WATER RESOURCES MANAGEMENT PLANNING: CONCEPTUAL FRAMEWORK AND CASE STUDY OF THE SHASTA BASIN

A Report for The National Fish and Wildlife Foundation

PROJECT TEAM:
ANN WILLIS, ANDREW NICHOLS, CARSON JEFFRES, MIKE DEAS

CENTER FOR WATERSHED SCIENCES
UNIVERSITY OF CALIFORNIA, DAVIS
ONE SHIELDS AVENUE
DAVIS, CA 95616

WATERCOURSE ENGINEERING, INC.
424 SECOND STREET, SUITE B
DAVIS, CA 95616
(530) 750 – 3072

SEPTEMBER, 2013

Recommended Citation: Willis, A.D., Nichols, A.L., Jeffres, C.A., Deas, M.L., 2013. Water Resources Management Planning: Conceptual Framework and Case Study of the Shasta Basin. Report prepared for: National Fish and Wildlife Foundation

Table of Contents

Table of Figures

Table of Tables

Executive Summary

Watershed planning activities are undertaken to provide water and ecosystem management strategies required to balance the often competing needs of both aquatic ecosystems and water users. Approaches to watershed planning typically include a stepwise process wherein stakeholders are identified, outreach processes are implemented, initial concerns identified, and goals and objectives defined. Subsequently, the stages of watershed characterization, monitoring and studies, solution identification, and plan implementation occur. However, such planning activities generally focus on narrow objectives that meet individual regulatory agency or stakeholder interests. As such, they do not provide for long-term, viable, multi-objective water use. This document presents an alternative conceptual framework for the development of water resources management plans. This framework explicitly recognizes that realistic potential exists to support multiple and competing water uses (i.e. “coequal goals”) in a river basin, and that identified “coequal goals” can be met by developing management solutions that provide water of suitable quantity and quality, at the appropriate place and time, such that the water needs of multiple users are met.

<u>QQST – A Guiding Principal</u>

The central thesis of this conceptual framework is that potentially conflicting water uses can be accommodated by management strategies that identify and incorporate the spatial (S) and temporal (T) distribution of water quantity (Q) and quality (Q) needs of both the aquatic ecosystem and water users (QQST). Coupling water quantity and quality needs with specific locations (space) and specific periods (time) provides a means to efficiently identify competing water demands and develop flexible solutions needed meet water needs.

<u>Management Strategies: Interim, transitional and long-term measures</u>

Recognizing QQST as a guiding principal to water resources management allows the development of three types of management strategies required to achieve established co-equal goals: interim, transitional, and long-term measures. Each management strategy is implemented depending on the condition of aquatic ecosystem, which can be defined by periods of ecosystem degradation, recovery, and reconciliation.

Interim measures are viewed as “emergency” measures meant to stem the imminent degradation of aquatic habitats and the organisms that depend on them. These measures may incur substantial costs, particularly if the degraded condition is extreme; however, they are not intended to be permanent solutions.

Transitional measures are implemented as the aquatic ecosystem enters a period of recovery – either coincident with or following the completion of interim measures. Transitional measures help provide resource managers with the information necessary to develop a comprehensive and sustainable long-term management strategy that meets the QQST needs for each water user, and phase out resource-intensive interim actions.

Long-term goals and management actions are developed to meet established co-equal goals. Conducted as aquatic ecosystem conditions reach a state of reconciliation with competing water uses, long term management actions may be an extension of previously implemented interim and transitional measures, or may be enacted once interim and transitional measures have been largely completed.

<u>Shasta Basin Case Study</u>

This conceptual framework for watershed planning is applied to the Shasta Basin of northern California. Historically, the Shasta River was one of the most productive salmon streams in California. Cold and nutrient-rich groundwater springs provided nearly ideal aquatic habitat conditions supportive of large Chinook and coho salmon populations. However, more than a century of aquatic and riparian habitat degradation along the Shasta River and its tributaries has resulted in dramatic declines in wild salmon populations, and particularly the federally threatened coho salmon. Elevated water temperature is the primary factor limiting coho abundance in the Shasta River, and restoration of cold-water flows is the key to coho population recovery. The observed decline of coho in the Shasta River coincided with the development of surface and groundwater sources in support of irrigated agricultural activities throughout the Shasta Basin. Water development led to reductions in the quantity and quality of cold-water habitats required by rearing coho salmon. Developing a collaborative approach to water resource management is critical to both recovering coho salmon and maintaining a viable agricultural community with the Shasta Basin – without involving all stakeholders, successful solutions cannot be developed for either user group. Key to such an approach is the generation of a comprehensive water resources management plan that identifies collaborative solutions to providing water of suitable quantity and quality, at the appropriate place and time, such that the water needs of both the aquatic ecosystem and agricultural community are met.

In the Shasta Basin, examples of short-term/interim measures include the protection of known thermal refugia and thermally suitable reach-scale aquatic habitats, development of life-stage appropriate flow cues, and management of fish. Many of these interim measures have already been enacted. Areas of thermally suitable habitat (e.g., Big Springs Creek, Kettle Springs Creek) have largely been protected through various conservation and restoration measures. Water transactions involving agricultural/municipal water users have been enacted to provide appropriate flow cues during key juvenile coho rearing periods. And the California Department of Fish and Wildlife is actively engaged in the trapping and transport of juvenile coho to thermally suitable rearing habitats.

With many interim measures to stem the decline of the coho population in the Shasta Basin already completed, basin planning efforts in the basin should focus on the development of both transitional and long-term measures. Potential transitional measures include comprehensive habitat suitability assessments, a quantification of coho population recovery goals, and the identification of agricultural water use needs and capacity. Information gathered through the completion of transitional measures will help develop management actions supportive of the following long-term goals: 1) build and maintain a sustainable coho population; and 2) maintain a reliable water supply to support a viable agricultural economy. Management actions to support these long-term goals should be developed by basin stakeholders. Example long-term management actions include the development of plans to manage groundwater, surface water, and riparian land use. Within these broad plans, a range of potential management actions can be considered.

The Shasta Basin Water Management Plan is an evolving process that encompasses a range of measures to address the changing condition of water resources in the basin. While the framework developed in this document is applied in the context of water resource issues in the Shasta Basin, it can be used as a guide for resource planning in other basins for a range of resource issues or conditions. Fundamentally, what this framework establishes is the basis to address resource management given a range of conditions by defining specific types of measures. Specifying various categories of measures helps provide clarity as to the potential resources needed to address resource conditions as well as an understanding of the suitable expectations for those activities. For resources that are severely impaired, interim measures may be warranted. By describing measures in the context of this framework, stakeholders may be more willing to support interim measures to stem resource degradation if those measures are presented as part of a broader strategy and not as an end unto themselves. Similarly, those who are advocating for interim measures can do so with the knowledge that additional activities must compliment those management actions to transition away from broad, resource-intensive management actions to more sustainable, targeted long-term measures.

Water resources in the Shasta Basin are at varying levels of degradation, recovery, and sustainability depending on location within the watershed. Similarly, both short-term and transitional measures have been implemented, and currently available information is sufficient to identify general actions that would provide critical stability to water resources use in the basin. Specific recommendations for other interim, transitional, and long-term measures should be developed by basin stakeholders through a collaborative planning process to achieve sustainable water resources management in the basin.

Water Resources Management Planning: Conceptual Framework and Case Study of the Shasta Basin

1. Introduction

Throughout many watersheds of the western United States, water resource stakeholders struggle to balance the often competing needs of both aquatic ecosystems and water users. In the Shasta Basin of northern California, this struggle is primarily concentrated around the water resource needs of both cold-water fish species and irrigated agriculture. Through much of the past century, as in many watersheds in the western United States, water resource development in the Shasta Basin was focused on agriculture supply without an explicit in-stream allocation to support aquatic ecosystem needs. After several decades, these actions resulted in degraded aquatic habitat conditions detrimental to fish in the Shasta Basin, specifically coho salmon. In 1997, coho salmon were listed under the federal Endangered Species Act (ESA) a as “threatened” throughout the Southern Oregon/Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) (NOAA, 2012), including the Shasta River. The listing came as a result of decreased local abundance, degraded habitat, and reduced population distribution throughout the region.

Currently, there are a range of important recovery efforts in the Shasta Basin focused on coho salmon, including actions to maintain instream flow, protect cold water habitats, and other habitat restoration efforts. Regulatory frameworks have been a principal tool in these efforts. Water quality, including beneficial uses designated for “cold” water species that include salmon, is largely regulated through the implementation of total maximum daily load (TMDL) limits (NCRWQCB, 2006). An incidental take permitting program (ESA, 2009a, 2009b) was proposed in recent years to manage the incidental taking of coho salmon during routine agricultural activities, and to complete restoration actions consistent with previously established recovery tasks presented by the Shasta-Scott Coho Salmon Recovery Team (SSRT, 2003). Finally, certain stakeholders and interested parties are exploring methods to maintain instream flow in critical reaches and at critical times of year via water rights and water use mechanisms that are largely overseen by the California Department of Water Resources (DWR) through the California water code, as well as the 1932 Shasta River adjudication (CADWR, 1932). Coordination between these regulatory and management programs has been limited and inconsistent, in part due available resources and funding. However, narrow agency mandates also limit regulators’ abilities to effectively balance water needs of both aquatic ecosystems and existing agricultural activities at the watershed scale. Furthermore, local stakeholders generally have not proactively engaged in resource management issues associated with aquatic system restoration. The cumulative result of incomplete planning and coordination at the agency and stakeholder level has been delayed and ineffective aquatic ecosystem recovery.

To help support the recovery process and provide some guidance as to the potential future condition of the Shasta Basin, this document presents a framework for a comprehensive water resources management plan (hereafter referred to as the “basin framework” or “framework”). This framework defines multi-objective water use as co-equal goals, and uses the concept of quantity, quality, space, and time (QQST) to guide management efforts. This approach helps identify interim, transitional, and long-term actions associated with aquatic system restoration that will lead to a balanced use of water for agricultural activities and instream conditions for coho salmon (and other cold water species). Interim actions are often required to provide immediate relief to a degraded system – in this case, such actions would focus on interrupting the decline of the coho population and, ideally, result in a stable or even increasing population. However, by their very nature, interim measures do not provide the mechanism to recover the population to sustainable levels. Rather, long-term measures are required to attain a more robust, persistent recovery status for the fisheries population, which is a necessary condition to achieve a balance between multiple water uses (i.e., agriculture and instream uses). Transitional, or intermediate, measures are implemented to bridge the gap between interim and long-term measures.

A framework that provides guidance on interim, transitional, and long-term measures is particularly important in watersheds such as the Shasta Basin where there are competing uses for available water, complex system dynamics, and quick solutions are not readily available. Further, given the unique attributes of the Shasta Basin (as with many watersheds), there is no one-time “fix” or “silver bullet” solution for this watershed. Rather, several inter-related measures that target specific limitations, and occur at different locations and times, will provide the most efficient and robust approach to recovery. Thus, the central thesis of this framework is that potentially conflicting water uses can be accommodated in a way that results in the long-term viability of each objective by incorporating the four QQST elements into a water management strategy. Quantity and quality refer to how much water and of what quality is required to meet a desired use. Space and time refer to where and when this quantity and quality are required that also support the desired use. By building a framework based on these four elements, interim, transitional, and long-term measures can be targeted to multiple uses. For example, coho salmon require specific flow and temperature regimes to be successful; however, these conditions are not necessarily required at all locations at all times. Similarly, agriculture has different quantity and quality requirements that may occur at spatial and temporal scales different from specific life-stage fisheries needs. By explicitly accounting for quantity, quality, space, and time, solutions can be developed that target the needs of individual uses, and provide critical flexibility to meet the coequal goals of sustainable fisheries and agricultural (and other) water uses.

This basin framework acknowledges that watershed plans are commonplace in local, state, and federal planning efforts. This approach is not intended to replace broad-based watershed planning efforts, wherein a systematic assessment or step-wise process is implemented. Rather, the basin framework proposed herein aims to augment standard watershed planning efforts, and focuses on specific actions that address unique attributes of the Shasta Basin’s aquatic ecosystem deemed critical to restoring cold water fishes, particularly coho salmon. The University of California, Davis Center for Watershed Sciences (UC Davis) and Watercourse Engineering, Inc. (Watercourse) have been contracted by NFWF to address watershed planning efforts in the Shasta Basin. Studies, analysis, and other efforts in the basin over the last 10 to 15 years (and particularly work completed in the last five years) provide a solid foundation upon which a basin framework can be developed to guide water resources stakeholders through a process of balancing the competing water use needs to support a functioning aquatic ecosystem and a sustainable agricultural industry.

1.1. Report Organization

This report is organized into three parts. The first part presents the conceptual overview of the basin framework. The second part presents a case study of the Shasta Basin and how the framework could be applied to develop a comprehensive water resources management plan that supports the long-term viability of multi-use water resources objectives. The information presented in each part is organized as follows:

Part 1: Conceptual Framework presents the framework approach in terms of its key three concepts: co-equal goals; the quantity, quality, space, and time (QQST) approach; and the role of interim, transitional, and long-term measures.

Part 2: The Shasta Basin includes a general description of the project area, a summary of background information describing water use in the basin, a discussion of contributing factors to the basin's water management problems, and an example of how the conceptual planning framework applies to the Shasta Basin.

Part 3: Basin Framework and the Shasta Basin presents examples of how each component of the framework can be applied to the Shasta Basin to resolve decades of conflicting water demands.

The report concludes with a discussion of how the framework can be applied to any basin regardless of the condition of its water resources, aquatic ecosystem, or user groups. Next steps are identified to facilitate the implementation of the framework's principles into water resources planning processes.

2. Part 1: Conceptual Framework

The basin framework presented in this document is meant to complement existing watershed planning processes. To illustrate how the framework can enhance the watershed planning process, an overview of watershed planning is provided. Then, the conceptual framework is described. These descriptions can help provide guidance to resource planners by identifying key steps in the planning process and areas where the conceptual framework can help develop effective, long-term solutions to conflicting resource demands.

2.1. Watershed planning

Watershed planning has been identified as the most effective approach to address water resources management at the basin-scale (USEPA, 2013). Over the past several decades, watershed planning has evolved to include step-wise processes and programs, templates, and guidelines that provide clear direction for a wide-ranging audience: extending from local landowners to experienced practitioners and resource managers. Planning guidance can be found in EPA (USEPA, 2008, 2013), Shilling et al. (2005), and Sabatier et al. (2005), to name only a few. For example, a six-step process presented by EPA (2013) is summarized in Figure 1. There is extensive literature on developing watershed plans, including watershed planning software, handbooks, templates, and other resources that will be invaluable when basin stakeholders undertake this important task. These approaches typically include a stepwise process wherein stakeholders are identified, outreach processes are implemented, initial concerns identified, and goals and objectives defined. Subsequently, the stages of watershed characterization, monitoring and studies, solution identification, and plan implementation occur. The approach outlined herein assumes these well-documented steps are useful and should be considered. However, while the theory underlying basin planning is reasonable, in practice, basin planning tends to illustrate a less effective process. Watershed stakeholders that pursue this framework are encouraged to delve into these and other resources to address the foundational elements of a watershed planning effort.

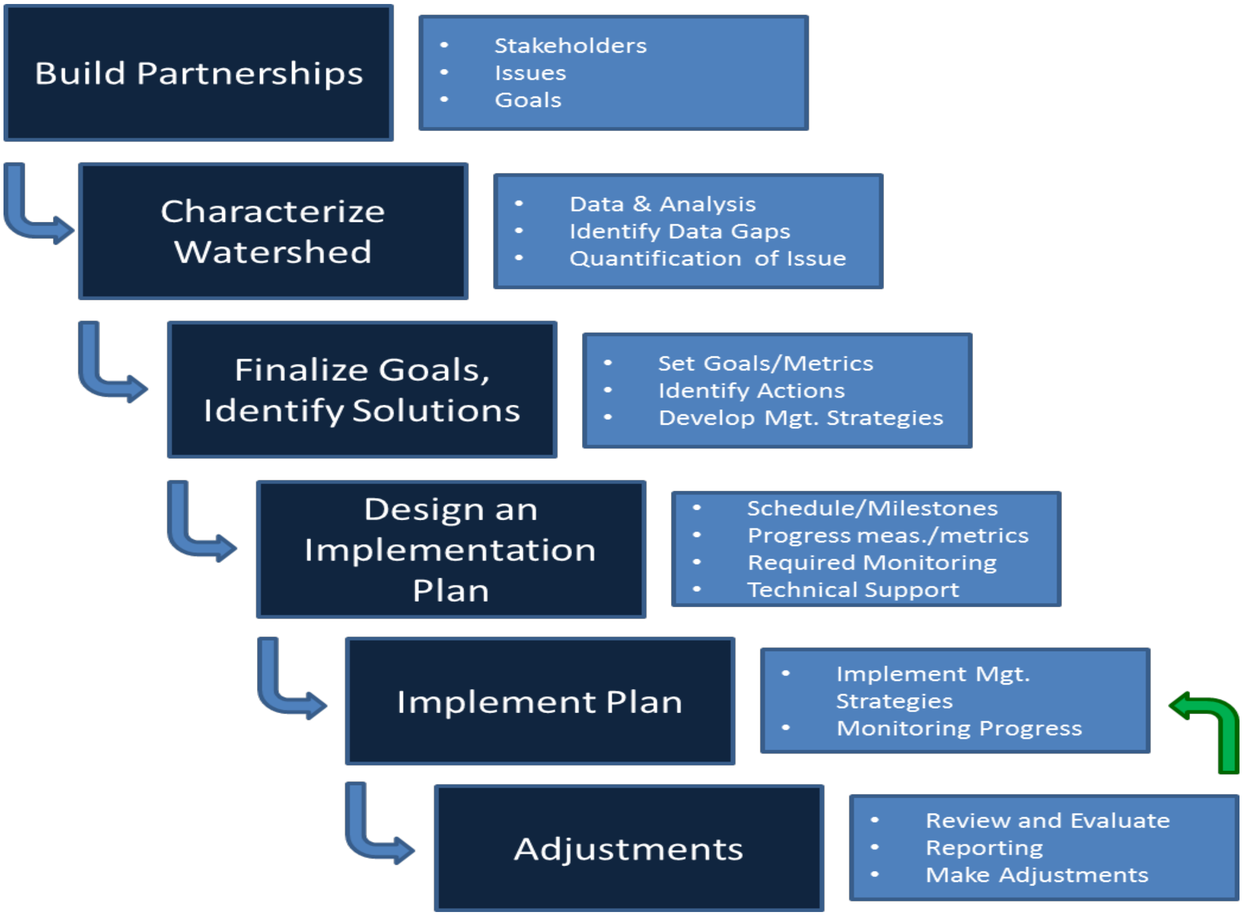

Figure 1. Six step process for watershed planning (adapted from EPA (2013)).

For decades water resources planning has often been managed by discrete, single-function federal and state agencies, each tied to its own legal mandate (Kamieniecki and Kraft, 2005). Decision making in this environment has been constrained by institutional processes, often leaving decisions to agency staff or experts who are not representative of the diverse community of watershed stakeholders. Further, the planning process often addresses specific concerns or specific pollutants, but lacks a holistic approach. Kamieniecki and Kraft (2005) argue that a shift from a top-down, agency-dominated approach, towards a more collaborative bottom-up approach increases trust, improves the likelihood of reaching and implementing agreements, legitimizes watershed management processes, and improves successful and sustainable outcomes to today's complex water quality and water resources problems. While this collaborative approach addresses who should be a part of watershed (or basin) planning groups, it does not provide a framework for encompassing diverse stakeholder needs in a basin plan.

2.2. Framework Approach

One fundamental assumption of any basin plan is that realistic potential exists to support multiple and competing water uses. This basin framework is based on the concept of reconciliation ecology, where humans are now are fundamental part of the landscape and incorporating human activities into ecological solutions is necessary to create a sustainable ecosystem (Hobbs and Norton, 1996). Accepting this premise means that a new approach should be taken to basin planning. As such, this approach is designed around three key concepts:

1. Water user objectives are considered co-equal goals,

2. Co-equal goals can be accommodated by addressing the quantity, quality, space, and timing (QQST) of each user's needs, and

3. Interim, transitional, and/or long-term measures can be implemented depending on the condition each water user objective to move towards a sustainable period of reconciliation.

The concept of co-equal goals is not new to watershed planning processes, and has already been introduced to water use planning in some basins. However, specifying needs based on quantity, quality, space, and timing (QQST) brings a higher level of resolution to water management actions than are typically included in basin plans. In this section, a description is provided of co-equal goals, how the QQST approach can help effectively and equitably allocate limited water resources, and how those concepts help determine interim, transitional, and/or long-term measures to address basin conditions in periods of degradation, recovery, and reconciliation.

2.2.1. Co-equal goals

Establishing co-equal goals is useful in basins where limited resource demands conflict. The concept of coequal goals is not a new concept in water resources planning and management. In the Sacramento-San Joaquin Delta, the concept of coequal goals to address ecosystem needs and water supply is the basis for ongoing activities under the guidance of the Delta Stewardship Council[1]. The concept of coequal goals is also consistent with the North Coast Integrated Regional Water Management Program[2] (NCRP, 2013). Currently under development, the NCIRWMP presents a wide range of goals and objectives that are consistent with general watershed planning efforts, but also delve into important regional issues (NCRP, 2013). These include goals that address both water supply and salmonid restoration, among others. Further, objectives developed under these two specific goals include ensuring water supply reliability for municipal, domestic, agricultural, and recreational uses while minimizing impacts to sensitive

[1] California Water Code, Section 85054 identified that "'Coequal goals' means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem."

[2] Senate Bill 1672 created the Integrated Regional Water Management (IRWM) Act to encourage local agencies to work cooperatively to manage and improve the quality, quantity and reliability of local and imported water supplies. The passage of Propositions 50, 84 and 1E has provided funding for the IRWM grant program and helped to provide the initial incentive for stakeholders in the North Coast to work collaboratively on water and energy management challenges to reduce conflicts, integrate federal, state, regional and local priorities and utilize a multi-benefit approach to identify and seek funding for the region's highest priority water and energy-related projects. (http://www.northcoastirwmp.net/)

resources and enhancing salmonid populations. Both of these programs speak to coequal goals, and are large, regional planning efforts or frameworks that may be useful starting points to guide planning activities in other basins.

2.2.2. Quantity, Quality, Space, and Time (QQST)

The concept of identifying specific requirements of the quantity and quality of water necessary to meet water use needs is already part of general watershed planning activities. The question of quantity and quality are commonly used metrics for a wide range of aquatic system restoration and agricultural activities, as well as many other resource management activities. Coupling them with specific locations (space) and specific periods (time) provides a means to efficiently address competing water demands. Often proponents of a particular water use (e.g., agricultural, environmental, hydropower, etc.) argue that certain conditions on quantity and quality be met at all locations at all times. However, where competing uses are present, this often leads to an impasse. At best, such impasses lead to delays in restoration, uncertainty in water supply, and inefficient use of resources; and at worst, lead to litigation, abandonment of collaborative efforts, and missed opportunity for resolution.

The QQST approach is used to extend conventional watershed planning processes, which tend to focus on single issues or impairments, to support the development of watershed plans that provide for the long-term viability of multi-objective water use. These four factors can be determined through a baseline assessment of physical, chemical, and biological elements of the underlying aquatic ecosystem to quantify conditions through a science-based approach. With the information gathered from this comprehensive baseline assessment, spatially and temporally specific limiting factors can be identified, as well as the cause of those factors. This information can be used to evaluate interim measures and determine how (or if) they could be extended to develop long-term management strategies. In other words, the QQST approach helps resource managers transition from broad, resource-intensive management activities to a long-term strategy that targets specific limiting factors at specific places and times. This targeted approach introduces the flexibility that is important to supporting multi-objective water use.

2.2.3. Interim, transitional, and long-term measures

Interim, transitional, and long-term measures can be implemented during periods of aquatic ecosystem degradation, recovery, and reconciliation. The type of measure that is implemented generally depends on the current condition of the resource (e.g., coho habitat) (Figure 2). Interim measures tend to occur primarily during degraded periods. Transitional measures may begin once stability has been achieved and extend into the period of recovery. Long-term measures can be an extension of interim or transitional measures. Each type of measure plays an important role in the overall resource management process; however it is also important to understand the limitations of each.

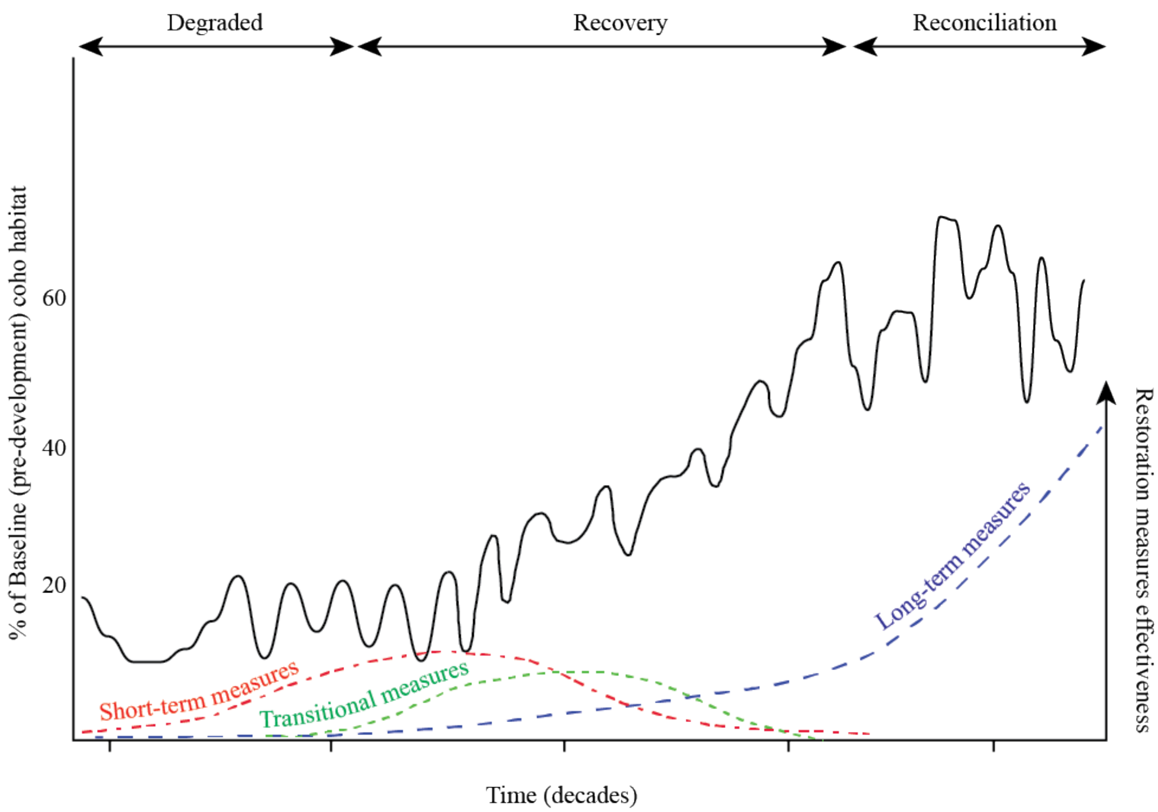

Figure 2. A conceptual illustration of the different measures that may be implemented to address resource conditions.

Interim measures are activities that are rapidly implemented to “turn the tide” for declining populations. Such actions are often not intended, nor even appropriate, to be implemented in perpetuity – many such actions are resource intensive, expensive, and highly managed (and thus difficult to maintain for extended periods). Rather, such actions should be designed to “sunset” and be replaced by transitional or long-term measures that are more resource efficient, relatively inexpensive to implement, and require low management efforts such that the improved condition can be maintained for extended periods of time. While actions implemented under interim measures may address a specific limiting factor or factors, they may not target those that are principally responsible for the systemic degradation. Furthermore, in basins where limited data exists to describe the underlying physical, chemical, and biological elements of the aquatic ecosystem or water use demands, interim measures may be based on conceptual knowledge of those water uses that may or may not be representative of the specific basin being managed. As such, these measures tend to provide the least direction regarding the QQST needs and are unsustainable as a long-term strategy. Nevertheless, they provide critical stability to a degraded system and create the opportunity to develop a more refined long-term resource management strategy.

Transitional measures provide the foundation for the development of long-term resource management strategies and are initiated after short-term measures have begun to stabilize the degraded resource. Unlike short-term measures, which are designed to address a broad range of potential limiting factors, transitional measures help narrow the focus of management activities and are used to guide the development of long-term goals and management actions. Specifically, transitional measures help identify the QQST needs for each resource user that are critical to designing an effective, multi-objective water resources management plan. However, while transitional measures help identify limiting factors, they may not completely address those factors. Rather, transitional measures provide the underlying information upon which long-term measures can be identified to effectively address limiting factors and the mechanisms that cause them.

Long-term measures build upon the knowledge gained from transitional measures to maintain viable multi-objective water use through a period of reconciliation. These measures may be extensions of interim measures, or may be new measures that were developed given an improved understanding of the system. They are typically based upon the QQST needs of the various water uses and provide flexibility to address potentially conflicting demands. In the absence of new impairments or changes to the underlying physical, chemical, and biological functions of the ecosystem, long-term measures are meant to provide enduring stability to reconciled multi-use objectives. However, precisely because they are founded on extensive background information, they are poorly suited as emergency measures to stabilize critically degraded systems.

2.3. Summary

Watershed planning requires numerous steps ranging from initial assessment to goal setting and plan implementation. While basic planning steps are clearly articulated in numerous and readily available guidance documents, the planning process is often geared towards addressing a single factor/problem, and typically does not generate successful and sustainable outcomes to the complex water quality and water resources problems found in watersheds throughout the western United States. The planning framework presented in this document builds on the general watershed planning process by specifying competing water needs as coequal goals and identifying spatial and temporal variability in the quantity and quality of water required to meet these needs.

Interim, transitional, and long-term measures are defined to help illustrate the range of activities that may occur during periods of resource degradation, recovery, and reconciliation. Each type of measure has a unique purpose and limitations; by understanding how these measures fit into the broader context of basin planning, appropriate measures can be implemented to address existing conditions. With these concepts, the framework has been established with which to extend conventional watershed planning approaches. A case study examines how this framework could be used to support multi-objective basin planning in the Shasta Basin of northern California. Before the framework is applied, some background information of the Shasta Basin and its water use issues is presented.

3. Part 2: The Shasta Basin

Numerous Shasta Basin-specific watershed planning efforts, or efforts that include the Shasta Basin as a component in a larger-scale watershed plan, have been developed within the past two decades. Completed planning documents include, but are not limited to, the National Marine Fisheries Service (NMFS) Klamath River Basin 2010 Report to Congress (NMFS, 2011); Shasta River Total Maximum Daily Load (NCRWQCB, 2006); the Water Quality Control Plan for the North Coast Region (NCRWQCB, 2011); the California Department of Fish and Wildlife Incidental Take Permit (ITP) process (ESA, 2009a, 2009b); Shasta-Scott Pilot Program for coho recovery (SSRT, 2003); Shasta Watershed Restoration Plan (SRCRMP, 1997); and the SONCC Coho Salmon Recovery Plan (NOAA, 2012). Additional planning documents currently under development are the North Coast Integrated Water Management Plan (NCRP, 2013) annotated outline (out for public comment) and the stewardship report for the Shasta Basin being completed by the North Coast Regional Water Quality Control Board (NCRWQCB) through the Klamath Basin Monitoring Program (KBMP). However, these documents focus on narrow objectives that meet individual agency or stakeholder interests. Furthermore, substantial information gaps have hampered this process. As such, they do not provide for long-term, viable, multi-objective water use.

Over the last five to ten years, detailed studies by several agencies, resource scientists, and others have led to a considerable increase in knowledge about the role several stream reaches in the Shasta River watershed play (e.g., Parks Creek, Big Springs Creek, the Shasta River in the vicinity of Big Springs and Parks Creek, the Shasta River canyon, etc.). Some of these studies utilized techniques that were not available or too expensive only a decade ago, including isotope analysis to track sources of nutrients and food web interactions, otolith microchemistry to identify the origin of salmon, and fish tagging and tracking techniques to assess movement and migration, just to name a few. Now, the available information is sufficient to identify a well-defined path towards a balanced approach that addresses current water uses and the needs of the aquatic ecosystem. This is not to say that the current level of information answers all questions. However, there comes a time when action is necessary to embark on a long-term solution. Such a solution will not be without change: change in current definition of fishery needs, change in current land and water use practices, change in policy and institutional structures, and change in other areas as well. The most basic need addressed through such change is long-term stability in the basin for all. Given the influx of new information, the logical next step was to use this knowledge to construct a basin planning framework.

The context of water resource use in the Shasta Basin is important to understand before outlining the proposed framework. First, an overview is presented of the Shasta Basin and the geographic scope that is included in this framework. Then, background information is provided to describe the underlying aquatic ecosystem function, existing water development and infrastructure, major water users, and the various entities that manage discrete or overlapping water resource objectives. Next, contributing factors to water management problems in the Shasta Basin are identified. This information is presented to provide context for how the proposed basin framework can be applied to help stakeholders progress through the current water use challenges.

3.1. Project Area

The objective of this basin framework, and the resources available to develop it, limit the scope of this project. Because the current impediment to water supply reliability in the

Shasta Basin is the threatened status of coho salmon, this plan generally focuses on developing actions/measures necessary to recover declining anadromous salmonids (coho salmon in particular, though other anadromous species, such as Chinook salmon and steelhead, are considered) within a working agricultural landscape. In the event that coho salmon are delisted at a future time throughout the SONCC ESU, other factors that affect water management in the Shasta Basin can then be addressed.

The spatial scope includes the Shasta River downstream from Lake Shastina and the following tributaries: Parks Creek (insofar as the upper reach is diverted for storage in and eventual release from Lake Shastina and the downstream reach is utilized by anadromous fish), Big Springs Creek, Little Shasta River, and Yreka Creek (Figure 3). The tributaries (and their respective drainages) are not treated in detail, but are acknowledged as important elements of the system that should be included in a comprehensive water management plan for the basin. Similarly, reaches upstream from Dwinnell Dam and Lake Shastina are also acknowledged as important elements of the system; however, this report focuses on the current limits of anadromy. Furthermore, this plan was designed based on the current configuration of water resources use in the Shasta Basin. Consideration of potential large scale changes to environmental policy, water resources policy, existing water resources infrastructure, or other factors (e.g., climate change) is beyond the scope of this project – rather, the proposed framework is envisioned to accommodate such changes in an adaptive manner.

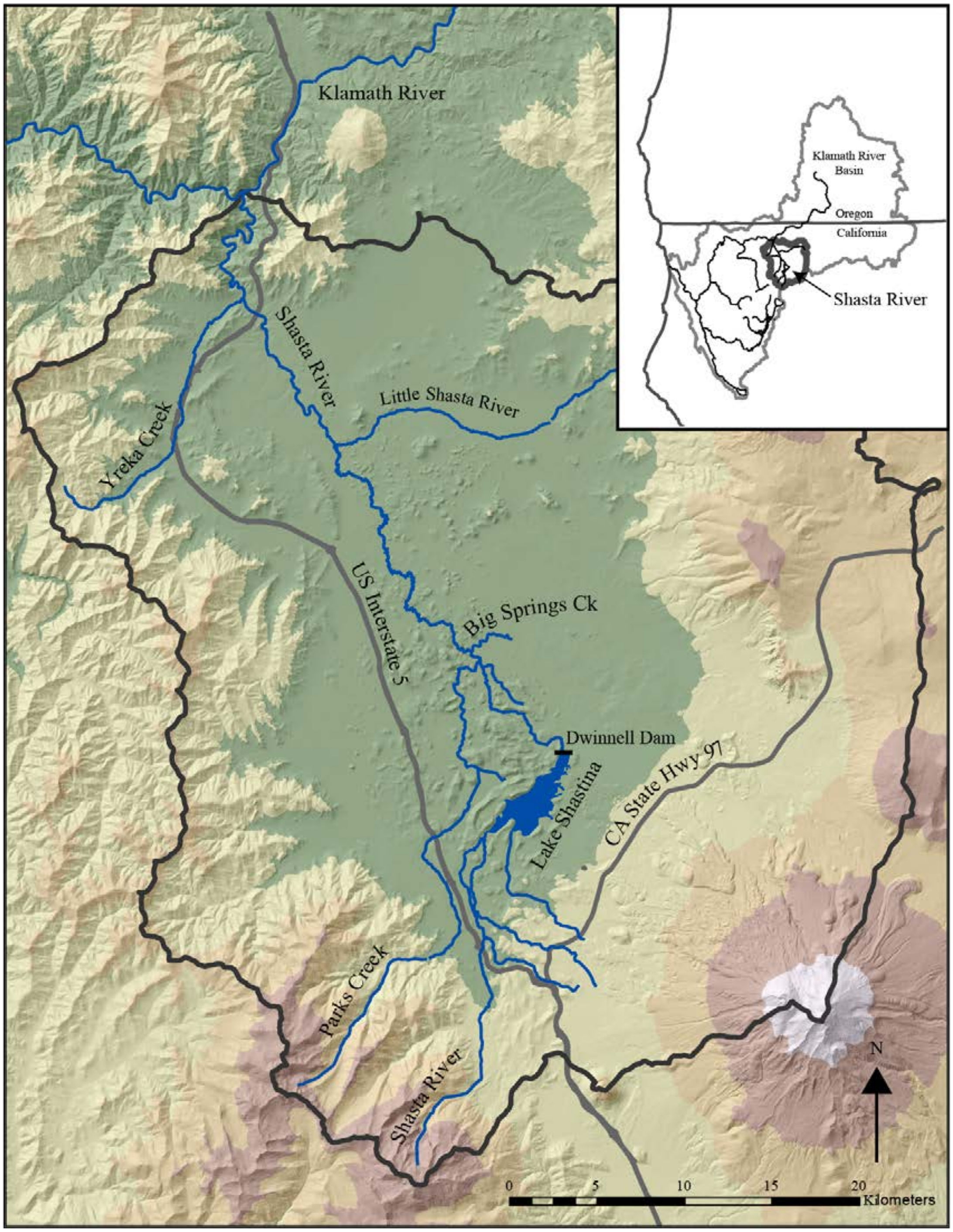

Figure 3. A map of the geographic scope of the project area. As the current extent of anadromy is limited to reaches downstream of Dwinnell Dam, reaches upstream of that site are not included in the planning framework at this time.

3.2. Background

Three principal elements form the basis of water resources management in the Shasta Basin: aquatic ecosystem function as it relates to coho salmon and other anadromous fish, existing water resources development, and institutional management of water resources.

The description of the aquatic ecosystem function provides a brief overview of physical and biological attributes that make the Shasta Basin particularly well-suited to support anadromous fish. The description of existing water resources development provides an overview of agricultural water users and major water storage and delivery infrastructure. Finally, the description of institutional management identifies the various federal, state, and local agencies, non-governmental organizations (NGOs), and others that manage or are affected by the management of the basin's natural resources. This background provides the basis for identifying contributing factors that may constrain effective and balanced water resources use in the Shasta Basin.

While the elements described in this section provide the basis for understanding the fundamental mechanisms that drive water resource demands by the aquatic ecosystem and irrigated agriculture, other elements must also be considered during the development of a comprehensive basin plan to address water resources management. These elements may include a broader set of issues, such as water law, regulatory mechanisms and requirements, land use regulations, market forces on agriculture, county governance, and others. While specifically addressing these issues is beyond the scope of this project, formulating and defining these broader issues within the overall basin plan framework objective of identifying the quantity, quality, location, and timing of streamflow to balance competing demands will retain the flexibility necessary to successfully incorporate new information into a basin planning exercise.

3.2.1. Aquatic Ecosystem Function

The Shasta River exhibits an aquatic ecosystem largely unique to the Lower Klamath Basin. These unique ecosystem attributes are derived from the Shasta River's geographical and geological setting adjacent to the Cascade Volcanic Range. Much like the other major tributaries to the Lower Klamath River (Trinity, Salmon, and Scott Rivers), the Shasta River originates along the steep slopes of the Klamath Mountains, where its headwater streams rise and fall with seasonal snowmelt and rainfall, and elevated gradients and seasonally high flows maintain gravel-bedded channels. However, as the Shasta River flows northward through the low-gradient Shasta Valley, gravels diminish and numerous groundwater springs and several spring-fed creeks join the Shasta River. The largest of these springs are located along Big Springs Creek (Figure 4) and are sourced from melting snow that infiltrates porous volcanic rocks high on Mount Shasta. This groundwater acquires nitrogen and phosphorous from underlying rock formations, ultimately discharging stable, cool, and nutrient-rich water to Big Springs Creek. Much smaller quantities of groundwater discharge from springs located northwest of Lake Shastina, the volume of which are influenced by reservoir levels (Davids Engineering, 2011). Groundwater spring contributions throughout the Shasta Valley help buffer flow variations and water temperatures, while also fueling a highly productive aquatic ecosystem (Dahlgren *et al.*, 2010). The Shasta River maintains its spring-fed character as it flows through the northern end of the Shasta Valley, where it is joined by the Little Shasta River, Yreka Creek and several smaller tributaries, before descending through a steep canyon and entering the Klamath River.

The headwaters of the Shasta River are impounded behind Dwinnell Dam in Lake Shastina (Figure 3). With only minimal downstream flow releases from Dwinnell Dam, the nutrient-rich and thermally stable spring flows largely determine ecosystem structure in the Shasta River (Jeffres *et al.*, 2009, Jeffres *et al.*, 2010, Nichols *et al.*, 2010). Available nitrogen and phosphorous, largely from springs, enables the prolific growth of aquatic plants, which provide structural habitat and a food source for prolific numbers of aquatic insects. These aquatic plants also control channel hydraulics, create velocity refuge and overhead cover for rearing salmon, and provide shade (Willis and Deas, 2011) to many stream reaches largely devoid of riparian vegetation. Available food resources, optimal water temperatures, and structural habitat associated with aquatic plants provide intrinsically high quality fish habitat, allowing coho salmon in the Shasta River reaches in the vicinity of these springs to grow extraordinarily quickly. Further, juvenile salmon can use certain spring-fed tributaries as refuge during occasional seasonal floods following large rainfalls or snowmelt.

The influence of groundwater spring flows on salmon habitat tends to diminish with the distance downstream from spring sources (Nichols *et al.*, 2010). With respect to streamflow, the stable spring-fed hydrology becomes more strongly influenced by tributary inflows and seasonal surface water diversions. For water temperature, atmospheric conditions overwhelm the thermal conditions provided by spring flow with increasing distance from spring sources (Nichols *et al.*, 2013). Regarding water quality, spring and summer nutrient uptake by aquatic plants reduces nutrient concentrations in lower portions of the Shasta River. In general, aquatic habitat conditions in the Shasta River downstream from Big Springs Creek become less driven by characteristics of the spring water, and more influenced by ambient environmental conditions and water management decisions.

The aquatic ecosystem structure of the Shasta River is largely dependent upon the cool-water habitat provided by large groundwater springs. These spring sources are located at distinct locations and have definable limits to their downstream impacts on aquatic ecosystem conditions. Understanding how these springs function within a framework of water resources use and cool-water management in the Shasta Basin is critical to identifying and managing ecosystem needs.

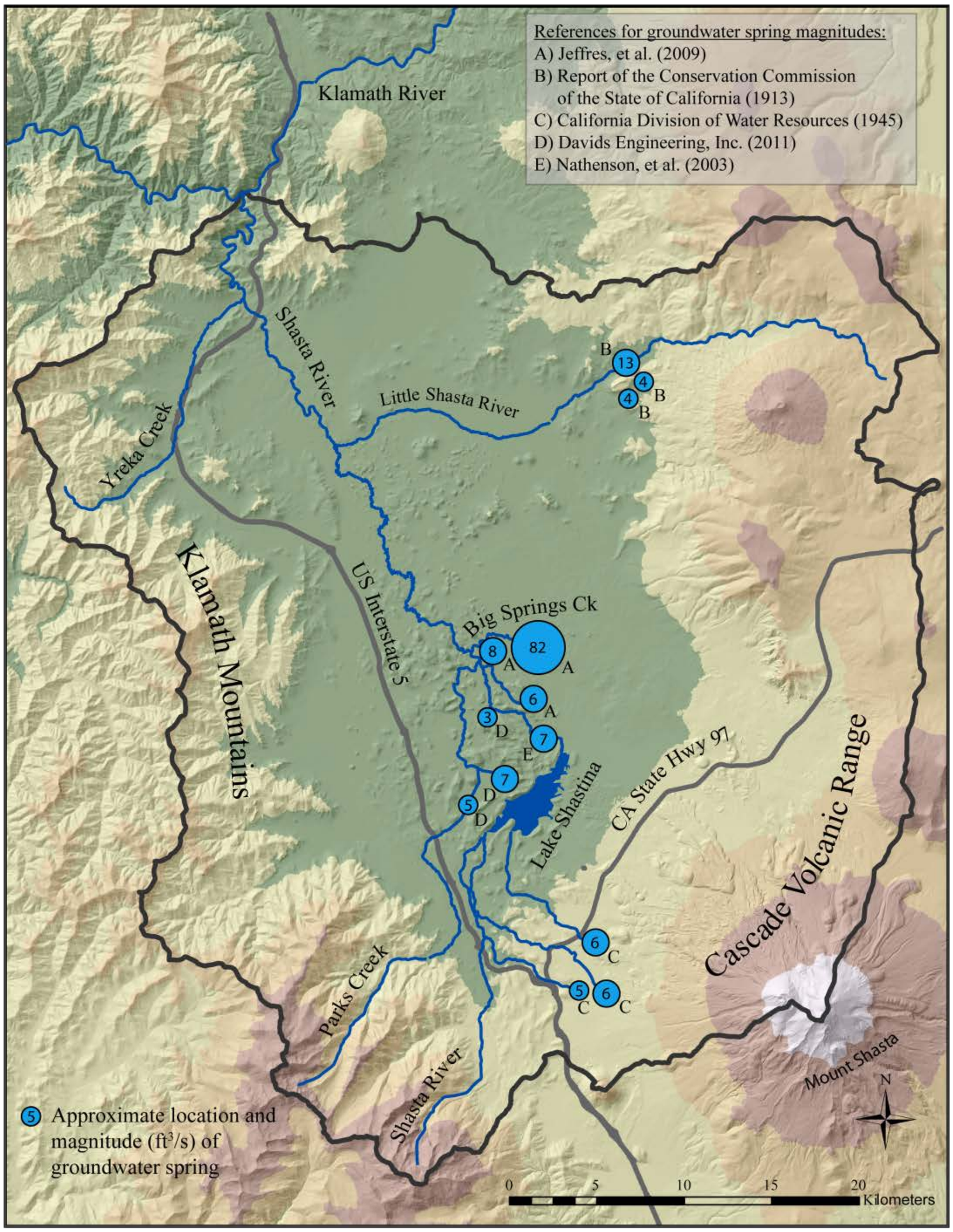

Figure 4. The Shasta River originates as snowmelt and rainfall runoff in the Klamath Mountains. Due to impoundment in Lake Shastina, the majority of streamflow in the Shasta River comes from a series groundwater springs (only major, and predominantly perennial tributaries to the Shasta River are shown).

3.2.2. Existing Resources Development/Infrastructure

Water resources use in the Shasta Basin primarily consists of agricultural supply (i.e., irrigation and stockwater), though other uses (e.g. municipal, industrial, recreation, fish and wildlife) also play a role in the overall water resources development and use. Agricultural water demands are met in four principal ways: 1) the direct diversion of surface water from the Shasta River and its tributaries; 2) diversion of surface water stored in reservoirs (principally Lake Shastina); 3) pumping from groundwater supplies;

and 4) re-use of applied irrigation water. This section provides a description of some of the major agricultural and municipal water users in the Shasta Basin as well as the water resources infrastructure used to store and deliver water for its various applications.

3.2.2.1. Water users

Though water resources development in the Shasta Basin began in the mid-1800s, the current structure of water use is largely based on the 1932 statutory adjudication of surface water rights (CADWR, 1932, 1965). Riparian rights below Dwinnell Dam and groundwater rights throughout the Shasta Valley were not adjudicated in 1932. From 1934 through 2011, the California Department of Water Resources Watermaster Service apportioned surface water in the Shasta River in accordance with the adjudication proceedings. In 2012, Watermaster service in the Shasta Valley was transferred from the California Department of Water Resources to the private Scott Valley and Shasta Valley Watermaster District.

There are nearly 53,000 acres of irrigated land in the Shasta Valley (CADWR, 1964, 1965, 2008). Estimates made by the California Department of Water Resources (CADWR) in the year 2000 (as provided in CADWR, 2008) indicate that of all applied irrigation water in the Shasta Valley, roughly 152,000 acre-feet (87%) comes from surface water, while 23,000 acre-feet (13%) is sourced from groundwater. Surface water diversions in the Shasta River and its tributaries appropriate more than 600 ft^3/s of water during the irrigation season (NCRWQCB, 2006). With estimated unimpaired summertime baseflows in the Shasta River of approximately 150 ft^3/s (Null *et al.*, 2010) – and typical summer flows much less – return flow is an integral part of the water supply in the valley as it is subsequently diverted in downstream reaches. Many small private surface water users account for a considerable portion of appropriated water. Remaining surface water is appropriated by four major water service agencies (Figure 5). The Shasta River is fully appropriated (often over-appropriated) and senior water rights holders preclude junior water rights holders from using their full entitlement almost every year.

The largest water diverters from the Shasta River and its spring sources below Dwinnell Dam are four water service agencies that deliver water to agricultural and/or municipal water users annually between April 1 and October 1. These agencies include: the Shasta River Water Association (SRWA), Grenada Irrigation District (GID), Big Springs Irrigation District (BSID) and Montague Water Conservation District (MWCD) (Figure 5). SRWA, GID and BSID maintain a cumulative appropriative surface water right of approximately 112 ft^3/s (~40,000 acre-feet per irrigation season) (CADWR, 1965), while MWCD stores up to 49,000 acre-feet of winter flows from the Shasta River and Parks Creeks stored in Lake Shastina to deliver water to its irrigation and municipal customers during the same April 1 to October 1 period (CADWR, 1964). Each of these agencies serves a specified acreage with their water rights, though BSID has developed groundwater resources to service its district in lieu of its surface water right.

Groundwater supplies provide roughly 13% of applied irrigation water in the Shasta Valley (CADWR, 2008). According to CADWR (2008), as of 2003, 195 wells in the

Shasta Valley were used for irrigation, with 170 additional wells constructed for undetermined uses, potentially including irrigation, stockwatering, domestic supply, and other uses. Several of the largest irrigation wells are located in the vicinity of Big Springs Creek and are maintained and operated by BSID and MWCD (Figure 5). There are 1,825 domestic and 30 public/industrial groundwater wells in the Shasta Valley. Although groundwater use in the Shasta Valley is not adjudicated, MWCD can be restricted from pumping groundwater in the vicinity of Big Springs Lake if lake levels drop enough to limit gravity diversions to adjacent lands (CADWR, 2000). No other groundwater users are specifically restricted based on available surface water supplies.

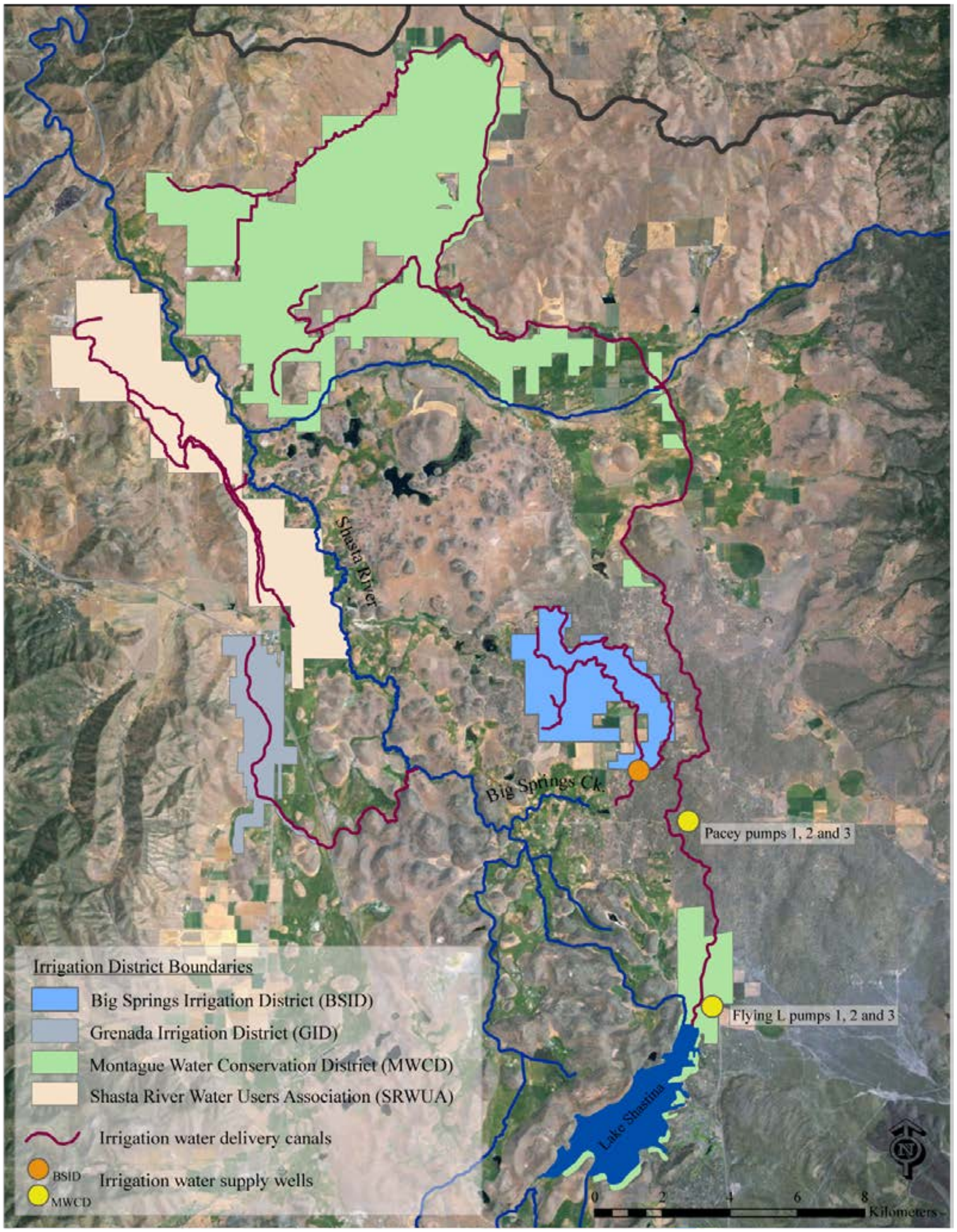

Figure 5. Shasta Valley water service agency locations and service areas.

3.2.2.2. Water resources infrastructure

Water is delivered to users in the Shasta Basin through various means, including canals, diversion facilities, pumps, and storage infrastructure. These storage and delivery systems are maintained by water service agencies or private water users. A majority of the water delivery infrastructure is maintained by the water service agencies, and operate independently, but consistent with Watermaster service requirements. Private water users maintain a wide array of water delivery infrastructure, generally consisting of either pump or gravity diversions from the Shasta River and its tributaries. The Watermaster oversees those rights that are decreed in the adjudication. This section provides a description of the principal components of this water storage and delivery infrastructure in the Shasta Basin.

3.2.2.2.1. Water Agencies

The four major water service agencies in the Shasta Valley utilize an extensive infrastructure to deliver water to their customers. The components of this water delivery infrastructure are presented in Figure 5 and briefly described below.

MWCD provides water to municipal users in the City of Montague and to approximately 11,000 irrigable acres within its water service district. Water is stored and delivered using roughly 60 miles of canals, numerous diversions, pumps, and storage facilities (Figure 5) (Booher *et al.*, 1959). Delivered water comes principally from Lake Shastina, where approximately 49,000 acre-feet of water from the Shasta River and Parks Creek (via seasonal diversion from Parks Creek to the Shasta River) is stored behind Dwinnell Dam (Booher *et al.*, 1959, Vignola and Deas, 2005). The MWCD main canal conveys water approximately 20 miles north from Lake Shastina to its irrigation district and municipal customers. Two sets of groundwater wells and associated pumps (Flying L and Pacey wells) are located along the canal (see Figure 5) and can augment delivery to users. MWCD also delivers water to prior rights users located along the Shasta River downstream from Dwinnell Dam. Releases of up to 10 ft^3/s are delivered from the main canal and through a cross-channel located downstream of Dwinnell Dam to fulfill these irrigation season water rights (CADWR, 1963, Vignola and Deas, 2005).

BSID owns and operates groundwater wells (with associated pumps) and canals to supply and deliver water to its customers across the 3,600-acre irrigation district (Figure 5). Three pumps, located roughly a mile northeast from Big Springs Lake, are used to supply approximately 25 ft^3/s of irrigation water. Two canals, referred to as the Upper Lift Ditch and Main Canal, use a series of 24 check structures to deliver water to users along the 11.5 mile canal system (FAI, 2006). Formed in 1927, BSID historically used a 30 ft^3/s right to water in Big Springs Lake (~10,500 acre-feet per irrigation season), and delivered this water to irrigable land located north of the lake. Since the late 1980s, BSID has used groundwater in the place of surface water from Big Springs Lake (CADWR, 2000).

GID has the right to divert and deliver up to 40 ft^3/s (approximately 14,000 acre-feet per irrigation season) of surface water from the Shasta River. This water is delivered to district customers spread across 1,427 irrigable acres located to the west of the Shasta River near the town of Grenada (GID, 2012) (Figure 5). Downstream water rights with senior priority preclude GID from using its full entitlement in some years (CADFG, 1997). The GID diversion infrastructure consists of a variable speed pump system and fish screen built in 2012. Water is conveyed through several miles of canal to district lands. Historically, the GID diversion facility was also used to deliver up to 11.9 ft^3/s water to the Huseman Ditch for use downstream along the Shasta River (CES, 2002). In 2012, the Huseman Ditch diversion point was moved approximately 4.7 miles downstream, and now uses variable drive pumps to divert water from the Shasta River as per the proposed scope of work (GID, 2009).

SRWA serves approximately 6,600 acres of irrigated agricultural land located southwest of the town of Montague. Formed in 1912, SRWA has a surface water right of 42 ft^3/s from the Shasta River (~15,000 acre-feet per irrigation season). SRWA uses two recently constructed boulder riffles at RM 18 to create a flow through impoundment along the Shasta River that allows four variable speed pumps, with a total pump capacity of 45 ft^3/s, to deliver water to agency customers (SVRCD, 2012). This water is delivered to customers along roughly 13.5 miles of canals located to the west of the Shasta River (CADWR, 1964).

3.2.2.2.2. Private users

Private water users typically pump water directly from the Shasta River and its tributaries, or maintain smaller dams and weirs to facilitate seasonal gravitational or off-channel pumping diversions. With more than 200 private water users in the Shasta River Valley (Clements, 2006), a detailed description of the infrastructure associated with each diversion is impractical. However, generalized descriptions of private diversion infrastructure can be provided.

Private water users utilize direct diversions or pumps to divert water to adjacent agricultural lands. Many (if not all) diversions in the Shasta River below Dwinnell Dam are screened to avoid entrainment of juvenile salmonids. This is consistent with CADFW statewide fish screening policies that require all surface water diversions located within the critical habitat of a federally (ESA) listed anadromous species (e.g. coho salmon) to be screened.

Earthen dams are also used by private water users to seasonally impound flow at the head of selected creeks throughout the Shasta Basin. Impoundment allows gravitational or pumped diversions to surrounding agricultural lands through interconnected ditches and pipes. Many of the small earthen dams in the Shasta Basin are located at the heads of spring-fed creeks. Additionally, Greenhorn Dam on Greenhorn Creek, a tributary to Yreka Creek, historically impounded water for City of Yreka water supply. Today, the impoundment serves as a centerpiece to Greenhorn Park, a recreational facility.

Along mainstem reaches of the Shasta River and its tributaries, flashboard dams are utilized check streamflows and enable pump or gravitational diversions (CES, 2002). Throughout the irrigation season, vertical slatboards in these dams are re-configured to change check elevations or to control water volumes released through the dam. Many of the historical flashboard dams previously identified by CADFW (1997) the NRC (2004) have been replaced with structures and associated pumping facilities that are amenable to fish passage and reduce impoundment-related backwater areas that can lead to seasonal water quality impairment.

3.2.3. Institutional Management

Governmental entities, landowners, non-governmental organizations (NGOs), private groups, Native American tribes, and others have an interest in the natural resources of the Shasta Basin. The specific management goals and objectives for each entity can vary due to many factors, including but not limited to, established mission and purpose, legislative or institutional requirements (for federal, state, and local governments), available resources. As such, their actions can directly or indirectly affect the natural resources of primary concern in this Shasta Basin planning framework: anadromous fish and agricultural water supply. Some of these entities have overlapping mandates or missions, which may conflict or cause confusion as to specific responsibilities. Further challenges include the broad mission statements for these entities, which are appropriate for conveying the general intentions, but introduce ambiguity to planning and management actions at the basin scale. Conversely, these mandates can also leave remarkable gaps in water resource management activities. Finally, the direct management actions of each entity can indirectly affect the management of other natural resources. Nonetheless, the principal challenge appears to be coordination and communication among agencies, particularly regarding the finer details that ultimately make restoration and management effective.

In this section, entities are identified that are involved in the management of anadromous fish and agricultural water supply. A brief description is provided of each entity's management activities and how the directly or indirectly affect the management of natural resources. At the end of this section, these entities and management activities are summarized in Figure 6 and Table 1.

3.2.3.1. Anadromous Fish Management

The direct management of anadromous fish is principally tasked to a consortium of state and federal agencies, with agency-specific mandates directing management strategies. Also, many additional federal, state, local, and other entities indirectly participate in fisheries recovery efforts in the Shasta Basin through other natural resource management actions ranging from water quality regulation to habitat restoration funding. Understanding the role (either direct or indirect) each entity plays in the management of anadromous fish is critical to formulating effective strategies that are not encumbered or undermined by conflicting objectives.

3.2.3.1.1. Direct Management

Federal and state agencies legislatively mandated to directly manage fish species in the Shasta River include:

- the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA-NMFS),
- United States Fish and Wildlife Service (USFWS),
- and the California Department of Fish and Wildlife (CADFW).

NOAA-NMFS is the federal agency principally responsible for the management of anadromous fish species such as coho salmon. NOAA-NMFS activities in the Shasta Basin include fish habitat conservation, protection (including legal enforcement) and recovery of aquatic resources listed under the federal Endangered Species Act (ESA), salmon hatchery management, and ocean fishery/harvest management. In 2012, NOAA-NMFS published a draft “Coho Recovery Plan” for Southern Oregon/Northern California Coast (SONCC) region (NOAA, 2012), which included recommended recovery actions for the Shasta Basin.

USFWS is the federal agency responsible for managing freshwater fish (i.e., non-anadromous) found in the Shasta River. USFWS activities in the Shasta Basin principally include fisheries and habitat conservation activities conducted by the Yreka Fish and Wildlife Office. Many of USFWS activities provide technical assistance and funding opportunities for fish habitat conservation (including salmon) projects developed with other state and federal partners.

CADFW is the state agency directly responsible for managing salmon in the Shasta River. Programmatically, CADFW activities range from management actions associated with the recovery of depressed salmon populations to environmental review and permitting - including activities conducted under the California Endangered Species Act (CESA). CADFW is also responsible for the management of the Iron Gate Fish Hatchery on the Klamath River. Locally, CADFW performs fisheries research and manages the Shasta Valley Wildlife Area.

3.2.3.1.2. Indirect Management

Numerous federal, state, local, and other entities indirectly affect fish in the Shasta Basin through other natural resource management actions. Federal agencies whose management activities indirectly affect salmon in the Shasta Basin include the

- United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS),
- United States Forest Service (USFS), and
- United States Bureau of Reclamation (USBR).

California state agencies that indirectly affect fisheries management in the Shasta Basin include:

- State Water Resource Control Board (SWRCB),
- North Coast Regional Water Quality Control Board (NCRWQCB), and
- California Department of Water Resources (CADWR).

USDA-NRCS primarily works with resource conservations districts (RCDs) and other private or governmental partners to develop and implement conservation practices protective of terrestrial and aquatic habits. Much of the USDA-NRCS work is performed on private agricultural lands. Examples of USDA-NRCS conservation actions in the Shasta Basin include providing funds for the construction of cattle exclusion fencing on riparian lands and the implementation of agricultural tailwater reduction projects. Such activities can affect fish through alteration to the riparian and aquatic habitats the fish depend on.

USFS activities principally consist of resource planning associated with National Forest Lands and the natural resources contained within them. Based on these planning activities, USFS funds or implements management activities generally associated with timber supply and water quality. Such activities indirectly affect salmon via changes in aquatic habitat conditions.

USBR functions as a federal water management agency, overseeing numerous programs, initiatives and projects necessary to meet existing water needs. While the USBR does not implement water projects in the Shasta River (its focus is limited to the mainstem Klamath River), the federal agency's management of many of the water resources in the larger Klamath Basin indirectly affects the fish of the Shasta River. Recently, USBR involvement in the development and implementation of the Klamath Basin Restoration Agreement (KBRA) and Klamath Hydroelectric Settlement Agreement (KHSA) has promoted funding of water quality and fisheries investigations in the Shasta River and some of its tributaries.

SWRCB maintains joint authority over water allocation and water quality protection in California. As such, SWRCB allocates water rights and develops statewide water quality standards and protection plans. Further, SWRCB oversees the nine Regional Water Quality Control Boards. In the Shasta River, the SWRCB is primarily responsible for issues regarding surface water rights.

NCRWQCB principally develops a legislatively mandated water quality control plan for the North Coast Region of California. This plan designates beneficial uses and water quality objectives (including TMDL development) for water bodies throughout the North Coast Region. Ultimately the plan is used for permitting and resource management, as well as a regulatory tool. The primary task of the NCRWQB in the Shasta River is the implementation and management of water quality TMDLs.

CADWR is the state agency generally tasked with managing the state's water resources. The primary functions of the agency are to develop the California Water Plan, as well as inform flood management, water supply and environmental questions. In the Shasta Basin, CADWR's primary roles include hydrologic data collection and water supply planning. Historically, CADWR provided Watermaster service to Shasta River water users. However, in 2012 Watermaster services were transferred from CADWR to the privately operated Scott Valley and Shasta Valley Watermaster District.

Numerous local entities indirectly affect Shasta River fishes through their management actions. The Shasta Valley Resource Conservation District (RCD) generally implements local natural resource conservation projects (e.g., tailwater efficiency, water quality planning, irrigation dam removal), while also providing community outreach activities for local landowners (e.g., Shasta River Coordinated Resource Management & Planning Committee). Local irrigation districts use storage facilities and delivery infrastructure to manage water and deliver it to their customers. Management of the timing and magnitude of irrigation district diversions can strongly influence available salmon habitat. Siskiyou County and local municipal governments tend to influence recreational and municipal water use, while also providing a forum for local citizens to voice concerns over existing or proposed water resource management.

Other organizations actively operating in the Shasta River Valley primarily focus on funding conservation actions geared towards fish habitat restoration include The Nature Conservancy, California Trout, National Fish and Wildlife Foundation, and others similar organizations that focus on fisheries or aquatic habitats. The Nature Conservancy (TNC) has used land acquisition and stream restoration actions to improve salmon habitat and improve local water efficiencies. California Trout (Cal Trout) typically funds both conservation science and local habitat restoration actions, while also providing programmatic support to conservation initiatives. The National Fish and Wildlife Foundation (NFWF) provides funding through its Lower Klamath Basin Initiative to support salmon habitat monitoring, while also supporting local conservation groups such as the Shasta River Water Trust.

Other entities and non-governmental organizations (NGOs) actively operating in the Shasta River Valley include PacifiCorp, (which funds a $500,000 per year program for coho ennhancement of parat of their Habitat Conservation Plan), Native American tribes, and others.

3.2.3.2. Agricultural Water Supply Management

The direct management of agricultural water supply falls to several state, local and private entities, each legally mandated to either quantify water use or physically deliver water to agricultural or municipal users. However, numerous federal and state regulatory agencies do indirectly affect agricultural water supply through the enforcement of regulatory actions aimed at managing resources dependent upon the water used by municipalities or for agriculture. Understanding the role (either direct or indirect) these entities play in the management of agricultural water supply is critical to formulating effective strategies that leverage existing resources while not encumbering water supply managers or users with conflicting objectives.

3.2.3.2.1. Direct Management

The California State Water Resources Control Board (SWRCB), Shasta Valley Watermaster District, California Division of Water Resources (CADWR), local irrigation districts and private diverters directly manage agricultural water supply in the Shasta Basin. Through the allocation of surface water rights, SWRCB legally determines and authorizes the location and quantities of agricultural water use. The Shasta Valley

Watermaster District (Watermaster services were previously performed by CADWR) monitors diversion quantities and ensures surface water allocation in accordance with existing water rights. Under the guidance of legal requirements specified by the SWRCB and instructions from the Watermaster, local irrigation districts/water agencies and private entities divert water necessary to meet their agricultural needs.

3.2.3.2.2. Indirect Management

While agricultural water use is legally determined by established water rights and diversion infrastructure, numerous entities indirectly influence water supply management, particularly through instream flow recommendations or regulatory processes. For example CADFW and SWRCB have recently collaborated in an attempt to identify the instream flows required to allow anadromous fish to effectively rear in the Shasta River. In a similar vein, NCRWQCB has attempted to address instream flows needed to meet water quality objectives specified under the Shasta River Total Maximum Daily Load (TMDL) (NCRWQCB, 2006). From a regulatory perspective, entities such as NOAA-NMFS and CADFW have legal authority to change irrigation diversion quantities or infrastructure if actions associated with a given diversion harm threatened or endangered fish species.

Agricultural water supply in the Shasta Basin is also indirectly managed through resource conservation studies and projects implemented by entities such as the USDA-NRCS, the California Farm Bureau, and Shasta Valley RCD. For example, tailwater return and irrigation efficiency studies funded by the RCD provide water use guidance to local irrigators, while irrigation infrastructure improvements funded and carried out by USDA-NRCS help increase irrigation efficiencies.

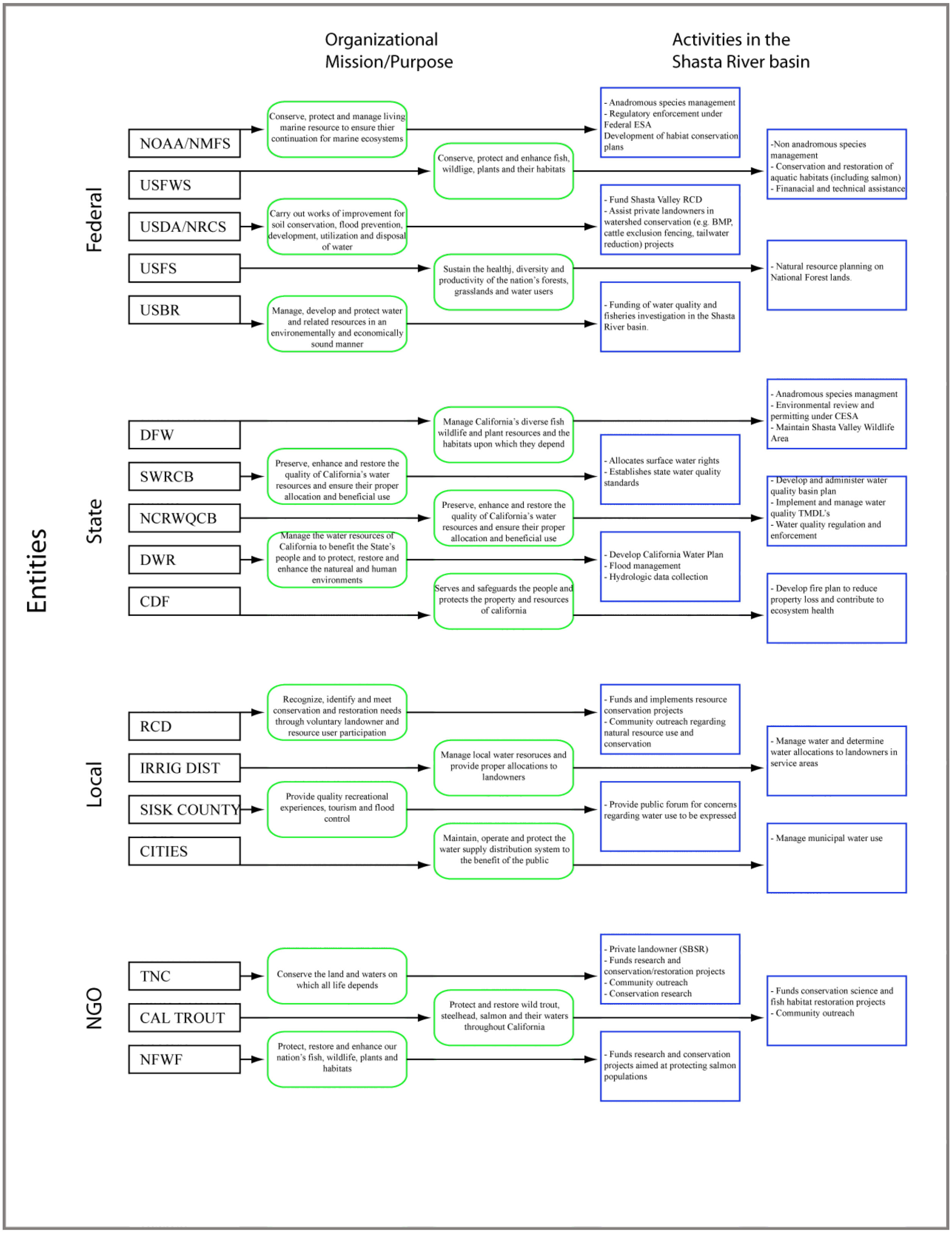

Figure 6. Primary roles of federal, state, and local government entities, and other entities that participate in water resources management processes in the Shasta Basin.

Table 1. A summary of federal, state, local, and NGO entities whose management practices directly or indirectly affect anadromous fish and/or agricultural water supply

Entities	Resource Management [Direct(D)/Indirect(I)]	
	Anadromous Fish	Agricultural Water Supply
Federal		
NOAA/NMFS	D	I
USFWS	D	I
USDA/NRCS	I	I
USFS	I	I
USBR	I	I
State (CA)		
DFG	D	I
SWRCB	I	D
NCRWQCB	I	I
DWR	I	I
CDF	I	I
Local		
Shasta Valley RCD	I	I
Irrigation Districts/Water Agencies	I	D
Private Diverters	I	D
Siskiyou County	I	I
Municipalities	I	I
N.G.O.		
The Nature Conservancy	I	I
California Trout	I	I
NFWF	I	I

3.3. Contributing Factors to Water Management Problems

Identifying factors that limit the sustainability of the aquatic ecosystem and agricultural water user in the Shasta Basin is a critical step towards balancing those water uses and restoring and managing natural resources. Like many watersheds throughout the western United States, the historic adjudication of water rights in the Shasta Basin did not consider the quantity and quality of water that must be left instream to maintain the sustainability of native fish species – particularly coho salmon. As a result, surface water supplies are managed to prioritize agricultural and other water use; the quantity and quality of the remaining instream flow is insufficient to support a sustainable aquatic ecosystem. Over time, evolving state and federal regulations have attempted to develop water quantity and quality standards for the Shasta River that protect the aquatic ecosystem, but in a way that prioritizes water supplies for the aquatic ecosystem. Without identifying specific places and times for the recommended quantity and quality, this approach establishes the framework for similarly unbalanced water use by prioritizing an alternate demand (i.e., the aquatic ecosystem).

In this section factors are identified that contribute to the current challenges to meeting the water supply and aquatic ecosystem needs in the Shasta Basin. First, factors contributing to the degradation of the Shasta River aquatic ecosystem are presented. Specifically, the spatial and temporal distributions of limiting water quantity and quality conditions for coho salmon are identified. Additional limiting factors to coho habitat suitability and use are also presented. Next, factors limiting agricultural water use within the Shasta Basin are described. Finally, the general institutional barriers preventing coho salmon recovery within the water use framework of an agricultural basin are discussed. While the contributing factors that are identified in this document are specific to the Shasta Basin, they illustrate how challenging basin planning can be when recommended prescriptions to address broad resource degradation are not accompanied by recommended locations and times for those prescriptions.

3.3.1. Aquatic Ecosystem (coho salmon)

Suitable coho salmon habitat in the Shasta Basin is spatially restricted, contributing to a depressed population of the threatened salmon species. The current low abundance of coho salmon in the Shasta River can be partially attributed to an inability to meet the appropriate life stage water quantity and quality needs of coho. Identifying when and where coho water quantity and quality needs are inadequate is a critical first step toward generating management strategies to recover depressed populations. Below, the location and timing of water quantity and quality limitations for coho salmon in the Shasta River are presented. To illustrate how these limitations are spatially and temporally specific, each limitation is graphically illustrated over the mainstem Shasta River. At the end of this section, the quantity and quality illustrations are combined to show how, though much of the Shasta Basin contains inadequate aquatic habitat for coho, the type and place of that limitation varies throughout the year. These limitations may be a result of other water use in the basin, or may reflect the natural limitations of any system (i.e., even in undeveloped systems, optimal water quantity and quality conditions are unlikely to be found throughout the entire system for every life stage at all times). The specific limiting factors that are identified in this section represent some of the most significant ones affecting coho salmon, but are not an exhaustive list. Additional factors that prevent access to suitable habitat or limit habitat suitability are also identified.

3.3.1.1. Water Quantity

Streamflow magnitude is a critical element of aquatic habitat suitability for coho salmon in the Shasta River. Because each life stage has variable life-history tactics, coho demand flow characteristics are similarly variable. For example, early winter spawning requires flows sufficient to provide upstream passage for adult salmon to available spawning reaches. In contrast, the springtime outmigration of 1+ coho and the distribution of 0+ coho to favorable oversummering habitats (Nichols *et al.*, 2013) requires flows that differ in volume, locations, and timing from those needed for spawning. Herein, the spatial and temporal distributions of limiting flow conditions for coho salmon in the Shasta River are identified. Declining flows can also lead to other limiting conditions (i.e., elevated water temperatures) separate from available physical aquatic habitat. These conditions are discussed separately in this report. This section considers flow limitations that are directly addressed by identifying specific magnitudes, timing, frequency, or duration of flows.

A portion of the mainstem Shasta River where flow magnitude is the primary factor limiting coho habitat use is the river reach from Dwinnell Dam to Parks Creek. Throughout this reach, streamflows are determined by releases and seepage from Dwinnell Dam, and inflows from several small groundwater springs. In total, flow magnitudes below Dwinnell Dam generally do not exceed 10 ft^3/s. The low flow magnitudes throughout this reach directly affect coho salmon in two ways: they limit migratory passage for various life stages, and prevent sediment transport that would help maintain intermittent patches of spawning gravels. Migratory passage for spawning adults is limited during the late-fall/early-winter, (Figure 7); Flow regulation by Dwinnell Dam alters flow characteristics that support the downstream migration for 0+ and 1+ coho rearing within Shasta River between the dam and Parks Creek. More specifically, the lack of flows that mimic the snowmelt recession seen in Parks Creek alters the flow cues that encourage 0+ coho to migrate towards thermally favorable habitat near the Big Springs and Shastina Spring Complexes, and 1+ coho to emigrate to the Klamath River.

Another example of water quantity limitations relates to the annual onset and end of irrigation activities. Throughout the Shasta River, sharp decreases and increases in flow typically occur at the beginning and end of each irrigation season. These changes, and particularly the rapid reductions in early-April flow magnitudes, pose a risk to coho salmon and other rearing salmonids that may become stranded or displaced from preferred habitats (on the channel margins) or cue juvenile salmon to migrate towards the Klamath River where rearing conditions are generally poor.

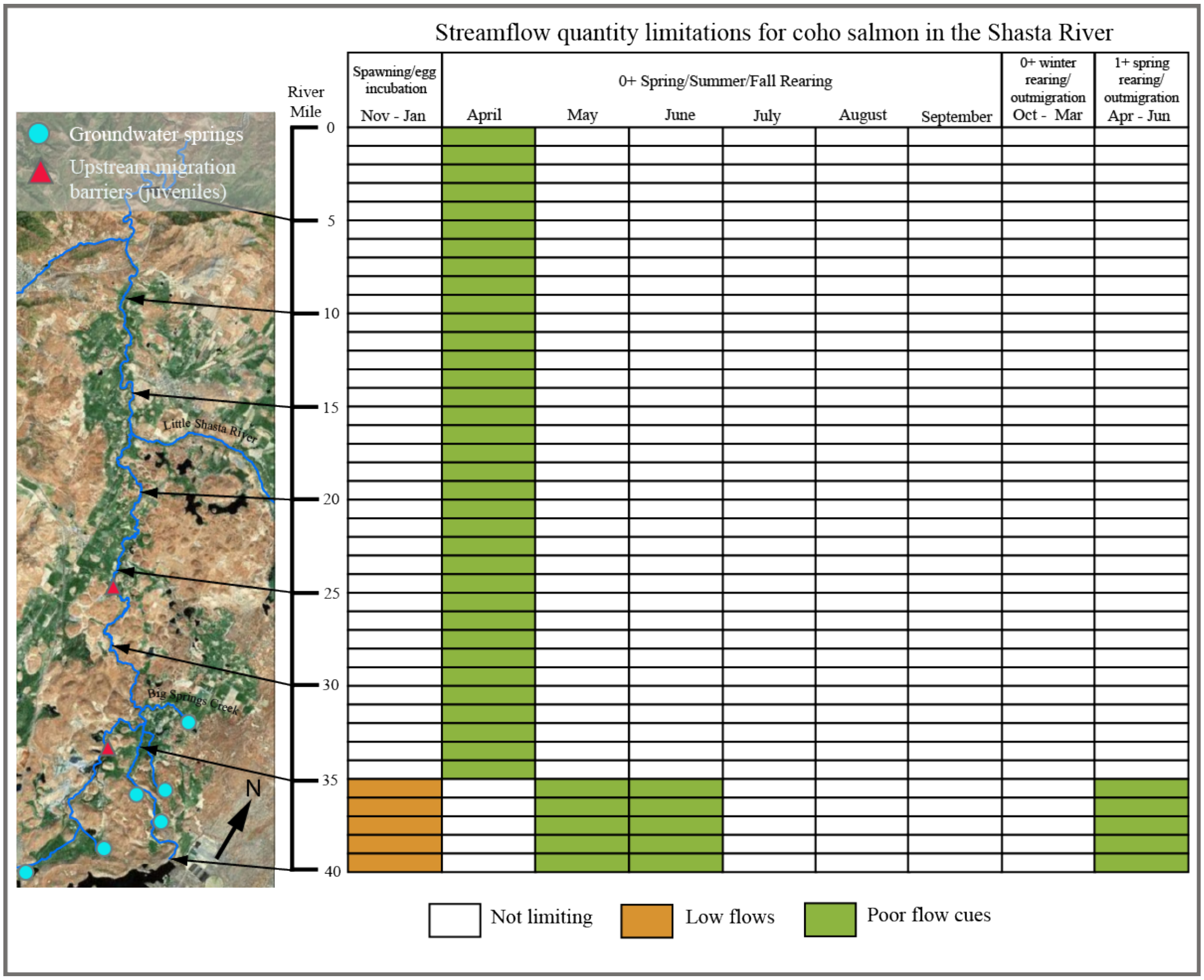

Figure 7. Spatial and temporal distribution of streamflow quantity limitations for coho salmon in the mainstem Shasta River.

3.3.1.1. Water Quality

Seasonally-elevated water temperatures are well-established limiting factors for coho salmon in the Shasta River, and are subject to TMDL regulations (NCRWQCB, 2006). The Shasta River TMDL (NCRWQCB, 2006) also identifies dissolved oxygen as a limiting factor for coho salmon throughout the mainstem Shasta River though little information is available regarding how reduced dissolved oxygen concentrations may currently limit coho habitat suitability throughout the Shasta River (see NCRWQCB, 2006). Due to complex interactions between available streamflows, water use, agricultural return flows, and both riparian and instream vegetation growth, water quality characteristics in the Shasta River exhibit large spatial and temporal variation. Water temperature conditions and their relationship to the aquatic ecosystem have been extensively documented, though some data gaps still remain. Because the goal is to illustrate the spatial and temporal bounds of a specific limitation, a general discussion of water temperature limitations is presented here. This variation is presented in Figure 8, and discussed below.

Small springs and seeps are located throughout the stream reach from Dwinnell Dam to Parks Creek (Stenhouse *et al.*, 2012; Chesney *et al.*, 2009), which create thermal refugia in a generally low-flow reach and function as oversummering coho salmon habitat. However, these spring sources do little to alter reach-scale water temperature conditions, which are driven by flow, channel conditions, and meteorology. Consequently, overall thermal conditions throughout much of this reach of the Shasta River may not be suitable for rearing coho salmon from late May through early September, with the exception of refugia.

Water temperature in the Shasta River from the Parks Creek confluence to Big Springs Creek is largely determined by water temperatures inherited from Parks Creek inflows, where thermal conditions are principally determined by the response of snowmelt runoff-derived flows to meteorological conditions. Generally, this reach becomes thermally-unsuitable for coho from late May through early September, when snowmelt-derived flows diminish and water diversions from Parks Creek increase. Small springs throughout this reach (e.g. Hole in the Ground Creek) can provide localized thermal refugia for juvenile coho (CADFW, 2012).

Water temperatures throughout Big Springs Creek and the Shasta River below Big Springs Creek generally provide suitable, reach-scale habitat conditions for all life stages. Undesirable water temperatures may occur in the spring and early summer, when little shade from emergent macrophytes is present in Big Springs Creek, and the wide and shallow creek is vulnerable to heating. As emergent aquatic vegetation grows and provides shade to the creek, maximum water temperatures decrease throughout the summer and fall. As water from Big Springs Creek flows into the Shasta River, it continues to provide cool water temperatures to the river for several kilometers downstream. Through late-spring and summer, the extent of the downstream reach affected by the cool water is reduced as flow volumes decrease due to the diminishment of snowmelt runoff, diversions, and seasonal stream heating rates increase.

Downstream of Highway A-12, water temperatures in the Shasta River are generally unsuitable for coho salmon. Low-flows, agricultural return flows, and prolonged exposure to thermal loading associated with meteorological conditions, all contribute to poor thermal conditions for 0+ and 1+ coho throughout this reach. Other tributaries also influence the Shasta River in the reach between Highway A12 and the mouth; however, water temperature conditions in those tributaries are not well characterized. Of these tributaries, only Yreka Creek and the Little Shasta River are known to historically support populations of coho salmon. The Little Shasta River receives cold water from spring sources in upstream reaches that can provide local thermal refugia. However, access to these areas and suitability or use of these thermal refugia is incompletely understood.

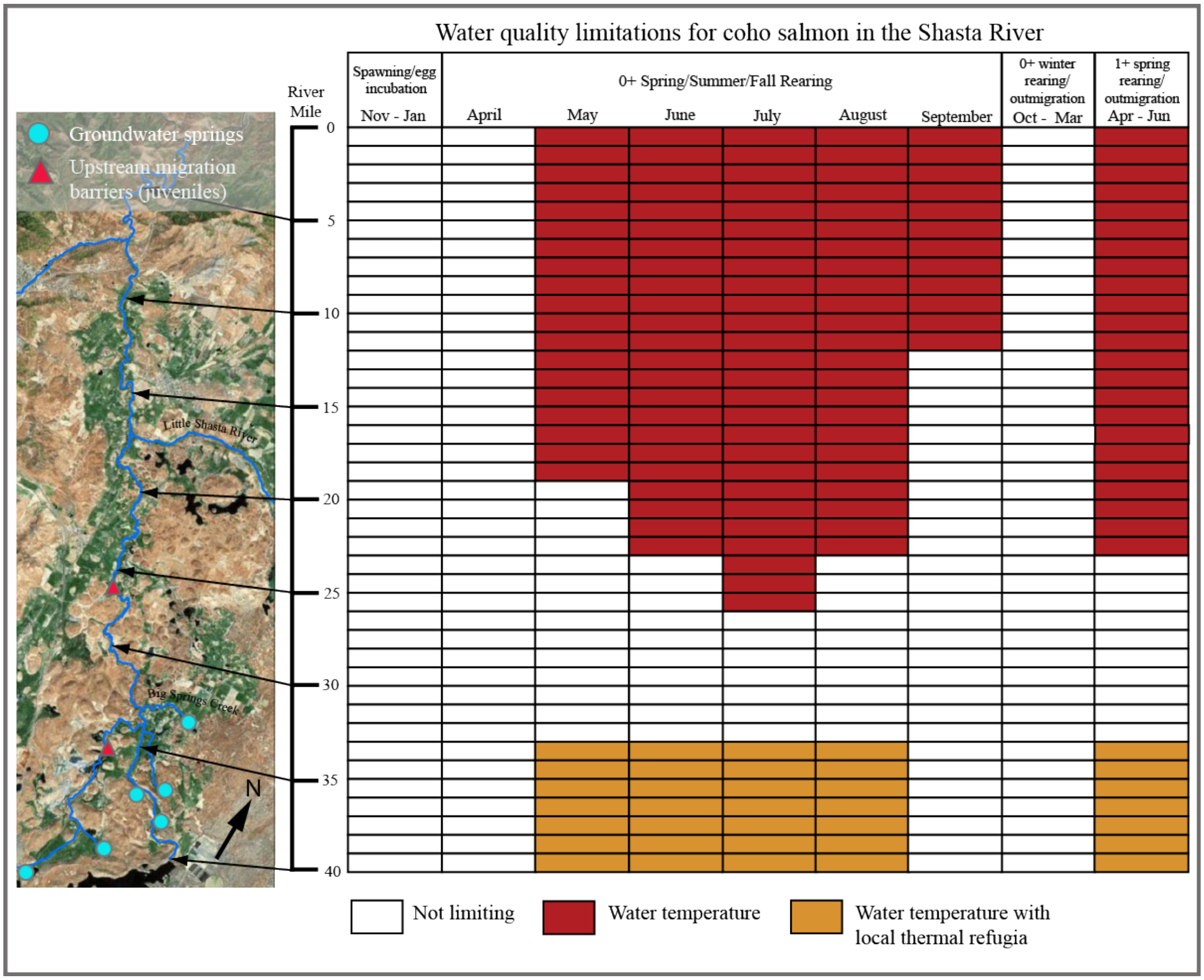

Figure 8. Spatial and temporal distribution of water quality limitations for coho salmon in the mainstem Shasta River.

3.3.1.2. Other Factors

Water quantity and quality are the principal limiting factors for coho populations in the Shasta River. Without providing flow and water quality conditions that meet life-stage specific needs for coho, recovery goals are unlikely to be met. However, in addition to water quantity and quality limitation, other limiting factors also contribute to low population numbers. These include instream barriers, riparian vegetation, geomorphology and other factors. These can be assessed in a basin planning process and addressed appropriately based on QQST criteria.

3.3.1.3. Summary

Complex interactions between habitat characteristics (e.g., geomorphology, food resources, instream cover) and the previously discussed limiting water quantity and quality characteristics determine the spatial and temporal distribution of coho habitat use throughout the mainstem Shasta River (Figure 9). Outside of the April through September irrigation season, habitat conditions for spawning adult coho and rearing 0+

and 1+ juvenile coho are generally not limiting. One exception is that low flows in the Shasta River between Dwinnell Dam and Parks Creek may limit access for adult coho to intermittent spawning gravels. Generally, adult coho spawn in either the Shasta River Canyon or near the Big Springs or Shastina Springs complexes (Jeffres and Moyle, 2012).

As the annual irrigation season progresses, the spatial extent of suitable water quantity and quality for coho salmon diminishes. By May, 0+ and 1+ coho rearing in the lower 20 miles of the Shasta River begin to face adverse flow and water temperature conditions and are probably forced to migrate to the Klamath River and proceed to the ocean or find suitable rearing habitats. At this same time, juvenile coho rearing in the vicinity of the Big Springs and Shastina Springs complexes begin to migrate towards more thermally suitable habitat in the Shasta River and its tributaries. As spring transitions into summer, the extent of thermally suitable habitat extending downstream from the spring complexes diminishes. As late summer progresses into early fall, the spatial extent of suitable water temperatures expands until appropriate quantity and quality of flow can be found throughout the Shasta River at the end of the irrigation season. Some of these limitations would occur as part of pre-development conditions; however, the effects of these limitations can be exacerbated by undesirable natural conditions such as poor ocean conditions, hot and dry water years (drought), and other natural events. The combined effect of these limitations has resulted in the population's current status as part of a "threatened" population within the SONCC ESU.

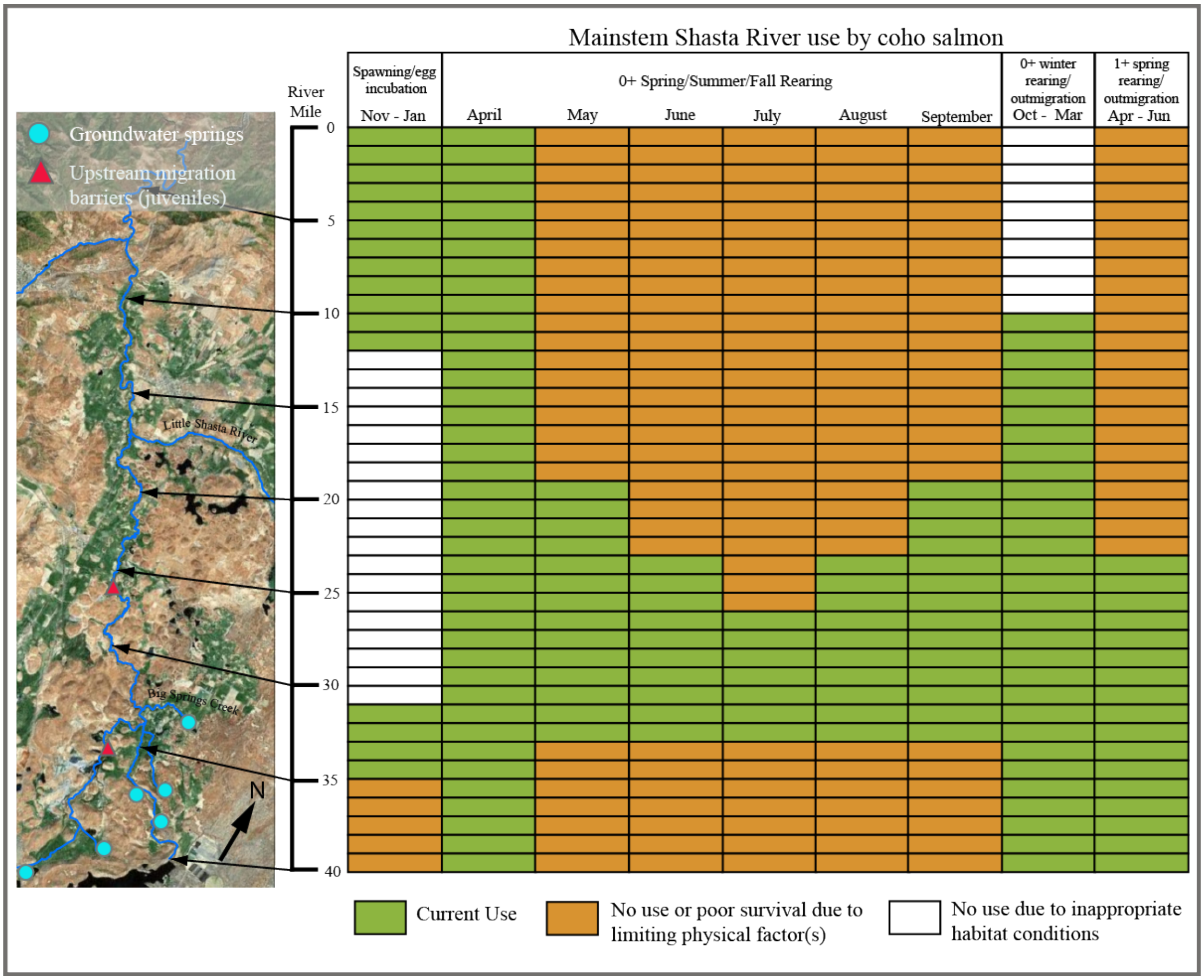

Figure 9. Spatial and temporal distribution coho habitat use in the mainstem Shasta River.

3.3.2. Agricultural Water Users

While recovery of the aquatic ecosystem function is the immediate issue confronting water users in the Shasta Basin, a co-equal goals approach to watershed management requires that issues regarding reliable supply of water to agricultural water users also be identified. Currently, water rights the Shasta Valley are administered via the 1932 adjudication. As noted previously, aquatic system requirements were not considered at the time of the adjudication, or if they were implicitly considered are not supportive of coho salmon needs in today's environment. Once the issue of environmental water use became a critical component of basin-scale water management, few mechanisms were available – aside from regulatory actions – to accommodate the priority rights structure that was established in the adjudication. Recently, additional tools have been proposed, such as instream flow dedications or flow transaction, to introduce flexibility into the constraints of the water rights system. Addressing the need for improved aquatic system function under coequal goals requires improved instream conditions while maintaining a sustainable agricultural community. This is a considerable undertaking.

Before solutions can be proposed to balance agricultural water use with environmental demands, defining agricultural water demands using QQST is important to identifying the key limitations that affect irrigation. Similar to aquatic ecosystem demands, agricultural water demands also vary in quantity, space, and time. Water quality is typically not an issue for agricultural water use (those other uses, such as municipal, may be affected by water quality); however, water quantity can be a constraint, particularly in dry years.

Irrigation on the mainstem Shasta River is restricted to April through September, and occurs from below Dwinnell Dam to approximately Interstate 5 above the while irrigation on the tributaries is permitted from March through October. Agricultural water users operate under a range of hydrologic and meteorological conditions. While some lower priority water right holders may have a portion of their allocation delivered during wetter years, generally only the higher priority water right holders receive water during normal or dry years. Other factors also compound the reduced water supply during dry years, including infrastructure and quantification challenges. These challenges exacerbate the general condition of competing uses between agricultural water use and aquatic ecosystem demands. Yet there are clear opportunities in the Shasta Basin, including infrastructure and operational improvements that can lead to improved efficiencies and yield additional water for instream flows. However, to achieve such outcomes, accurate quantification of existing water uses and instream flows are required.

A first step to reaching this goal requires reliable and complete water availability and use records. This information can be collected at existing stream gaging locations and via the Watermaster service provider. This information can subsequently be used to consider infrastructure improvements for delivery and irrigation systems that can reduce water loss and improve water supply reliability, support instream flow, or both. Further, flow transactions that include water quality and habitat benefits, as well as agricultural opportunities (e.g., an agricultural to agricultural transaction) can be developed among willing landowners and facilitated by agencies. These activities would necessarily consider QQST criteria to identify high priority actions for recovery of coho salmon. While useful initial steps can be taken in the short-term, particularly in reaches with substantial agricultural demands or operational water management, basin-scale planning for long-term balancing of water use should include the broader agricultural community.

3.3.3. Institutions

The previous section identified contributing factors that physically impair the recovery of coho salmon populations. However, institutional factors also contribute to the challenges facing coho salmon recovery within the agricultural watershed of the Shasta River. A primary institutional factor is regulatory uncertainty. Regulatory uncertainty occurs both among agencies as well as between the agency and the regulated community. This uncertainty takes the form of evolving legal conditions, new scientific information, changing regulatory criteria, variability in resources, lack of clarity in regulatory proceedings, and other issues. Some of these may be uncontrollable factors inherent in the complex field of water and natural resources management, and must simply be acknowledged as uncertainties and managed as such. However, some of these regulatory uncertainties can be addressed, and in certain cases must be remedied before the dual goals of functional aquatic ecosystem conditions and sustainable agricultural practices can occur.

One of the regulatory uncertainty challenges that can be addressed by natural resource managers in the Shasta Basin is coordination. For federal, state, and local regulatory agencies that play active roles in managing resources in the Shasta Basin, a principal challenge is coordinating the often overlapping efforts to manage anadromous fish recovery and maintenance. For example, multiple agencies address water temperature for anadromous fish either directly or indirectly, including the North Coast Regional Water Quality Control Board Basin Plan and TMDL's (NCRWQCB, 2006), the National Marine Fisheries Service (NMFS, 2012) assessment, and the California Department of Fish and Wildlife (e.g., Stenhouse et al., 2012). Each of these agencies has developed water temperature targets deemed protective of anadromous fish. These targets have each been designed with the same general objective (the recovery of coho salmon or anadromous fish), yet they range from basic guidance metrics to formal regulatory compliance targets. Further, identified water temperature targets generally do not consistently account for natural spatial and temporal variability of water temperature conditions or individual life history needs of anadromous fish throughout the Shasta Basin. Rather, these criteria are at times applied at all locations for all times. Developing temperature criteria is a challenging endeavor and agencies and institutions in this example act in good faith to improve water temperature conditions in the Shasta River to hasten recovery of threatened species. However, coordination among agencies to produce common criteria, clear quantifiable metrics, and well-defined interim and long-term recovery goals will translate directly into reduced uncertainty for landowners and water users that make up the regulated community

Institutional success in the Shasta Basin is also hindered by limited resources, too little collaboration between regulators and the unregulated community, and constrained agency mandates. Regulatory agencies are more often than not limited by available resources, which often change from year to year, and are affected by the political climate and economy. These factors result in uncertain funding levels, making it difficult for such agencies to coordinate and collaborate with each other and stakeholders, complete the necessary studies, and ultimately develop and implement the elements of a comprehensive recovery and management strategy. This type of uncertainty leads both resource agencies and agricultural water users planning for the short-term. The result is piecemeal efforts that do not successfully achieve the desired outcome: in this case, recovered coho salmon populations.

Finally, individual agency mandates often restrict the approaches and range of solutions that can be considered. Such mandates can conflict or compliment other agency's mandates, presenting conflicting or unclear messages to landowners and stakeholders. Further, in certain cases, agency mandates are vague regarding the balancing of multiple uses, resulting in regulators concentrating on limited aspects of the overall problem. This condition often results in conflict between regulating agencies and the regulated community.

While the issues of regulatory uncertainty, limited resources, and agency specific mandates are difficult to overcome for agencies and stakeholders alike, a collaboratively developed, comprehensive basin plan constructed upon the principals presented herein will provide the best approach to characterizing and prioritizing watershed issues, presenting a restoration strategy (with metrics and milestones), and ultimately leading to a solution that supports both instream uses and agriculture.

4. Part 3: Basin Framework and the Shasta Basin

The present basin plan framework is based on a range of information, including available reports and data gathered by a range of entities that have completed work in the Shasta Basin. This information was used to characterize aquatic ecosystems and agricultural water use, and their limiting factors in previous sections. Using the information gathered to characterize the aquatic ecosystem and water user needs, as well as identify limiting factors to effective management of those resources, a conceptual framework for the basin plan is presented. This framework includes interim (i.e., short-term), transitional, and long-term measures for water resources users and managers. The intention is that the framework be flexible and adaptable, and that resource managers and stakeholders would tailor the program to address specific needs in a collaborative process.

While there have been an array of planning efforts in the Shasta Basin, most efforts have been single purpose or limited to specific actions. In the Shasta Basin, the current primary competing water uses are the recovery of the aquatic system to support coho salmon populations and the use of water resources to support agriculture. These two uses are assumed to effectively encompass other uses, such that addressing conflicts between these two specific uses will also address activities associated with other uses. For example, restoring aquatic system conditions for coho salmon presumes that such actions would also benefit Chinook salmon, steelhead, and other native fishes (Figure 10). Similarly, addressing agriculture needs would also lend insight into managing other important water uses in the valley (e.g., municipal, industrial, etc.). By focusing on coho salmon and agriculture, most, if not all, of water use conflicts that result from multi-objective water use may be resolved. Thus, for the purposes of this document there are two principal “users” of water: coho salmon and agriculture.

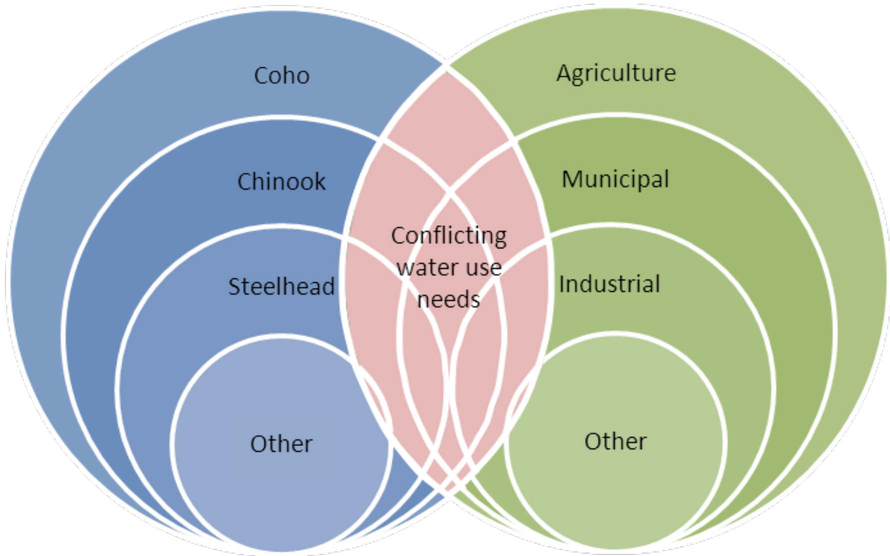

Figure 10. A conceptual illustration of how addressing water use needs of dominant users (e.g., coho and agriculture) can also address needs of related, but less restrictive, water users.

Because the two principal users can represent competing demands, a basin plan objective is identified herein to guide resource allocation decisions. Specifically, the objective aims to:

Balance water resource demands to support the long-term viability of multi-objective use by identifying the necessary quantity, quality, location, and timing of water to meet those needs.

In the Shasta Basin, this approach would balance the demands of a self-sustaining aquatic ecosystem for coho salmon while maintaining viable agricultural practices. Available studies suggest that the Shasta Basin has a high potential for recovery of coho salmon populations, and support a range of agricultural activities. The concept of focusing on quantity, quality, location, and timing to identify a balanced use of water resources that supports both ecological processes and a sustainable working landscape for agriculture is the foundation for this plan.

The purpose of this case study is not to develop a comprehensive basin plan in itself. Rather, described herein is a path through which stakeholders can address the immediate problem of coho salmon population recovery and, ultimately, the issue of long-term balanced water use in the Shasta Basin. Using a science-based, objective-driven process, the spatial and temporal complexities of water needs by the aquatic ecosystem and irrigated agriculture can be taken into account. In short, the objective of this case study is to illustrate how a sustainable aquatic ecosystem and viable agriculture can be achieved by refining basin planning activities that are already underway. This framework can then be employed by local stakeholders and agencies – those in the best position to define a sustainable balance of water resources – to develop a detailed, basin-specific plan.

Planning efforts have been most successful where basic program elements are clearly described. The basin plan framework presented herein is based upon two key elements:

co-equal goals, and the quantity, quality, space, and time (QQST) approach. Coequal goals are necessary to provide a reliable water supply for agriculture and instream needs. The needs of these coequal goals can be addressed through the identification of water demands that specify the quality, quantity, space, and timing needed to balance water use in the basin.

4.1. Coequal Goals

Coequal goals for agricultural water use and instream flow needs are a logical starting point in the Shasta Basin where agricultural land use is the dominant land use activity (ESA, 2009a) and has implications on aquatic system resources (e.g., coho salmon). As previously stated, agriculture accounts for the greatest proportion of developed water use in the Shasta Basin. Similarly, coho salmon water quantity and quality needs are generally more restrictive than those for other fish species in the basin. By identifying water use for coho salmon and agriculture as co-equal goals, the framework is established to provide an equitable assessment of those uses.

4.2. Quantity, Quality, Space, Time - QQST

The QQST approach effectively narrows the scope of water management activities to focus on key periods of conflicting uses. The approach establishes clear spatial and temporal limits to specific quantity and quality recommendations, which provides flexibility to other water users. In this way, limited resources can be effectively directed to high-value activities.

Using the Shasta River coho salmon life history and seasonal irrigation water use as a simple example can help illustrate this approach. A simplified coho life-history periodicity for adult migration, spawning and egg incubation, juvenile rearing and outmigration, and summer rearing in space and time is presented in Figure 11. This life-history "map" is then overlaid with seasonal irrigation demands in the Shasta Basin. Quantity and quality needs, as described in previous sections, are assumed to be constraints in the development of these space-time graphics. For example, coho migration and spawning requires sufficient flows to provide migratory passage from the river mouth to the upper portions of the system. Spawning and egg incubation occurs in reaches where there are gravels and other suitable conditions. Juvenile rearing and outmigration, like spawning, requires sufficient conditions for fish to move from upstream reaches to the mouth of the river. Finally, summer rearing, for this example is assumed to occur in reaches where spring inflows provide cool summer rearing habitats. When the seasonal irrigation demands are laid over these life history stages, it becomes apparent that only two stages coincide, which helps narrow the focus of planning efforts to address conflicting objectives. A program can be adaptively managed to incorporate this new information and refine ongoing water resources management activities.

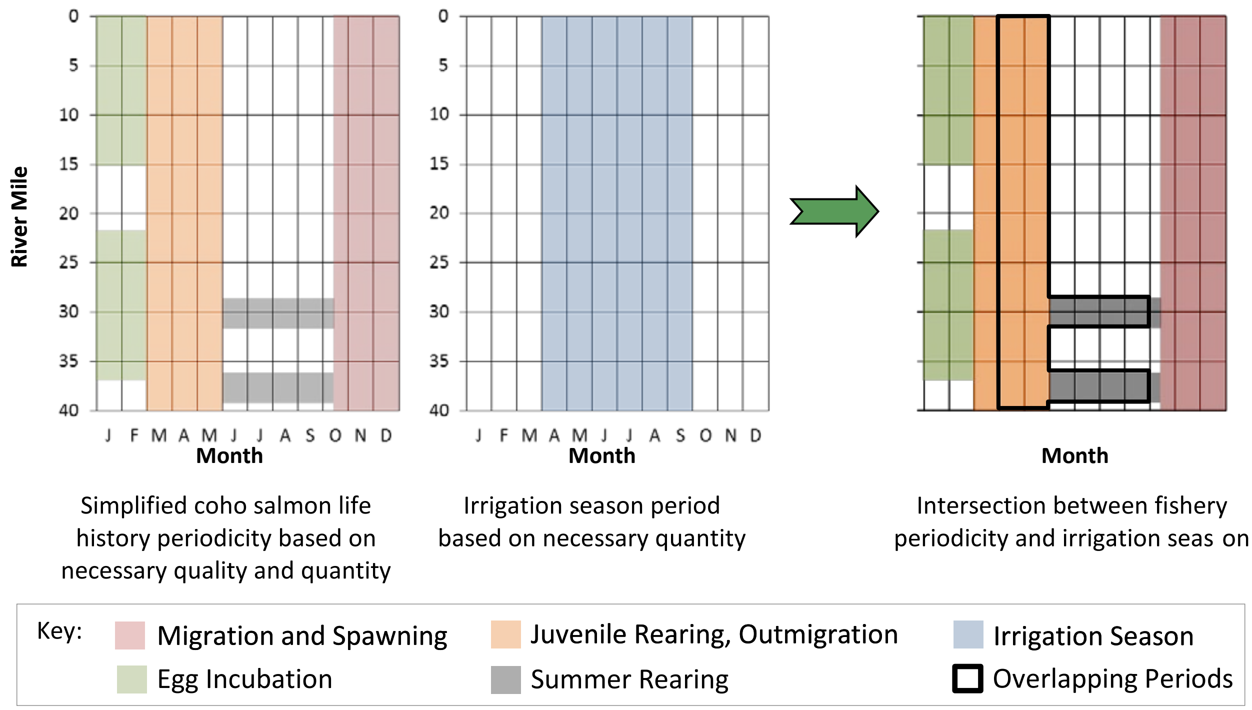

Figure 11. Hypothetical quantity-quality-space-time (QQST) exercise.

The usefulness of tracking QQST in this rudimentary exercise quickly illustrates that conflicting uses occurs over approximately 20 percent of the space-time graphics. Certain reaches and certain periods of the year experience no conflict between the two principal water uses identified in this example. Focusing on areas where there are competing uses allows for the development of priority actions that would make the most efficient use of resources to develop interim, transitional, and long-term measures. This exercise could be updated with new information and knowledge at predetermined periods to adaptively manage potential changes to water use activities throughout the system.

Using the information provided by the QQST approach, interim, transitional, and long-term measures can be developed to address degraded, recovering, or reconciled resource conditions (Figure 12). In this illustration, the metric used to gage conditions in the basin is the percent of baseline (pre-development) coho population. The intact conditions may represent, for example, a "natural," "pre-development," or other defined condition. This condition exhibits a range of natural system variability around some mean, akin to a "dynamic" equilibrium. This variation is an integral and important characteristic of the natural system (Pulliam 1988, Sousa 1984). The subsequent degradation period results in a decline in overall system function, including suppression of the intact system variability. Such conditions can, for example, lead to reduced habitat, reduced food availability, increased water quality impairment, invasive species competition, and other factors that do not support desired life history strategies for species of concern (e.g. coho salmon). The recovery period starts with the initiation of rehabilitation, which helps stabilize and improve the population. Eventually, the system would reach a period of reconciliation with sufficient variability to sustain desired aquatic habitat conditions. The reconciled target population will likely not be at historic levels due to the fundamental change to the landscape, but the population should be self-sustainable with natural variability (Hobbs and Norton, 1996), while also supporting other water uses.

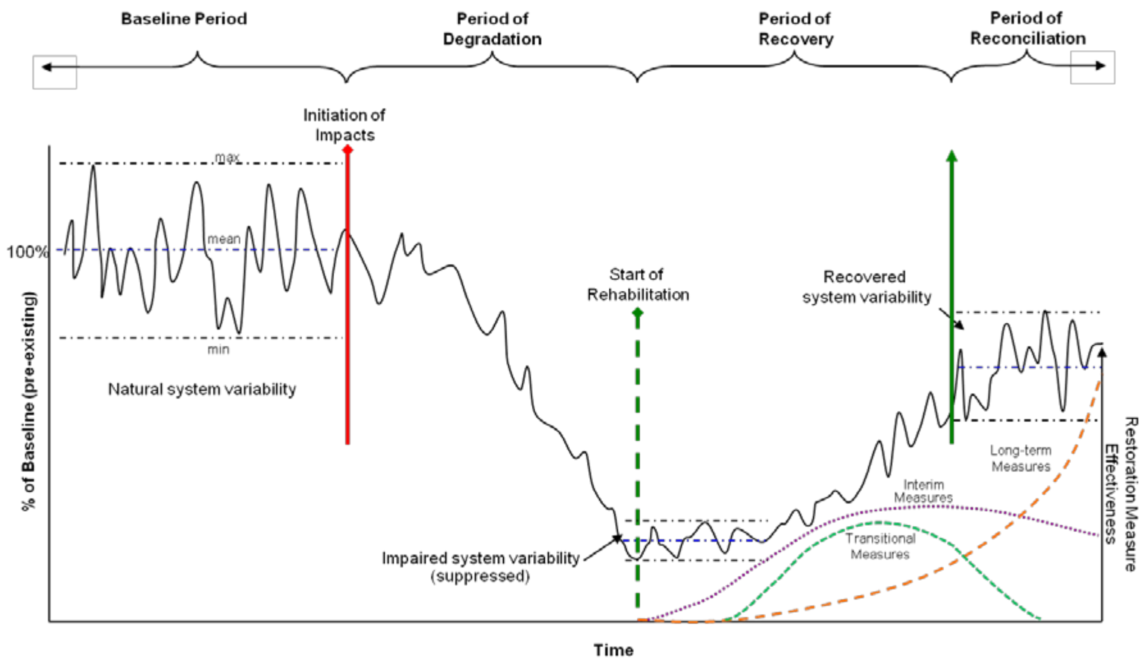

Figure 12. Temporal conceptualization of a system transitioning from a baseline state, through a degraded condition, and into recover with implementation of (a) interim and long-term measures and (b) only long-term measures. Initiation of impacts depicted by red vertical line, and start of rehabilitation with green vertical line. Interim measures depicted by the dotted purple line and long-term measures by the orange dashed line.

The framework for the Shasta Basin Water Management Plan is based on the previously identified spatial and temporal analysis of water quantity and quality needs for the co-equal goals of aquatic system function for coho salmon and sustainable agriculture, and focuses on resolving instances when these needs conflict. Based on the previously identified QQST needs, as well as available information for the Shasta Basin, three types of management strategies are identified to achieve the co-equal goals: interim, transitional, and long-term measures. Each management strategy is implemented depending on the condition of the resource (i.e., whether it is in a degraded, recovering, or reconciled condition). Interim measures can be characterized as “emergency” measures that are meant to stem the imminent degradation of the resource. These measures may incur substantial costs, particularly if the degraded condition is extreme; however, they are not intended to be permanent solutions. Transitional measures are implemented as the resource enters the period of recovery; they help provide resource managers with the information necessary to develop a comprehensive and sustainable long-term management strategy, and phase out resource-intensive short-term actions. Essentially, transitional measures help refine resource management strategies by identifying the QQST needs of competing resources users. Finally, long-term measures are implemented to manage the resource through its new equilibrium during the period of reconciliation. For the Shasta Basin, the condition of the resource is represented by the percent of available coho habitat relative to pre-development conditions (Figure 12). The measures identified in this document are based on currently available information about the basin's aquatic ecosystem and water use needs, which range from highly detailed studies in some reaches to conceptual descriptions of others. Despite this range, sufficient information has been gathered in the Shasta Basin that specific activities can be identified that are important to interim, transitional, and long-term water management strategies. These activities are not comprehensive and would be augmented by agencies and stakeholders during a comprehensive basin planning process. Examples of activities associated with each measure are described in detail in the following sections.

4.3. Interim measures

Interim measures have already been implemented throughout the Shasta Basin to address the degraded aquatic habitat. These measures have focused on stemming the decline of cold water fish, particularly coho salmon, and generally have been resource intensive; however, these extreme measures have been an appropriate response given the low population of the coho salmon. Three examples of issues currently addressed by interim measures are:

1. Thermal refugia,
2. Flow cues, and
3. Fish management

Specific actions related to each interim measure are described in the following sections.

4.3.1. Thermal refugia

Elevated water temperatures have been a detrimental impairment causing the persistent decline of coho salmon populations. The complex interactions between various underlying hydrologies, natural background water temperature conditions, and water management activities will require extensive study before a water management plan to conserve cold-water resources and provide reach-scale thermally appropriate aquatic habitat in the Shasta Basin can be developed. However, while the management strategies of such a diverse plan are developed, preserving the quality of and access to existing thermal refugia is an important action to stem the population decline of coho salmon. Various cold-water refugia have been identified throughout the Shasta Basin. Preliminary investigations have begun to identify the various volumes, thermal characteristics, chemistry, and underlying sources of these refugia. While these studies will provide information that can guide the long-term water management strategies in the Shasta Basin, preserving these refugia provides immediate oversummering habitat to juvenile coho (and other cold-water species) in a range of mainstem and tributary locations.

Short-term measures to maintain the quality and access to existing thermal refugia have included alteration (or, in some cases, cessation) of irrigation practices that relied on cold-water sources, preferential irrigation practices to divert warm water from reaches where other cold-water sources are located, temporary electric fencing of the riparian corridor to provide immediate cattle exclusion, and instream barrier removal to improve access to refugia. Through the wide-spread implementation of these actions, thermal refugia have been preserved throughout the Shasta Basin, particularly in the Big Springs and Shastina Springs complexes (Figure 13). Some of these actions have already been extended as part of a long-term management strategy for water resources in the Shasta Basin, such as replacing temporary electric fencing with permanent fencing. Other actions, such as ceasing irrigation practices in areas that rely on water rights associated with cold-water sources, are less sustainable long-term strategies. Actions, particularly those that appear to present a zero-sum trade-off between coho salmon populations and irrigated agriculture, should be examined to identify the QQST needs for those sources. By doing so, balanced use of those resources will support the long-term viability of both the aquatic ecosystem and agriculture.

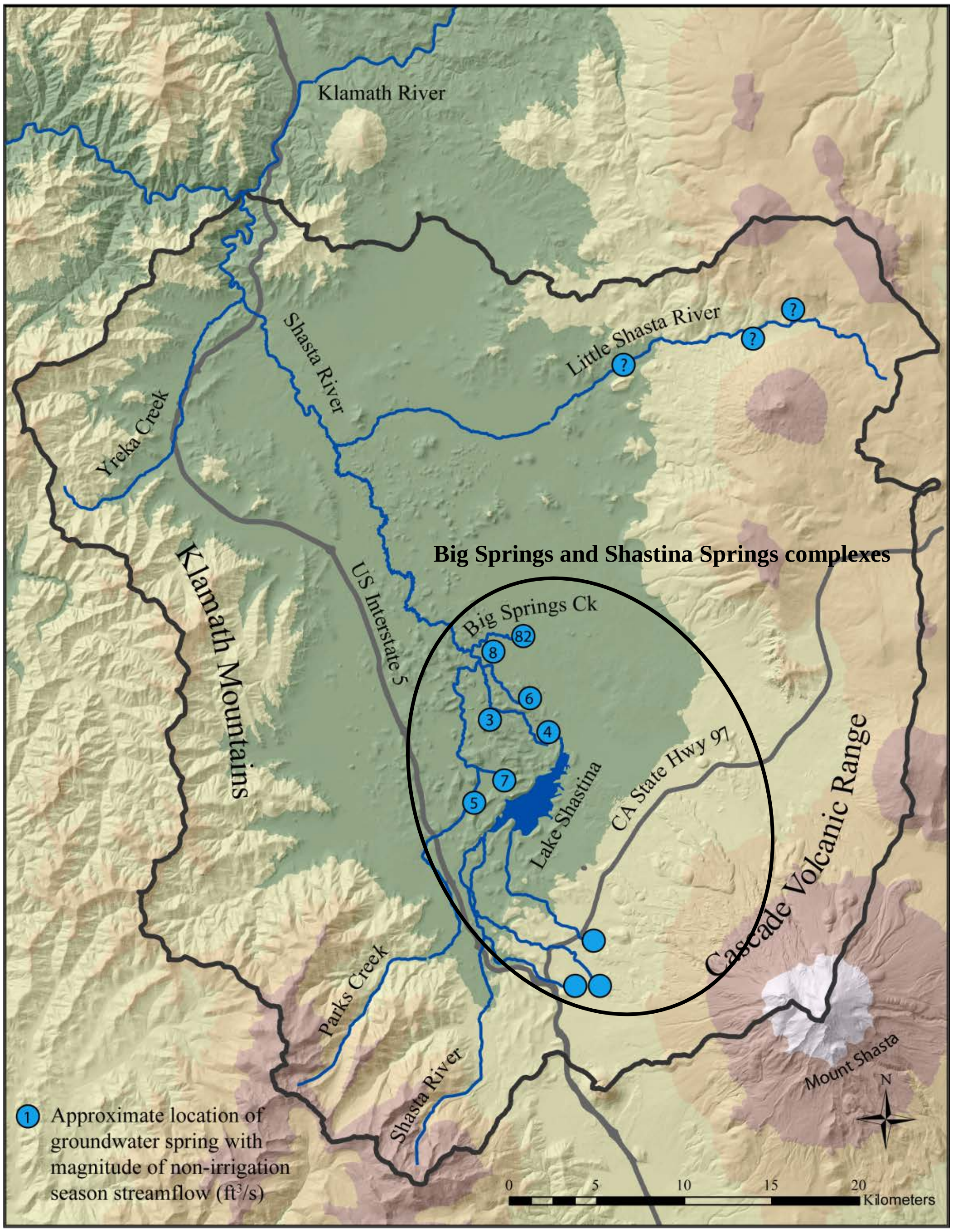

Figure 13. The general location of discrete springs associated with the Big Springs and Shastina Springs complexes.

4.3.2. Flow

Flow regimes are another element of the aquatic ecosystem that has been affected by historical water resource management in the Shasta Basin. Seasonal variations in hydrology driven by naturally occurring snowmelt and rainfall runoff patterns have been altered by the onset and conclusion of the irrigation season as well as year-round water management activities to store surface flows. The extent to which these water management activities have affected coho salmon populations on a basin scale is poorly understood. Preliminary investigations have examined interim flow needs for various stream reaches and life history stages, as well as how various water resources could be managed to supply those flows (McBain & Trush 2012). However, until these investigations can identify the QQST needs for instream flows, extensive flow experiments have been proposed or implemented throughout the basin. These activities aim to increase instream flows during specific life stages to reduce the potential, but as yet poorly quantified, effects on water supply management activities. These activities typically involve water rights holders foregoing their water rights for a prescribed period of time to provide these instream flows. With no quantification of the effects of these instream flows on the aquatic ecosystem, and no clear direction as to the long-term role these activities may play in basin-scale water management, this short-term measure incurs a large cost for an insufficiently quantified benefit, creates uncertainty regarding available water supply, and is generally unsustainable as a long-term measure in its current form. However, by identifying the QQST needs for instream flows to support aquatic habitat, resource managers and water users can confidently assess which water sources play a valuable role as instream flows for specified periods as well as determine which water sources are better suited for irrigation.

4.3.3. Fish management

The final example of interim measures that have been implemented to stem the decline of the coho population is the active management of individual fish to increase survival. This measure has included activities such as trapping 0+ coho juveniles in stream reaches where high mortality rates have been observed and transporting them to cool oversummering habitat in Big Springs Creek. This approach is designed to manage individual fish, and is important when population numbers are very low. As with the other short-term measures, this activity becomes a less effective (and less needed) use of resources over the long-term as recovery and reconciliation are achieved. As sufficient coho numbers are supported in other, more suitable reach-scale habitats in the Shasta Basin, losses in poor-quality habitat would be acceptable and this activity would be phased out.

4.3.4. Summary

Because short-term measures are intended to provide a rapid response to address critical levels of ecosystem degradation, they are meant to encompass broad elements that are part of the overall ecosystem function. The advantage to this approach is that the actions address multiple limiting factors and are likely to address the principal causes of the systemic degradation; however, the drawback is that substantial resources may also be directed to address factors that play a relatively small role in the overall degraded condition, or are so resource-intensive that they place unsustainable demands on resource managers and/or water users. Thus, it is important to incorporate studies and analyses to determine which short-term measures should be incorporated into the long-term management strategy for the resource and which should be phased out. These studies are part of transitional measures, which can be implemented after the short-term measures have addressed the first priority: stabilizing the declining coho population.

4.4. Transitional Measures

In the Shasta Basin, transitional measures bridge the activities associated with interm measures (enacted the population decline of coho) and long-term management actions necessary to support sustainable coho populations while maintaining a viable agricultural economy. Examples of three transitional measures that would support the development of balanced water resource use in the Shasta Basin include:

1. habitat suitability assessment,
2. quantified population objectives, and
3. quantified water use capacity.

Transitional measures may incorporate a range of studies, experiments, pilot projects, and other investigations. The findings of these investigations can help identify the QQST needs of coho salmon and irrigated agriculture, identify periods where these needs compete, and also provide criteria to evaluate success. They also lay the groundwork for on-going successful water management activities. The information gathered during transitional measures is critical to providing clear objectives for long-term management activities as well as identifying areas where flexibility can be incorporated so that all users understand the implications of enacting certain prescriptions (e.g., the potential impact or effect on an individual's water use).

4.4.1. Habitat Suitability Assessment

Assessment of coho habitat suitability is critical to understanding the spatial and temporal limitations for habitat use across all coho life stages. Habitat suitability assessments address structural suitability for coho at different locations throughout the year, as well as whether water quantity and quality needs are met. Comprehensive baseline assessments of physical, chemical, and biological characteristics of river reaches in targeted coho recovery areas are well suited to this task.

Several comprehensive baseline assessments (Jeffres *et al.*, 2008, Jeffres *et al.*, 2009, Nichols *et al.*, 2010) and habitat suitability studies (McBain & Trush, 2010) have been conducted in the Shasta River, Big Springs Creek, and Parks Creek. These documents have been used to evaluate spatial and temporal variability of suitable habitat for coho salmon. Importantly, the data contained with these reports and others are being used to inform spatially and temporally-specific water quantity and quality needs (e.g. McBain & Trush, 2013) in targeted stream reaches. Ultimately, spatially and temporally-specific water quantity and quality needs should be developed for stream reaches within the Shasta Basin that are accessible to coho. Flow and water quality prescriptions need to be cognizant that not all river reaches will be suitable for all (or any) coho life stages at all times.

4.4.2. Quantify Population Goals

Numerical population recovery targets for coho are necessary metric that inform agencies, landowners, and stakeholders of the interim and long-term goals for recovery. While established targets must be appropriate to maintain a genetically-viable population, they must also recognize existing habitat access limitations and existing agricultural water use.

Broad recovery targets for coho salmon have been developed by the National Ocean and Atmospheric Administration National Marine Fisheries Service (NOAA, 2012). NOAA-NMFS identify the current depensation threshold for the Shasta River at 531 spawning adult coho. Spawning populations below the depensation threshold have a greater likelihood of extirpation. Since 2001, the number of spawning adult coho has not exceeded 400 in any year (NOAA, 2012). NOAA-NMFS has also established biological recovery objectives (abundance, productivity, spatial structure, and diversity) of 8,700 total spawners as the minimum number needed to meet delisting criteria for SONCC coho salmon, which include the Shasta River returns. Further, juvenile populations must be distributed over greater than 70% of suitable rearing habitat. These population targets are largely derived from "habitat-based proxies for historical use and environmental capacity as a measure of a population's carrying capacity" (Williams *et al.*, 2006). Habitat proxies are generated from a GIS model that predicts "intrinsic potential (IP)" for suitable habitat for a given coho life stage.

The population goals identified by the various resource management agencies are a useful because they help define clear criteria for success. Additional criteria could provide reasonable flexibility to the measures of success. For example, examining the 3-5 year running average of returning spawners could help account for external factors (e.g., ocean conditions) that affect population numbers but are not related to basin conditions. Furthermore, a timeline for success could also clarify expectations for progress – in other words, measures could be identified that help achieve population goals over several years (i.e., interim targets) if the timeline for success was defined over years or decades. Without these additional criteria, time and resources are ineffectively directed towards broadly defined, unsustainable interim measures that undermine the long-term viability of any water use objective.

4.4.3. Identify Water-Use Capacity

Irrigated agriculture faces similar challenges as the coho salmon population when the basin-scale, long-term condition of the land use is considered. Just as the unlimited development of irrigated agriculture has led to the degradation of the coho salmon population, unlimited sacrifice of the industry to support coho recovery would result in its extirpation in the basin. To help formulate long-term watershed management strategies, identifying existing irrigation and municipal water demands (e.g. quantity and timing) is important. Irrigated agriculture and municipal water users throughout the Shasta Basin rely on surface water and groundwater supplies. These water supplies are finite, and are used to meet a variety of beneficial uses, including uses that benefit aquatic ecosystems. By knowing how much water each agricultural or municipal water user needs, and when/where the user needs it, flexible water use strategies around QQST can be developed to meet balance uses.

4.4.4. Summary

Transitional measures are designed to provide information that can support the development of a balanced, comprehensive resource management strategy. Because the focus includes information-gathering, outcomes from these measures may not necessarily be realized. Thus, they are insufficient to address critical impairments that require rapid improvements. However, they are important to developing sustainable and balanced long-term resource management strategies. Transitional measures in the Shasta Basin will help determine the viable limits of water use given the co-equal aquatic ecosystem and agricultural objectives. Using the findings from the transitional measures, long-term goals and management actions can be determined.

4.5. Long-Term Measures and Management Actions

Maintaining a sustainable coho salmon population and a viable agricultural community in the Shasta Basin requires the establishment of long-term goals and management actions. Long-term goals and management actions may be an extension of previously implemented short-term and transitional measures, or may be enacted once short-term and transitional measures have been largely completed. In the Shasta Basin principal long-term goals are to build and maintain a sustainable coho population, and maintain a reliable water supply to support a viable agricultural economy. Specific management actions to support these long-term goals should be developed by basin stakeholders who are representative of the various water users and resource managers in the basin. However, while the development of a balanced, comprehensive water resources management plan is the purview of basin stakeholders, enough information is available that specific areas of water resources management can be identified. Examples in these areas include:

1. the development of groundwater,
2. surface water, and
3. riparian land use management plans.

Within these areas, a range of potential management actions could be considered. The information gathered through the implementation of transitional measures can help identify effective long-term measures by specifying the QQST needs for each water user.

4.5.1. Groundwater Management Plan

Groundwater in the Shasta Basin is the foundation for the cool-water habitat available to coho salmon because it provides extensive physical habitat and, through its thermal and geochemical characteristics, supports a robust aquatic ecosystem. Groundwater development also provides a reliable, supplemental water supply to surface water resources. Simply stated, the Shasta Basin's groundwater resources are key to supporting both the aquatic ecosystem and irrigated agriculture in the Shasta Basin. However, poorly understood connections between groundwater and surface water, as well as the potential unregulated development of groundwater resources to enhance surface water supplies, make this key characteristic of long-term sustainable ecosystem function and water use extremely vulnerable. To reduce its vulnerability, a groundwater management plan is recommended so that the various sources and demands of groundwater resources are clearly and transparently identified.

Maintaining cool groundwater spring sources is key to providing both local thermal refugia and reach-scale cold-water habitat for coho in the Shasta Basin (Null *et al.*, 2010, Nichols *et al.*, 2013). While water temperatures at most spring sources in the Shasta Basin are ideal for rearing coho (12-14 °C), spatially variable flow volumes (see Figure 1) make some springs better suited for generating local thermal refugia, while other are suited for creating reach-scale cold water habitat. For example, large volume spring flows at the head of Big Springs Creek (80-90 ft^3/s) generate suitable thermal habitat for coho in Big Springs Creek and in the Shasta River for almost 10 kilometers downstream. In contrast, many of the low-volume springs (1-5 ft^3/s) along the Shasta River (e.g., Clear Springs) provide suitable thermal refugia, but do little to alter reach-scale (i.e., kilometers) water temperature conditions. A groundwater management plan should be developed to manage spring sources in ways appropriate to their influence on surface water temperatures. Large volume spring sources should be managed such that flow volumes do not diminish over time due to increased groundwater extraction, thus decreasing the extent of reach scale thermal habitat. Small volume springs should be managed to maintain local thermal refugia, which may include considering maintaining Shasta River flows at levels that do not degrade or eliminate certain refugia.

Understanding the relationship between groundwater and surface water flows throughout the Shasta Basin is also necessary to generate water supply necessary to meet both coho salmon lifestage requirements and surface water uses. Limiting local effects of groundwater pumping on surface water supplies exist (e.g., Montague Water Conservation District agrees to limit its groundwater use when surface water elevations in Big Springs Lake reach a specified level) (CADWR, 2000). Furthermore, preliminary hydrogeological assessments identify a connection between flow magnitudes throughout the Shastina Springs Complex and water levels in Lake Shastina (Davids Engineering, 2011). Ultimately, the effects of 1) groundwater development on surface water flows; 2) Lake Shastina levels and local spring-flow volumes; and 3) effects of irrigation on local groundwater conditions should be analyzed, and a comprehensive management plan developed.

4.5.2. Surface Water Management Plan

Providing sufficient quantity and quality of water at the appropriate place and time (QQST) is a critical objective of managing surface water resources to benefit both coho salmon and agricultural water users. With conflicting surface water demands, providing clear guidance for surface water use is necessary, and providing multiple water management options to meet those needs is similarly important. Currently, surface water use is directed by the adjudication, which does not reflect environmental changes in the basin over the last 80 years. Though groundwater resources provide the foundation for the robust cool-water ecosystem, surface water management (including management of spring water) is likewise important in maintaining the ecosystem and supporting a viable agricultural industry in the Shasta Basin.

Managing surface water resources to maintain reach-scale and local thermal refugia and expand the downstream extent of thermally appropriate habitat is a critical step in recovering the coho population. Once instream flow recommendations (see transitional measures) are established that meet the physical and thermal habitat needs for coho, a surface water management plan can be developed to maintain reliable, reach-scale habitat. However, such a management plan must recognize that cold-water habitat in the Shasta River naturally declines throughout the spring and summer.

Effective management of surface water is also important to meeting the water quantity demands of agricultural and municipal water users. Groundwater pumping in certain areas of the Shasta Basin provides irrigation water, but also affects spring flow volumes at important cold-water sources for the aquatic ecosystem. To help meet existing agricultural and instream flow needs, responsible conjunctive use and improved water delivery and use efficiencies must be achieved. As such, necessary components in a surface water management plan must include improvements to storage, delivery, and irrigation infrastructure. Most water used for irrigation is transported through canals and applied through flood irrigation (CADWR, 2000, NCRWQCB, 2006). Increased storage, delivery, and application efficiencies can increase the quantity of water available for use by junior water right holders, reduce the demand on groundwater resources to supplement surface water supplies, or support coho salmon recovery (if the water meets the quality, location, and timing of the coho population’s needs).

A surface water management plan should also introduce flexibility into the water supply delivery and use system by establishing a framework in which water can be exchanged or traded, such as a water transaction program. Water transaction programs expand the potential sources of water for alternative demands, as well as establish a way for landowners to support aquatic ecosystem needs and be compensated for their actions. This flexibility would provide a mechanism to balance surface water resources in the Shasta Basin that supports life-stage specific habitat requirements (physical and thermal) of coho salmon by providing water as needed, while also seeking to meet the water needs of agricultural users. This will require flexible actions based on rapidly changing habitat needs and water availability.

4.5.3. Riparian Lands Management Plan

Management of riverside lands to meet both land use and aquatic system needs throughout the Shasta River Valley is an important step towards maintaining and extending suitable habitats for coho salmon. Reach-scale thermal habitat suitability can be compromised by diminishment of both in channel and riparian vegetation that shades the stream and its tributaries from thermal loads associated with incoming solar radiation. Thermally suitable habitats can also be degraded by point-source pollution from tailwater inputs. Thus, while management of cold spring-water is a critical long-term measure for generating reach-scale habitats necessary support a growing coho population, developing a riparian lands management plan would encourage land-use practices that support desired instream habitat conditions. Principal components of such a plan include basin-wide cattle management (e.g., limted grazing, exclusion, etc.) for instream and riparian areas, and agricultural tailwater management.

Evidence suggest that cattle exclusion from instream and riparian areas is critical to meeting long-term goals of increasing the extent of cold-water habitat for coho salmon and helping to maintain and build the coho population in systems such as the Shasta Basin. Such efforts on Big Springs Creek are an example where limiting access to the stream resulted in riparian and instream aquatic vegetation growth, bank stabilization, increases in water depth, reduced rate of stream heating, and providing fish habitat (Willis *et al.*, 2012). . In the Shasta River proper, such activities would produce some of these benefits as well.

Tailwater inputs can degrade thermal conditions at both the local and reach scale. For example, tailwater can mix with cold-spring inputs, degrading or even eliminating local thermal refugia. Cumulatively, tailwater contributions can also degrade reach-scale habitat suitability through contributions of warm water to the stream. Tailwater management plans (e.g. Aqua Terra Consulting, 2011) that identify tailwater inputs and their affects on coho habitat suitability are critical in developing long term solutions to managing riverside ranching activities that utilize available lands and water without degrading riparian and riverine habitats for coho salmon.

4.5.4. Summary

Long-term measures are the final component to establishing and maintaining a balanced use of water resources to meet co-equal goals. Their scope is ambitious – the successful development of long-term measures will require a high level of information and collaboration in the Shasta Basin. Currently, some progress has been made towards that condition: a broad range of stakeholders are already engaged in multiple activities to help improve understanding of water resources and the multi-objective demands on those resources. With this improved understanding, effective long-term measures can be identified by a representative group of stakeholders that will encourage broad support. However, the current level of information is insufficient to identify all of the specific and effective long-term measures to reach balance in water resource management. Examples of potential interim, transitional, and long-term measures to address water use during various phases of recovery in the Shasta Basin are provided in Figure 14.

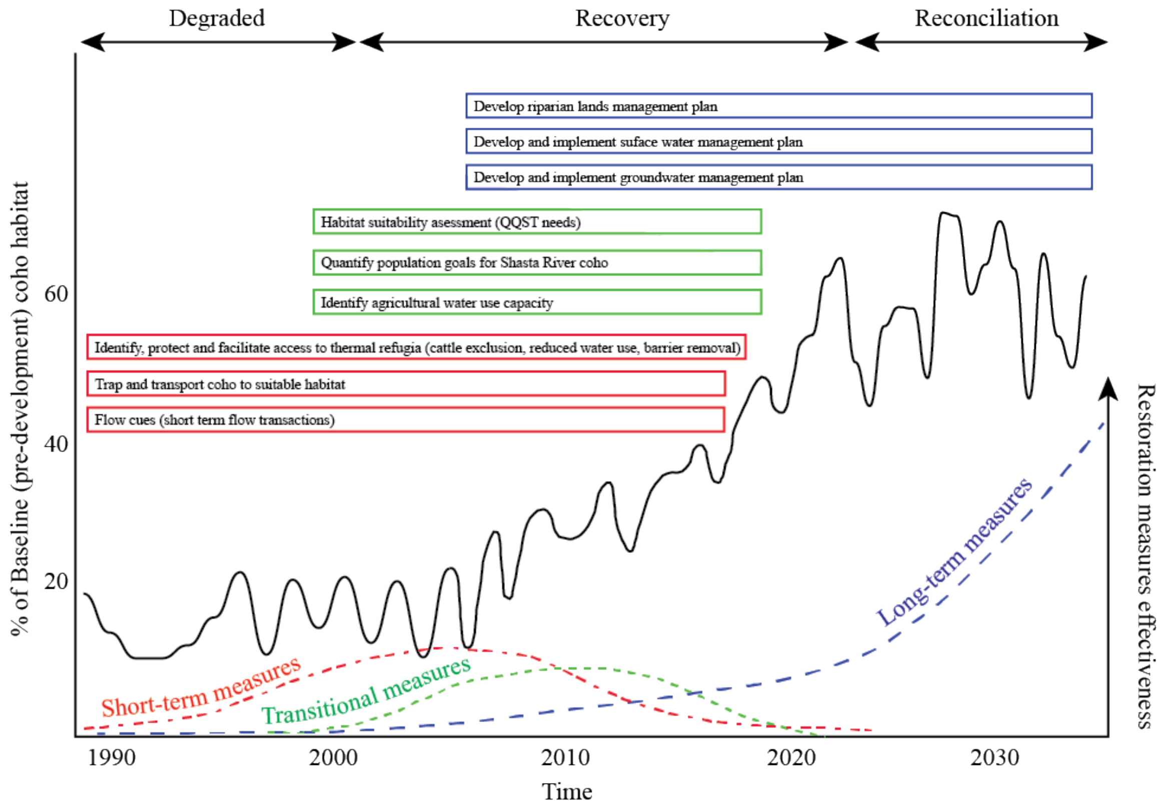

Figure 14. A summary of the various phases in the resource recovery process, and previously implemented or potential short-term, transitional, and long-term measures to support the balanced use of water resources in the Shasta Basin.

5. Conclusions and Next Steps

Watershed planning is an important process to effectively and responsibly manage water resources for multiple objectives. However, current planning activities tend to focus on a single objective, and lack sufficient background information to refine water quantity and quality goals over defined stream reaches and periods. Furthermore, when watershed plans are developed in basins with severe resource degradation, the management strategies identified in these plans are designed to achieve substantial, short-term improvements, but do not account for the extensive resources that would be needed to sustain these interim measures indefinitely. By establishing multiple water uses as co-equal goals and using the QQST approach, a framework is provided to develop watershed plans that support the long-term viability of potentially conflicting water uses. In addition, the management strategy should be extended to consider watershed conditions other than degraded, such as those in a period of recovery or reconciliation. An effective watershed plan should aim to extend beyond interim measures that focus on short-term, critical impairments. Transitional and long-term measures can be developed and implemented as the resource stabilizes and begins recovery. By engaging in the development of interim, transitional, and long-term measures, basin stakeholders acknowledge the potential to support multi-objective water use, which is also a considerable achievement.

Water resources in the Shasta Basin are at varying levels of degradation and recovery, depending on the reach. Similarly, both short-term and transitional measures have been implemented, and currently available information is sufficient to identify general actions that would provide critical stability to water resources use in the basin. Specific recommendations for other interim, transitional, and long-term measures should be developed by basin stakeholders through a collaborative planning process; some examples have been identified in this document. These measures may include establishing a basin planning consortium to provide a forum where stakeholders who represent the diverse water resource interests in the basin can collaborate. The Shasta Basin Science Consortium, which was established to encourage the collaboration of multidisciplinary scientists, agencies, and other organizational representatives to support the coordination of basin-wide recovery activities, could be a model to consider.

The case study of the Shasta Basin offers valuable lessons to stakeholders in other basin. Watershed planning is recommended for all basins where potential development of water resources for multi-objective uses may occur. Stakeholders will conserve time, funds, and resources by proactively planning for water resource use. By proactively addressing water resource use conflicts, stakeholders can reduce the potential burden of complicated regulatory issues, which they may have to address in addition to developing a comprehensive basin plan. One concept that all stakeholders can agree on is that existing water resources are insufficient to support the unlimited demands of any single user. By approaching watershed planning using the concepts of co-equal goals, QQST, and interim, transitional, and long-term strategies, stakeholders choose a robust foundation upon which multi-objective water use can be sustained.

6. Acknowledgements

We would like to thank NFWF, The Nature Conservancy, and California Trout for providing funding to support this work. We would also like to thank the many landowners and water users who, over the years, have shared their knowledge, concerns, and hopes for resolution to many of the issues raised herein. They are too many to list individually, but much of the thinking outlined herein is largely a compilation of many individual ideas and aspiration.

We wish, in particular, to remember and acknowledge Jim Sedell of NFWF who sponsored this project. He was a wonderfully unique individual that was endlessly optimistic, supportive, and thoughtful. Jim listened patiently to all view points and was able to bring diverse groups people together through his endless encouragement. Throughout his career, his commitment to ecology and conservation was significant. His contributions at NFWF are likewise noteworthy, first as aquatic science advisor and then Director of Freshwater Fish Conservation, as identified by his remarkable contributions to NFWF's freshwater initiatives. He is remembered by colleagues as being keenly interested in making measurable differences over short time periods. Our goal is that this project will contribute to Jim's vision in the Shasta Basin.

7. References

AquaTerra Consulting. 2011. Shasta Valley Tailwater Redction Plan. Prepared for Shasta Valley Resource Conservation District.

Booher LJ, Houston CE, Reed AD, Maxwell MV and Nelson SD. 1959. Analysis of the Montague Water and Conservation District, prepared by the University of California Agricultural Extension Service, Yreka, CA.

CADFG. 1997. A biological needs assessment for anadromous fish in the Shasta River, Siskiyou County, California, prepared by the California Department of Fish and Game, 29 p.

CADFW. 2012. Unpublished CADFW data

CADWR. 1932. Shasta River Adjudication and Decree, No. 7035, recorded in Siskiyou County Superior Court.

CADWR. 1963. California Department of Water Resources - Watermaster Service in Northern California, 1961 Season.

CADWR. 1964. Shasta Valley Investigation, Bulletin No. 87, prepred by the California Department of Water Resources.

CADWR. 1965. Land and Water use in the Shasta-Scott Valleys Hydrographic Unit, Volume 1: Text. Bulletin No. 94-5, prepred by the California Department of Water Resources.

CADWR. 2000. Summary of operations for watermaster service in northern California - 1998 season.

CADWR. 2008. Shasta Valley, Siskiyou County, groundwater data needs assessment (draft).

CES. 2002. Shasta River preliminary engineering report for fish screening/passage improvements, prepared by Cascade Earth Sciences, Ltd. for Great Northern Corporation.

Chesney WR, Adams CC, Crombie WB, Langendorf HD, Stenhouse SA and Kirkby KM. 2009. *Shasta River Juvenile Coho Habitat and Migration Study*. Prepared for U.S. Bureau of Reclamation, Klamath Area Office by California Department of Fish and Game.

Clements JP. 2006. CDWR participation in multi-agency fisheries restoration efforts in the Scott and Shasta Rivers, prepared for California Water and Environmental Modeling Forum (http://www.cwemf.org/Asilomar/ClementsPres.pdf).

Dahlgren RA, Jeffres CA, Nichols AL, Deas ML, Willis AD and Mount JF. 2010. Geologic sources of nutrients for aquatic ecosystems. American Geophysical Union, Fall Meeting 2010, abstract #H52D-03.

Davids Engineering I. 2011. Shasta Springs Ranch Irrigation Efficiency Study. Prepared by Davids Engineering, Inc. for the California Department of Fish and Game.

ESA. 2009a. Shasta River Watershed-Wide Permitting Program. Final Environmental Impact Report. FEIR Volume 1: Revisions to the Draft EIR Text.

ESA. 2009b. Shasta River Watershed-Wide Permitting Program. Final Environmental Impact Report. FEIR Volume 2: Comments on the Draft EIR and Responses.

FAI. 2006. Big Springs Irrigation District Water Conservation Study. Report prepared for the Shasta Valley Resource Conservation District and the California Department of Fish and Game (Project No. P0310327) prepared by Forsgren Associates, Inc.

GID. 2009. Shasta River fish passage - GID dam removal and fish screen installation project statement of work (Siskiyou Project HB M147)

GID. 2012. Grenada Irrigation District (GID) website (http://grenadairrigationdistrict.com/)

Hobbs RJ and Norton DA 1996. Towards a Conceptual Framework for Restoration Ecology. *Restoration Ecology* **4**, 2: 93-110. 10.1111/j.1526-100X.1996.tb00112.x

Jeffres CA, Buckland E, Hammock B, Kiernan JD, King AM, Krigbaum N, Nichols AL, Null SE, Deas ML, Mount JF and Moyle PB. 2008. Baseline Assessment of Salmonid Habitat and Aquatic Ecology of the Nelson Ranch, Shasta River, California, Water Year 2007. Prepared for the United States Bureau of Reclamation, Klamath Area Office.

Jeffres CA, Dahlgren RA, Deas ML, Kiernan JD, King AM, Lusardi RA, Mount JM, Moyle PB, Nichols AL, Null SE, Tanaka AD and Willis AD. 2009. Baseline Assessment of Physical and Biological Conditions Within Waterways on Big Springs Ranch, Siskiyou County, California. Prepared for California State Water Resources Control Board by U.C. Davis Center for Watershed Sciences and Watercourse Engineering, Inc. Available online (http://watershed.ucdavis.edu/pdf/Jeffres-et-al-SWRCB-2009.pdf).

Jeffres CA and Moyle PB 2012. When Good Fish Make Bad Decisions: Coho Salmon in an Ecological Trap. *North American Journal of Fisheries Management* **32**, 1: 87-92.

Jeffres CA, Nichols AL, Willis AD, Deas ML, Mount JM and Moyle PB. 2010. Assessment of Restoration Actions on Big Springs Creek, Shasta River, California 2009-2010. Prepared for The National Fish and Wildlife Foundation by U.C. Davis Center for Watershed Sciences and Watercourse Engineering, Inc.

Available online (http://watershed.ucdavis.edu/pdf/Jeffres-et-al-Big-Springs-2010.pdf).

Kamieniecki S and Kraft ME. 2005. Series Forward. In: Sabatier, P.A., Focht, W., Lubell, M., Trachtenberg, Z., Vedlitz, A., and Matlock, M., eds. Swimming Upstream: Collaborative Approaches to Watershed Management. Massachusetts Institute of Technology.

McBain & Trush I. 2010. Spawning gravel evaluation and enhancement plan for the Shasta River, CA, prepared for Pacific States Marine Fisheries Commision and California Department of Fish and Game, 185 p. Accessed on 3/1/2012 (http://svrcd.org/wordpress/uploads/SRSGEEP-Final%20Report%2011-30-10.pdf)

McBain & Trush I. 2013. Shasta River Big Springs Complex Interim Instream Flow Needs Assessment (Final Draft), prepared by McBain & Trush, Inc. Humboldt State University Deparment of Environmenal Resources Engineering for Ocean Protection Council and California Department of Fish and Game.

NCRP. 2013. Draft North Coast Integrated Regional Water Management Plan, Phase III, Annotated Outline – PUBLIC COMMENT DRAFT. Prepared by North Coast Resource Partnership.

NCRWQCB. 2006. *Staff Report for the Action Plan for the Shasta River Watershed Temperature and Dissolved Oxygen Total Maximum Daily Loads*. Santa Rosa, CA. Available online (http://www.swrcb.ca.gov/northcoast/water_issues/programs/tmdls/shasta_river/staff_report.shtml)

NCRWQCB. 2011. Water quality control plan for the North Coast Region, prepared by the North Coast Regional Water Quality Control Board, p. 274. (http://www.swrcb.ca.gov/northcoast/water_issues/programs/basin_plan/083105-bp/basin_plan.pdf)

Nichols AL, Jeffres CA, Willis AD, Corline NJ, King AM, Lusardi RA, Deas ML, Mount JF and Moyle PB. 2010. Longitudinal Baseline Assessment of Salmonid Habitat Characteristics of the Shasta River, March to September, 2008. Prepared for U.S. Bureau of Reclamation Klamath Basin Area Office by U.C. Davis Center for Watershed Sciences and Watercourse Engineering, Inc. Available online (http://watershed.ucdavis.edu/pdf/Jeffres-et-al-Shasta-Longitudinal-Baseline-2010.pdf).

Nichols AL, Willis AD, Jeffres CA and Deas ML 2013. Water temperature patterns below large groundwater springs: Management implication for coho salmon in the Shasta River. *River Research and Applications* 14. 10.1002/rra.2655

NMFS. 2011. Klamath River Basin 2010 Report to Congress. http://swr.nmfs.noaa.gov/klamath/Klamath_2010.pdf.

NOAA. 2012. SONCC Coho Recovery Plan (DRAFT). Prepared by National Marine Fisheries Service, Southwest Regional Office.

NRC 2004. *Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies of Recovery*. Washington, DC: The National Academies Press.

Null SE, Deas ML and Lund JR 2010. Flow and Water Temperature Simulation for Habitat Restoration in the Shasta River, California. *River Research and Applications* **26**, 6: 663-681. DOI: 10.1002/rra.1288. 10.1002/rra.1288

Pulliam HR 1988. SOURCES, SINKS, AND POPULATION REGULATION. *American Naturalist* **132**, 5: 652-661. 10.1086/284880

Sabatier PA, Focht W, Lubell M, Trachtenberg Z, Vedlitz A and Matlock M 2005. Swimming Upstream: Collaborative Approaches to Watershed In: Sabatier, P.A., Focht, W., Lubell, M., Trachtenberg, Z., Vedlitz, A., and Matlock, M., eds. Swimming Upstream: Collaborative Approaches to Watershed Management. Massachusetts Institute of Technology.

Schilling F, Sommarstrom S, Kattelmann R, Washburn B, Florsheim J and Henly R. 2005. The California Watershed Assessment Manual, Volume 1. Prepared for the California Resources Agency and the California Bay-Delta Authority.

Sousa WP 1984. THE ROLE OF DISTURBANCE IN NATURAL COMMUNITIES. *Annual Review of Ecology and Systematics* **15**, 353-391. 10.1146/annurev.ecolsys.15.1.353

SRCRMP. 1997. Shasta Watershed Restoration Plan. Prepared by the Shasta River Coordinated Resources Management and Planning Committee.

SSRT 2003. Shasta and Scott River Pilot Program for Coho Salmon Recovery: with recommendations relating to Agriculture and Agricultural Water Use, prepated for the California Department of Fish and Game by Shasta-Scott Coho Salmon Recovery Team.

Stenhouse SA, Bean CE, Chesney WR and Pisano MS 2012. Water temperature thresholds for coho salmon in a spring-fed river, Siskiyou County, California. *California Fish and Game* **98**, 1: 17-37.

SVRCD. 2012. Shasta Valley Resource Conservation District website (http://www.svrcd.org/srwa.html)

USEPA. 2008. Handbook to Developing Watershed Plans to Restore and Protect our Waters. Washington D.C. EPA 841-B-08-002.

USEPA. 2013. A Quick Guide to Developing Watershed Plans to Restore and Protect our Waters. Office of Wetlands, Oceans, and Watersheds Nonpoint Source Control Branch (4503T). Washington D.C. EPA 841-R-13-003.

Vignola E and Deas ML. 2005. *Lake Shastina Limnology*. Prepared for the U.C. Davis Information Center for the Environment and the California North Coast Regional Water Quality Control Board by Watercourse Engineering, Inc.

Williams TH, Bjorkstedt EP, Duffy WG, Hillemeier D, Kautsky G, Lisle TE, McCain M, Rode M, Szerlong RG, Schick RS, Goslin MN and Agrawal A. 2006. Historical population structure of coho salmon in the southern Oregon/northern California Coasts Evolutionary Significant Unit. NOAA Technical Memorandum NMFS.

Willis AD and Deas ML. 2011. Preliminary investigation of macrophyte shade in Big Springs Creek, Watercourse Engineering, Inc. Technical Memorandum submitted to The Nature Conservancy, 5 p.

Willis AD, Deas ML, Jeffres CA, Mount JF, Moyle PB and Nichols AL. 2012. Executive Analysis of Restoration Actions in Big Springs Creek, March 2008-September 2011. Report prepared by the UC Davis Center for Watershed Sciences and Watercourse Engineering, Inc. for the National Fish and Wildlife Foundation (http://watershed.ucdavis.edu/pdf/Willis_etal_2012.pdf).