1 PURPOSE

The purpose of this document is to describe three strategies for restoring the mainstem San Joaquin River (SJR) between Friant Dam (RM 267.5) and the confluence with the Merced River (RM 118.2). These three restoration strategies have been developed for the Friant Water Users Authority (Authority) and the Natural Resources Defense Council coalition (NRDC) as part of the parties' efforts to settle for *NRDC v. Rodgers*. The Authority and NRDC are engaged in a settlement process to develop a plan that restores the mainstem San Joaquin River in balance with water supply needs and beneficial uses of San Joaquin River water according to certain mutual goals developed by NRDC and the Authority. This document is designed to contribute to the settlement process by describing three restoration strategies, each representing a different mix of options, to provide decision-makers with flexibility in crafting a settlement agreement. Participants in the settlement process may find it possible to integrate one of the strategies described in this document with mutually acceptable water supply options defined in the Final Water Supply Study (URS 2002), which has been developed in parallel with the Draft Restoration Strategies Report. It is also possible that participants in the settlement process will blend individual components of the three restoration strategies defined in this document, thereby creating the foundation of a new restoration strategy, as they integrate restoration options with water supply options in the settlement process. Any such new strategy would likely require further analysis.

It is important to note that this Draft Restoration Strategies Report does not constitute a restoration plan for the San Joaquin River. This document is the culmination of a reconnaissance, planning-level effort designed to identify and explore conceptual approaches to restoring the San Joaquin River in order to inform a settlement process. The development of a restoration plan for the San Joaquin River will require the acquisition and consideration of more site-specific information and a broader involvement by local landowners and stakeholders. Much of the information contained in this report is designed to be useful for any future effort to develop a restoration plan for the San Joaquin River, but the restoration strategies defined in this document, and their constituent components, do not represent decisions or final recommendations regarding restoration of the San Joaquin River.

This document builds on and complements other reports that have been created to support the development of a settlement agreement for the restoration of the San Joaquin River. Most notably, the San Joaquin River Restoration Study Background Report (Background Report) (McBain and Trush 2002) describes historical and existing conditions of the San Joaquin River and surrounding landscape. This Draft Restoration Strategies Report uses or references much of the information contained in the Background Report. The restoration Objectives for the San Joaquin River report (Restoration Objectives Report) (Stillwater Sciences 2003) defines restoration targets and guidelines for key ecosystem components. The strategies described in the Draft Restoration Strategies Report are designed to achieve the targets and follow the guidelines defined in the Restoration Objectives Report. The Final Water Supply Study (URS 2002) explores water supply options for the San Joaquin River that will be instrumental in developing the necessary water supplies for restoration. The Draft Restoration Strategies Report and the Final Water Supply Study were developed in parallel, but in isolation from one another to prevent each process from imposing constraints or otherwise altering the outcome of the other, leaving any constraints that were used as the product of separate negotiations that were a part of the development of both documents. By separating the development of restoration options and water supply options, the Authority and NRDC wanted to ensure a broader range of options and greater flexibility in developing the tools that will inform their settlement efforts.

The Draft Restoration Strategies Report has benefited from the advice and review of several individuals, including the Friant and NRDC technical co-managers, members of the Restoration Oversight Team (ROST), and independent scientific reviewers. Although these experts have made significant contributions to the pool of ideas and information from which this report is drawn, this report ultimately reflects the technical syntheses and professional judgment of the authors. No inference should be implied that the analysis and conclusions contained in this report have been endorsed by any of the litigants.

2 INTRODUCTION

Development of the three restoration strategies was guided by the Framework for Restoration Strategies document (Stillwater Sciences 2002), which was drafted in consultation with the Friant and NRDC technical co-managers and the ROST. The Framework document broadly sketches the structure of the three restoration strategies to ensure that they provide a range of options that aid participants in the settlement process by providing the flexibility to assist the negotiation of a settlement agreement. The three restoration strategies are structured by two organizing principles: an overarching theme, and four key issues for which the settlement process would require options to ensure flexibility.

2.1 Planning Area

The San Joaquin River drains the southern portion of California's Central Valley. The river basin is bounded by the Sierra Nevada to the east and the Coast Ranges to the west; its southern boundary is the divide that separates it from the Tulare Lake basin, and its northern boundary is the Delta near Stockton. The river, which drains a 13,536-square-mile watershed, originates in the Sierra Nevada and flows for approximately 350 miles before joining the Sacramento-San Joaquin River Delta (Figure 2-1). Elevations in the watershed range from 11,000 feet at the headwaters to sea level at the Delta. Friant Dam (RM 267), which impounds Lake Millerton, is the primary mainstem dam controlling flows on the San Joaquin River. Friant Dam was constructed in 1939 and has a reservoir storage capacity of 520,500 acre-feet.

The San Joaquin River restoration planning area includes 148 miles of the mainstem San Joaquin River and its associated tributaries, sloughs, canals, and bypass channels between Friant Dam and the confluence of the Merced River (RM 118) (Figure 2-1). The planning area includes portions of Madera, Fresno, and Merced counties. The width of the river corridor planning area varies and is defined on the basis of the estimated riparian corridor width under historical conditions, as assessed from historical information on soil and vegetation conditions (see Figure 1-5 of the Background Report).

For the purposes of restoration planning, the planning area has been divided into five reaches based on physical and flow characteristics of the river and key infrastructure (Figure 2-1). These reach descriptions were developed largely from the information included in the Background Report (McBain and Trush 2002).

Reach 1 begins at Friant Dam and ends at Gravelly Ford (RM 229), the historical transition between gravel- and sand-bedded reaches. Reach 1 is gravel-bedded, of moderate slope, and is confined by bluffs and terraces. The river in Reach 1 flows north of Fresno, then passes near the communities of Herndon and Biola. Reach 1 is divided into two subreaches separated by the Southern Pacific Railroad Bridge (State Route 99). Subreach 1A extends from Friant Dam to State Route 99. Confined by bluffs, Subreach 1A is the steepest portion of Reach 1. Subreach 1B begins at State Route 99 and extends downstream to Gravelly Ford. Subreach 1B is much steeper than Subreach 1A and is confined by terraces. It encompasses the current transition zone from gravel bed to sand bed. Gravel mining and agriculture are the primary land uses in this reach. Key features of Reach 1 include:

- Friant Dam and beginning of Reach 1: RM 267

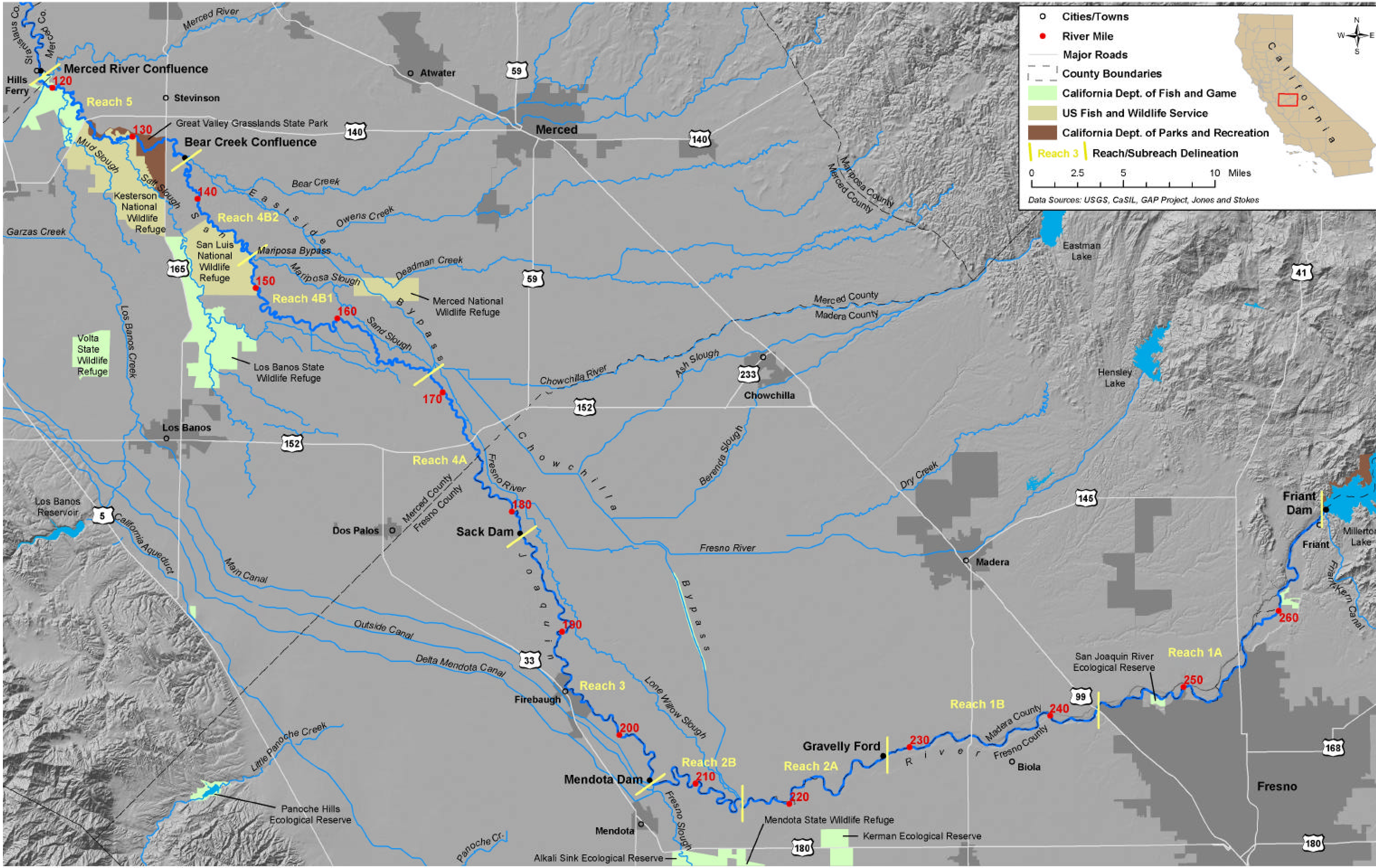

Figure 2-1. San Joaquin River Restoration Project planning area.

- State Route 41 Bridge (Lanes Bridge): RM 255
- Community of Herndon: RM 244
- State Route 99, Southern Pacific Railroad Bridge, and boundary of Subreaches 1A and 1B: RM 243
- Community of Biola: RM 237
- State Route 145 Bridge: RM 234
- Gravelly Ford and end of Reach 1: RM 229

Reach 2 extends from Gravelly Ford (RM 229) to Mendota Dam (RM 205). Reach 2 is entirely sand-bedded, and meanders across the unconfined Pleistocene alluvial fan of the San Joaquin River. The downstream boundary at Mendota Dam marks the location where the river turns north, intersecting the north-south axis of the valley, and where slope decreases. Reach 2 is divided into two subreaches that are separated by the Chowchilla Bifurcation Structure (RM 216). Subreach 2A begins at Gravelly Ford and extends downstream to the Chowchilla Bifurcation Structure. Subreach 2B extends from the Bifurcation Structure downstream to Mendota Dam, passing near the community of Mendota. Both subreaches have confining levees protecting agriculture land uses. Key features of Reach 2 include:

- Gravelly Ford and beginning of Reach 2: RM 229
- Chowchilla Bifurcation Structure boundary of Subreaches 2A and 2B: RM 216
- Lone Willow Slough: RM 216
- Community of Mendota: RM 205
- Fresno Slough: RM 205
- Mendota Pool: RM 205
- Mendota Dam and end of Reach 2: RM 205

Reach 3 extends from Mendota Dam (RM 204) to Sack Dam (RM 182). Reach 3 is sand-bedded and meandering, and passes near the community of Firebaugh. Unlike other reaches, Reach 3 currently contains perennial flows of up to 600 cfs, due to water deliveries from the Delta Mendota Canal, through the San Joaquin River channel, and to the Sack Dam diversion into Arroyo Canal. Agriculture is the primary land use in this reach, and the river is confined by local dikes and canals on both banks. Key features of Reach 3 include:

- Mendota Dam and beginning of Reach 3: RM 205
- Avenue 7 ½ Bridge (13th Street Bridge or Firebaugh Bridge): RM 195
- Community of Firebaugh: RM 195
- Arroyo Canal: RM 182
- Sack Dam and end of Reach 3: RM 182

Reach 4 extends from Sack Dam (RM 182) downstream to the confluence with Bear Creek and the Eastside Bypass (RM 135). Reach 4 is sand-bedded and meandering, and is usually dewatered due to the diversion at Sack Dam. Reach 4 is divided into two subreaches separated by the Sand Slough Control Structure (RM 168). Subreach 4A, extending from Sack Dam downstream to the Sand Slough Control Structure is bounded on the western bank by the Poso and Riverside canals, and on the eastern bank by local dikes. The flows in Subreach 4A are usually negligible due to the Sack Dam diversion, but flood control flows are periodically conveyed such that a channel is defined through the reach. Subreach 4B begins at the Sand Slough Control Structure and extends downstream to the confluence with Bear Creek and the Eastside Bypass. The upstream portion of Subreach 4B no longer conveys flows because the Sand Slough Control Structure diverts all flows into the bypass system. As a result, the channel in the upstream portion of Subreach 4B is poorly defined, filled with dense vegetation, and often plugged with fill material. Subreach 4B is no longer bounded by canals, but is confined by small local dikes downstream to the confluence with the Mariposa Bypass at the San Luis National Wildlife Refuge. Project levees begin at the Mariposa Bypass and continue downstream on both banks. Agriculture is the primary land use throughout the reach. Key features of Reach 4 include:

- Sack Dam and beginning of Reach 4: RM 182
- State Route 152 Bridge (Santa Rita Bridge): RM 173
- Sand Slough Control Structure boundary of Subreaches 4A and 4B: RM 168
- Mariposa Slough Control Structure: RM 168
- Turner Island Road Bridge: RM 157
- Mariposa Bypass confluence: RM 147
- Bear Creek/Eastside Bypass confluence and end of Reach 4: RM 135

Reach 5 begins at the confluence with Bear Creek and the Eastside Bypass (RM 135) and extends downstream to the Merced River confluence (RM 118). Reach 5 is sand-bedded and meandering. It passes near the community of Stevenson, and flows continuously due to agricultural return flows. Reach 5 is bounded by project levees to the Salt Slough confluence and on the eastern bank to the Merced River confluence. Key features of Reach 5 include:

- Bear Creek/Eastside Bypass confluence and beginning of Reach 5: RM 153
- Community of Stevenson: RM 133
- State Route 165 Bridge (Lander Avenue): RM 132
- Salt Slough confluence: RM 127
- State Route 140 Bridge (Fremont Ford): RM 125
- Mud Slough confluence: RM 121
- Merced River confluence (Hills Ferry Bridge) and end of Reach 5: RM 118

2.2 Themes

Each of the three restoration strategies is governed by an overarching theme that serves as an organizing principle to help structure the individual components of a strategy. The three themes selected to organize the strategies are: (1) existing flood conveyance capacity; (2) salmonid-oriented management; and (3) riparian-oriented management. A theme does not suggest that restoration efforts for a given ecosystem component (e.g., salmonids and riparian vegetation) are exclusive to that strategy. For example, restoration efforts targeted at salmonids are not limited to the salmonid-oriented management strategy; salmonid restoration is a component of all three strategies. Similarly, the restoration of riparian vegetation is not exclusive to the riparian-oriented management strategy; it is an objective of each restoration strategy. A theme simply facilitates the selection and design of specific restoration activities by providing an organizing principle that helps direct prioritization of the types and magnitudes of elements to include in the strategy.

2.2.1 Existing Flood Conveyance Capacity Theme (Strategy 1)

Each reach of the mainstem San Joaquin River has an advertised flood conveyance capacity that reflects the volume of discharge that can be contained within the existing channel and floodplain configuration and levee system. It is possible to expand the flood conveyance capacity of a stream reach by setting back, strengthening, or raising levees, and by modifying channel and floodplain geometry. However, modifying levees, channels, and floodplains usually requires significant effort, time, and resources to achieve because of the scale of earthwork involved. Enhancing the flood conveyance capacity of one reach can also necessitate the expansion of flood conveyance capacity in downstream reaches as well, which must be able to accommodate the additional discharge passing from upstream. Because of this interconnectedness of flood conveyance capacity between reaches, expansions of flood conveyance capacity can require modifications to a large portion of the system.

Recognizing that an expansion of the flood conveyance capacity of the San Joaquin River would require a significant investment in time and resources, the participants in the restoration planning process determined that one strategy that minimized modifications of the existing flood conveyance system. The aim of this strategy is to explore the potential for restoration with only strategic expansions of flood conveyance in reaches that represent current hydraulic chokepoints.

2.2.2 Salmonid-oriented Management Theme (Strategy 2)

The salmonid-oriented management theme places special value on salmonid species for commercial, recreational, and aesthetic reasons. Anadromous salmonids utilize all reaches of the planning area, which makes them good focal species because they have broader habitat requirements than fish species that use only a portion of the planning area. Satisfying the life history needs of salmonids within the planning area may be expected to yield benefits to other native resident fish as well.

As described above, each of the three restoration strategies targets the restoration of salmonid populations; however, the salmonid-oriented management strategy features salmonids more prominently, tailoring restoration actions to enhance their benefit to salmonid species. The emphasis on salmonids means that this strategy focuses on the river channel and associated aquatic habitat, as well as nearby floodplain habitat, used by the different life history stages of salmonid species.

2.2.3 Riparian-oriented Management Theme (Strategy 3)

The riparian-oriented management theme focuses on restoring native vegetation along the San Joaquin River to create a diverse riparian corridor. Rivers serve as important movement corridors for both fish and wildlife species. This theme focuses on balancing efforts to improve aquatic and floodplain habitat for fish species with efforts to enhance the ecological function(s) of the aquatic, riparian and terrestrial systems and to provide a diversity of wildlife habitat at a landscape scale.

2.3 Four Key Issues

In addition to its theme, each strategy is structured by four key issues that were identified earlier in the planning process as topics for which options would be required to allow flexibility for in the settlement process. Generally, each issue is associated with key physical features of the river corridor and associated water management infrastructure. The four issues involve: (a) flood conveyance capacity; (b) the primary location for salmonid rearing; (c) fish and water routing through or around Mendota Pool; and (d) fish and flow routing in Reach 4B. For each of these key issues, two options have been developed. Each restoration strategy (detailed in Sections 5 through 7) is based on one overarching theme presented above and includes a different mix of options for the four key issues (Figure 2-2).

THEMES

KEY ISSUES		STRATEGY 1: Existing Conveyance Capacity Strategy	STRATEGY 2: Salmonid-oriented Strategy	STRATEGY 3: Riparian-oriented Strategy
Floodway capacity	existing	X		
	expanded		X	X
Juvenile salmonid rearing	focused in Reach 1	X		X
	focused in all reaches		X	
Mendota Pool Bypass	no Mendota Pool Bypass Channel	X		
	route flows through Mendota Pool Bypass Channel		X	X
Flow routing through Reach 4B	reconstruct channel and route flows through Reach 4B	X		X
	route flows around Reach 4B through Eastside Bypass		X	

Figure 2-2. Summary of key issues and themes governing each of the three restoration strategies.

2.3.1 Existing or expanded conveyance capacity

As described above, enhancing flood conveyance capacity in one reach can have ripple effects on other reaches, and would require significant time and resources in order to achieve channel-floodplain modifications; levee construction, setback, and raising; and alterations to flood management infrastructure. However, maintaining the current flood conveyance capacity of channel reaches imposes constraints on restoration potential. For example, the limited conveyance capacity of downstream reaches limit the release of flows to levels that are below ecologically significant thresholds. Similarly, levees that closely border river channels reduce the amount of floodplain area available for establishing riparian vegetation and limit the ability for channel meander.

To provide information and flexibility in developing a settlement agreement, the participants in the restoration planning process determined that one strategy examine restoration potential involving limited modifications to the flood conveyance system. Strategy 1, the Existing Capacity Strategy, features minimal changes to the current flood conveyance capacity of the mainstem channel. Strategy 2, the Salmonid-oriented Management Strategy, and Strategy 3, the Riparian-oriented Management Strategy, include more significant expansions of flood conveyance capacity.

2.3.2 Salmon rearing focused in Reach 1 or all reaches

Young spring-run chinook salmon typically rear in the river for over a year before emigrating as smolts. Similarly, young steelhead trout generally rear in their natal streams for two years before emigrating as smolts. Because these species rear in the river year-round, including during the warm summer months, they will need to rear in Reach 1, close to Friant Dam where water temperatures will be suitable. In contrast, young fall-run chinook salmon usually rear in their natal streams for just a few months before emigrating as smolts. Consequently, they often rear in the channel and on floodplains as they migrate downstream, so that they are of suitable size for smolting by the time they leave fresh water.

This issue includes two options:
- One approach to management of fall-run chinook salmon rearing involves focusing rearing in Reach 1, where it is easier to maintain suitable water temperatures during the rearing phase, and where a reconnaissance survey of invertebrates suggests that food supply may better for rearing salmonids. This approach does not imply that rearing is focused exclusively in Reach 1—rearing will also occur, to a lesser extent, during lower reaches in wetter water year types and on floodplain surfaces that are constructed as part of any downstream channel modifications.
- Another approach involves providing rearing habitat along the length of the river in the planning area. The aim of this approach is to provide rearing opportunities along the emigration route for juveniles so as to optimize growth potential, which may require a relatively greater commitment of water to maintain suitable water temperatures in lower reaches.

This issue has significant implications for the amount of water required to maintain suitable habitat and temperatures for rearing salmonids in the spring. Consequently, the participants in the restoration planning process determined that one strategy emphasize rearing in Reach 1, and at least one strategy that provided rearing opportunities in all reaches of the planning area. Strategy 1, the Existing Capacity Strategy, and Strategy 3, the Riparian-oriented Management Strategy, emphasize rearing in Reach 1. Strategy 2, the Salmonid-oriented Management Strategy, features opportunities for rearing in all reaches within the planning area.

2.3.3 Routing flow, fish, and sediment through or around Mendota Pool and Dam

Mendota Dam is a key element of the water supply infrastructure in the San Joaquin River. The current dam is scheduled to be replaced by a new structure, which provides an opportunity to integrate modern fish passage facilities to enhance the upstream migration of adult salmonids and the downstream migration of young salmonids. However, Mendota Pool presents a hazard to young salmonids emigrating from the system. Mendota Pool is inhabited by several species of native and non-native fish that prey on juvenile salmon, and small salmon can be entrained in the unscreened diversions that siphon water from Mendota Pool.
This issue has two options:
- The risk of salmonid mortality risk in Mendota Pool can be reduced by screening the diversions and increasing flows as part of emigration pulses to reduce residence time in the Pool, thereby reducing the time of exposure to predators. Mendota Dam and Pool also disrupt sediment continuity by trapping sediment during normal operations. Periodically, releases from Mendota Dam flush some of the sand accumulated in Mendota Pool into downstream reaches, thereby preserving the storage capacity of the Pool. However, these sediment releases deliver sediment

downstream infrequently and in relatively large pulses, which reduces the environmental benefit of the sediment supply and may actually cause damage to ecosystem components.

A bypass channel can be constructed that routes San Joaquin River water, fish, and sediment around the Mendota Pool complex without significantly disrupting water supply operations of the dam (i.e., delivery of water via the Delta-Mendota Canal [DMC]). A bypass channel can avoid the potential predation and entrainment problems associated with Mendota Dam and Pool, and it provides an opportunity for restoring sediment continuity with downstream reaches.

The participants in the restoration planning process determined that one strategy should include routing flow and fish through Mendota Dam and Pool, and at least one strategy should include routing flow and fish through a bypass channel that avoided the dam and pool. Strategy 1, the Existing Capacity Strategy, routes flow and fish through Mendota Pool and Dam. Strategy 2, the Salmonid-oriented Management Strategy, and Strategy 3, the Riparian-oriented Management Strategy, involve routing fish and water though a Mendota Pool bypass channel.

2.3.4 Routing flow and fish through a restored mainstem channel in Reach 4B or through an alternative pathway

Reach 4B of the mainstem San Joaquin River has a current rated capacity of 1,500 cfs; however, the actual capacity of the channel is estimated to be much lower, approximately 300 cfs. The Sand Slough Control Structure defines the upper boundary of Reach 4B, and current operation of the structure routes all flow into the Sand Slough bypass channel, depriving Reach 4B of water. The elimination of flow in Reach 4B deprives the channel of the energy required to scour and maintain channel geometry. Also, land use practices have contributed to filling in the channel, and the narrow channel that remains supports dense vegetation, further reducing the conveyance capacity of the reach. Flow continuity cannot be restored to the San Joaquin River with Reach 4B in its current condition.

This issue includes two options:

- Reach 4B channel can be re-constructed, with a functional floodplain, so that it is able to convey flows restored to the San Joaquin River and provide fish passage. Re-constructing the channel would likely need to be complemented by the construction of levees to contain flood flows, because there are no natural features or existing flood management infrastructure for most of Reach 4B.
- Flows and fish can be routed through one of the sloughs or flood bypass channels that border the mainstem San Joaquin River channel in Reach 4B. Such an approach would require less effort than reconfiguring the mainstem channel in Reach 4B.

The participants in the restoration planning process determined that one strategy should route flow and fish through a restored channel in Reach 4B, and at least one strategy should route flow and fish through an alternative slough or bypass channel. Strategy 1, the Existing Capacity Strategy, and Strategy 3, the Riparian-oriented Management Strategy, both involve re-constructing the mainstem channel in Reach 4B and routing flow and fish through the restored channel. Strategy 2, the Salmonid-oriented Management Strategy, includes routing fish and water through Eastside Bypass channel.

2.4 Structure of this Document

Chapter 3 of this document describes some of the conceptual models and governing assumptions that permeate the three restoration strategies, including assumptions about the general target condition for key components of the San Joaquin River ecosystem, including salmonids, native resident fish, and riparian and wetland vegetation and wildlife habitat.

Chapter 4 describes restoration actions that are common to the three restoration strategies. That is, some restoration actions will be required as part of any restoration strategy that is selected. For example, some of the spawning riffles in the first few miles of Reach 1 currently lack gravel depths sufficient to support salmon spawning; consequently, all of the restoration strategies will require augmenting these spawning riffles with gravel. Chapter 4 describes these common actions by reach. Chapter 5 describes Strategy 1: the Existing Conveyance Capacity Strategy. Similarly, Chapter 6 describes Strategy 2: the Salmonid-oriented Management Strategy. And Chapter 7 describes Strategy 3: the Riparian-oriented Management Strategy. Each chapter describes the flood conveyance capacity of each reach; assumed flow-routing rules; projected hydrographs under the restored condition; and a description of key locations and restoration actions specific to the strategy.

2.5 Uncertainty

Development of the restoration strategies has utilized the best available information on physical and biological characteristics and processes for the San Joaquin River. Information on historical and current conditions in the river corridor is limited, however, necessitating the use of information from other rivers and the reliance on preliminary analyses drawn from reconnaissance-level investigations of the San Joaquin River. Of course, the salmon runs that are targeted for reintroduction under the restoration strategies no longer exist, and so the development of appropriate restoration actions for these populations is inherently speculative, based on the best available scientific data and professional judgment. Also, because basic information on water resources, such as flow levels and temperatures, is very limited, development of restoration strategies has relied on extrapolation of available information using modeling, other analytical tools and, when necessary, professional judgment. Some of the key uncertainties involved in development of the restoration strategies are described below.

2.5.1 Satisfying the restoration objectives

The three restoration strategies described in this report are required to satisfy the restoration objectives defined for key resource components described in the Restoration Objectives for the San Joaquin River (Stillwater Sciences 2003). These restoration objectives are designed to describe the restored condition for key processes, habitats, and species that comprise the San Joaquin River ecosystem, thereby defining a target at which restoration is aimed and establishing guidelines for restoration. The restoration objectives defined for the San Joaquin River include parameters such as: temperature targets for different life history stages of salmon species and flow targets that support riparian vegetation establishment.

The restoration objectives defined for the San Joaquin River were derived both from a review of current scientific literature and an analysis of data from Central Valley rivers. The parameters and values established in the literature, and the data collected on other rivers, are based on research conducted in river systems that are very different from the San Joaquin River. For example, much of the information about the habitat needs of chinook salmon are based upon research that has been conducted on river systems throughout the range of chinook salmon, which includes the Pacific Northwest and Alaska. Before their extirpation, the stock of chinook salmon in the San Joaquin River represented the southernmost extent of chinook salmon populations, and the environmental conditions to which they were adapted were very different from river systems in the Pacific Northwest and Alaska. Because so little information is available regarding the historical populations of chinook salmon in the San Joaquin River and the environmental conditions to which they adapted, the development of restoration objectives relied upon values established in the scientific literature for other river systems. As a result, it is uncertain if many of the restoration objectives that have been delineated for restored populations of chinook salmon in the San Joaquin River define an appropriate target in light of local conditions.

For example, there are several restoration objectives for fall-run chinook salmon that define temperature targets for different life history stages. Based upon values established in the scientific literature, one objective includes maintaining water temperatures below 65°F for adult fall-run salmon as they migrate upstream to spawn. A similar target is to maintain water temperatures below 56°F to protect incubating salmon eggs buried in redds, again based upon values established in the scientific literature. The temperature target for salmon outmigrants is maintaining water temperatures below 68°F during the period of outmigration. Two of these targets are exceeded periodically on the Tuolumne River. Adult fall-run salmon migrate up the Tuolumne principally during the month of October, and water temperatures in the lower reaches of the Tuolumne often exceed the target temperature value of 65°F established for the San Joaquin River. Similarly, juvenile salmon outmigrate from the Tuolumne River in April and May, and during this period water temperatures have exceeded the target of 68°F. Table 2-1 shows the percentage of days within a given month (corresponding to a particular life history stage of fall-run chinook salmon) in which various temperature criteria were exceeded at sites in the Tuolumne River and a site in the mainstem San Joaquin River 3.7 miles downstream of the Tuolumne River mouth, together with the number of such days and the total number days for which data were available at each site. La Grange Dam is at river mile 52.2.

Table 2-1. Exceedances of water temperature criteria in the Tuolumne River, 1987–1997. (Turlock and Modesto Irrigation Districts 1998).

River Mile	Years of record	October days exceeding 65°F	November days exceeding 56°F	April days exceeding 68°F	May days exceeding 68°F
Tuolumne River					
49.1	1990–1997	15% (28/186)	1% (2/180)	0% (0/240)	8% (20/248)
48.0	1987–1989	2% (1/62)	2% (1/58)	0% (0/88)	14% (13/93)
42.0	1987–1994	12% (27/217)	17% (36/209)	0% (0/178)	6% (13/209)
36.5	1987–1997	32% (90/279)	18% (48/269)	0% (0/328)	29% (100/341)
31.0	1987–1991	56% (52/93)	18% (16/89)	3% (5/150)	59% (91/155)
24.9	1988–1996	48% (105/217)	45% (94/209)	9% (21/240)	42% (103/248)
12.3	1988–1996	40% (87/217)	34% (71/209)	16% (28/180)	57% (106/186)
3.4	1987–1997	48% (133/279)	44% (118/269)	14% (45/327)	49% (166/341)
San Joaquin River					
80	1988–1997	40% (99/248)	40% (95/239)	11% (33/300)	45% (139/310)

Many of the restoration actions that comprise the three restoration strategies, especially hydrograph components, strive to always achieve a stated restoration objective, such as a water temperature target. The experience with water temperatures on the Tuolumne River suggests that fall-run salmon populations are able to persist despite the fact that targets are not always satisfied. Designing the three restoration strategies to satisfy the restoration objectives means that the strategies are targeted at achieving nearly optimal conditions. The process of restoring salmon populations to the San Joaquin River may demonstrate that populations can withstand periods of environmental stress that are not reflected in the restoration objectives, which should be evaluated as part of a monitoring and adaptive management program. Adapting the restoration objectives in response to monitoring and scientific review would in turn influence the design of restoration actions, especially the timing and magnitude of flow releases.

2.5.2 Water temperatures

As described later in this report, the timing and magnitude of hydrograph components is influenced greatly by the need to satisfy water temperature objectives. However, very little water temperature data is available for the planning area. Consequently, there is considerable uncertainty in the relationships posited between flow and water temperature. A water temperature model developed by Jones & Stokes Associates (JSA) was used to support the development of the restoration strategies. Because of the paucity of water temperature data for the planning area, there are limited opportunities for calibrating this water temperature model over a range of flow conditions. The water temperature predictions of the model are likely to be most accurate in upstream reaches, because uncertainty in the relationships grows with distance from Friant Dam. During the development of the restoration strategies, the JSA water temperature model was used to predict relationships between flow and water temperature between Friant Dam and RM 150. For the lower reaches of the planning area between RM 150 and the confluence with the Merced River, we relied upon water temperature data collected at the Fremont Ford and Stevinson gauges, which had only short periods of record for water temperature data.

Developing hydrographs for the restoration strategies is also complicated by the fact that there is no clear, predictable relationship between flow magnitude and water temperatures. Flow and temperature data from the Fremont Ford gauge indicate that ambient air temperatures and weather can have much more significant effects upon water temperatures than the magnitude of a flow. For example, flow records from the Fremont Ford gauge indicate that the San Joaquin River had a sustained winter flood from late February through mid-April in 1986, with the flow peaking at a discharge of approximately 18,100 cfs on March 18th. In contrast, during the same time period in 1987, flows at the Fremont Ford gauge were considerably lower, with flows exceeding 1,000 cfs only a few days. Nevertheless, water temperature data collected at the Fremont Ford gauge shows that water temperatures were actually lower in 1987, despite the considerably lower flows. Table 2-2 shows discharge and water temperature in the San Joaquin River at Fremont Ford Bridge for the month of March, for the years 1986 through 1989. The great contrast in discharge between 1986 and the other years is not reflected in water temperatures. Similarly, the large flow pulse in the second week of March, 1987 does not seem to be associated with any conspicuous changes in water temperature for the same period.

Table 2-2. Discharge and water temperature in the San Joaquin River at Fremont Ford Bridge.

Date	Discharge (cfs)				Water temperature (°F)			
	1986	1987	1988	1989	1986	1987	1988	1989
1-March	6,200	256	389	213	60.8	54.5	60.8	57.2
2-March	5,600	258	449	234	61.7	56.3	59.0	54.5
3-March	5,150	252	471	295	61.7	57.2	59.9	52.7
4-March	4,860	231	449	401	62.6	57.2	60.8	52.7
5-March	4,320	309	435	515	63.5	55.4	62.6	53.6
6-March	4,230	522	431	415	63.5	56.3	63.5	57.2
7-March	3,860	1,080	422	355	62.6	57.2	62.6	60.8
8-March	2,940	1,380	432	322	61.7	58.1	62.6	61.7
9-March	4,080	1,260	426	321	59.0	59.0	61.7	63.5
10-March	5,280	1,070	398	309	55.4	58.1	57.2	63.5
11-March	7,140	908	382	291	55.4	60.8	53.6	65.3
12-March	10,900	769	393	306	56.3	61.7	54.5	65.3
13-March	13,100	642	384	307	56.3	61.7	56.3	61.7
14-March	14,200	621	394	313	55.4	59.9	58.1	60.8
15-March	13,800	625	427	313	53.6	58.1	58.1	61.7
16-March	14,700	698	446	314	51.8	57.2	58.1	60.8
17-March	16,900	793	459	309	52.7	58.1	59.0	61.7
18-March	18,100	777	444	311	54.5	59.0	60.8	61.7
19-March	17,400	716	421	311	56.3	57.2	62.6	62.6
20-March	15,800	642	400	308	59.0	56.3	63.5	62.6
21-March	14,600	593	372	319	60.8	56.3	63.5	64.4
22-March	13,600	579	378	292	61.7	56.3	62.6	66.2
23-March	12,800	596	384	287	60.8	56.3	63.5	66.2
24-March	12,400	587	348	300	60.8	56.3	61.7	66.2
25-March	12,200	575	315	326	60.8	58.1	61.7	63.5
26-March	12,000	543	311	369	61.7	59.0	64.4	61.7
27-March	11,800	516	308	487	62.6	59.9	60.8	62.6
28-March	11,600	501	289	622	63.5	59.0	54.5	64.4
29-March	11,500	480	305	516	64.4	59.9	57.2	64.4
30-March	11,300	458	290	399	64.4	62.6	57.2	65.3
31-March	11,200	426	296	303	64.4	64.4	56.3	66.2

The requirement to satisfy the restoration objectives, coupled with the limited availability of water temperature data, has produced some hydrograph components that differ significantly from unimpaired conditions. For example, each of the hydrographs for the three restoration strategies includes a pulse flow released in October to support the upstream migration of adult fall-run salmon. However, the shape of this hydrograph component is not dictated by the need to provide fish passage past flow-related barriers. Rather, the projected magnitude of this flow (3,500 cfs) is dictated by the drive to maintain water temperatures below the restoration objective of 65^{o}F during the period when migration needs to occur in order for juveniles to emerge and outmigrate before temperatures become too high. The water temperature model and the water temperature data at Fremont Ford and Stevinson gauges suggest that it will not be possible to achieve this temperature target in all river reaches in early October, even with discharges up to 7,000 cfs. In the pre-dam flow regime, flows at the USGS Friant gauge exceeded 3,000 cfs during the month of October only once, in 1919. Nevertheless, fall-run salmon were able to migrate upstream to spawn. Historically, fall-run salmon may have migrated in later October and November, when air temperatures, and eventually water temperatures, were growing cooler. However, our analysis of fall-run salmon suggests that under current conditions, adult fall-run salmon migrating in November, and spawning in late November and early December, would likely produce juvenile salmon that will emerge too late in the winter to outmigrate before water temperatures grow too warm in late May and early June.

Restoring flows to all reaches of the San Joaquin River will provide the opportunity to collect more water temperature data, which will contribute significantly to a better understanding of the relationships between flow and water temperatures. Better water temperature data will support better modeling, which will likely posit different relationships between flow and water temperature than are used in this report. Before they were extirpated, fall-run salmon may have migrated upstream in water temperatures considerably warmer than the 65^{o}F temperature objective. So the restoration of salmon populations to the San Joaquin River will also necessitate revisiting the restoration objectives through monitoring and adaptive management.

2.5.3 Extirpated salmon populations

Many native resident and anadromous fish populations have been extirpated from the San Joaquin River, which limits our knowledge of how fish used existing habitats within the river and how reintroduced fish may adapt to local conditions. Restoring salmon populations to the San Joaquin River will require selecting parent stock from a different river basin, which introduces uncertainty about how a transplanted population will behave. For example, there is no population of spring-run chinook salmon in the San Joaquin River basin, so parent stock for a restored population of spring-run salmon will have to come from the Sacramento River basin. We examined the life history timing of several spring-run stocks in the Sacramento River basin, and we selected Butte Creek population because their life history timing seemed best suited to the current conditions of the San Joaquin River. As described in Section 3.2.5.1, Butte Creek spring-run adults migrate upstream between February and April (a period when it is relatively easy to achieve the temperature target of 65^{o}F for adult migrating salmon), and they spawn in September. However, it is unclear if a restored population of spring-run salmon on the San Joaquin River will exhibit the same life history timing of its parent stock. Changes in life history timing could precipitate changes in the timing of hydrograph components, which in turn could stimulate significant changes in the projected flow magnitudes for a given hydrograph component. Similarly, a restored salmon population will provide the opportunity to reassess the restoration objectives under a monitoring and adaptive management program, especially the water temperature targets for different life history stages. Changes to the restoration objectives could have significant ripple effects upon the timing and magnitude of the hydrograph components projected in this report.

2.5.4 Hydraulic modeling

The hydraulic modeling used in developing the restoration strategies relies on topographic information derived from merging elevation data generated from aerial photogrametry and bathymetry. The spot elevation data from these two sources were then used to create a digital terrain model (DTM) of the 150-mile river corridor. The individual cross sections used in the hydraulic (HEC) modeling were generated using the DTM rather than conducting more laborintensive ground surveys. The accuracy of the DTM-derived cross sections has been assumed adequate for the preliminary, strategic level planning needed for restoration strategy development. However, we have no precise quantitative estimate of their accuracy relative to traditional, ground-surveyed cross sections, nor do we have estimates of how any errors in cross section data might affect HEC model outputs. Another potential uncertainty relates to the various flow splits among low or high water channel found in some reaches that are not likely to be fully captured by the HEC model. This can affect our predictions of location and area of inundation under various flow scenarios, which in turn would affect predictions of fish floodplain rearing habitat or maximum potential riparian seedling recruitment area. Another critical uncertainty affecting fish habitat and riparian recruitment modeling predictions is the assumption of static channel geometry and stage-discharge relationships for each cross section. We know that channel geometry can change over time, particularly in the sand-bedded reaches under the higher flows they would experience if flood conveyance capacity is increased. Changes in channel geometry, particularly channel incision, could substantially alter stage-discharge relationships and introduce an unknown amount of error into predictions of inundated habitat or recruitable area under various flow scenarios.

2.5.5 Groundwater dynamics

Groundwater dynamics have been highly altered by historical and current land and water uses in the project area. Some reaches that were historically gaining reaches are now losing reaches. Resumption of perennial baseflows throughout the river corridor, coupled with higher-magnitude flows prescribed for various ecological restoration objectives, will provide additional groundwater recharge compared with current conditions. The ultimate effects of these changes in flow management regime on local and regional groundwater dynamics are unknown. The interactions between surface water and groundwater in the project area are poorly understood, at least at the finer scale that would affect site-specific restoration efforts. For example, in the San Joaquin River Riparian Recruitment Model, a 1:1 relationship is assumed between surface water elevation and the elevation of the shallow groundwater table critical to riparian plants. Deviations from this assumed relationship could cause substantial over- or underestimation of the potential area available for natural recruitment of riparian vegetation. Additional site-specific information on spatial and temporal variability in surface water and groundwater interactions would be very valuable in moving from conceptual restoration strategies to the development and implementation of a detailed restoration plan.