CHAPTER VI
POTENTIAL ECOSYSTEM RESTORATION PLAN COMPONENTS

This section provides a discussion of the ecosystem restoration measures preliminarily retained for further consideration. These restoration measures will be combined with other project measures to form alternative plans that collectively meet the goals and objectives of the SLWRI. These measures were developed specifically to address the identified environmental problems and needs consistent with the goals and objectives of the SLWRI. Although developed for ecosystem restoration, there is the potential to consider several of these measures as elements in alternative plans for the purpose of mitigating negative impacts caused by other plan components.

MEASURES RETAINED FOR FURTHER CONSIDERATION

Based on a preliminary screening of measures discussed in Chapter V, the following potential ecosystem restoration measures were retained for further evaluation and consideration:

- A1 – Construct Shoreline Fish Habitat around Shasta Lake
- A5 – Construct Instream Fish Habitat on Tributaries to Shasta Lake
- A7 – Restore Inactive Gravel Mines on Sacramento River
- A8 – Construct Instream Habitat Downstream from Keswick Dam
- A9 – Replenish Spawning Gravel in Sacramento River
- A10 – Additional Modifications to Shasta Dam for Temperature Control
- A12 – Enlarge Shasta Lake Cold Water Pool
- A13 – Modify Storage and Release Operations at Shasta Dam
- B10 – Riparian and Floodplain Restoration along Sacramento River

Each of these measures contributes to one or more of the goals and objectives of the study, although no individual measure is capable of fully meeting study goals. The extent to which each measure contributes to these goals varies significantly and, in some cases, is difficult to quantify without further study. For this reason, it was necessary to make preliminary assumptions regarding the application, extent, size, and/or cost of the measures for the purpose of this initial evaluation. In addition, measure features may have changed somewhat from those presented in Chapter V based on further evaluation and investigation.

The measures are discussed below in terms of their actions and accomplishments, compatibility with other potential measures, implementation issues, and estimated cost. The level of detail of the discussion is appropriate for initial evaluation and to determine how these ecosystem restoration components might combine with other project components to form alternative plans. However, additional investigation and refinement of these measures would be required to develop alternative plans. Preliminary, order-of-magnitude costs were developed for the purpose of comparing measures. Because initial costs and long-term costs can vary between measures,

costs are presented in terms of *first cost* (the sum of initial construction, lands, planning, engineering, and design costs), and *annual cost* (including anticipated annual operation and maintenance costs, replacement costs, and other periodic costs). First cost indicates the initial investment that would be required to implement the measure. Annual cost, on the other hand, includes future costs that will be required annually to maintain benefits and provides a common platform on which measure costs can be compared. Annual costs are presented as relative comparisons to the first costs.

A1 – Construct Shoreline Fish Habitat around Shasta Lake

Shallow, warm-water areas along the shoreline of Shasta Lake provide preferred habitat for juvenile fish and other adult resident fish species. However, whereas the shorelines of most natural lakes and water bodies are lined with trees, rocks, debris, and other structures that provide cover, the shoreline of Shasta Lake is comparatively barren, increasing juvenile mortality. The lack of shoreline cover and suitable shallow-water fish habitat is due to several factors, including the steep topography, soils, wave action, and seasonal water fluctuations in the reservoir. These factors cause erosion and prevent vegetation from becoming established within the reservoir drawdown area. In addition, large woody debris entering the lake from its tributaries is removed annually due to boating concerns. This measure would improve shallow, warm-water habitat around the shoreline of Shasta Lake by planting resistant vegetation and placing large woody debris, boulders, and other aquatic 'cover' structures within the drawdown area of the lake.

Actions and Accomplishments

The measure would involve the installation of artificial fish cover including anchored complex woody structures (root wads, trunks, and other large woody structures) and boulders, and the planting of water tolerant and/or erosion resistant vegetation at prescribed locations within the reservoir drawdown area. Specific applications would be chosen as appropriate to site-specific shoreline conditions, such as bank slope, rate of erosion, proximity to tributaries, soils, and the presence of existing cover or vegetation. It is estimated that about 20 structures and approximately 400 selective plantings would be required for each acre of shoreline restored. The estimated life of the artificial cover structures is 10 to 15 years; however, additional vegetation recruitment could be encouraged that would extend the benefits beyond this preliminary estimate.

It is estimated that locations near the mouths of tributaries would be targeted for restoration because the lower reaches of many tributaries provide favorable spawning conditions, and juvenile fish leaving the tributaries would benefit from improved adjacent shoreline habitat. Although intermittent streams provide some seasonal rearing habitat, the mouths of perennial tributaries would be favored. Further, shoreline areas with gradual slopes provide a wider, shallow-habitat area and would be more appropriate than steep banks that are prone to accelerated erosion. In addition, the sites would need to be undeveloped, provide reasonable construction access, and not be subject to significant recreational disturbances (i.e. adjacent to marinas, picnic areas, campgrounds, or other areas that attract large numbers of people). There are several major and minor tributaries to Shasta Lake that appear to have a high potential for application of this measure. For the purpose of this initial evaluation, it is estimated that sites at

the mouths of eight of these perennial tributaries would be selected with approximately five acres of shoreline suitable for restoration at each site. Other areas may also have a high potential and would be evaluated in future studies.

The availability of cover for juvenile fish can significantly improve survival. The establishment of vegetation could also benefit land-based species that inhabit the shoreline of Shasta Lake. This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area. Increased shallow-water fish survival would also enhance recreational sport-fishing opportunities in the lake, supporting the secondary recreation objective of the SLWRI.

Compatibility with Other Measures

Potential measures to raise Shasta Dam would increase the reservoir drawdown area during dry periods that is subject to erosion and other factors that diminish shoreline habitat. This measure would be compatible with potential measures to raise Shasta Dam because the habitat treatments could be extended, as needed, into the additional drawdown area. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects in the vicinity of Shasta Lake.

Implementation

DFG participates in fish stocking and monitoring in Shasta Lake and would be the likely non-federal sponsor for this measure, possibly through the WCB. Actions would need to be coordinated with Reclamation (the primary landowner) and the FS (the primary land manager).

A potential implementation issue concerns the creation of submerged hazards for watercraft users. Shasta Lake is a key recreational draw for the area, primarily due to the opportunities for fishing, boating, and other water-related sports and activities. Fishermen and recreational boaters favor the mouths of tributaries, which are the areas targeted for shoreline restoration. However, potential shoreline hazards would be limited to a relatively narrow area because the shoreline of Shasta Lake is generally steep. Specific restoration sites could be marked with buoys or signs, and cautionary notes could be added to the boating guidelines produced by the FS. In addition, artificial cover structures should be firmly anchored to prevent them from dislodging and becoming floating hazards. This potential issue is not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of the measure in achieving its intended accomplishments is moderate. There are numerous factors affecting the sustainability of habitat within the drawdown area of the lake. An adaptive management approach may be needed to monitor and modify the restoration elements.

Preliminary Cost

It is estimated that a total of 40 acres of shoreline restoration would be performed under this measure, consisting of about five acres of restoration at each of eight sites. This would include the placement of about 20 artificial cover structures per acre and selective plantings of 400 plants per acre. Land acquisition would not be required because the shoreline areas are already under

Federal ownership. The first cost, including planning, engineering, design, and initial implementation of this measure, is estimated to be about $1.6 million.

Some short-term monitoring and maintenance of revegetation sites would be required for up to three growing seasons following installation, and the habitat structures would need to be periodically inspected to ensure that they remain anchored. Depending upon short-term monitoring, an adaptive management approach may be necessary to ensure measure success. It is estimated that habitat structures would need to be replaced, on average, about every 12 years during the life of the project. Accordingly, the estimated annual costs would be relatively moderate to high compared to the first cost.

A5 – Construct Instream Fish Habitat on Tributaries to Shasta Lake

Tributary streams are an important environmental resource in the primary study area, supporting a variety of native and non-native fish and other aquatic organisms. However, the quality and quantity of instream aquatic habitat has decreased over the last century due to the construction of dams, modification of stream hydrology, and other human influences. This measure would improve and restore instream aquatic habitat along the lower reaches of the major tributaries to Shasta Lake using various structural techniques to trap spawning gravels in deficient areas, create pools and riffles, provide instream cover, and improve overall instream habitat conditions.

Actions and Accomplishments

Structural treatments would vary depending upon stream conditions. Generally, they would include the installation of gabions, log weirs, boulder weirs, and other anchored structures. Spawning and rearing habitat would be created by providing instream cover with large root wads and by the use of drop structures, boulders, gravel traps, and/or logs that cause scouring and help clean gravels.

Although both perennial and intermittent streams would benefit from structural habitat improvements, the lower reaches of perennial tributaries to Shasta Lake would be targeted for aquatic restoration under this measure because they provide year-round fish habitat. The measure could be applied along numerous perennial streams tributary to Shasta Lake. Although up to nearly 20 miles of stream could be considered for this measure, not all of the streams would be chosen for implementation. The initial implementation would likely be restricted to the larger tributaries, after which the potential to expand to smaller tributaries could be assessed. The estimated life of structural aquatic restoration measures is 10 to 15 years, but would be highly dependent on localized streamflow hydrology and the occurrence of large flood events.

The quality and availability of aquatic habitat can significantly improve the survival of fish that reside on the tributaries to Shasta Lake. Both native and non-native fish would benefit, including some lake fish that spawn on the lower reaches of the tributaries. It could also benefit steelhead, a native species that must be planted in the lake annually, because some natural steelhead reproduction occurs on the lower reaches of the tributaries to Shasta Lake. This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving aquatic habitat conditions. Improving aquatic habitat would also enhance

recreational sport-fishing opportunities in the area, supporting the secondary recreation objective of the SLWRI.

Compatibility with Other Measures

This restoration measure would complement potential measure A1 to restore shoreline fish habitat in Shasta Lake because many juveniles that utilize shoreline habitat hatch on the lower reaches of the tributaries; improving and restoring aquatic habitat on the tributaries would increase the number of juveniles entering Shasta Lake. This measure would be compatible with potential measures to raise Shasta Dam, and does not conflict with any of the other ecosystem restoration measures that were preliminarily retained. This measure does not conflict with other known programs or projects in the vicinity of Shasta Lake.

Implementation

The DFG, Cantara Trust, or McCloud River CRMP are potential non-federal sponsors for instream habitat restoration. Each of these groups has participated in similar restoration activities in Shasta County. Restoration actions should be coordinated with local restoration groups, tribes, landowners, and the DFG, as appropriate.

A potential implementation issue concerns obtaining agreements with landowners to perform restoration along tributaries located on private lands, and/or gaining access through private lands to restoration sites. This issue could be avoided by selecting stream reaches that are located exclusively on public or conservation lands, and/or restoring sites on private lands only if proposed by their respective landowners.

The estimated certainty of this measure in achieving its intended accomplishments is high. Similar activities have been accomplished with success on other, similar stream systems. In addition, most of the major tributaries to Shasta Lake are highly regulated, reducing the potential for improvements to be damaged or destroyed during extreme flow events.

Preliminary Cost

The cost of this measure would be low relative to the cost of other measures identified, depending on the number and length of stream reaches selected for restoration. It is estimated that instream aquatic restoration would be performed along 8 miles of stream, or 2 miles along the lower reaches of each of the four major tributaries to Shasta Lake. The measure would involve the construction of about 40 complex boulder/log structures per mile stream to create gravel traps, pools, and riffles. It is estimated that all restoration activities would be conducted on Federal lands. The first cost, including planning, engineering, design, and initial implementation of this measure, would be approximately $600,000.

Some long-term monitoring and maintenance would be required after construction. It is estimated that habitat structures would need to be replaced, on average, about every 12 years during the life of the project. Accordingly, the estimated annual costs would be relatively moderate to high compared to the first cost.

A7 – Restore Inactive Gravel Mines on Sacramento River

Instream gravel mining has degraded aquatic and floodplain habitat, creating large, artificial pits along the river that disrupt natural geomorphic processes and riparian regeneration. Aquatic conditions at former gravel mining sites are typically unsuitable for spawning and rearing. High fish mortality occurs at many abandoned pits that lose their connection with the river during low flow periods, stranding fish and encouraging unnatural predation rates. Due to changes in flow regime and reductions in coarse sediment input, the river is not capable of refilling and restoring many of these pits naturally. This measure includes acquiring, restoring, and reclaiming several inactive gravel mining operations along the Sacramento River to create valuable aquatic and floodplain habitat.

Actions and Accomplishments

Gravel pit restoration would involve filling deep pits (potentially requiring the importation of suitable fill material from local sources) and re-contouring the stream channel and floodplain to mimic more natural conditions. Side channels and other features could be created to encourage spawning and rearing. Soil may need to be imported to replenish areas where gravel mining has resulted in a significant loss of fine sediments. Revegetation using native riparian plants would be performed on restored floodplain lands. Hydrologic, hydraulic, and sedimentation studies would identify optimal restoration conditions and any actions necessary to offset or minimize undesirable hydraulic conditions caused by restoration. Potential sites for gravel mine restoration along the Sacramento River between Keswick Dam and Red Bluff are listed in Table VI-1.

TABLE VI-1
POTENTIAL GRAVEL MINE RESTORATION SITES
ALONG THE SACRAMENTO RIVER

Location	Approximate Rivermile	Bank	Approx. Size in Acres
Red Bluff near Salt Slough	247	Left	140
Upstream of Stillwater Creek	282	Right	320
Redding	287-288	Right	135
Redding	287.5-288	Left	65
Redding	288.5-290.3	Left	305
Redding	292.5-294	Left	230
		TOTAL	**1,055**

One or more of these sites would be selected for restoration under this measure, pending more detailed evaluation of site-specific conditions. Most of these sites consist of one or more deep pits surrounded by partially disturbed land, with the majority of the site consisting of disturbed lands that would require minimal restoration actions. It is estimated that gravel mine restoration would have lasting benefits for the environment because more natural physical and biological processes would be restored.

Restoring stream habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining cold-water spawning areas available to anadromous fish. This measure

would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by eliminating stranding in abandoned gravel pits and restoring aquatic, riparian, and wetland habitat. The measure also supports the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River through the restoration of riparian and floodplain habitat.

Compatibility with Other Measures

This measure would combine favorably with potential measures to modify Shasta Dam because increased cold-water releases and other operational changes at the dam would further enhance the habitat restored by this measure and increase opportunities for anadromous fish to utilize the restored habitat. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained. It would combine favorably with measures involving floodplain restoration and gravel replenishment along the Sacramento River. This measure does not conflict with other known programs or projects on the upper Sacramento River.

Implementation

The DFG and DWR are potential non-federal sponsors for this measure. There appears to be a high degree of public agency and local interest for gravel pit restoration. DWR has performed several studies of instream and offstream gravel resources and stream geomorphology within the Keswick Dam to Red Bluff reach.

A potential implementation issue consists of access to and restoration of gravel pits located on or adjacent to private lands. However, there may be opportunities to work with landowners and incorporate design elements that would also benefit adjacent lands, such as constructing low berms to prevent nuisance flooding or incorporating erosion protection for hardpoints. To ensure that project benefits are lasting and sustainable, land would need to be acquired for the project if not already in public ownership.

Another potential implementation issue concerns movement of the river channel after restoration actions have been performed. One goal of gravel pit restoration is to return the river to a more natural state, including geomorphic channel forming processes that naturally support healthy aquatic and riparian habitat. Three of the potential restoration sites are located near or adjacent to urban development. Restoration actions should be designed such that nearby development is protected from potentially damaging bank erosion, floodwaters, or lateral channel movement. These potential implementation issues are not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of this measure achieving the intended accomplishments is very high. Similar restoration projects in other areas have provided favorable, sustainable results.

Preliminary Cost

The cost of this measure would be moderate to high relative to the cost of other measures identified, depending upon the number and size of the sites selected for restoration. For the purpose of this preliminary evaluation, it is estimated that one mining site totaling 150 acres would be selected for restoration, and a real estate interest would be acquired for those lands.

Intensive restoration would occur around gravel pits or extraction sites themselves, while minimal revegetation and earthwork would be performed on the remainder of the site. The first cost, including land acquisition, planning, engineering, design, and initial implementation of the measure, is estimated to be approximately $8 million.

It is anticipated that no elements of this measure would need to be replaced or reapplied during a 50-year project life. Short-term maintenance of revegetated areas would be required for up to three growing seasons following installation, and some long-term maintenance would be required; maintenance costs would not increase the total cost of this measure significantly. Estimated annual costs would be moderate compared to the first cost.

A8 – Construct Instream Habitat Downstream from Keswick Dam

Keswick Dam represents the upper-most barrier to anadromous fish migration on the Sacramento River. Immediately downstream from Keswick Dam, the Sacramento River channel is entrenched in bedrock with very little coarse gravel and vegetation. Releases from the dam have scoured the channel bottom and the dam blocks the passage of gravels, bed sediments, and woody debris that were replenished historically by upstream tributaries. As a result, aquatic habitat is poor for spawning and rearing of anadromous fish and predation can be high due to the lack of instream cover. Despite these unfavorable channel conditions, cold-water releases from Keswick Dam attract large numbers of spawners to the reach. This measure consists of constructing complex aquatic habitat in and adjacent to the Sacramento River downstream from Keswick Dam to encourage use of this reach for anadromous fish reproduction.

Actions and Accomplishments

Aquatic habitat restoration would involve acquisition of lands adjacent to the Sacramento River; earthwork along the riverbank to construct side channels for spawning; and the strategic placement of manmade instream cover structures within the river channel using large boulders, anchored root wads, and other natural materials. The structures would be designed to improve the complexity of aquatic habitat in this reach, help retain sediment and gravel, provide cover from predators, and encourage the formation of spawning beds. Side channels would be constructed immediately below the dam and gravel would be imported to the site to create spawning beds. Structures would be anchored to prevent movement during flood releases from Keswick Dam.

The potential site is located on the Sacramento River immediately downstream from Keswick Dam. Although planning, engineering and design would be needed to refine the components of this measure, it is estimated that in-channel treatments would extend approximately ¾ mile below the dam and include 20 to 35 log/boulder structures, two constructed side-channel spawning areas, and 500 tons of imported gravel. The beneficial life of the measure would be highly dependent on hydrology. Instream structures and imported gravel, in particular, are subject to movement during high flows and flood conditions. Depending upon the materials used, the estimated life of instream structures is estimated to be 5 to 10 years. The beneficial life of the side spawning beds is assumed to be significantly longer, as they would only be subject to damage during the most extreme flood events. However, replacement and/or replenishment of

spawning gravel in the beds could be required on a frequent basis, depending upon hydraulic conditions and the effectiveness of gravel retention measures.

The restoration of aquatic habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining spawning corridors available to anadromous fish along the Sacramento River. Large numbers of anadromous fish are attracted to the proposed restoration site because it is situated at the upper-most end of the migration corridor and releases from Keswick Dam provide cool water temperatures. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by restoring important spawning habitat below Keswick Dam.

Compatibility with Other Measures

This measure would combine favorably with potential measures to modify Shasta Dam because increased cold-water releases and other operational changes at the dam would further enhance the habitat restored by this measure and increase opportunities for anadromous fish to utilize the restored habitat. This measure would not conflict with any of the other ecosystem restoration measures that were preliminarily retained. It would combine favorably with measures involving gravel replenishment along the upper Sacramento River. This measure would not conflict with other known programs or projects on the upper Sacramento River.

Implementation

Because of the high peak flood flows expected for fairly frequent events in this reach of river, success of this measure would depend on reconstructing primary measure elements every 5 to 10 years by a non-federal sponsor. Because of such a long-term commitment needed to credit this measure as a viable project purpose, there would likely be limited Federal interest in its inclusion in a larger project. However, there may be interest by DFG or DWR to be a non-federal sponsor for this measure. Local conservation organizations may also be interested in participating or contributing to the project. There may be a high degree of public agency interest for restoration in this reach, which is highly visible due to the presence of Keswick Dam and its related fish facilities.

A potential implementation issue concerns the ability to design instream restoration features that are capable of withstanding scouring flows from Keswick Dam. Structural elements such as boulders, root wads, and other complex features should be anchored to the channel bottom to prevent movement during floods and other periods of high dam releases. Another potential implementation issue concerns the ability to construct side channels within the bedrock present at the site; a geologic evaluation would be required to fully assess construction feasibility. It may also be difficult for construction equipment to access the channel. Mitigation would be provided for any construction-related impacts. This potential issue is not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of this measure in achieving the intended accomplishments is moderate. There are numerous factors affecting the sustainability of healthy spawning areas in the reach of river downstream from Keswick Dam. These are primarily related to the potential for high

releases from the dam to damage habitat improvements. An adaptive management approach may be warranted to monitor and modify the spawning areas to achieve the desired benefits.

Preliminary Cost

The cost of this measure would be moderate relative to the cost of the other measures identified. Cost would depend on the length of stream channel selected for restoration and the extent of channel modification needed to create suitable side spawning areas. It is estimated that instream aquatic restoration would be performed along a ¾ mile reach of river immediately downstream from Keswick Dam. Restoration actions would involve placement of instream aquatic cover structures, placement of 500 tons of imported spawning gravel, and construction of two side channels along the banks of the river for spawning. It is estimated that 50 acres of land would be acquired for the side spawning channels. The total first cost, including land acquisition, planning, engineering, design, and initial implementation costs, is estimated to be approximately $800,000.

Monitoring, maintenance, and periodic gravel replacement would be required after construction. It is anticipated that major habitat structures would need to be replaced, on average, about every 10 years during the life of the project. For cost estimating purposes, gravel replacement is assumed to occur every 5 years. Annual and periodic costs would be relatively high compared to the first cost.

A9 – Replenish Spawning Gravel in Sacramento River

Historically, the tributary watersheds upstream from Keswick and Shasta Dams provided a source of gravel and other coarse sediments to the Sacramento River. Gravels were continually replenished as they moved down the river system. Gravel recruitment is of particular importance to anadromous fish, which require clean gravels for their spawning beds. Today, dams, river diversions, gravel mining, and other obstructions have blocked or reduced natural gravel sources. Suitable spawning gravel has been identified as a potential limiting factor in the recovery of anadromous fish populations on the Sacramento River. Several other programs, including CALFED and the Anadromous Fish Restoration Program (AFRP), have participated in gravel replenishment on the Sacramento River in selected locations. However, these efforts were single applications with short-term benefits, and no long-term program exists to continue and maintain gravel replenishment efforts. This measure would help replenish spawning-sized gravel in the Sacramento River between Keswick Dam and Red Bluff.

Actions and Accomplishments

This measure would involve transporting and injecting gravel into the Sacramento River downstream from Keswick Dam. Suitable spawning gravel would consist of uncrushed, natural river rock, washed and placed in the river at strategic locations. Hydraulic and geomorphic evaluations are needed to determine the most effective gravel size distribution and the most appropriate locations for the injections. The size and amount of gravel is first determined by the hydraulic characteristics of the river at the injection site and secondarily by the spawning characteristics of the targeted fish species. For the purpose of this evaluation, it is estimated that

a total of 10,000 tons of gravel between 1-inch and 3 inches in diameter would be injected at three sites.

Injecting the gravel in relatively stable reaches that lack natural gravel sources, preferably those with complex structures or large woody debris to trap and retain gravel, would increase the success and longevity of the measure. The reach immediately downstream from Keswick Dam has no natural gravel sources and currently provides marginal spawning habitat. Gravel injections would be concentrated in this uppermost reach, between Anderson and Keswick Dam. Gravel is typically moved downstream from the site of injection by high flows that occur, on average, about every five years; therefore, this measure would need to be reapplied periodically to maintain site-specific benefits. However, injected spawning gravels continue to benefit the stream environment as they move through a river system, although the benefits tend to be less distinct the farther one moves downstream.

The restoration of aquatic habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining spawning corridors available to anadromous fish along the Sacramento River. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by contributing to the replenishment of spawning gravels used by anadromous fish.

Compatibility with Other Measures

This measure would combine favorably with measures involving aquatic habitat restoration, such as measures A7 and A8, because complex aquatic structures tend to trap and retain gravel longer. Combining these measures would increase effectiveness and longevity. This measure would also combine favorably with potential measures to modify Shasta Dam because increased cold-water releases and other operational changes at the dam would increase opportunities for anadromous fish to utilize spawning habitat created by the gravel injections. This measure would complement potential measures to raise Shasta Dam because improved cold-water release flexibility would enable anadromous fish to take greater advantage of restored spawning habitat. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects on the upper Sacramento River.

Implementation

Success of this measure would depend on the regular and recurrent injection of spawning gravels into the Sacramento River over the life of the Federal project by a non-federal sponsor. Because of such a long-term commitment needed to credit this measure as a viable project purpose, there would likely be limited Federal interest in its inclusion in a larger project. However, there may be significant interest by DFG, DWR, or the Western Shasta RCD to be a non-federal sponsor. Spawning gravel replenishment programs have been successful along the Sacramento River in the past. This would infer a high certainty that the measure will achieve the desired benefits.

Another potential implementation issue would be the perception that injected gravels could eventually contribute to deposition problems around agricultural water diversion facilities further downstream. However, due to the limited volume injected, desirable size range for spawning

gravels, and careful selection of injection sites, it is likely that there would be minimal adverse impacts to facilities on the river.

Preliminary Cost

The cost of this measure depends on the size of the restoration effort. Generally, it would have a low initial cost but a moderate cumulative cost over the 50-year project life. A total of 10,000 tons of gravel would be injected at three sites along the Sacramento River. Real estate interests would likely be minor and consist of acquiring the sites for gravel injection, easements to access the sites, and potential interests in borrow areas. The first cost for planning, engineering, design, and initial gravel injection would be approximately $400,000.

As mentioned, gravel injections would need to be repeated periodically as part of project operation in order to maintain the benefits and efficacy of this measure. For cost estimating purposes, it is estimated that 10,000 tons of gravel would be re-injected, on average, about every 5 years. The estimated annual costs would be very high compared to the first cost.

A10 – Additional Modifications to Shasta Dam for Temperature Control

The TCD installed at Shasta Dam allows operators to make selective releases from various reservoir depths in order to regulate water temperatures in the Sacramento River. The TCD works well in helping regulate the release temperature through the powerhouse. However, it could be improved, as some amount of warm-water leakage occurs near the lake surface, which reduces its effectiveness. This measure would provide additional structural modifications to the outlets and existing TCD at Shasta Dam for the purpose of temperature control, allowing additional flexibility in making cold-water releases during critical spawning periods and extending the area of suitable spawning habitat in the Sacramento River.

Actions and Accomplishments

The existing temperature control device consists of a submersed multi-level intake structure that hangs from the upstream face of the dam. The shuttered structure is 250 feet wide and 300 feet high, with a low-level intake that is 125 feet wide and 170 feet high. Under this measure, the existing device would be widened to increase intake capacity and the device would be extended to a greater depth. This would involve a modification to the existing multi-level intake structure to reduce leakage. It could also involve major modifications such as the intake structure connections to the powerhouse penstocks and may require additional coring or drilling into the face of the dam.

The benefits of additional modifications to the cold-water release capabilities of the dam are not likely to be as dramatic as those achieved with construction of the existing temperature control device. Consequently, there is some uncertainty as to the cost effectiveness of this measure unless it is combined with other measures involving major modification to Shasta Dam.

Water temperature is one of the most important factors contributing to the success of anadromous fish reproduction. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by improving the ability to provide desirable water temperatures for spawning, rearing, and out-migration. This measure

may also support the secondary objective to increase hydropower generation, although the benefits to hydropower may have been fully realized with the construction of the existing temperature control device. The existing temperature control device maximizes power generation by routing cold-water releases through the powerhouse turbines, and has allowed Reclamation to produce additional hydroelectricity during its use.

Compatibility with Other Measures

This measure would complement potential measures to raise Shasta Dam because additional temperature control improvements could be incorporated into the design of a dam raise and further improve cold-water releases. It would also combine well with measures to improve aquatic spawning habitat in the Sacramento River, as better water temperature regulation could allow anadromous fish to take greater advantage of these habitat improvements. This measure does not conflict with other environmental restoration measures preliminarily retained herein or other known programs or projects on the upper Sacramento River.

Implementation

The State of California through the DFG was a funding partner for construction of the existing temperature control device. Accordingly, DFG would be a potential candidate for non-federal sponsorship of this measure.

This measure would involve significant modifications to the existing intakes at Shasta Dam. However, knowledge gained during design and construction of the existing temperature control device should help overcome any physical construction issues associated with the measure. This includes using underwater construction techniques to reduce the need to draw down the lake. More importantly, there may be limits to the degree of dam modifications allowable while maintaining the structural integrity of the dam; the existing temperature control device weighs almost 9,000 tons. For this reason, it may be more feasible to implement this measure in combination with other modifications to the dam, such as a dam raise.

The estimated certainty of this measure in achieving its intended accomplishments would be high. As mentioned, it would not provide the same degree of benefits achieved when the existing TCD was constructed. However, it would likely be much more effective if combined with other measures to increase the cold water pool in Shasta Lake.

Preliminary Cost

The cost for this measure would be high relative to the other measures identified. The existing TCD cost about $80 million to plan, design, and construct (1995 price levels). It is difficult to estimate the cost of additional modifications to the device prior to preliminary planning and design. However, it is anticipated that the cost for this measure could be fairly low for improvements to resolve the existing leakage problems to high, similar to the initial construction cost, for higher dam raises.

A12 – Enlarge Shasta Lake Cold Water Pool

Water temperature has been identified as one of the most important factors in achieving recovery goals for anadromous fish on the Sacramento River. Cold water released from Shasta Dam significantly influences water temperature conditions on the Sacramento River between Keswick Dam and Red Bluff, and can have an extended influence on river temperatures even farther downstream. This measure includes increasing the volume of the cold water pool in Shasta Lake to help maintain colder releases for anadromous fish during certain periods by raising Shasta Dam and enlarging Shasta Reservoir.

Actions and Accomplishments

This measure involves increasing the volume of the cold water pool in Shasta Lake to permit greater flexibility in making releases beneficial to anadromous fish. The increased volume of cold water would be achieved through raising Shasta Dam and enlarging Shasta Reservoir. Dam raises ranging from about 6.5 feet to about 200 feet have been considered in previous studies by Reclamation. A dam raise of about 6.5 feet creating an increase in lake storage of about 290,000 acre-feet was suggested in the CALFED ROD. Other dam raises are also being evaluated. As an example, a dam raise of about 200 feet would create an increase in lake storage of about 9.3 million acre-feet. The increased cold water pool from the dam raises could be used to target increasing cold-water discharges during the summer, which could significantly extend the downstream reach of suitable spawning habitat. Changes in the timing and magnitude of releases from the increased pool consistent with measure A13 could also be considered to improve the quality of aquatic habitat by cleaning spawning gravels, and to improve attraction flows that cue in-migration and temperatures that cue out-migration.

The primary benefits of this measure are improved water temperature control, extension of suitable spawning habitat, and improvement in overall physical aquatic habitat conditions. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River. It wold also benefit the primary objective of increasing water supply reliability.

Compatibility with Other Measures

This measure could combine favorably with other primary and secondary planning objectives. It could also complement measures to improve aquatic habitat conditions on the Sacramento River, such as rehabilitating spawning and rearing areas. This measure would not conflict with other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects on the upper Sacramento River.

Implementation

Implementation would require coordination with multiple Federal and State agencies, which may include the California Bay-Delta Authority, Corps, FWS, DFG, NOAA Fisheries, FERC, DWR, and the Reclamation Board. Raising Shasta Dam and enlarging Shasta Reservoir would result in impacts to reservoir rim natural resources and infrastructure requiring significant mitigation and relocations. Impacts associated with dam raises less than about 18 feet would be significant but likely manageable. Higher dam raises result in major impacts to reservoir area resources and

infrastructure with a resulting significant reduction in likely economic justification. Very high dam raises (100 to 200 feet), besides having extreme impacts in the Shasta Lake area, might also result in major impacts to natural resources conditions downstream along the Sacramento River. Impacts would likely be so great as to eliminate serious consideration of higher dam raises. However, no mater what magnitude of dam raise is considered, careful planning would be required to identify and offset impacts to these resources and infrastructure. The estimated certainty of this measure in achieving its intended accomplishments would be high.

Preliminary Cost

Preliminary estimates of first costs for this measure range from about $210 million for raising Shasta Dam 6.5 feet to about $5 billion for raising the dam 200 feet. Annual costs would be relatively low compared to the first cost.

A13 – Modify Storage and Release Operations at Shasta Dam

As mentioned, water temperature has been identified as one of the most important factors in achieving recovery goals for anadromous fish on the Sacramento River. Cold water released from Shasta Dam significantly influences water temperature conditions on the Sacramento River between Keswick Dam and Red Bluff, and can have an extended influence on river temperatures even farther downstream. This measure would modify reservoir storage and dam release operations to benefit anadromous fisheries on the Sacramento River by providing greater flexibility in meeting water temperature targets and/or flow stability to help restore suitable spawning habitat and related channel conditions.

Actions and Accomplishments

This measure would involve revising reservoir storage and release criteria throughout the year to permit greater flexibility in making releases beneficial to anadromous fish. Operational changes could target increasing cold-water discharges during the summer, primarily during dry and critically dry years, which could significantly extend the downstream reach of suitable spawning habitat. Changes would also be made to the timing and magnitude of releases to improve the quality of aquatic habitat by cleaning spawning gravels, and to improve attraction flows that cue in-migration and temperatures that cue out-migration. Further, the measure could provide additional control and dilution of acid mine drainage from Spring Creek.

Shasta Dam already operates for multiple objectives including water supply, flood control, water temperature, hydropower, and others. As mentioned, modifying existing storage and release operations would likely impact water supply or other beneficial uses of the water stored in the reservoir, which would be contrary to SLWRI goals and objectives. Therefore, this measure would require some amount of additional water storage in Shasta Lake by raising Shasta Dam to offset any negative impacts to water storage.

The primary benefits of this measure are improved water temperature control, flow stability, extension of suitable spawning habitat, and improvement in overall physical aquatic habitat conditions. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River.

Compatibility with Other Measures

This measure would combine favorably with measures to increase the capacity of Shasta Dam, which would increase opportunities to change existing storage and release operations and minimize impacts to hydropower or water supply. It would also complement measures to improve aquatic habitat conditions on the Sacramento River, such as spawning gravel injection or improvements to the complexity of aquatic habitat. This measure would not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor would it conflict with other known programs or projects on the upper Sacramento River.

Implementation

Implementation would require coordination with multiple Federal and State agencies, which may include the Corps, FWS, DFG, NOAA Fisheries, FERC, DWR, and the Reclamation Board.

As mentioned, without enlarging the cold water pool in Shasta Lake, this measure would have the potential to negatively impact water supply, hydropower production, or flood control. Careful planning would be required to identify and offset impacts to the other beneficial uses of Shasta Dam and Reservoir, possibly requiring additional water supply. This would include hydrologic and hydraulic modeling, and reservoir operation simulations. In general, the process of changing a reservoir's operation criteria is politically and institutionally difficult because it involves multiple agencies and a wide group of stakeholders. These potential issues could threaten successful implementation of this measure.

The estimated certainty of this measure in achieving its intended accomplishments would be moderate. Successful implementation would be highly dependent upon the extent of dam modifications and reoperation that could be implemented while offsetting or minimizing adverse impacts to water supply or hydropower. It would also depend on a non-federal sponsor to share in the implementation, operation, and maintenance costs. However, the likelihood of achieving the intended accomplishments would increase considerably if combined with other measures to increase the capacity of Shasta Lake.

Preliminary Cost

The potential cost of this measure would be directly linked with other actions to increase the storage space in Shasta Lake.

B10 – Riparian and Floodplain Restoration along Sacramento River

Riparian areas provide habitat for a diverse array of plant and animal communities along the Sacramento River, including numerous threatened or endangered species. Riparian areas also provide shade and woody debris that improve the complexity of aquatic habitat and its suitability for spawning and rearing. Lower floodplain areas, river terraces, and gravel bars play an important role in the health and succession of riparian habitat. These areas are seasonally flooded on a frequent basis, interacting with dynamic river processes such as erosion and deposition. Riparian and floodplain terrace habitat along the Sacramento River is limited between Keswick Dam and Red Bluff. This is partially due to the natural topography and hydrography of the region; the Sacramento River is naturally more entrenched in this reach, and

floodplains are narrow compared with the broad alluvial floodplains found lower in the Sacramento River system. Over the last century, human land development and urbanization in the Redding, Anderson, and Red Bluff areas have further reduced riparian habitat along the Sacramento River. This measure would involve restoring riparian and floodplain habitat along the Sacramento River to promote the health and vitality of the river ecosystem.

Actions and Accomplishments

This measure would involve acquiring and revegetating floodplain terraces and adjacent riparian areas with native plants. It is estimated that a limited amount of land contouring and imported fill material would be required at several locations where the historic floodplain has been disconnected from the river or disturbed by human activity. Suitable locations for restoration would be in areas with a 20 percent to 50 percent chance of flooding in any year (commonly referred to as 2-year to 5-year floodplains). Locations near the confluences of major tributaries with the Sacramento River have the potential to provide the maximum benefits because they interact with riparian areas on tributary streams. Continuity is also important to the health and vitality of riparian areas; small, isolated patches of riparian habitat tend to be less productive than larger, continuous stretches of habitat. Potential restoration sites are listed in Table VI-2. These preliminary sites were identified based on flood frequency, previous human disturbances, lack of existing riparian vegetation, proximity to tributary confluences, land use, and proximity to other healthy riparian areas.

TABLE VI-2
POTENTIAL RIPARIAN AND FLOODPLAIN RESTORATION SITES ALONG THE SACRAMENTO RIVER

General Location	Approximate Rivermile	Bank	Approx. Size in Acres
Near RBDD	242-244	Left	300
Red Bluff u/s Sand Slough	247	Left	140
Near Bend Bridge	258	Left	200
Inks Creek confluence	264-265	Right	175
South of Battle Creek confluence	271-272	Left	55
North of Battle Creek confluence	271-272	Left	100
Ash Creek confluence	277-277.5	Left	85
Cow Creek confluence	280	Left	60
Stillwater Creek confluence	281.5	Left	16
		TOTAL	**1,131**

For the purpose of this preliminary evaluation, it is estimated that a total of 500 acres would be restored at one or more sites. Planting mix, composition, and density would be determined by a more detailed site analysis, but could include native cottonwood, willow, boxelder, valley oak, western sycamore, elderberry, and a variety of understory brush species. Temporary irrigation would be provided on an as-needed basis. The revegetated areas are expected to develop into self-sustaining riparian habitats within one to four years of initial planting, based on the results of previous riparian restoration projects along the Sacramento River. Re-graded floodplain areas are expected to change over time depending upon hydrologic conditions. The site would be fenced to reduce the potential for access by livestock.

This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by restoring native riparian habitat and associated floodplain lands. Riparian habitat contributes to species diversity, water quality, and the quality of instream aquatic habitat, providing shade and a source of woody debris. In this manner, this measure indirectly supports the primary study objective to increase the survival of anadromous fish on the Sacramento River.

Compatibility with Other Measures

This measure would combine favorably with potential measures to modify Shasta Dam because operational changes could benefit the natural riverine processes that drive riparian habitat regeneration. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects on the upper Sacramento River. Restoration would support the goals of the SRCA, CALFED, and other programs associated with riparian restoration along the Sacramento River.

Implementation

There appears to be local support for this type of restoration project along the Sacramento River. Potential non-federal sponsors include the DFG and various local agencies and organizations, including the Western Shasta RCD, TNC, and local watershed groups.

The principal implementation issue concerns ownership and access to lands selected for restoration. If sites selected for restoration were not already in public ownership, conservation easements could be purchased from landowners interested in performing restoration on their lands, or lands could be purchased in fee-title from willing sellers. For the purpose of this initial evaluation, and to ensure continued protection of restored lands, it is assumed that land would be acquired in fee-title. This potential issue is not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of this measure achieving the intended accomplishments is very high. Similar restoration projects along the Sacramento River have provided favorable, sustainable results.

Preliminary Cost

The cost of this measure would be moderate to high relative to the cost of other measures identified, depending upon the size of the site(s) selected for restoration. It is estimated that one site totaling 500 acres would be selected for restoration, and a real estate interest would be acquired for those lands. The measure would involve land acquisition, floodplain contouring and other earthwork, and revegetation. The total first cost, including land acquisition, planning, engineering, design, and initial implementation, is estimated to be approximately $9 million.

It is anticipated that no elements of this measure would need to be replaced or reapplied during the 50-year project life. Short-term maintenance of revegetated areas would be needed for up to three growing seasons following installation. Some long-term maintenance would be required, primarily to monitor plant density and maintain site security, but is not expected to involve

significant cost. The annual costs for this measure would likely range from moderate to high compared to the first cost.

POTENTIAL PLAN COMPONENTS

Figures 11 and 12 illustrate the approximate locations of the potential ecosystem restoration measures in the Shasta Lake and Tributaries and Shasta Dam to Red Bluff sub-areas, respectively. The preliminarily retained ecosystem restoration plan components are summarized in Table VI-3. The summary table compares the measures and their estimated first cost, annual cost, benefits or advantages, and implementation issues or disadvantages. It also provides overall comments and conclusions that identify several of the measures as highly recommended.

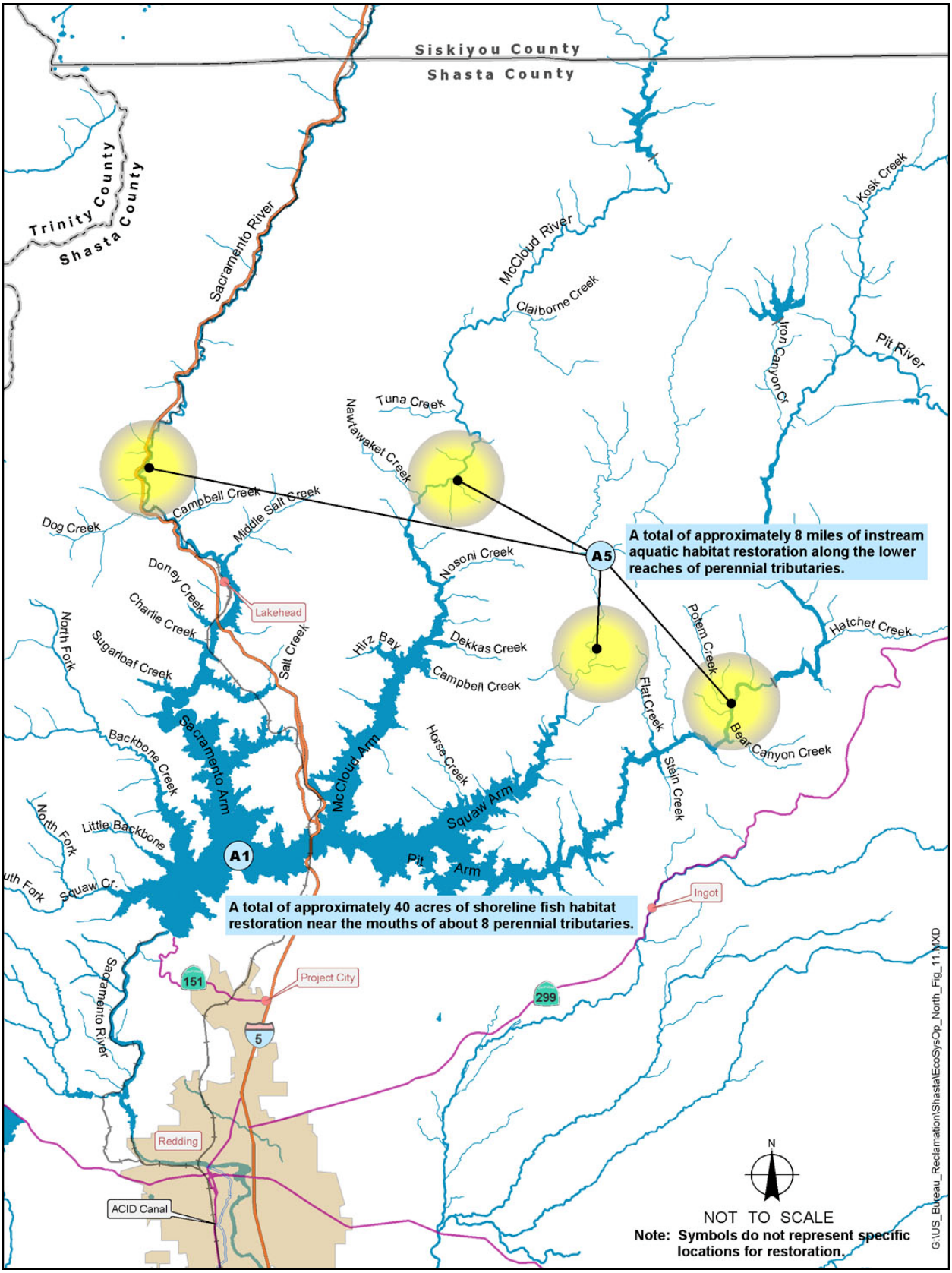

Figure 11 – Preliminary Ecosystem Restoration Components, Shasta Lake and Tributaries

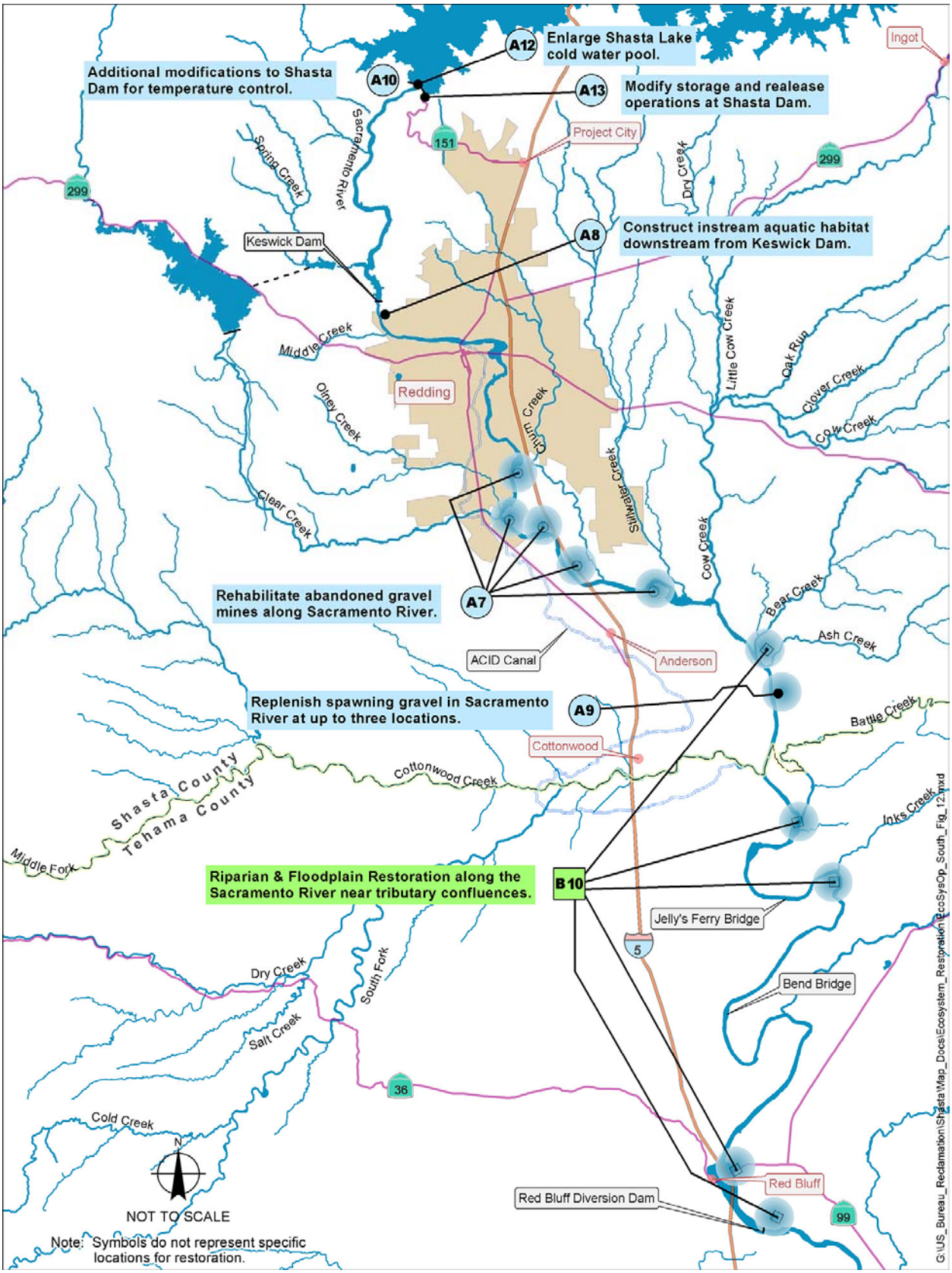

Figure 12 – Preliminary Ecosystem Restoration Components, Shasta Dam to Red Bluff

TABLE VI-3
PRELIMINARY ECOSYSTEM RESTORATION PLAN COMPONENTS

ID No.	Measure Description	First Cost[1] / Annual Cost[2]	Benefits / Advantages	Implementation Issues / Disadvantages	Comments and Conclusions
A1	**Construct Shoreline Fish Habitat around Shasta Lake** *20 acres of shallow-water habitat restoration around Shasta Lake.*	$1.6 million Moderate – High	Improve shallow, warm-water fish habitat in drawdown area; improve juvenile rearing; increase angling opportunities.	May create submerged hazards for watercraft; likely high operation and maintenance, as structures would need to be replaced periodically.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Moderate uncertainty
A5	**Construct Instream Fish Habitat on Tributaries to Shasta Lake** *8 miles aquatic habitat restoration along lower reaches of perennial tributaries to Shasta Lake.*	$0.6 million Moderate – High	Improved spawning and rearing habitat in Shasta tributaries.	Habitat structures would need to be replaced periodically; site access may be problematic.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Low uncertainty
A7	**Restore Inactive Gravel Mines on Sacramento River** *Restoration of 150 acres of land formerly mined for gravel.*	$8 million Moderate	Provides benefits for both aquatic and floodplain habitats; reduced mortality at pits and improved spawning success.	Land acquisition would be required to ensure long-term benefits.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Benefits both terrestrial and aquatic habitats ▪ Low uncertainty
A8	**Construct Instream Habitat Downstream from Keswick Dam** *¾ mile of aquatic habitat restoration on the Sacramento River downstream from Keswick Dam.*	$0.8 million Moderate – High	Improved spawning success in a reach currently unsuitable for spawning; reduced mortality below dam.	Design and construction constraints related to site conditions and dam releases; high operation and maintenance, as habitat structures would need to be replaced periodically; low potential for inclusion in Federal projects.	▪ High long-term cost for restoring a relatively small, although strategically located, reach of river ▪ Moderate uncertainty ▪ Potential for non-federal consideration
A9	**Replenish Spawning Gravel in Sacramento River** *10,000 tons spawning gravel injected at three sites between Keswick Dam and Red Bluff.*	$0.4 million Very High	Improved aquatic habitat / spawning success; gravel may become limiting factor in fisheries restoration; benefits would continue as gravel moves through system.	Very high operation and maintenance, as gravel injections would need to be repeated at frequent intervals to maintain benefits over project life; concerns over downstream impacts to infrastructure; low potential for inclusion in Federal projects.	▪ Very low initial cost but higher long-term cost ▪ Moderate uncertainty ▪ Potential for non-federal consideration

TABLE VI-3 (CONT.)
PRELIMINARY ECOSYSTEM RESTORATION PLAN COMPONENTS

ID No.	Measure Description	First Cost[1] / Annual Cost[2]	Benefits / Advantages	Implementation Issues / Disadvantages	Comments and Conclusions
A10	**Additional Modifications to Shasta Dam for Temperature Control** *Expansion of existing temperature control device at Shasta Dam.*	Similar to existing TCD Low	Improved temperature control would support spawning success.	Potential for high initial cost depending on other modifications to Shasta Dam.	▪ **High Recommendation** ▪ High potential to combine with other measures ▪ Moderate uncertainty
A12	**Enlarge Shasta Lake Cold Water Pool** *Raise Shasta Dam between about 6.5 and 18 feet and enlarge Shasta Reservoir by between 290,000 and 630,000 acre-feet, respectively.*	$210 to $290 million Low	Increased cold water release capability from Shasta Dam would improve meeting downstream water temperature goals and spawning and rearing success and likely water supply reliability, hydropower, and lake area recreation benefits.	High initial costs; adverse impacts to reservoir rim physical and natural resources requiring significant mitigation measures.	▪ **High recommendation** ▪ Consistent with CALFED ▪ High initial costs ▪ Strong potential to combine with other measures ▪ Low uncertainty
A13	**Modify Storage and Release Operations at Shasta Dam** *Reoperate Shasta Dam to benefit anadromous fisheries.*	Low (without mitigation) Low	Greater flexibility in meeting fishery needs would improve spawning and rearing success.	Would only be feasible with measures to mitigate likely adverse impacts to water supply reliability and other resources.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Moderate uncertainty
B10	**Riparian and Floodplain Restoration along Sacramento River** *500 acres of floodplain and riparian habitat restoration near tributary confluences.*	$9 million Moderate – High	Restores floodplain and riparian habitat, with residual benefits to aquatic habitat (source of shade and woody debris); restore natural processes.	Land acquisition would be required to ensure long-term benefits.	▪ Good potential to combine with other measures ▪ Benefits both terrestrial and aquatic habitats ▪ Low uncertainty

Notes:
1. *First Cost includes initial construction, real estate, planning, engineering, and design; represents the initial cost required to implement the measure.*
2. *Relative comparison to first cost. Annual Cost includes annual monitoring, operation, and maintenance costs, and any periodic or recurring costs associated with the measure.*

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