposals within each research question. This allows for independent evaluation of proposals while focusing the SAB effort on the highest quality proposals.
- In cases where additional peer review is desired for a particular RFP/research question(s) (e.g., SAB does not have relevant experience) it is possible to assemble a group of ‘SAB-like’ scientists to review and rank projects.

Step 6: Develop Science Proposal (May)

The IDT recommends which portfolio of projects to fund based on the workgroup and SAB reviews. This recommendation is documented along with rationale in a memorandum to the EDO.

Step 7: Present Science Proposal (May)

The IDT will provide updates on the annual science planning process at quarterly TMC meetings. In particular, the IDT will prepare and present a summary of the annual science planning process and recommended portfolio of projects along with detailed rationale for the recommendations to the TMC one month in advance of the June TMC meeting. This is an important step to ensure that the TMC has the necessary information to make a funding decision.

Step 8: Funding Decision (June)

The EDO presents the budget to the TMC. The budget includes the proposed science budget (i.e., projects to address key uncertainties and core activities). The TMC votes on the budget as per the terms described in the Program Document.

Step 9: Contracting (Oct)

The EDO is responsible for administering contracts on behalf of the Program.



Appendix A - TRFE Central Hypotheses

The management actions prescribed by the TRFE and adopted by the ROD were designed to address production bottlenecks as they were understood using the best science available at the time. The three central hypotheses listed below detail expected response to prescribed management.

1. Habitat diversity in the upper Trinity 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.
2. 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.
3. Salmonid smolt survival will improve as a result of better temperature conditions that increase growth and promote smoltification and reduced travel time associated with emigration.

These original hypotheses are tied to three aspects that continue to be identified as required for the success of the Program: Form, Function, and Fish (Section 3.2). AM requires a set of measureable responses for stated hypotheses to inform future changes to management. A few examples from the TRFE are provided below:

- Channel geometry needs to be described via transects, and 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 salmonids.
- The amount of habitat suitable for spawning and rearing needs to be measured annually and extrapolated to the entire 40 miles.
- The length and weight of juvenile Chinook salmon young-of-year can be sampled every few weeks, and substantial trapping effort at the downstream end of the study segment is needed to estimate the total numbers of juveniles leaving the segment.

Central Hypothesis 1

The first central hypothesis 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.

- What we have learned
 - This hypothesis is redundant with the second central hypothesis. While habitat diversity is not specifically referenced in the second central hypothesis it is implied as habitat diversity is a desirable quality for juvenile salmonid rearing.
- A discussion of relevance, gaps, and potential revisions
 - The river's form is still relevant as it moderates the flux of energy and materials that allow the river to function.



- The desired condition described in the TRFE is insufficient and a river corridor plan with location specific desired outcomes for restored river form would provide context for nondescript terms such as diversity, complex, dynamic, quality, and quantity needed to measure progress.
- Habitat diversity can result from changing flows not just manipulating channel form. Consideration of how habitat changes with flow is essential to effective management.

Central Hypothesis 2

The second central hypothesis 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.

- What we have learned
 - The original definition of juvenile rearing habitat referred specifically to physical aspects of juvenile habitat area. Habitat quality also includes elements, such as food availability and access to optimal temperatures for salmonid growth, which should be included in the list of factors evaluated for limiting salmonid production.
 - Actions have affected habitat diversity at the site scale and to a much lesser degree the system scale, mainly due to changes in the aggregate of sites.
 - Habitat diversity at both meso- and micro- scales can be increased through manipulation of flows as well as channel restoration.
 - We have seen a small increasing trend in physical habitat quantity at baseflow over time (~ 1.5% per year). Lack of systemic estimates of habitat quantity over a range of flows prior to 2016 prevent long-term assessments of progress.
 - Rehabilitation sites provide more juvenile rearing habitat at moderate flows or suffer less severe “habitat dips” than the unrestored channel.
 - Most sites show large increases in juvenile rearing habitat immediately after construction, but the trajectory of evolution at too many sites shows a gradual decrease in physical habitat availability, though the habitat availability at restored sites remains higher than pre-construction conditions in all cases.
 - There is strong evidence that increases in adult-to-smolt production of juvenile Chinook salmon can be attributed to habitat (either as originally defined or as should be expanded) gains associated with implementation of the ROD flows (Pinnix et al. 2022).
 - There is not convincing evidence that the cumulative effect of rehabilitation sites has translated into any trends in outmigrating populations of juvenile Chinook salmon (Pinnix et al. 2022). Potential hypotheses for this include: that physical habitat projects are not affecting population production, that physical habitat projects are benefitting production and compensating for observed negative population pressures such as reduced fecundity and adult abundance, or hydrologic limitations on habitat availability caused by drought and flow management prevent fully realized benefits from physical habitat projects.



- The increases in discharge (magnitude, duration, frequency) prescribed by the TRFE and the reduced volume of supplied gravel have not caused the amount of geomorphic change predicted outside of constructed areas by the TRFE.
- On average, most juveniles have migrated out of the Restoration Reach prior to elevated discharge beginning in April, thereby minimizing benefits from increased habitat availability.
- A discussion of relevance, gaps, and potential revisions
 - It is possible that physical habitat measures as originally defined may not sufficiently indicate quality of habitat and may not be the factor limiting juvenile production
 - Survival studies and full life cycle models should be used to identify population bottlenecks.
 - Juvenile rearing habitat conditions relative to flow need to have a more defined target than “stable” physical habitat availability.
 - Focus on habitat complexity and dynamism, previously not considered elements of habitat “quality,” such as flow and temperature, may lead to important insights.
 - Seasonal conceptual models suggest that habitat should be supply and demand driven, and that temperature, flow, and seasonal food resources are critical components of habitat, although not all elements may be limiting at all times of year.

Summary:

Juvenile salmonid rearing physical habitat, believed to be limiting smolt production in the Trinity River, did increase in both quantity and quality following the implementation of the 2000 ROD recommendations in Phase 1 and 2. Site-level persistence of restoration benefits varies, but baseflow rearing habitat area increased by approximately 25% and suffers less “dip” across flows. A doubling of habitat will require adjustments to rehabilitation footprints and/or strategy and flow regimes that inundate surfaces for longer durations during the rearing period.

Revised hypothesis:

By increasing the connectivity of the river with the valley bottom via contemporary hydrology and flow redistribution to promote ecological process and aquatic ecosystem restoration, improvements to habitat quality and target species productivity will be obvious.

Central Hypothesis 3

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.

- What we have learned
 - The opposite is true: colder temperatures due to elevated releases in the spring during the period of thermal stratification in Trinity Reservoir have limited growth and caused a reduction in Chinook salmon smolt size (and in turn survival based on widely held and supported beliefs regarding correlations with fish size).
 - Adult returns of salmon to the Trinity River have decreased, while steelhead populations have increased. There are many factors driving adult population trends, some of which we likely can control (e.g., size and timing at out-migration).



- A discussion of relevance, gaps, and potential revisions
 - It is not clear if any of the juvenile abundance gains associated with the increased ROD flows have ties to water temperature. However, given size-survival relationships, we're likely underperforming the potential afforded by the ROD flows due to the slower juvenile salmonid growth that has occurred from the ROD flows.
 - We need to change management of flows and water temperatures to realize the previously anticipated improvement in growth.
 - Size dependent survival and timing of transit to the Klamath River and ocean entry are demographic rates of interest connected to temperature.

Summary:

Juvenile Chinook salmon populations have more than doubled since 2004 (Pinnix et al. 2022) as a result of implementation of the ROD in Phase 1. However, there is no evidence that water temperature conditions contributed to this increase, and decreased growth and more consistent timing of emigration have been observed.

Revised Hypothesis:

By reducing temperature suppression during the period of juvenile rearing and outmigration and increasing the area of aquatic habitat inundated prior to and during emergence and early rearing, behavioral benefits and increased growth will result in more fit outmigrants with higher survival.



Appendix B - Management Actions

This section includes a short summary describing the evolution of thinking and the current understanding for each of the ROD management actions. Summaries include a description of the action and why it was originally implemented, what has been done so far, what has been learned, and identifies remaining uncertainties. Infrastructure is not discussed in this appendix as uncertainties and lessons learned were not relevant. This appendix documents the Program scientists' understanding of the evolution of learning for each management action in a concise and readily accessible way which represents a significant advancement given the range of perspectives among Program partners. Where different perspectives could not be resolved, they are stated here as uncertainties.

Channel Rehabilitation

River rehabilitation on the Trinity River has undergone a series of changes as the philosophies and expectations of what the existing stream power could accomplish were tested. The two ends of the philosophical restoration spectrum are, design a site to set up the processes that will result in the desired features and river function, or construct the desired features and let it evolve from there. The TRRP has shifted between these philosophies through time as designers learned from each rehabilitation effort, starting out embracing the "set up the process and let the river do the work", and then moving toward a more "build-as-desired" approach assuming it will not change dramatically. Presently most designs follow a build big approach, constructing many of the desired features but also setting up the processes that will facilitate larger changes into the future.

After the TRFES was completed, rehabilitation took the form of removing vegetation along the low water edge and laying back the banks of the channel to create floodplain connectivity at Hocker Flat (RM 79.0) (2005). The hypothesized response was that the channel would evolve and function as an alluvial channel once the shackles (for example, confining berms) had been removed. The responses at sites with this treatment were slow to manifest, and while they did create features such as mid channel bars and small vegetated islands, the simple channel largely remained with a trajectory returning to nearly the pre-rehabilitated condition.

The next set of sites retained berm removal and floodplain lowering but added off-channel features, such as side channels, alcoves, point bars, and large wood to create hardpoints and encourage channel evolution post-construction. These were desirable features, and based on results of the previous rehabilitation projects, it became evident the river didn't have the stream power to create these features in the necessary timeframe. Indian Creek Side Channel (2007; RM 94.6-RM 94.0), Cableway and Bucktail/Dark Gulch (2008; RM 106.2) are examples of this strategy. This method created much higher immediate gains in habitat, in part because the large wood facilitated geomorphic process and acted as cover for juvenile and adult salmonids. Through time, many of the constructed side channels had sediment deposits in the entrances or exits that made them function as alcoves rather than side channels at low flows. While not necessarily a bad result, future designs looked at ways to ensure side channel entrances remained unobstructed for longer periods.

The most extreme example of 'build as desired' was at Sven Olbertson (2008; RM 111.4). This site is very close to Lewiston Dam. The absence of any tributaries above the site ensured that dam releases were the only source of flow variation the site would experience. This site had a network of small side



channels, some of which flowed into a previously disconnected duck pond making it suitable for salmonids. Large wood features were scattered throughout the site enhancing habitat features and routing flow through the various channels.

Starting in 2009 the amount of wood and size of wood structures increased by orders of magnitude. Sawmill had some of the first log jam type features and a few hundred trees were placed throughout the site. Wood continued to play a major role in all sites since Sawmill was constructed. Quantity, location, and arrangement of physical habitat continued to improve through time.

Lowden (RM 104.7) and Reading creek (RM 93.0) were constructed in 2010. These sites incorporated larger scale adjustments in the form of channel relocation. The forced meander at Lowden Meadows shifted the mainstem a full channel width and the old mainstem became an alcove. This strategy was employed at numerous subsequent restoration locations.

By this point it was largely accepted that a heavier hand was required to scale the river to the flows allowed by the ROD. These types of features and their general arrangement on the landscape were consistently employed from around 2011 through 2021. The biggest difference between rehabilitation locations during this period was the scale of the sites. This was largely driven by valley width and the volume of sediment deposits from pre-dam flows or mine tailings which need to be moved to facilitate river processes.

As rehabilitation moves forward, questions that need to be addressed are the role of revisiting sites to take advantage of areas not incorporated in the initial design, e.g., Bucktail (RM 105.7) was constructed in 2008 and revisited in 2015, and the occurrence and frequency of maintenance at prior rehabilitation sites if deemed appropriate. The Program has been unable to attribute any positive population responses in juvenile Chinook salmon to the habitat changes occurring at channel rehabilitation sites. This result has prompted some Program partners to encourage a critical evaluation of the restoration site design and implementation processes, with the hope that refined techniques will lead to measurable population responses. However, other Program partners disagree and believe refined techniques are already being introduced into the site design and implementation process and the Program should continue with current design and implementation practices.

Flow Management

Background

Flow management was recognized as critical for sediment management as early as 1980 (Trinity River Stream Rectification Act, Pub. L. No. 96-335), and in 1984 substantially reduced instream flows were recognized as a primary cause of degraded fish habitat and population declines in the Trinity River downstream of Lewiston Dam (Trinity River Basin Fish and Wildlife Management Act, Pub. L. No. 98-541). The 1984 act mandated the implementation of the Trinity River Flow Evaluation Study (TRFES), which, among other management actions, recommended specific annual flow releases to address sediment management and meet fishery restoration goals. These annual flow releases were formalized with the signing of the Record of Decision (ROD, U.S. DOI 2000) and the finalization of the EIS in 2000 (USFWS et al. 2000). Flow management remains one of the most important tools available to sustain and restore ecosystem function and fishery populations in the Trinity River.



Five general purposes of reservoir releases were presented in the TRFE (Section 7.1.1, USFWS and HVT 1999): (1) prescribe flows based on water year classification to restore inter-annual variation; (2) restore snowmelt hydrograph components; (3) prescribe variable releases to rejuvenate and maintain alluvial processes; (4) prescribe releases that provide suitable habitat for all life stages of anadromous salmonids; and (5) prescribe releases that meet salmonid temperature needs. Flow releases since full implementation of ROD flows in 2004 have addressed all these purposes with varying degrees of success.

Implementation

The ROD included specific water volume allocations for each of five water year types from Critically Dry to Extremely Wet, determined annually in April based on projected inflow to Trinity Reservoir for the water year October 1 to September 31 (<https://cdec.water.ca.gov/snow/bulletin120/index2.html>). Elevated releases in accordance with the ROD began in 2001 but were limited by court order until the first full ROD volumes were released in 2005. Since that time, actual restoration releases have been within 1% of the allocated volume in all but 5 years and have not exceeded a difference of 3% (Buxton 2021). Each year the TRRP Flow Work Group develops hydrographs, models the performance of candidate hydrographs, and provides a recommendation to the Trinity Management Council for approval and subsequent implementation by USBR Central Valley Operations. Candidate hydrographs are evaluated based on a combination of programmatic objectives, a list of functional flow considerations recommended by the Flow Work Group, and results from available models for quantifying success toward meeting objectives and functional flow considerations.

ROD findings

Inter-annual variation in the volume, peak magnitude, duration of elevated flows, and other metrics have increased since implementation of ROD flows. However, there remains no inter-annual variability in releases from Lewiston Dam during summer and winter baseflow periods. Whereas the winter period comprises the greatest amount of inter-annual variability under natural flow conditions. Snowmelt hydrograph components have been restored through annual releases starting in mid-April, though current flow management extends this period beyond what would be observed under natural flow conditions in many years. Variable releases in combination with coarse sediment augmentation have increased changes in active alluvial bars upstream of Indian Creek since implementation of the ROD, but less change in the active channel has been observed in downstream reaches (Curtis et al. 2015). Increased water volume releases under ROD management have also increased the amount of bedload transport, which is a necessary component of alluvial processes.

Releases intended to provide suitable habitat for all life stages of anadromous salmonids were integrated into annual ROD flow schedules, but they have had a mixture of results. For example, elevated flows in spring and early summer increase availability of physical habitat (e.g., appropriate depths, velocities, and access to cover) for juvenile salmonids, but at the same time cause temperature suppression that limits growth. However, the increase in physical habitat in the restoration reach occurs after more than half of the juvenile Chinook salmon have emigrated out of this section of the river. Summer baseflow provides suitable temperatures for holding adult spring Chinook salmon, but also cause temperature suppression close to Lewiston Dam that may limit growth of juvenile Coho salmon and steelhead that rear year-round. Static and low winter baseflow was intended to provide spawning habitat and to protect early life stages of salmonids, but the effectiveness toward meeting these objectives has not been directly evaluated. Winter baseflow was informed largely by the PHABSIM model, which was accepted and widely used in the industry at the time but has since been recognized as



deficient in many respects (e.g., see Railsback 2016). Modeling by Goodman et al. (2018) indicates an ascending and variable baseflow in fall provides more spawning habitat across a range of flows than static baseflows. The roles of timing, duration, and magnitude of flows and the interactions among these factors in providing habitat is being re-evaluated in the Program.

Due to the lack of a temperature control device in Trinity Reservoir, flow management and temperature management are inextricably linked, thus prescribed releases are directly linked to salmonid temperature needs. This has, in part, led to varying success toward meeting temperature targets, which in turn encouraged the re-evaluation of existing targets and the recognition that a rearing target is needed. Temperature targets for holding adult salmonids have largely been met since implementation of the ROD, and violations of targets have been minimal when they have occurred. In contrast, juvenile outmigration temperature targets at Weitchpec are exceeded annually and by a considerable amount in some years. A recent re-examination of outmigration targets conducted by the Fish Work Group have resulted in adoption of a rearing temperature target range and the dismissal of the Weitchpec outmigration targets by Trinity Management Council (TRRP 2022). There has been widespread recognition within the Program that temperatures in the restoration reach are suppressed by spring dam releases beginning in mid-April, which is presumed to have resulted in suppression of growth and smaller size at outmigration.

Evolution of strategy

Implementation of annual ROD flow releases have provided numerous benefits to the Trinity River. In combination with other management actions, flows have essentially eliminated the fine sediment impairment that existed upstream of Douglas City, increased coarse sediment transport, improved temperature conditions for holding adult spring Chinook salmon, and increased juvenile salmon production.

However, some lessons have been learned about how flow management, and by extension temperature management, can be improved. Providing suitable temperatures for rearing juvenile salmonids was not an explicit objective of ROD releases, but there has been a growing awareness within the Program that elevated flows beginning mid-April and extending into summer cause suboptimal cold temperatures, particularly within the restoration reach, that are presumed to suppress growth of juvenile salmonids and delay their emigration to the lower Klamath River. Performing geomorphic work to promote dynamic alluvial processes¹⁶ was an explicit objective described in the ROD, and a sustained peak flow was presumed to accelerate these processes with available water. Subsequent research indicated that sediment transport rates were not maintained for the several days of sustained peak flows, but rather transport rates decreased through time at a given flow level, a phenomenon known as clockwise hysteresis (Gaeuman and Steward 2017). Peak flows have since been modified to incorporate shorter duration peaks to improve efficiency and preserve water for meeting other objectives. Promoting recruitment of riparian hardwood trees on variable upslope elevations was also an explicit objective of ROD releases. Early work by Program scientists led to a better understanding of how this objective could be achieved by adjustments in flow management to provide better recession rates from peak and snowmelt flow releases and time them to coincide with cottonwood seed dispersal and germination (HVT and McBain & Trush, 2013). The timing and magnitude of flows necessary to achieve riparian recruitment objectives conflict with the desire to provide optimal rearing temperatures for juvenile

¹⁶ The Program lacks a coherent definition for 'alluvial process', while sediment transport is one component, it does not tell the whole story of 'alluvial processes'.



salmonids in spring and early summer so long as temperature and flow cannot be managed independently.

As of water year 2020, functional flow considerations included primary production and invertebrate community development via floodplain inundation duration, preventing scour of foothill yellow-legged frog egg masses, riparian recruitment, fine sediment and bed load transport, geomorphic change, up-ramp and down-ramp rates, temperature objectives, encouraging emigration of hatchery releases, and effects on in-channel construction (Buxton 2022). Population-level impacts to juvenile Chinook salmon have informed flow planning through the use of S3 (Perry et al. 2018), but the application of this model in recent years suggest that differences among proposed hydrographs are potentially too small to cause measurable differences in population responses. Lastly, there have been considerable improvements in accuracy of methods to forecast reservoir inflow volumes, which ultimately determines the water volume available for release to the Trinity River. This improved capacity has yet to be leveraged for the benefit of the river but provided the basis for new methods of flow management advanced as the preferred alternative in an Environmental Assessment (DOI, BOR, TRRP 2022).

Remaining Uncertainties

Despite considerable learning and adapting since implementation of the ROD, some uncertainties remain regarding the effects of managed flow releases in the Trinity River. This should by no means be considered a comprehensive list.

- How does the timing, frequency, and magnitude of flows affect macroinvertebrate community succession and thus the timing and magnitude of food availability for rearing juvenile salmonids? Can changes in flow management benefit the foodscape of the Trinity River?
- How does the timing and magnitude of spring releases affect the growth, survival, and timing of juvenile salmonid outmigrants, especially with respect to conditions in the lower Klamath River?
- Can dam infrastructure be updated to allow temperature control independent of flow?
- What is the appropriate balance between achieving riparian hardwood recruitment (elevated flows with a protracted ramp down) and achieving juvenile rearing temperature targets (earlier return to summer baseflow), so long as temperature and flow cannot be managed independently?
- What proportion of desired geomorphic change, necessary for habitat creation to support restored fisheries, can be accomplished through flow actions?
- Once desired geomorphic and habitat conditions are achieved, are current limited flow releases from Lewiston Dam capable of maintaining and/or renewing habitats?
- Are ROD volumes and flow management sufficient for recovery of fisheries and ecosystem function?
- Do current summer and winter baseflows meet programmatic objectives and can water volume currently released between mid-April and mid-August be redistributed to other times of year to better meet programmatic objectives?
- As a response to climate change, “greater emphasis will need to be placed on conserving the cold-water pool in Trinity Reservoir, much like is currently adopted in Shasta Reservoir management” to protect incubating salmonid eggs (Asarian et al. in review).
- An assessment of multiyear drought effects on Trinity Reservoir storage levels, water temperatures, and the resulting ability to meet temperature criteria in the Trinity River should be conducted (Asarian et al. in review).



- Development of a tool for accurately predicting Trinity River water temperatures in summer at flows lower than RBM10's current lower limit of around 350 cfs (Asarian et al. in review).

Gravel Augmentation

Gravel augmentation was among the management actions proposed in the TRFE and authorized in the ROD. However, gravel augmentation began on the Trinity River well in advance of these efforts, in 1972. This is because the construction and operation of the Trinity River Division in the early to mid-1960's stopped the transport of all but the finest particles to the Trinity River below Lewiston Dam. One of the fundamental things that a river does is transport and sort sediments. These sediments provide critical habitat for a variety of organisms. In the absence of natural recruitment of sediments from upstream the stream bed coarsens as smaller more mobile sediments (silt, sand, gravel) are evacuated at a faster rate than larger skeletal components of the streambed (cobbles, boulders, bedrock). A more uniform and coarse bed provides habitat for fewer organisms and can reduce productivity. This type of habitat degradation was apparent in reaches of the Trinity River near Lewiston Dam soon after dam construction and is widely documented in other regulated rivers.

Gravel augmentation has been implemented nearly annually since the ROD and is conducted at both low and high flow. Augmentation has taken place at five locations above Grass Valley Creek and as part of numerous channel rehabilitation projects. Water year specific annual high flow augmentation volumes prescribed by the ROD have been reduced as monitoring has shown that flow releases have less capacity to transport gravel than previously estimated. High flow augmentation volumes were traditionally developed with the goal of producing a "balanced" sediment budget and have been placed at low flow prior to a peak release or during the ascending limb and peak of flow release. Contemporary augmentation volumes are based on the amount of gravel predicted to pass monitoring sites where transport relationships have been developed for flow and are placed at low flows prior to a peak release or at intermediate flows. Augmentation at high peak flows is avoided, as this often leads to sediment being stored on high surfaces away from the channel near the augmentation site.

However, the conceptual model at the time of the TRFE, the "conveyor belt", has not reflected observed coarse sediment transport patterns. Instead, it appears that there are both sources (tributary deltas, abandoned floodplain terraces, mine tailings, bars) and sinks (scoured channel bed, low floodplains, wide channels), that interrupt coarse sediment transport and result in variable storage times and transport rates in different stream reaches. Individual gravel and cobble particles in transport tend to become trapped in developing depositional features whereas particles mobilized from active erosional areas replace them in downstream transport. We have documented increases in habitat and channel complexity after augmentation efforts, but also a subsequent reduction of habitat and complexity if augmentation continues at the same location after any deficit has been corrected. Some observers have also begun to question whether a balanced sediment budget will drive channel form change in the desired direction. Alternatively excess supply provided to a reach in deficit or reduced supply to a reach in surplus may yield more desirable change.

More recent augmentation recommendations under consideration include:

- Include finer grain sizes to improve habitat conditions for a variety of organisms.
- Augment sediment supplies upstream of newly restored sites to promote site evolution.
- Define site specific objectives for local change rather than focusing on supplying sediment to downstream reaches.



- Suspend augmentation at sites without sediment deficit.
- Increased frequency directly below Lewiston Dam where the natural supply of bed material is zero.
- Avoid augmentation at peak flows by placing gravels at low flows or targeting intermediate flows to encourage gravels to remain in the channel.
- Avoid overloading the same reach with repeated coarse sediment augmentation as this has been found to result in decreased topographic complexity.

Areas of uncertainty include:

- Locations and volumes of sources and sinks.
- Biological effects on primary, secondary, and tertiary productivity in aquatic systems and productivity of riparian of deficit, surplus and transport. A first step would be to articulate hypotheses for the relationship between sediment and each of the potential biological effects.
- Over what geographic and time scales is a balanced sediment budget appropriate, if any?

Documentation of these lessons learned and ongoing efforts to inform adaptive management can be found in: Buxton (2021); Gaeuman (2008); Gaeuman and Krause (2011); Gaeuman (2013); Gaeuman (2014); Gaeuman (2020); Gaeuman and Stewart (2017); Gaeuman et al. (2016); Kondolf and Minear (2004); Krause (2012); Matthews (2015); Matthews (2020); McBain and Trush Inc (2007); Ock et al. (2015); TRRP (2007); TRRP (2012a); TRRP (2012b); USFS and USBR (2006); Wilcock (2010).

Watershed Restoration

Watershed restoration was among the management actions proposed in the TRFE and authorized in the ROD. At the time the management action was characterized as addressing fine sediment sources within the watershed and improving fish passage. Both issues were well established in the literature of the time due to recent impacts of extensive road construction to facilitate logging in sensitive watersheds throughout Pacific salmon habitat. Many watersheds have begun to recover from this widespread disturbance and best management practices of logging have improved dramatically both in scope and scale of implementation. On the Trinity River, impoundments on Grass Valley Creek (i.e., Buckthorn Dam and, recovery of watersheds, and reintroduction of high flows all resulted in an astonishing recovery from the fine sediment impairment present in the 1980's and early 1990's. Flows have been sufficient to maintain the gravel bed and scour fines from naturally occurring holes on the Trinity River.

Watershed restoration funding has been awarded on nearly an annual basis since the ROD and averaged \$500,000 per year. The geographic scope over which watershed work can occur has ranged depending on interpretation and opinion of USBR over the 20+ years since the ROD. The most expansive range is the entirety of the watershed below Lewiston Dam including the South Fork Trinity River (ROD preferred alternative, page 14). Operationally the watershed upstream of the North Fork Trinity River to Lewiston Dam was used for several years. Projects have ranged from those originally identified, road maintenance and decommissioning and barrier removal, to channel rehabilitation and instream flow projects. However, the mechanisms for selecting and awarding projects within the current structure of both the TRRP and USBR have led to significant issues selecting projects for award and providing funding, resulting in several years of unsuccessful implementation of the grant program.



Recent reporting suggests that there is now a fine sediment deficit in the Trinity River upstream from Indian Creek. As a result, dredging of sediment collection ponds, Hamilton Ponds, on Grass Valley Creek has been recommended to be suspended and there is consideration of adding fine grains to augmentation gravels (*Fine Sediment*). Conversely, priorities of ground water recharge and storage and forbearance for water users have risen in importance to address concerns during the ongoing multi year drought/s California is experiencing.

Recent funding opportunity announcements have expanded the interpretation of fish passage to include lateral habitat connectivity and instream flows. While the interpretation of fine sediment management includes restoration of tributary habitats to facilitate natural sediment storage and routing. The current geographic extent considered for projects is the watershed below Lewiston Dam and upstream of Weitchpec. Recently a third-party administrator ([National Fish and Wildlife Foundation; nfwf.org](https://www.nfwf.org)), experienced with similar programs, has been assigned the responsibility of selecting and awarding projects. There is also a hope that the Integrated Fisheries Restoration Monitoring Plan for the Klamath Basin, in development by the USFWS, will be used to prioritize restoration within the watershed and guide project selection in the future.

Documentation of prior justification and description of the watershed actions and ongoing efforts to inform adaptive management include: Buxton (2021); CDWR (1978); Dickenson (2008); Gaeuman and Krause (2013); Krause (2012); Larsen (2003); Lisle and Hilton (1992); Madej (2007); Milhous (1994); TRRP (2012); NMFS (2020); Stalnaker and Wittler (2000).

Fine Sediment Reduction

The Trinity River is listed on the U.S. Environmental Protection Agency's Section 303(d) List for impairment or threat of impairment to water quality associated with sediment. Much effort from various government agencies and non-governmental organizations was applied to correcting this impairment over the past several decades. A Total Maximum Daily Load (TMDL) was also developed (EPA 2001) and this was almost entirely based on the needs of anadromous fishes in the Trinity River. The sediment remediation work in the Trinity River watershed, coupled with frequent high-flow releases from Lewiston Dam that flush fine sediment from the Trinity River channelbed, have led to an obvious reduction in fine sediment in the channelbed of the Trinity River (Figure 7).



Figure 7. Photos of the same photo-points before and after ROD flows and watershed-scale fine sediment-reduction activities. From Buxton (2021).

Buxton (2021b) reported that this reduction in fine sediment in the channelbed, particularly in the reach between Lewiston Dam and Rush Creek, has led to a condition where the channelbed is actually deficient in fine sediment. This deficiency can be problematic for geomorphic processes as well as limiting habitat for aquatic and riparian species. The report also recommended augmenting fine sediment in the aforementioned reach.

The TMDL has affected the Program primarily through turbidity limits during channel rehabilitation and sediment augmentation projects. Gravel placed during both types of work is processed so that essentially all sediment < 2.0 mm in diameter is removed. The TMDL, at face value, also precludes deliberately adding fine sediment to the Trinity River similar to how coarse sediment is augmented. These regulatory requirements related to the 303(d) listing strongly contrast with recent scientific findings and recommendations, so the Program considered pursuing de-listing of the Trinity River. TRRP staff met with representatives of the North Coast Regional Water Quality Control on 12 May 2021 to reconcile the scientific findings with regulatory requirements (Gutermuth pers. comm.). It was acknowledged that not all parts of the Trinity River watershed had recovered enough, or had threats reduced enough, to warrant de-listing. More importantly, it was found that management actions to address fine sediment deficiencies could be implemented without de-listing. For example, project level permits, or waivers, could be issued to allow un-processed or bank-run sediment to be introduced to the Trinity River to more closely mimic natural sediment inputs and realize the ecological benefits they provide. Also, proposed Lewiston Dam releases that are synchronized with the natural tributary floods that introduce fine sediment to the Trinity River are expected to distribute fine sediment more naturally. At present, the Program will continue to provide information to regulatory agencies that will support an eventual de-listing if conditions warrant it. In the meantime, projects to address fine sediments are intended to be proposed, with waivers sought from regulatory agencies when 303(d) listing would prevent implementation.



Appendix C - Objectives and Targets

This appendix provides a brief overview of the Program’s objectives and targets, including why they are important, how they were developed and provides long-term guidance on how they should be updated over time.

Specific objectives and numerical targets are necessary to guide implementation of management actions and evaluate progress towards Program goals. The IAP (TRRP and ESSA 2009) provided an extensive objectives hierarchy and preliminary performance measures and targets where possible to achieve Program goals. Over time, the Program determined that these needed to be refined, reduced, and reorganized. In Spring 2022, the IDT prepared an updated objectives and targets report (TRRP 2022). The report describes the process each of the four work groups (fish, flow, physical, and Riparian and Aquatic Ecology) engaged in to evaluate objectives from the IAP and to consider new objectives, which culminated in a smaller refined set of objectives that can be affected by management actions within the scope of TRRP. Objectives were considered complete at the time of reporting, but associated targets were in various stages of development. The status of targets fell into three categories: (1) complete, (2) not yet addressed, or (3) intentionally deferred to a later time when additional information becomes available. Incomplete targets will continue to be addressed as per the process described below, while completed targets are used to guide monitoring and research.

The TMC endorsed the Objectives listed in the report during the June 2022 Quarterly TMC meeting and gave TRRP workgroups the responsibility for developing or updating associated targets.

Process for finalizing or updating targets:

A subgroup is formed for a given target, including the identification of a lead.

- The target is agendized for discussion during a work group meeting. Discussions provide space for the whole work group to first brainstorm towards development of a target.
- The subgroup works offline (outside of meetings) to develop a proposed target, including thorough written documentation of the justification for the target with reference to peer reviewed articles and TRRP documents.
- The proposed target along with documentation is presented to the workgroup. The workgroup discusses and provides feedback to the subgroup.
- The subgroup incorporates workgroup feedback to develop a final recommended target and presents this to the workgroup.
- If consensus is not immediately achieved, then presentation of a proposed target, feedback from the work group, and incorporation of that feedback is expected to be an iterative process until a target is complete that has consensus within the work group.
- When consensus is achieved, the subgroup proposes their target, along with supporting information, in a memorandum to the IDT for review.
- The IDT reviews the proposed target for redundancy and/or conflicts with existing targets and when satisfied forwards the memorandum to the science coordinator.

Targets for some objectives will be classified as: “unquantified”- (e.g., Pacific lamprey production), indicating that the objective can philosophically guide the Program, but progress towards this is not



presently intended to be evaluated. Targets for other objectives may be classified as “no consensus”, where consensus cannot be achieved within a workgroup on how to monitor and evaluate an objective. In these cases, the issue will be documented and elevated to the IDT for consideration. If the IDT cannot agree on a plan to complete the target, the objective may be removed.

The Objectives and Targets Report should be considered a ‘living document’ that is updated as new information becomes available and Program scientists deem it necessary. Adjustments should be made according to the process defined above. At the end of Phase 3, the entire document should be reviewed and updated.



Appendix D – DOI: Problem Scoping Key for Adaptive Management

The following key copied from (Williams et al. 2009) can help in dissecting a particular management problem and determining whether adaptive management is an appropriate approach to decision making. If the answer to any question in the key is negative, then an approach other than adaptive management is likely to be more appropriate.¹⁷

1. Is some kind of management decision to be made?
(see Sections 1.1, 2.1, 2.3, 3.1, and 5.5)
No – decision analysis and monitoring are unnecessary when no decision options exist.
Yes – go to step 2.
2. Can stakeholders be engaged?
(see Sections 1.1, 1.2, 2.1, 3.1, and 4.2)
No – without active stakeholder involvement an adaptive management process is unlikely to be effective.
Yes – go to step 3.
3. Can management objective(s) be stated explicitly?
(see Sections 1.2, 2.1, 2.2, 2.3, 3.1, 4.2 and 5.1)
No – adaptive management is not possible if objectives are not identified.
Yes – go to step 4.
4. Is decision making confounded by uncertainty about potential management impacts?
(see Sections 1.1, 1.2, 2.1, 3.1, 4.1, 4.2 and 5.2)
No – in the absence of uncertainty adaptive management is not needed.
Yes – go to step 5.
5. Can resource relationships and management impacts be represented in models?
(see Sections 1.2, 3.1, 4.2, and 5.1)
No – adaptive management cannot proceed without the predictions generated by models.
Yes – go to step 6.
6. Can monitoring be designed to inform decision making?
(see Sections 2.1, 2.3, 3.1, and 4.2)
No – in the absence of targeted monitoring it is not possible to reduce uncertainty and improve management.
Yes – go to step 7.
7. Can progress be measured in achieving management objectives?
(see Sections 1.1, 3.1, 4.1, and 4.2)
No – adaptive management is not feasible if progress in understanding and improving management is unrecognizable.
Yes – go to step 8.
8. Can management actions be adjusted in response to what has been learned?
(see Sections 1.2, 2.1, 3.1, 4.1, 4.2, 5.3, and 5.4)
No – adaptive management is not possible without the flexibility to adjust management strategies.
Yes – go to step 9.
9. Does the whole process fit within the appropriate legal framework?
(see Sections 2.3, 2.4, 3.2, 4.1, and 4.2)
No – adaptive management should not proceed absent full compliance with the relevant laws, regulations, and authorities.
Yes – all of the basic conditions are met, and adaptive management is appropriate for this problem.

¹⁷ <https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf>



Appendix E – Science Priorities

Key Uncertainties – Rationale

The following four questions suggested by the IAP (TRRP and ESSA 2009) are provided to aid in future prioritization of key uncertainties by the IDT:

1. Will assessing this key uncertainty result in revised management actions via AM? Which Actions?
2. Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal?
3. What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?
4. Is there a sequential nature required to resolve key uncertainties? If so, where in the sequence is this key uncertainty?

Responses to the first three of these questions, for key uncertainties identified for the initiation of Phase 3, are captured below. Timing and sequencing (i.e., question 4) is addressed in Section 3.2.3.

Wetted width – Can adjusting site rehabilitation and flow management strategies result in increased rates of wetted width expansion over a range of discharges? [GOAL 1: Form]

Will assessing this key uncertainty result in revised management actions via AM? Which Actions?

Yes. Evaluation of this uncertainty will provide direct feedback for revision of both channel rehabilitation and flow management strategies.

Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal?

Yes. Assessing this uncertainty will allow scientists and managers to better track progress towards goal (1) restoration of the form and function of the Trinity River

What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?

Potential consequences of not assessing this uncertainty include the continued focus on baseflow habitat availability as an assessment of habitat available to juvenile salmonids, and benchmark towards the Program Goal. Considering a more dynamic habitat availability template afforded by changes to the site rehabilitation and flow management strategies could reveal compounding benefits.

Nutrient flux – Can changing management actions result in greater transfer of energy through trophic levels? [GOAL 1: Function]



Will assessing this key uncertainty result in revised management actions via AM? Which Actions?

Yes. Assessment of this uncertainty could result in changes to channel rehabilitation and flow management strategies.

Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal?

Assessment of this uncertainty will track progress towards TRRP goal (1) restore the form and function of the Trinity River.

What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?

Not assessing this key uncertainty may result in a disconnect between restored channel form and the potential for increased transfer of energy through trophic levels and resulting benefits to fish survival and adult abundances. A fully restored channel that is not functioning to produce aquatic biomass will not result in a restored fishery.

Temperature regime – Can we manage temperatures to benefit multiple life stages of salmonids while meeting other species needs? [GOAL 1: Function]

Will assessing this key uncertainty result in revised management actions via AM? Which Actions?

Yes. Assessment of this uncertainty could result in changes to channel rehabilitation and flow management strategies.

Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal?

Yes. Assessment of this uncertainty will track progress of restoration of function (Goal statement #1).

What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?

Not assessing this key uncertainty may result in a disconnect between restored channel form and the potential for increased habitat thermal diversity, benefits to fish growth, survival, and resulting adult abundances.

Fish production – At what life stage and/or what habitat resource do bottlenecks to production occur? [GOAL 2&3: Fish]

Will assessing this key uncertainty result in revised management actions via AM? Which Actions?

Yes. Assessment of this uncertainty could result in changes to channel rehabilitation and flow management strategies.



Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal?

No. Assessing this uncertainty will help us decide which other uncertainties are most important to assess for tracking progress towards the TRRP goal.

What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?

Not assessing this key uncertainty may result in continued significant investment of resources to restore an aspect of the environment that may not be limiting productivity of fisheries.

ROD effectiveness – Can we achieve the Program goals with the tools and decision space provided by the ROD? [GOAL 1,2 & 3: Form, Function, Fish]

Will assessing this key uncertainty result in revised management actions via AM? Which Actions?

Yes. Assessment of this uncertainty could result in changes to all management actions or to what are considered management actions.

Will assessing this key uncertainty improve tracking progress towards the TRRP goal? Which attribute of the goal?

Not per se, but assessment of this uncertainty will track alignment of Program goals and benchmarks with what the current physical, biological, and political environment affords.

What are the consequences of not assessing this key uncertainty? Why and how would these consequences occur?

Not assessing this key uncertainty may result in continued investment of resources to restore the Trinity River after Phases 2 and Phase 3 without desired results.

Path Forward

Where necessary additional detail is provided to describe the path forward recommendations.

Implement active adaptive management of flows

Flow is the best opportunity for Phase 3 active adaptive management (Table 1) and is directly relevant to **Key Uncertainties 1, 2, and 3**. This means that with one management experiment, three science priorities can be addressed at least in part. This section provides an initial adaptive management plan for flow management. As noted in Figure 5, this preliminary plan needs to be further developed and vetted with both stakeholders and decision makers.

PLAN (Assess & Design): Frame problem, assess, and design actions from view of critical management uncertainties.



Problem Definition: The basic concept is to provide access to and/or expand habitat available to fish when they are there to use it and to provide seasonally appropriate disturbance and temperature regimes. Currently spring flows (April) occur after most juvenile Chinook salmon have emigrated out of the restoration reach, precluding those fish from taking advantage of habitat created by channel rehabilitation work. The current definition of habitat used by the Program (capacity) does not account for habitat quality relative to food and temperature. Current spring flows suppress temperature, negatively impacting juvenile fish growth. Winter and summer baseflows do not have sufficient intra/inter annual variability and are out of sync with natural hydrology (higher in summer, lower in winter, and static in both). Disturbance events that naturally occur in winter and affect seasonality, availability, and quality of food resources are absent in the upper river.

Action Description: There are two flow related management levers which we can adjust within Phase 3 scope. First, **shift the timing** of the water earlier in the year. Current spring releases begin in April, the natural wet season is Nov-April. Second, **increase variability** during the winter period to scour and inundate habitats prior to fry emergence.

- Hypotheses should be drafted to articulate the expected responses to changes in the management action. The recent report on winter flows (Abel et al., 2022) provides a good basis for this proposed adaptive management experiment and five hypotheses are articulated on pages 7 & 8.
- A Decision Support System like the one which has been used to select hydrographs might be useful to help select among active adaptive management flow experiments.
- If the Program decides to commit to active adaptive management, it should consider several alternative actions across years which can then be compared.

Timing: Learning is expected to begin immediately; however, it is anticipated that at least 3-5 years of implementation (and likely more depending on the number of experimental settings to be evaluated) and synthesis will be necessary to inform longer term recommendations. Current modeling results are limited to the current range of data.

Challenges: Flow management has been hampered by uncertainty in water year determination, the lack of ability to “bank” water in the reservoir, and reluctance to implement management changes to the hydrograph outside the original scope. However, improvements in forecasting have made the possibility of early water management a reality on other systems, and therefore should now be feasible on the Trinity River. Banking water could be a valuable tool in the face of extremes such as very wet water years which are not realized until late in the water year and multi-year drought.

**Engagement with stakeholders at the planning stage is critical and needs to be budgeted for.

DO (Implement & Monitor): Implement learning strategies and monitor actions using hypothesis testing and principles of experimental design.

Implementation

- Implement flow experiment as designed (with stakeholder and decision maker input) within water year constraints. Abel et al., (2022) provide a possible decision tree to inform implementation depending on the predicted water year.



Monitoring

- Changes to **juvenile salmonids** resulting from flow management, can be assessed through core monitoring (i.e., rotary screw trap). Outmigrant size and timing are expected to be easier to detect (i.e., greater signal to noise) than changes in outmigrant abundance.
- Changes to **temperature** resulting from flow management will be predicted by the upgraded RBM10 temperature model using existing core-monitoring temperature data from USFWS.
- Changes to **habitat** resulting from flow management will be informed by core monitoring (e.g., 5-year census and aerial imagery). However, the program needs to address the following items:
 - How to quantify habitat over time (e.g., at different flows).
 - How to quantify habitat complexity and dynamism.
 - How to evaluate habitat quality related to food and temperature (i.e., the interaction of physical habitat, temperature, and food).
- Changes to **salmonid food resources**, resulting from flow management, will be difficult to assess and further investigation is necessary. There are different perspectives on whether food is limiting production and it is difficult to measure without a survival study which is tough for early lifestages. It may be possible to assess whether changes to flow management (through scour and inundation) result in changes in primary and secondary productivity, but it will be difficult to then link such changes to tertiary productivity. Long term monitoring and evaluation of juvenile body mass index, benthic invertebrates, and drift food resources longitudinally and seasonally is one possible approach.
- Changes to **socio-economic or other stakeholder concerns**, resulting from flow management should be monitored to inform subsequent decisions.

LEARN (Evaluate & Adjust): Evaluate data to learn about effectiveness of actions and adjust management.

- Collect and analyze data every year, synthesize every five years to assess consistency of findings.
- Consider implications of learning to management and adjust as necessary (Section 3.3.2).

**Recognize the importance of reporting out to stakeholders on findings and consultation during the adjust step.

Complete a limiting factors assessment

A limiting factors analysis is useful to identify either a resource (e.g., food, physical habitat), or a mechanism (e.g., disease, predation) that is limiting population growth. The analysis carried out by USFWS and HVT (1999) was in a sense a limiting factors analysis, though not structured in a way to analyze each covariate, relative to others that were hypothesized to control salmonid populations. However, the tools, models, and state of the best available science have advanced considerably since 1999. Examples of limiting factors considered by USFWS and HVT (1999) on salmonid production other than habitat lost to the construction of Lewiston and Trinity dams include:

- Juvenile rearing habitat availability (physical space)
- Juvenile habitat quality (water temperature, flow)
- Water temperatures for adult salmonids (too high)
- Juvenile outmigration temperatures (too high)
- Poor spawning habitat.



USFWS and HVT (1999) hypothesized that juvenile rearing habitat was the factor most limiting salmonid production in the Trinity River. Habitat complexity and escape cover were not explicitly included in the analysis of USFWS and HVT (1999). The limitation on salmonid production of juvenile rearing habitat was largely based on channel form, weighted usable area, and habitat suitability criteria. However, these concepts are only considered correlative to the actual mechanistic reasons why production is limited. Correlative statistical models relating hydraulic variables to habitat preferences (habitat suitability curves based on use:availability ratios) are the most common form of habitat suitability models but face significant criticism on the grounds that habitat preference may not reflect the fitness consequences of habitat use (Naman et al 2019). Mechanistic bioenergetics-based models appear to provide more rigorous estimates of habitat suitability for drift-feeding stream fishes (Railsback 2016; Naman et al 2019; Naman et al 2020). The analysis by Rosenfeld and Ptolemy (2012) indicates that standard applications of PHABSIM systematically underestimate the effects of declining discharge on pool-rearing juvenile Coho salmon in small streams by inflating habitat quality at low flows. Applications of habitat suitability-based models like PHABSIM may systematically overestimate low-flow productive capacity for species that prefer low velocities (e.g., pools) but are dependent on energy fluxes generated in higher velocity habitats (e.g., riffles) (Rosenfeld and Ptolemy 2012; Rosenfeld et al 2016; Rosenfeld and Naman 2021).

Not only have the analysis tools, models and state of science changed in the last two decades, there are new factors that have emerged, and are thought to be causing mortality that was either unknown or not present at the time USFWS and HVT (1999) completed their analysis. Examples of new limiting factors not previously considered include:

- Change in the percentage of water year types that has or will occur resulting from climate change (e.g., Milly et al. 2008).
- Poor ocean productivity which is less productive than any historical time in the period of record or less productive for longer time periods than in the historical record.
- Food for juvenile salmonids in the upper Trinity River (i.e., too little food).
- Water temperature for rearing juveniles (i.e., too cold).
- Poor water quality during the summer months in the lower Klamath River.
- Juvenile fish disease in the lower Klamath River.
- Adult fish disease in the lower Klamath River.
- Not enough fine sediment.
- Predation (birds, marine mammals, brown trout).

The manifestation of a limiting factor at some point in the future can nullify years of targeted resource management (Hamilton and Murphy 2018). This could contribute to reducing or eliminating the benefits to fish populations from gains in habitat or some other limiting factor (Hamilton and Murphy 2018), like habitat rehabilitation on the Trinity River. For example, juvenile fish disease in the lower Klamath River has the potential to reduce the benefits of juvenile habitat projects in the upper Trinity River, if the fish disease ultimately results in fewer returning adults per juvenile despite habitat improvement. Complicating the analysis is the question of whether the mortality caused by the limiting factor is additive or compensatory mortality (Murray and Bastille-Rousseau 2020), because new limiting factors may then limit salmonid production such that salmonid population objectives for the TRRP become unachievable.



Hamilton and Murphy (2018) provide a useful and contemporary framework for how a limiting factors analysis could be structured and applied to the Trinity River. A new limiting factor analysis would have to be carefully designed to be effective at identifying factors which are truly limiting, and to be useful enough to inform adjustments in management actions if warranted. There is utility in reexamining the original hypothesis that salmonid production is limited by juvenile rearing habitat in the upper Trinity River and to identify potentially new limiting factors.

Implement core activities

Implement core activities as prescribed in Table 2.

Complete a review of Phase 2 channel rehabilitation sites

This task was already in process at the time this document was written. An RFP was issued in 2022. An important follow up activity is for the Program to take the contractor report and develop and implement a river corridor plan.

Review of long-term monitoring activities

This task should be conducted in 2023-2024, with the intention of implementing any new recommendations in 2025.

Complete a Phase 3 review to determine whether ROD actions are sufficient to achieve goals

This task needs to be further fleshed out before implementation begins in ~2031. The IDT should clarify whether this will be completed by the Program or whether external support is necessary. The IDT should draft a plan for evaluating this question through a combination of analysis and modeling. The SAB should be solicited for input on the plan.



Appendix F – Literature Cited

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