Final

Engineering Summary Appendix

Shasta Lake Water Resources Investigation, California

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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AB	aggregate base
AC	asphaltic concrete
APS	allowance for procurement strategies
AREMA	American Railway Engineering and Maintenance-of–Way Association
ASTM	American Society for Testing and Materials
AT&T	American Telephone and Telegraph
AWWA	American Water Works Association
BIL	basic impulse level
BLS	Bureau of Labor Statistics
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CIP	cast-in-place
CMP	corrugated metal pipe
CP	Comprehensive Plan
CPUC	California Public Utilities Commission
CPUC-GO 95	California Public Utilities Commission General Order 95
CSA	County Service Area
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
cy	cubic yards
DEIS	Draft Environmental Impact Statement
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EHD	Environmental Health Division
EIS	Environmental Impact Statement
elevation xxx	elevation in feet above mean sea level
ENR	Engineering News-Record
EPA	U.S. Environmental Protection Agency
ESRD	Emergency Spillway Release Diagram
FS	U.S. Forest Service Road
gpd	gallons per day
gpm	gallons per minute

GWh	gigawatt-hour
HHA	hydrologic hazard analysis
HMR 59	Hydrometeorological Report No. 59
hp	horsepower
ID	identification
IDC	interest during construction
km	kilometer
kV	kilovolt
kW	kilowatt
lbs	pounds
lf	linear feet
L-G voltage	voltage between phase conductor and ground
L – L	line to line
LTPP	Long Term Power Procurement
M&I	municipal and industrial
MAF	million acre-feet
Misc.	miscellaneous
mm	millimeter
mph	miles per hour
MSE	mechanically stabilized earth
msl	mean sea level
MW	megawatt
N	no
N/A	not applicable
NAVD88	North American Vertical Datum of 1988
NCAO	Northern California Area Office
NEIC	National Earthquake Information Center
NESC	National Electrical Safety Code
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NGS	National Geodetic Survey
NGVD29	National Geodetic Vertical Datum of 1929
NRA	National Recreation Area
O&M	operations and maintenance
PFR	Plan Formulation Report
PG&E	Pacific Gas and Electric Company
PMF	probable maximum flood
psi	pounds per square inch

PVC	polyvinyl chloride
RBPP	Red Bluff Pumping Plant
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROW	right-of-way
RWS	reservoir water surface
SDR	standard dimension ratio
sf	square feet
SLWRI	Shasta Lake Water Resources Investigation
SWP	State Water Project
TCD	temperature control device
UPRR	Union Pacific Railroad
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UV	ultraviolet
V	volt
Y	yes

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Chapter 1
Introduction

Scope and Purpose of Engineering Summary Appendix

The primary purpose of this Engineering Summary Appendix is to present information related to cost estimates and designs for the measures included in the Comprehensive Plans described in the SLWRI Environmental Impact Statement (EIS). The measures included in each of the Comprehensive Plans can be put into three categories: dam raises, reservoir area infrastructure, and ecosystem restoration. Information associated with these measures will be used to compare the Comprehensive Plans. Previous SLWRI milestone documents including the Draft Feasibility Report (Reclamation 2011b) were used as an initial basis for development of designs and cost estimates for this Engineering Summary Appendix.

Background

The following sections describe the study area location, study authorization, scope of work, purpose, and organization of this Engineering Summary Appendix.

Study Area Location and Description

The primary study area for the SLWRI includes Shasta Dam and Reservoir, lower reaches of four primary tributaries flowing into Shasta Lake (Sacramento River, McCloud River, and Pit River, and Squaw Creek) and all smaller tributaries flowing into the lake, Trinity Lake and Lewiston Reservoir, and the Sacramento River downstream to about the Red Bluff Pumping Plant (RBPP). Plate 1 is a vicinity map showing the primary study area within the Sacramento River basin. The RBPP is the point at which releases from Shasta Dam begin to have a negligible effect on Sacramento River water temperatures, and the river landscape changes to a broader, alluvial stream system.

Because of the potential influence of a modified Shasta Dam on other programs and projects, primarily in the Central Valley, an extended study area also encompasses the Sacramento River downstream from the RBPP, the Sacramento-San Joaquin Delta (Delta), parts of the lower American and Feather rivers, parts of the lower San Joaquin River; and facilities and water service areas of the Central Valley Project (CVP) and State Water Project (SWP).

Shasta Dam and Reservoir are located on the upper Sacramento River in Northern California about 9 miles northwest of the City of Redding (see Plate 1); the entire reservoir is within Shasta County. Shasta Lake has approximately 420 miles of shoreline. The reservoir controls runoff from about 6,420 square miles. The four major tributaries to Shasta Lake are the Sacramento River, McCloud River, Pit River, and Squaw Creek, in addition to numerous minor tributary creeks and streams.

Study Authorization

On August 30, 1935, in the Rivers and Harbors Bill, an initial amount of Federal funding was authorized for constructing Kennett (now Shasta) Dam. Fundamental authorization for the SLWRI derives from the 1980 Public Law 96-375 and 2004 Public Law 108-361. Public Law 96-375 authorized the Secretary of the Interior to engage in feasibility studies relating to (1) enlarging Shasta Dam and Reservoir, or constructing a replacement dam on the Sacramento River, and (2) using the Sacramento River to convey water from an enlarged dam. Public Law 108-361 again directed the Secretary of the Interior to conduct "...planning and feasibility studies for projects to be pursued with project-specific study for enlargement of…Shasta Dam in Shasta County…"

Appendix Organization

This Engineering Summary Appendix is organized as follows:

Chapter 1 introduces the SLWRI, provides background on the study, and describes the scope, purpose, and organization of this appendix.

Chapter 2 provides background information on Shasta Dam and Reservoir and describes the three dam raise and reservoir enlargement options included in the comprehensive alternatives presented in the SLWRI EIS. These alternatives include the 6.5-foot raise, 12.5-foot raise, and 18.5-foot raise.

Chapter 3 describes design considerations for the dam and appurtenances raise options.

Chapter 4 describes design considerations for reservoir area infrastructure modifications and/or relocations for the raise options.

Chapter 5 presents cost estimates developed for each of the Comprehensive Plans, and information and methodology used to develop the estimates.

Chapter 6 contains sources used to prepare this Engineering Summary Appendix.

Summary and detailed cost estimate worksheets, schedule discussion, and initial construction and project cost estimates are included in the following attachments to this Engineering Summary Appendix:

Attachment 1 – Summary Cost Estimates for Comprehensive Plans

Attachment 2 – 6.5-Foot Raise and Reservoir Area Infrastructure Cost Estimates

Attachment 3 – 12.5-Foot Raise and Reservoir Area Infrastructure Cost Estimates

Attachment 4 – 18.5-Foot Raise and Reservoir Area Infrastructure Cost Estimates

Attachment 5 – Preliminary Construction Schedule and Work Packages

Attachment 6 – CP4A Crystal Ball Estimate Summary

Attachment 7 – Construction Cost Estimate and Project Cost Estimate

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Chapter 2
Dam and Reservoir Raise Options

Shasta Dam and Reservoir Background

Shasta Reservoir is California's largest man-made lake, with a full pool storage capacity and surface area at the top of joint-use of 4,552,000 acre-feet and 29,600 acres, respectively. (Top of joint-use is measured at elevation 1,067 feet above mean sea level (msl) (elevation 1,067) according to the National Geodetic Vertical Datum of 1929 (NGVD29).) Shasta Reservoir has approximately 420 miles of shoreline when full, and a maximum depth of 517 feet. The Shasta Dam and Reservoir project was constructed by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), Region 2, as an integral element of the CVP from 1938 to 1945, for six purposes. These purposes include irrigation water supply, municipal and industrial (M&I) water supply, flood control, hydropower generation, fish and wildlife conservation, and navigation. The project also supports vigorous water-oriented recreation at the reservoir, which is located within the Shasta Unit of the Whiskeytown-Shasta-Trinity National Recreation Area (NRA). Table 2-1 presents pertinent Shasta Dam and Reservoir data Plate 2 shows the reservoir and numerous surrounding facilities.

Shasta Dam and Reservoir are located on the upper Sacramento River in Northern California about 9 miles northwest of the City of Redding. The entire reservoir is within Shasta County. The reservoir controls runoff from about 6,420 square miles from four major tributaries, including the Sacramento, McCloud, and Pit rivers, Squaw Creek, and numerous minor creeks and streams. Historically, essentially all outflow from Shasta Dam has traveled through Northern California to the Delta southwest of Sacramento. Total drainage area of the Sacramento River at the Delta is about 26,300 square miles. Average annual runoff to the Delta from the Sacramento River watershed is about 17.2 million acre-feet (MAF). This represents about 62 percent of total inflows to the Delta.

Shasta Dam is a curved, gravity-type, concrete structure 487 feet high above the streambed, with a total height above the foundation of 602 feet. Its crest is at elevation 1,077.5 NGVD29. Maximum seasonal flood control storage space in Shasta Reservoir is 1.3 MAF. Shasta Dam has a crest width of 30 feet and length of about 3,500 feet. The Shasta Powerplant consists of five main generating units with a current capacity of 710 megawatts (MW), and two station service units with a current capacity of 5 MW. Plan views of Shasta Dam and Powerplant are shown in Plate 3. Figure 2-1 shows the area-capacity curve for Shasta Reservoir.

Table 2-1. Pertinent Data – Shasta Dam and Reservoir

General			
Drainage Areas (excluding Goose Lake Basin)		**Mean Annual Runoff (1908 – 2006)**	
Sacramento R. at Shasta Dam	6,421 square miles	Sacramento R. at Shasta Dam	5,737,000 acre-feet
Sacramento R. at Keswick	6,468 square miles	Sacramento R. near Red Bluff	8,421,000 acre-feet
Bridge near Red Bluff	8,900 square miles	*Sacramento River Maximum Flows*	
Sacramento R. near Ord Ferry	12,250 square miles	At Shasta Lake 16 Jan 1974	216,000 cfs
Pit R. at Big Bend	4,710 square miles	Near Red Bluff 28 Feb 1940	291,000 cfs
McCloud R. above Shasta Lake	604 square miles	At Ord Ferry 28 Feb 1940	370,000 cfs
Sacramento R. at delta above Shasta Lake	425 square miles		
Shasta Dam and Reservoir			
Shasta Dam (concrete gravity)		**Shasta Reservoir**	
Crest elevation	1,077.5 feet	Full pool elevation (msl)	1,067.0 feet
Freeboard above full pool	10.5 feet	Minimum operating level	840.0 feet
Height above foundations	602 feet	Taking line	Irregular
Height above streambed	487 feet	*Surface Area*	
Length of crest	3,500 feet	Minimum operating level	6,700 acres
Width of crest	30 feet	Full pool	29,500 acres
Slope, upstream	Vertical	Taking line	90,000 acres
Slope, downstream	1 on 0.8	*Storage capacity*	
Volume of Concrete	8,430,000 cubic yards	Minimum operating level	587,000 acre-feet
Normal tailwater elevation	585 feet	Full pool	4,552,000 acre-feet
Spillway (gated ogee)		**Shasta Powerplant**	
Crest length		*Main units*	
Gross	360 feet	5 turbines, Francis type	515,000 hp (total)
Net	330 feet	5 units @ 142 MW	710 MW (total)
Crest gates (steel drum gate)		*Station units*	
Number and size	3 @ 110 feet x 28 feet	2 generators, 2,500 kW each	5,000 kW (total)
Top elevation when lowered	1037.0 feet	Elevation centerline turbines	586 feet
Top elevation when raised	1065.0 feet	Maximum tailwater elevation	632.5 feet
Discharge capacity at pool (1,065 feet)	186,000 cfs	Total discharge at pool (1,065 feet)	14,500 cfs

Table 2-1. Pertinent Data – Shasta Dam and Reservoir (contd.)

Shasta Dam and Reservoir (contd.)			
Spillway (gated ogee)		**Shasta Powerplant**	
Flashboard gates	3 @ 110 feet x 2 feet	Total discharge at pool (827.7 feet)	16,000 cfs
Top elevation when lowered	1,067.0 feet	Power outlets (15-foot steel penstocks)	
Bottom elevation when raised	1,069.5 feet	5 with invert elev. of intake	807.5 feet
Outlets 102-inch-diameter conduit with 96-inch-diameter wheel-type gate			
4 with invert elevation	737.75 feet		
8 with invert elevation	837.75 feet		
6 with invert elevation	937.75 feet		
Capacity at elevation 1,065 feet	81,800 cfs		
Capacity at elevation 827.7 feet	12,200 cfs		

Note:
Elevations given are in vertical datum NGVD29.
Key:
cfs = cubic feet per second
elevation = elevation in feet above mean sea level
hp = horsepower
kW = kilowatt
msl = mean sea level
MW = megawatt
NGVD29 = National Geodetic Vertical Datum of 1929
R = river

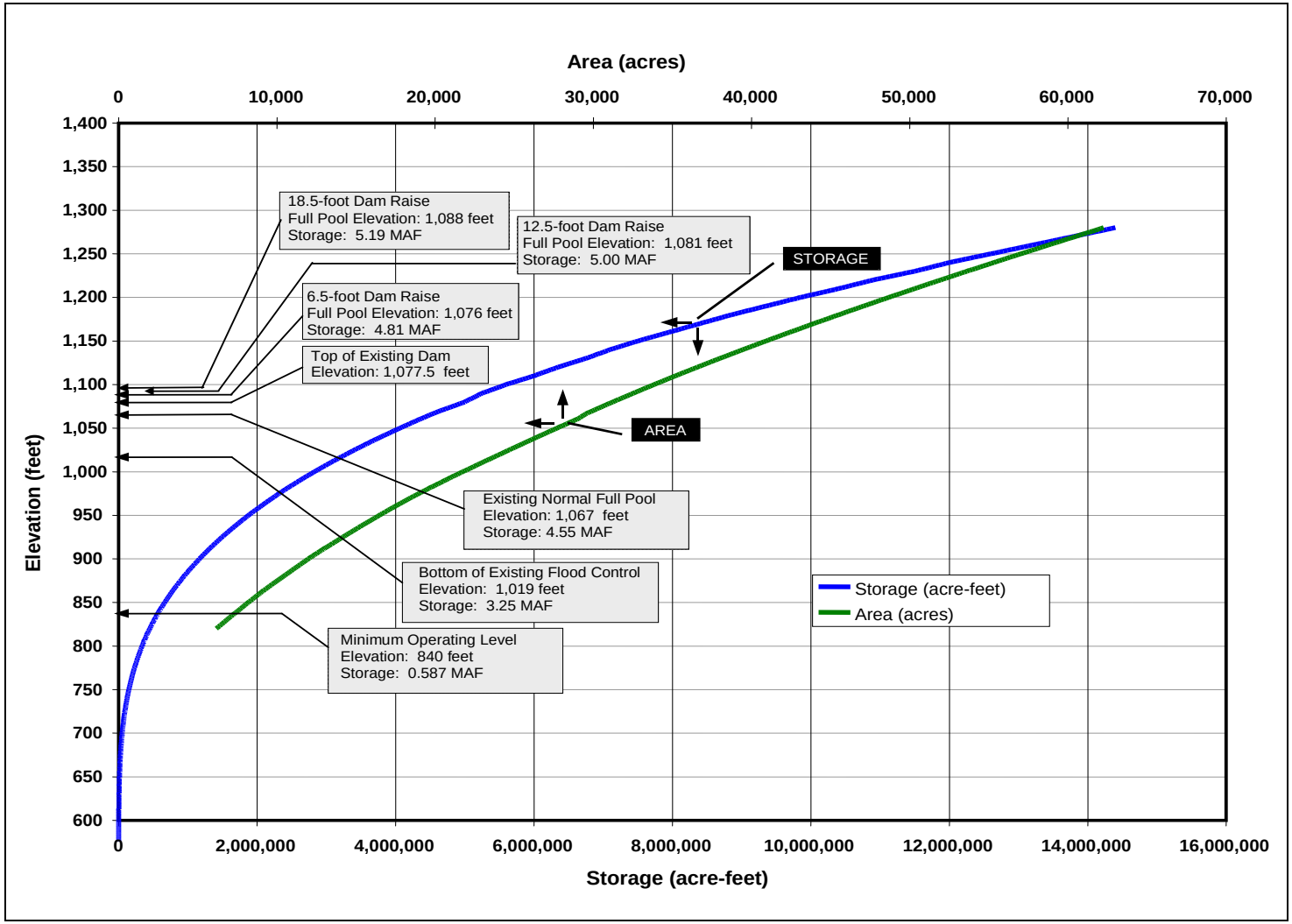

Figure 2-1. Area-Capacity Curve for Shasta Reservoir

Vertical Datum Differences

Currently, elevations listed in most reference materials related to Shasta Dam and Reservoir are in NGVD29. However, a 2001 aerial survey of the reservoir area was done using the North American Vertical Datum of 1988 (NAVD88). All current designs and plates for the dam and appurtenances are based on NGVD29. All current designs and plates for reservoir area infrastructure modifications and/or relocations are based on the 2001 aerial survey and use NAVD88, unless otherwise noted. These include the designs and plates of the protective dikes in the upstream reservoir.

According to the National Geodetic Survey (NGS) Program *VERTCON*, the difference between the vertical datums at Shasta Dam is 2.664 feet. Table 2-2 lists key elevations in both vertical datums for comparison and clarification.

Table 2-2. Vertical Datum Comparison

Feature	Existing (feet)	6.5-foot Dam Raise (feet)	12.5-foot Dam Raise (feet)	18.5-foot Dam Raise (feet)
Vertical Datum: NGVD29				
Dam Crest	1,077.5	1,084.0	1,090.0	1,096.0
Full Pool/Top of Joint-Use	1,067.0	1,075.5	1,081.5	1,087.5
Spillway Crest	1,037.0	1,037.5	1,043.5	1,049.5
Vertical Datum: NAVD88				
Dam Crest	1,080.2	1,086.7	1,092.7	1,098.7
Full Pool/Top of Joint-Use	1,069.7	1,078.2	1,084.2	1,090.2
Spillway Crest	1,039.7	1,040.2	1,046.2	1,052.2

Key:
NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929

Dam Raise and Reservoir Enlargement Options

The proposed Comprehensive Plans (CP) can be categorized into three dam raise options: 6.5 feet, 12.5 feet, and 18.5 feet. Each Comprehensive Plan includes, to some degree, the following common measures:

- Enlarge Shasta Lake cold-water pool
- Modify temperature control device (TCD)
- Increase water conservation storage
- Reduce water demand
- Modify flood control operations
- Modify hydropower facilities

- Maintain or increase recreation opportunities
- Maintain or improve water quality

6.5-Foot Raise Option (CP1)

The low-level option evaluated is a 6.5-foot raise of Shasta Dam. This would correspond to a raise in the top of joint-use pool elevation of about 8.5 feet, and increasing water storage capacity by approximately 256,000 acre-feet and reservoir surface area by 1,110 acres. This would increase water supply reliability and improve anadromous fish survival, with some benefit to other resources.

12.5-Foot Raise Option (CP2)

The 12.5-foot raise is considered in this Engineering Summary Appendix as an intermediate-level option between the 6.5-foot raise and the 18.5-foot raise. The 12.5-foot dam raise would correspond to a raise in the top of joint-use pool elevation of about 14.5 feet, increasing the water storage capacity by approximately 443,000 acre-feet and reservoir surface area by 1,750 acres. This would increase water supply reliability and improve anadromous fish survival, with some benefit to other resources.

18.5-Foot Raise Option (CP3, CP4, CP4A, CP5)

The 18.5-foot raise represents the largest practical dam raise that would not require relocating the Pit River Bridge. This would correspond to a raise in the top of joint-use pool elevation of about 20.5 feet. This option would increase water storage capacity by approximately 634,000 acre-feet and reservoir area by about 2,500 acres. Also, this option would increase water supply reliability and improve anadromous fish survival, with some benefit to other resources. CP3, CP4, CP4A and CP5 would all include the 18.5-foot dam raise. However, CP4 would dedicate about 60 percent of the new storage space (378,000 acre-feet) to increasing the cold-water supply for anadromous fish purposes, while CP4A would dedicate about 30 percent of the new storage space (191,000 acre-feet) to increasing the cold-water supply for anadromous fish purposes, and both include features for ecosystem restoration. CP5 would include features for ecosystem restoration and recreation facilities around Shasta Lake, in addition to those included in the other Comprehensive Plans.

Other Options Considered in Previous Studies

The potential enlargement of Shasta Dam has been studied since the 1970s. In addition to the low-level option (6.5 feet), Reclamation also presented descriptions and cost estimates for the intermediate-level option (102.5 feet), and high-level option (202.5 feet) raises of Shasta Dam (Reclamation 1998, 1999). Estimated total field costs for the intermediate- and high-level options were $2.9 billion, and $4.4 billion, respectively. The assessment concluded that the costs of the intermediate- and high-level options posed significant challenges in developing required financial packages. Results of the assessment led to the following recommendation: “It is recommended that feasibility

studies examining a low-raise option enlargement of Shasta Dam and Reservoir proceed." In a subsequent study, Reclamation identified the 18.5-foot raise as the major cost break-point. Higher raises require relocation of the Pit River Bridge, which would amount to nearly 50 percent of the total project cost (Reclamation 2003b).

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Chapter 3
Design Considerations for Dam and Appurtenances of Dam Enlargements

This section summarizes major features associated with enlarging Shasta Dam and Reservoir and modifying its appurtenances for all SLWRI dam raise alternatives. Total surface area that would be required for work limits and permanent features, and an estimate of materials needed to modify Shasta Dam and its appurtenances under each dam raise alternative are shown in Table 3-1. Detailed explanations of construction activities and considerations are discussed below.

Table 3-1. Physical Quantities for Proposed Modifications of Shasta Dam and Appurtenances for SLWRI Dam Raise Alternatives

Physical Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Quantity of Concrete (cy)	57,000	77,300	100,800
Quantity of Cement (tons)	128,600	170,500	213,000
Quantity of Metalwork (lbs)	19,654,400	20,435,900	21,751,200
Volume of Imported Fill Material (cy)	61,200	94,400	130,500
Volume of Excavation to Waste Material (cy)	1,600	1,600	1,600
Quantity of Demolished Material (cy)	25,400	29,200	31,600
Area of Permanent Structures (sf)	412,600	412,600	412,600
Area of Work Limits (sf)	460,900	460,900	460,900

Key:
cy = cubic yards
lbs = pounds
sf = square feet

Dam Crest Structure Removal

Before any enlargement of Shasta Dam, existing structures on the dam crest would need to be removed. These structures include the gantry crane, existing spillway drum gates and frames, spillway bridge, concrete in the spillway crest and abutments, upstream parapet walls, sidewalks, curbing, crane rails, and control equipment. The cost for this preparatory work would be the same for the 6.5-, 12.5-, or 18.5-foot dam raises.

Modifying the main dam would require the demolition, removal, and transportation of top-of-dam materials to an approved disposal area. This would include the demolition and removal of the upstream reinforced-concrete parapet wall and curb. Sawcuts would be used to aid in removing the upstream reinforced-concrete parapet wall and curb. In addition, sawcuts would be required along the upstream face and crest of the dam before the excavation of a 2-foot by 2 foot end area at the upstream face of the dam to embed a 12-inch polyvinyl chloride (PVC) waterstop. The existing dam crest would be prepared by using a high-pressure water jet on the concrete surface. The existing roadway drains would be backfilled with cement grout.

Equipment would be mobilized for drilling 4-inch-diameter drain holes on 10 foot centers from two different locations: from the existing dam crest to drain the surface contact, with each hole 2.5 feet long (248 holes), and from the existing dam crest for surface drainage at the downstream overhang, with one hole per block and each hole 6.5 feet long (50 holes). A 3-foot-diameter vertical shaft would be excavated through the concrete from the existing dam crest to the hoist gallery in Block 47 for installation of electrical conduit.

The existing spillway drum gates and piers would require removal according to a phased construction plan that would minimize impacts to reservoir operations during construction. Two drum gates and one pier would be removed to construct three new piers and install three new sloping fixed-wheel gates. This would be followed by removal of the remaining drum gate and pier to construct two new piers and install three new sloping fixed-wheel gates. This work would require two construction seasons to complete.

The spillway bridge and dam crest access road would be out of service for an extended period of time (over two years) during construction of the new spillway and dam crest raise. A detour route would be provided below the dam across an existing bridge.

Modifications to the TCD would be performed to minimize impacts to reservoir operations to the extent possible, but supplemental cold water releases may be required through the river outlets during a portion of the construction period. Control equipment for the TCD would be removed, stored, and reinstalled for the higher dam crest. The elevator tower would be out of service for about 4 months for construction of the dam crest raise and for replacement of the elevator car and hoist equipment.

Concrete Dam and Wing Dams

Shasta Dam is located on the Sacramento River, approximately 9 miles northwest of Redding, California, and is a major feature of the CVP. As mentioned, the dam was designed and constructed by Reclamation, and was completed in 1945. The concrete dam portion has a structural height of 602 feet,

a hydraulic height of approximately 480 feet (between reservoir water surface (RWS)) elevation 1,067 NGVD29 and the original streambed at the axis of the dam), a crest width of 30 feet, and a crest length of 3,460 feet at crest elevation 1,077.5 NGVD29. (Note that the following elevations presented in this section are based on the NGVD29 datum.) The downstream face of the concrete dam is vertical above elevation 1,050, with a slope of 0.8:1 below elevation 1,050, and the upstream face of the dam is vertical above elevation 720, with a slope of 0.5:1 below elevation 720. The concrete dam is slightly curved in plan view, with a large radius of 2,500 feet; however, the 375-foot-long spillway section located in the central portion of the concrete dam has a straight alignment. The volume of concrete in the main dam is 6,270,000 cubic yards. The dam impounds a reservoir with a total volume of 4,552,000 acre-feet at the top of joint-use storage, RWS elevation 1,067. The focus of the feasibility study and this document is a dam raise of 18.5 feet. However, pertinent factors related to other proposed Shasta Dam raise heights of 6.5 and 12.5 feet have been considered for development of cost estimates.

Enlargement of Shasta Dam and Reservoir under SLWRI dam raise alternatives raises would require raising Shasta Dam (the main gravity dam), and its left and right wing dams as indicated in Table 3-2.

Table 3-2. Physical Features for Proposed Modifications of Shasta Dam and Appurtenances for SLWRI Dam Raise Alternatives

Feature	Existing	Dam Raise Alternatives		
		6.5 feet	12.5 feet	18.5 feet
Main Gravity Dam				
Crest Raise (feet)	0	6.5	12.5	18.5
Crest Elevation	1,077.5	1,084.0	1,090.0	1,096.0
Upstream Parapet Wall Elevation	1,079.1	1,087.5	1,093.5	1,099.5
Reservoir Water Surface Elevation	1,067.0	1,075.5	1,081.5	1,087.5
Left Wing Dam				
Crest Raise (feet)	0	8.5	14.5	20.5
Crest Elevation	1,077.5	1,086.0	1,092.0	1,098.0
Upstream Parapet Wall Elevation	1,079.1	1,089.5	1,095.5	1,101.5
Right Wing Dam				
Crest Raise (feet)	0	6.5	12.5	18.5
Crest Elevation	1,077.5	1,084.0	1,090.0	1,096.0
Upstream Parapet Wall Elevation	1079.1	1,087.5	1,093.5	1,099.5

Note:
Elevations are based on the National Geodetic Vertical Datum of 1929 (NGVD29). All current designs and figures for Shasta Dam and appurtenant structures are based on NGVD29.
Key:
SLWRI = Shasta Lake Water Resources Investigation

The main dam raise would consist of mass and structural concrete placements for dam Blocks 15 through 38, and 46 through 71. The new dam crest would

have the same surface area as the existing dam crest and similar features, including gantry crane rails and surface drains. A new upstream parapet wall would provide flood protection to elevations indicated in Table 3-2. The dam raise would include a new utility gallery, and 5-inch-diameter formed drains on 10-foot centers. Two rows of post-tensioned anchors spaced on 10-foot centers would be installed from the new dam crest to a depth of 92.5 feet within Blocks 30 through 38, and 46 through 50, for dynamic stability of the raised dam crest during a large earthquake. The existing elevator tower in Block 46 and the existing hoist tower in Block 35 would be raised to maintain their functions. Plate 4 shows typical sections of the concrete dam raise.

The mass concrete placements would use lift heights between 5 feet and 10 feet above the existing concrete surface at elevation 1,077.5, between contraction joints, and to the required 30-foot width. The contraction joints in the raised portion of the main dam would match the existing contraction joints, and would be keyed and grouted. Artificial cooling of the mass concrete placements would not be required because limits would be imposed on the placement temperature, and the concrete mix would be designed to limit the heat of hydration. The mass concrete would have a design compressive strength of 4,000 pounds per square inch (psi) at 365 days and would have 370 pounds of cementitious material per cubic yard of concrete, consisting of 50 percent pozzolan and 50 percent cement. Five-inch-diameter formed drains on ten-foot centers would be located in the center of the blocks from elevation 1,077.5 to the new dam crest, and would have caps for future inspection and maintenance.

Structural concrete would be placed for the top of dam starting approximately 3.5 feet below the new dam crest including concrete for the roadway, the upstream and downstream parapets, and the walkway. The structural concrete would have a design compressive strength of 4,000 psi at 28 days, would have 564 pounds of cementitious material per cubic yard of concrete, and would be made up of 20 percent pozzolan and 80 percent cement. Reinforcing bars would be used around the utility gallery, and nominal temperature steel would be used for the exposed structural concrete surfaces. Two 6-inch-diameter steel top-of-dam drains would be furnished and installed in each block to drain to the upstream face.

At each contraction joint, 12-inch PVC waterstops would be furnished and installed across the dam block contraction joints and around the utility gallery to provide a grout seal. Mobilization and demobilization would occur for pressure grouting the contraction joints. The 1.5-inch-diameter standard pipe metal tubing and fittings for the grouting system would be furnished and installed. There would be a total of 144 grout hookups based on 3 hookups at each of the 48 joints for the main dam. The system would be water-tested before pressure grouting. The final mix for the grout would use Type II cement and is assumed to have a water-cement ratio of 0.9:1, which requires 0.7 bags/cubic yard. Assuming six times the final volume to cover waste, the volume of grout per contraction joint is assumed to be 1 cubic yard.

Zoned embankment wing dams were originally constructed on both abutments of the main dam to protect the contact between the concrete and the excavated foundation surface. The tops of the embankment wing dams slope longitudinally from the main dam crest at the abutments down toward the spillway, approximately parallel to the excavated surface of the dam foundation, except the top of the right upstream embankment wing dam, which is approximately 200 feet below the crest of the main dam. The upstream face slopes at 2.5:1 and the downstream face slopes at 2.4:1 for both wing dams. The left wing dam includes a 450-foot-long concrete core wall beyond the left end of the concrete dam above elevation 980. The embankment wing dams contain approximately 2,160,000 cubic yards of earthfill materials.

The left wing dam would be raised to the elevations indicated in Table 3-2 to maintain the same height above the top of joint-use storage as for existing conditions. This would involve extending the existing reinforced-concrete core wall to the raised dam crest, and placing a thick layer of large rockfill downstream from the core wall to a slope of 2.5:1. The upstream face would consist of a reinforced concrete or mechanically stabilized earth (MSE) wall, and a concrete parapet wall. The road from the concrete dam crest would be ramped up through the left wing dam to the new embankment crest. Roadways and security features on the existing dam crest would be relocated to the new dam crest (see Plate 5). The existing rotunda on the left abutment of the dam would be removed and reconstructed.

The right wing dam would be raised to the elevations indicated in Table 3-2, which would involve extending the main dam raise from Block 71 to the right abutment gantry crane storage area (Block 77) using mass and structural concrete founded on bedrock. Concrete was selected for the right wing dam in lieu of embankment to facilitate construction. The new right wing dam crest would have the same surface area and similar features as for the existing right wing dam crest, including gantry crane rails and surface drains. A new upstream parapet wall would provide flood protection to elevations indicated in Table 3-2. The right wing dam would include a new utility gallery and a foundation drainage curtain (see Plate 6). The right abutment access roads would be modified to match the new dam crest, as shown in Plate 7. Construction quantities for the major items of work for these features are summarized in Table 3-3.

Table 3-3. Concrete Dam and Wing Dams Construction Quantities for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives								
	6.5 feet			12.5 feet			18.5 feet		
	Main Concrete Dam	Right Wing Dam	Left Wing Dam	Main Concrete Dam	Right Wing Dam	Left Wing Dam	Main Concrete Dam	Right Wing Dam	Left Wing Dam
Concrete Removal (cy)	2,100	30	600	1,400	10	600	1,400	10	600
Concrete (cy)	25,200	3,800	1,500	40,300	6,100	1,800	57,000	8,800	2,900
Reinforcing Steel (lbs)	1,098,800	109,000	248,500	1,176,700	115,600	297,000	1,188,700	115,600	435,000
Crane Rails (lbs)	249,200	With main dam	N/A	249,200	With main dam	N/A	249,200	With main dam	N/A
Misc. Metalwork (lbs)	65,400	With main dam	N/A	65,400	With main dam	N/A	65,400	With main dam	N/A
Post-Tension Anchors (lf)	11,800	N/A	N/A	12,600	N/A	N/A	13,400	N/A	N/A
MSE Wall (sf)	N/A	N/A	1,000	N/A	N/A	2,700	N/A	N/A	6,100
Embankment Core (cy)	N/A	N/A	6,600	N/A	N/A	7,900	N/A	N/A	9,100
Embankment Filter (cy)	N/A	N/A	1,400	N/A	N/A	2,000	N/A	N/A	3,900
Embankment Rockfill (cy)	N/A	N/A	30,000	N/A	N/A	57,400	N/A	N/A	85,000
Embankment Riprap (cy)	N/A	N/A	1,900	N/A	N/A	5,400	N/A	N/A	8,000

Key:
cy = cubic yard
lbs = pounds
lf = linear feet
Misc. = miscellaneous
MSE = mechanically stabilized earth
N/A = not applicable
sf = square feet

More details regarding the concrete dam and wing dam raise designs are contained in Reclamation *Technical Memorandum No. SHA-8110-FEAS-2007 1 (2007e), No. SHA-86-68110-FEAS-2008-1 (2011d), No. SHA-86-68110-CD-2011-1* (2011a), and in Reclamation's *Left Wing Dam Raise Feasibility – Design Report (2009a) and Shasta Dam Raise Feasibility – Final Risk Analysis* (2012a).

Spillway

Spillway releases are controlled by three 110-foot-wide by 28-foot-high steel drum gates located within the concrete overflow (spillway) section of the dam. The drum gates are hinged and anchored along the upstream side to a reinforced-concrete cantilever wall section. Rubber seals are located on the ends and downstream lip of each drum gate to form a watertight seal, allowing regulation of the spillway gate heights by adjusting the water levels inside the float chambers. The total discharge capacity of the existing spillway is 186,000 cubic feet per second (cfs) at RWS elevation 1,065 NGVD29. (Note that the following elevations presented in this section are based on the NGVD29 datum). Two-foot-high steel flashboards operated from a walkway beneath the spillway bridge allow for reservoir storage between the top of the raised drum gates at elevation 1,065 and the top of joint-use storage at elevation 1,067.

Structural concrete would be used to raise the existing spillway crest based on the elevations indicated in Table 3-4, and to shape the raised spillway crest (see Plate 8). The existing spillway bridge, the two existing spillway piers, the cantilever wall sections, and the three existing drum gates and operating equipment would be removed. Five new spillway piers would be constructed at locations within the spillway designed to avoid existing overflow block contraction joints, and a new concrete spillway crest would be constructed between the piers. One row of post-tensioned anchors variably spaced (average 10-foot centers) would be installed from the top of each spillway pier to a depth of 100 feet for dynamic stability during a large earthquake. The locations of the new piers would result in different widths of spillway gates. The three existing 110- by 28-foot drum gates would be replaced with six sloping, fixed-wheel gates (four 48- by 38-foot and two 54- by 38-foot gates). The total spillway crest length would be reduced from 330 feet to 300 feet as a result. Sloping, fixed-wheel gates were selected in lieu of radial gates to reduce potential seismic loads on the spillway piers during a large earthquake. Cross-bracing would be installed at the tops of the spillway piers to serve as gate seats in the raised position, and to reduce the height of the gates. Stop log guides would be placed immediately upstream from the spillway crest for gate maintenance. Two sets of stop logs (48 and 54 feet long) would be provided to service the six gate openings.

Table 3-4. Spillway Feature Elevations for Proposed Modifications of Shasta Dam Spillway for SLWRI Dam Raise Alternatives

Feature	Existing	Dam Raise Alternatives		
		6.5 feet	12.5 feet	18.5 feet
Crest Raise (feet)	0	0.5	6.5	12.5
Crest Elevation[1]	1037.0	1,037.5	1,043.5	1,049.5

Note:
[1] Main dam and wing dam crest elevations are based on the National Geodetic Vertical Datum of 1929 (NGVD29). All current designs and figures for Shasta Dam and appurtenant structures are based on NGVD29.
Key:
SLWRI = Shasta Lake Water Resources Investigation

Additionally, an aeration system would be constructed in the spillway chute at approximately elevation 875 to mitigate potential cavitation damage during spillway releases, as shown in Plate 9. The total discharge capacity of the raised spillway is estimated to be 266,300 cfs.

A new bridge would be required to span the spillway to allow for vehicular traffic and for a gantry crane to travel from the right end of the dam to the far end of the spillway (see Plates 10 and 11). The existing spillway bridge consists of three 100-foot spans, while the new bridge would consist of six shorter spans. The spans would not be equal, because the pier locations were set to avoid the existing dam contraction joints. The spillway bridge is designed to be continuous over the pier supports; therefore, there are no deck expansion joint details except at the abutment ends of the bridge. Construction quantities for major items of work for this feature are summarized in Table 3-5. Figure 3-1 is an artist rendering of the 18.5-foot dam raise option.

Table 3-5. Spillway Construction Quantities for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Concrete Removal (cy)	8,600	6,900	3,100
Removal of 3 Drum Gates (lbs)	3,000,000	3,000,000	3,000,000
Removal of Bridge Superstructure (lbs)	755,000	755,000	755,000
Concrete (cy)	23,900	26,600	29,500
Reinforcing Steel (lbs)	1,647,900	1,762,900	1,978,400
Post-Tension Anchors (lf)	7,400	7,900	8,400
Sloping Fixed Wheel Gates (lbs)	3,000,000	3,315,600	3,315,600
Stoplogs and Guides (lbs)	1,038,000	1,038,000	1,038,000

Key:
cy = cubic yard
lbs = pounds
lf = linear feet

Figure 3-1. Shasta Dam 18.5-Foot Raise

More details regarding the spillway structural and hydraulic designs are contained in Reclamation *Technical Memorandum No. SHA-8110-FEAS-2007-1 (2007e), No. SHA-86-68110-FEAS-2008-1* (2011d), and *No. SHA-8130-FEAS-2011-1 (2013b).*

River Outlets

The outlet works consist of eighteen trash-racked, 102-inch-diameter steel-lined conduits that pass through the concrete overflow (spillway) section – six at elevation 942, eight at elevation 842, and four at elevation 742 NGVD29. Outlet releases are controlled by 102-inch-diameter tube valves for the four lower tier outlets, and by 96-inch-diameter wheel-type outlet gates for the fourteen middle tier and upper tier outlets. The river outlet works conduits, upstream from the regulating tube valves and outlet gates, can be closed by installing a portable coaster gate using the 125-ton gantry crane located on the crest of the dam. The single portable coaster gate is 11.05 feet square, and is stored within a structure at the right abutment of the dam. Total discharge capacity of the outlet works is 81,800 cfs at RWS elevation 1,067 NGVD29.

Because of existing operational limitations associated with the four lower tier 102-inch-diameter tube valves, these valves would be replaced by four 96-inch-diameter jet flow gates, as shown in Plate 12. A downstream air shroud and vent would be provided for each gate, which would discharge into the existing 102-

inch-diameter conduits. Construction quantities for the major items of work for this feature are summarized in Table 3-6.

Table 3-6. River Outlets Modifications Construction Quantities for all SLWRI Dam Raise Alternatives

Item	Quantity
Concrete Removal (cy)	350
Concrete (cy)	300
Reinforcing Steel (lbs)	30,000
Four 96-Inch Jet-Flow Gates (lbs)	375,400
Coaster Gate Guide Extensions (lbs)	178,200

Key:
cy = cubic yard
lbs = pounds

Power Outlets

The Shasta Powerplant contains five main generating units and two station service units fed by five 15-foot-diameter penstocks that pass through the concrete dam to the right of the spillway section (intake centerline at elevation 815 NGVD29). The steel penstock pipes extend over 500 feet from the downstream face of the dam to the powerplant structure, and are supported by concrete saddles. Each penstock pipe has a discharge capacity of 2,800 cfs and an upstream 15-foot by 19.05-foot coaster gate for emergency closure. The total discharge capacity of the powerplant is 14,000 cfs under a gross head of 480 feet. The maximum total generating capacity of the main units is 710 MW. Two of the five penstock pipes were modified in 1998 to supply water to a downstream fish hatchery located on the right bank of the downstream channel.

The existing steel penstock pipes have been determined to be adequate for the higher reservoir loads. Some modifications are anticipated for the power intake gate hoists to accommodate the higher dam crest. Although vulnerable to seismic loads, penstock failure due to an earthquake is not considered to be a dam safety issue, and modifications to the existing penstocks and concrete saddle supports are not proposed at this time. However, higher reservoir levels associated with the proposed dam raise alternatives would increase the normal head on the penstocks and associated damage in the event of a large earthquake. Construction quantities for the major items of work for this feature are summarized in Table 3-7.

Table 3-7. Power Outlets Construction Quantities for all SLWRI Dam Raise Alternatives

Item	Quantity
Relocate Hydraulic Hoist Systems (lbs)	105,000
Gate Stem Extensions (lbs)	12,500
Coaster Gate Guide Extensions (lbs)	15,000

Key:
lbs = pounds
SLWRI = Shasta Lake Water Resources Investigation

Temperature Control Device

Construction of the Shasta TCD to allow selective withdrawal of the cooler reservoir water for discharge through the five powerplant penstocks was completed in 1996 to enhance the downstream fishery. The TCD is a steel structure consisting of a shutter structure and a low-level intake structure that are attached to the upstream face of the dam. Plate 13 shows a plan view of the TCD, with elevations and sections shown in Plates 14, 15, and 16. Conservation of the cold-water pool is achieved by forcing withdrawal from the highest elevation possible. To that end, the upper shutter gates, followed by the middle shutter gates, followed by the pressure relief gates, are operated to access the highest permissible level of withdrawal based on the RWS elevation and downstream water quality objectives. The design flow through the TCD is 19,500 cfs. Major TCD modifications necessary for the 18.5-foot dam raise include the following:

- Disassemble, reinstall, and modify gate hoists to accommodate the longer ropes required.
- Remove and reinstall motor control centers and distribution switchboards.
- Remove and reinstall hoist platforms on new rigid frame box girders to elevate the gate hoist and electrical equipment above the raised maximum RWS elevation.
- Install new dam connections for new rigid frames.
- Remove upper segments of trash racks and replace them with barrier panels on the upstream face of the TCD with cladding panels along the sides of Shutters 1 and 5 to reduce undesirable mixing of reservoir water during controlled downstream releases.
- Extend gate guides, and cladding guides, barrier panels, cladding panels, and closure panels.

- Remove and reinstall miscellaneous metalwork (e.g., grating, pipe guardrails) and provide new miscellaneous metalwork (e.g., grating, pipe guardrails, platforms, ladders, safety cages) to account for the dam raise, modified platform member configurations, and safety requirements.

- Attach a new debris boom to existing lake and dam anchorages to exclude debris from the TCD and spillway (see Plate 17), and provide equipment to remove and transport debris from the lake.

Construction quantities for the major items of work for this feature are summarized in Table 3-8.

Table 3-8. Temperature Control Device Modifications Construction Quantities for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Steel Removal and Disposal (lbs)	253,000	253,000	253,000
Remove and Reinstall Hoist Platform Steel (lbs)	740,000	740,000	740,000
Remove and Reinstall Miscellaneous Metalwork (lbs)	150,000	150,000	150,000
Remove and Reinstall Hoists (each)	17	17	17
Rigid Frame Steel (lbs)	436,000	494,000	562,000
Hoist Platform Steel (lbs)	50,000	50,000	50,000
Miscellaneous Metalwork (lbs)	31,000	31,000	31,000
Cladding Panels and Guides (lbs)	146,000	172,000	199,000
Front Gate Guides (lbs)	249,000	289,000	329,000
Barrier Panels (lbs)	465,000	465,000	465,000
Debris Boom (each)	1	1	1

Key:
lbs = pounds
SLWRI = Shasta Lake Water Resources Investigation

More details regarding the TCD designs are contained in the Reclamation *Technical Memorandum No. SHA-8120-FEAS-2007-1* (2008d) and *Underwater Examination of Temperature Control Device* (2008b).

Visitor Center

The existing visitor center building is located on the left abutment of Shasta Dam, as shown in Plate 3, and provides office space for Reclamation's Northern California Area Office (NCAO) in addition to visitor space, storage areas, and visitor center staff offices. With the dam raise, visitors would have to be conveyed approximately 21 vertical feet to access the new dam crest for the 18.5-foot dam raise option. The current access point to the parking lot would not be usable because of the vertical realignment of Shasta Dam Boulevard and

the construction of a concrete retaining wall associated with the dam raise. The existing security office is housed in an adjacent building that would be too low with respect to the new dam crest elevation for effective observation of the site facilities.

As a part of the overall Shasta Dam raise designs were prepared for a new visitor's facility with a security office and associated site improvements. It is assumed that the existing building would be remodeled for sole occupancy by the NCAO and Shasta Dam administration staff. The remodel of the existing building is not currently included in the dam raise project.

The proposed 11,000-square-foot visitor center building would provide adequate space for visitors, storage, staff, and security functions, and feature a panoramic view of all facilities (see Plate 18). A modern theater would have state-of-the-art media equipment and a 14-foot-wide suspended screen. An outdoor, terraced lawn area would be integrated into the site design for picnics and viewing. A security checkpoint would be located at the beginning of the powerplant access road. An elevator, stairs, and a covered pedestrian bridge would provide access to the new dam crest. The new design would comply with all accessibility, life safety, and seismic safety standards, and would demonstrate a commitment to sustainable building design and alternative energy uses. The existing parking lot would be redesigned to provide efficient, safe, and secure vehicular and pedestrian circulation through the site for visitors, NCAO staff, security, and maintenance operations. Figures 3-2 and 3-3 are artist renderings of the proposed visitor center.

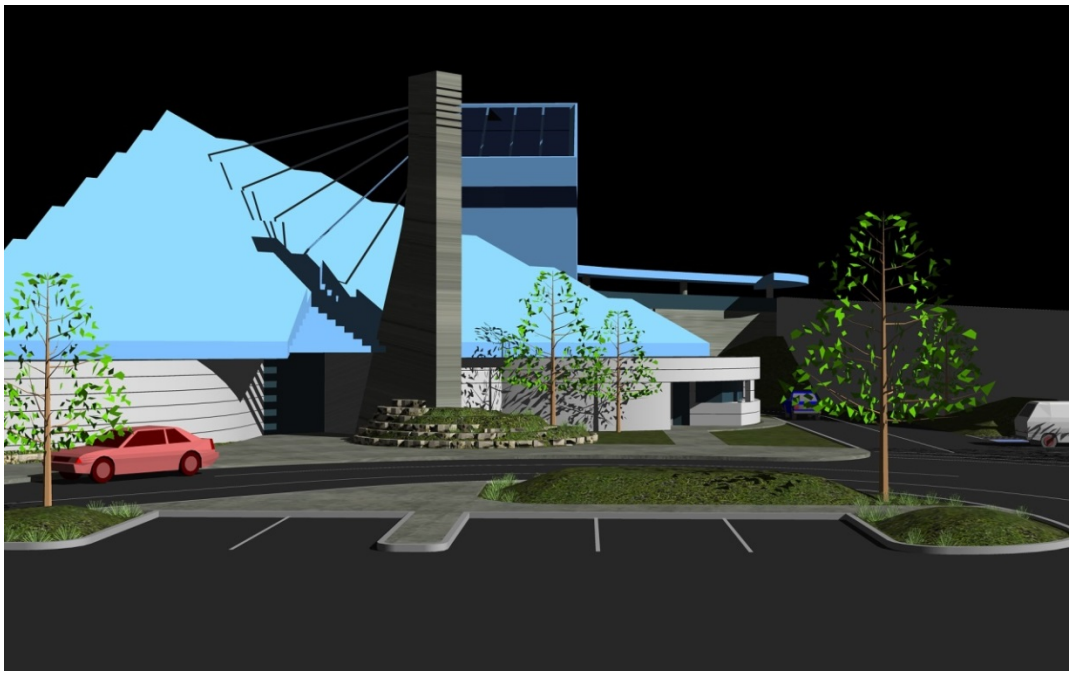

Figure 3-2. Visitor Center Entrance

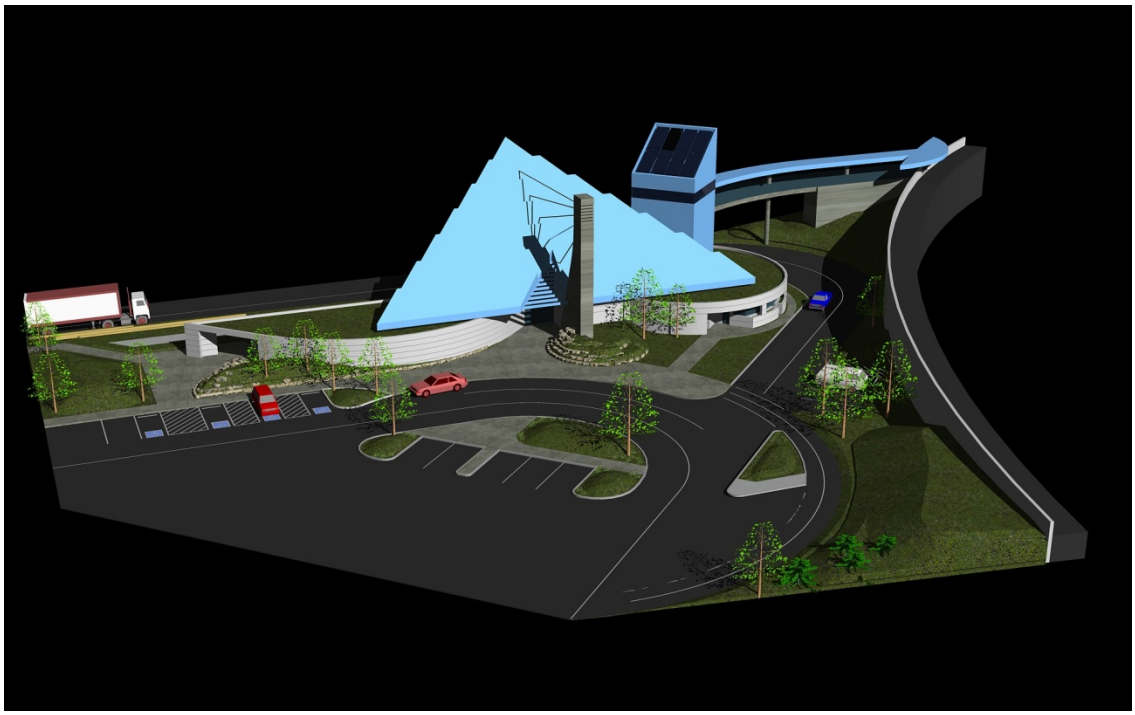

Figure 3-3. Visitor Center and Surrounding Area

The proposed architectural design would be visually compatible with the dam and with other outstanding regional features. A freestanding vertical, reinforced concrete pier structure with an array of tension rods would support the central beam of a triangular metal roof. The vaulted triangular roof would be stepped with north-facing vertical clear-story windows to provide an open and unimpeded view of the dam. Curved exterior concrete walls with earthen embankments would help moderate heat gain and loss. The ground floor security offices on the east side and visitor center staff offices on the west side would feature vegetated roofs of native grass species. An adjoining four-story metal building would contain a stairwell, elevator, and access to the theater, pedestrian bridge, and fourth floor security observation room. Construction quantities for the major items of work for this feature are summarized in Table 3-9.

Table 3-9. Visitor Center Construction Quantities for all SLWRI Dam Raise Alternatives

Item	Quantity
Site Excavation (cy)	9,400
Compacted Backfill (cy)	4,250
Topsoil (cy)	670
Asphalt Pavement (cy)	1,100
Solar Panels (sf)	11,800
Glass Curtain Wall (sf)	4,000
Exterior Metal Siding (sf)	5,100
Metal Roofing (sf)	13,545
Concrete (cy)	820
Reinforcing Steel (lbs)	115,000

Key:
cy = cubic yard
lbs = pounds
sf = square feet
SLWRI = Shasta Lake Water Resources Investigation

Lands

The Shasta Lake area lands valuation accounts for cost of acquiring public and private land required for the project because of new inundation, and permanent and temporary construction easements for reservoir area facility relocations. For the 6.5-foot, 12.5-foot, and 18.5-foot dam raise options, other than in the vicinity of Lakeshore, relatively few additional non-Federal acres of land would need to be acquired through easement or purchase. Table 3-10 shows the affected parcels by Comprehensive Plans. The Real Estate Appendix provides estimated land requirements and costs.

Table 3-10. Parcels Affected by SLWRI Comprehensive Plans

	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3 (18.5-Foot)	CP4/CP4A (18.5-Foot)	CP5 (18.5-Foot)
Total Non-Federal Parcels Affected	79 to 81	130 to 132	178 to 180	201 to 203	201 to 203
USFS Land Cabins Affected	23 to 25	26 to 28	27 to 29	27 to 29	27 to 29

Key:
CP = Comprehensive Plan
SLWRI = Shasta Lake Water Resources Investigation
USFS = U.S. Forest Service

Clearing of Reservoir Area

An increase in the height of Shasta Dam and Reservoir is expected to inundate varying areas of vegetated shoreline and riparian areas, depending on the final dam raise height. Inundated areas are described in Table 3-11; corresponding vegetation management is discussed in a later section. Inundation levels currently vary by water year and season at Shasta Lake, and this variation would continue if the dam were raised. Maximum water surface occurs during late spring, consistent with flood control operating guidelines. The reservoir is drawn down steadily throughout the summer in response to water supply demands. Based on this historic pattern, the new inundation zone would be exposed during most of the year for most water year types. Treatment windows and access are very limited by water levels and public use of the reservoir. Thus, a thorough vegetation removal strategy would be necessary to facilitate the continued safe operation of the dam and recreation area.

Table 3-11. Inundated Areas and Corresponding Vegetation Prescriptions for SLWRI Dam Raise Alternatives

Description		Vegetation Removal Prescription		
Dam Raise (feet)	Total Inundated Area (acres)	No Treatment (acres)	Overstory Removal (acres)	Total Removal (acres)
6.5	1,110	740	220	150
12.5	1,750	1,167	347	236
18.5	2,500	1,668	495	337

Key:
SLWRI = Shasta Lake Water Resources Investigation

Rationale and Need for Vegetation Management

The majority of the area now occupied by Shasta Lake was completely cleared of vegetation during construction of the original dam but some vegetation was left in place. The Pit River arm of the reservoir represents an area that was not cleared because of a shortage of available workers and resources. This area is an example of the effects of not clearing vegetation. Many snags are still standing in the Pit River arm, providing unique wildlife habitat. If left untreated, inundated upland vegetation is not expected to survive the first period of sustained inundation. Riparian vegetation would survive most of the expected inundation periods, although occasional mortality would be experienced over the life of the project.

The goals of preconstruction vegetation management are as follows:

- Reduce hazards to the public using the lake for recreation.

- Provide access to the shoreline near high-use areas.
- Maximize retention of habitat components that would survive inundation.
- Minimize impacts to operation of the dam and spillway.

If left in place, inundated vegetation could pose a hazard to the recreating public and physically block access to the newly created shoreline. Snags or fallen trees could pose a navigation hazard to boaters.

Brush, particularly manzanita, provides effective rearing cover for fish when inundated. Manzanita would be removed in clearing areas and stockpiled to be used for fish habitat structures placed in designated locations; however, willows, cottonwoods, and buttonbush would not be removed in and along riparian areas. Dead upland vegetation would provide some habitat during periods of inundation. Snags caused by inundation would provide habitat for birds and cavity nesters. During periods of reservoir drawdown, the residual root systems of inundated vegetation would provide support to newly created shorelines, reducing erosion. The benefits provided by dead vegetation would decrease over time as roots, plant skeletons, and snags decay.

To minimize operational hazards from small debris loading after vegetation removal, booms and other methods would be employed to capture debris, and are intended to provide better protection than currently exists for the dam and TCD. Plate 17 shows the plan, sections, and details for a proposed reservoir boom.

Proposed Vegetation Management Prescriptions

Three vegetation removal prescriptions are proposed for the areas around the reservoir that would be inundated, as described in the following sections.

Complete Vegetation Removal

Complete vegetation removal treatment would clear all existing vegetation from a designated treatment area and would generally be applied to areas along and adjacent to developed recreation areas, including boat ramps, day use areas, campgrounds, marinas, and resorts. Plate 19 shows the various vegetation management prescriptions around the reservoir. Exceptions would be made in areas with high shoreline erosion potential or in habitat for special-status species.

Timber would be harvested and removed to landings by ground skidding equipment if road access is available and slopes are less than 35 percent; otherwise, trees would be yarded by helicopter, and residual vegetation and activity-created slash would be piled and burned by hand. Where possible, trees would be felled into the reservoir during removal to minimize damage to reservoir embankments. Tree stumps would be cut to within 24 inches of the

ground surface and brush stumps would be cut flush to the ground. Stumps would be left in place to reduce shoreline erosion. This treatment is intended to maximize shoreline access and minimize the risk to visitors from snags and water hazards.

Overstory Removal

Overstory removal treatment would remove all trees greater than 10 inches in diameter at breast height or 15 feet in height from the treatment area, and would generally be applied to houseboat mooring areas or narrow arms of the reservoir where snags would pose the greatest risk to boaters. Trees would be harvested and removed to landings by ground skidding equipment if road access were present and slopes were less than 35 percent; otherwise, trees would be yarded by helicopter, and activity-created slash would be piled and burned by hand. The remaining understory vegetation would be left in place. Where possible, trees would be felled into the reservoir during removal to minimize damage to reservoir walls. Tree stumps would be cut to within 24 inches of the ground surface. Stumps would be left in place to reduce shoreline erosion. This treatment is intended to minimize the risk to visitors from snags and water hazards.

No Treatment

Designated areas of the inundation zone would be left untreated and no vegetation would be removed. This prescription would generally be applied to stream inlets, the upper end of major drainages, and the shoreline of wider arms of the reservoir. This prescription would also apply to special habitat areas, and is intended to maximize the habitat benefits of inundated and residual vegetation.

Vegetation Management Areas

Fifteen vegetation management areas have been delineated to facilitate the efficient removal of vegetation around the reservoir perimeter. The acreages of each management prescription are summarized in Table 3-12 by vegetation management area.

Table 3-12. Vegetation Management Prescription Summary by Area for SLWRI Dam Raise Alternatives

Landing Location	Dam Raise Alternatives											
	6.5 feet				12.5 feet				18.5 feet			
	Overstory Removal (acres)	Overstory Removal Quantity (board feet)	Complete Removal (acres)	Complete Removal Quantity (board feet)	Overstory Removal (acres)	Overstory Removal Quantity (board feet)	Complete Removal (acres)	Complete Removal Quantity (board feet)	Overstory Removal (acres)	Overstory Removal Quantity (board feet)	Complete Removal (acres)	Complete Removal Quantity (board feet)
Antlers	5	33,400	8	48,600	8	52,700	12	76,600	12	75,100	17	109,300
Bailey Cove	7	40,600	17	148,400	11	64,000	26	234,000	15	91,300	37	333,700
Beehive Point	24	102,300	3	5,400	38	161,300	4	8,500	54	230,100	6	12,100
Bridge Bay	0	0	9	51,800	0	0	14	81,600	0	0	20	116,400
Digger Bay	31	92,600	8	27,700	49	146,000	13	43,700	70	208,300	19	62,400
Hirz Bay	22	169,500	22	211,200	34	267,300	35	333,000	49	381,200	49	474,900
Jones Valley	51	328,000	17	81,700	81	517,100	26	128,800	116	737,500	38	183,700
Lakeshore East	2	12,500	17	58,800	4	19,700	27	92,800	5	28,100	39	132,300
Lower Salt Creek	15	62,700	14	96,300	24	98,900	22	151,800	35	141,100	31	216,500
McCloud Arm	0	0	4	14,900	0	0	7	23,500	0	0	10	33,500
Packers Bay	22	78,800	7	29,200	35	124,200	11	46,000	50	177,100	16	65,600
Pit Arm	0	0	2	22,400	0	0	3	35,300	0	0	4	50,400
Shasta Marina	13	89,400	1	17,900	21	141,000	2	28,200	30	201,100	2	40,200
Silverthorn	18	115,100	17	117,900	29	181,400	26	185,900	41	258,800	37	265,200
Turntable	8	88,700	5	33,100	13	139,900	8	52,200	19	199,500	11	74,400
Total	220	1,213,600	150	965,300	347	1,913,500	236	1,521,900	495	2,729,200	337	2,170,600

Key:
SLWRI = Shasta Lake Water Resources Investigation

Vegetation management activities would need to be complete before inundation of new areas created by enlarging the reservoir. A single staging area (landing) would serve each vegetation management area. Access for vegetation removal activities would most likely be limited to late summer and fall, when water levels are low and recreation use has decreased. Removal by helicopter would generally be limited to spring and fall because of the limited availability of helicopters during the summer fire season. Vegetation removal would also be limited during bird nesting season, typically early spring through mid-summer. Breeding bird surveys in suitable habitats would be performed to determine the appropriate time frame for vegetation removal activities and as an effort to avoid nesting species.

The average distance for helicopter trips per vegetation management area is described in Table 3-13. Note that because of distance and/or safety constraints, helicopters would not be used in the following vegetation management areas: Bridge Bay, Lakeshore East, Pit Arm, and McCloud Arm. Slash burning could take place during the winter following vegetation treatment, and would comply with all regulations set forth by the Shasta County Air Quality Management District. Vegetation management activities would need to be complete before inundation of new areas created by a dam raise.

Table 3-13. Average Flight Distance for Each Vegetation Management Area

Landings	Average Distance per Flight (miles)
Antlers	0.8
Bailey Cove	1.3
Beehive Point	1.2
Digger Bay	2.5
Hirz Bay	1.5
Jones Valley	2.7
Lower Salt Creek	1.1
Packers Bay	1.7
Shasta Marina	1.3
Silverthorn	1.0
Turntable	1.1

Reservoir Area Dikes

With Shasta Dam enlargement scenarios, dikes in the Lakeshore and Bridge Bay areas would be required to protect California Department of Transportation (Caltrans) highways, the Union Pacific Railroad (UPRR), and other infrastructure from inundation.

Two closure dikes and three railroad embankments in the Lakeshore area, and two closure dikes in the Bridge Bay area would be required in support of an 18.5-foot dam raise. Locations of the proposed dikes are shown in Plates 20 and

21. Table 3-14 summarizes the quantities of each type of material required for the proposed Lakeshore area and Bridge Bay dikes. The dikes are named to correspond with those presented in the Plan Formulation Report (PFR) (Reclamation 2007f). Some of the dikes originally proposed in the PFR were not required for feasibility-level analysis because of the new proposed alignments of the dikes. Doney Creek and Antlers Dikes were originally named Dikes 8 and 10, respectively, in the PFR.

Table 3-14. Estimated Material Quantities Required for Proposed Lakeshore and Bridge Bay Dikes and Railroad Embankments

Dike Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Lakeshore Dikes			
Doney Creek Dike			
Crest Elevation[1] (feet)	-	1087.2	1,098.7
Volume of Fill Material (core, drain, filter) (cy)	-	12,200	75,000
Volume of Riprap (cy)	-	1,000	5,900
Volume of Excavated Material (cy)	-	3,100	10,200
Site Clearing and Grubbing Below Dike (acres)	-	1.5	7.2
Antlers Dike			
Crest Elevation[1] (feet)	-	-	1,098.7
Volume of Fill Material (core, drain, filter) (cy)	-	-	4,900
Volume of Riprap (cy)	-	-	400
Volume of Excavated Material (cy)	-	-	300
Site Clearing and Grubbing Below Dike (acres)	-	-	0.9
North Railroad Embankment			
Crest Elevation[1] (feet)	varies[2]		
Volume of Fill Material (core, filter) (cy)	17,100	17,100	17,100
Volume of Riprap (cy)	400	400	400
Volume of Excavated Material (cy)	1,500	1,500	1,500
Site Clearing and Grubbing Below Dike (acres)	1.2	1.2	1.2
Middle Railroad Embankment			
Crest Elevation[1] (feet)	varies[2]		
Volume of Fill Material (core, filter) (cy)	13,400	13,400	13,400
Volume of Riprap (cy)	300	300	300
Volume of Excavated Material (cy)	4,000	4,000	4,000
Site Clearing and Grubbing Below Dike (acres)	2.9	2.9	2.9

Table 3-14. Estimated Material Quantities Required for Proposed Lakeshore and Bridge Bay Dikes and Railroad Embankments (contd.)

Dike Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
South Railroad Embankment			
Crest Elevation[1] (feet)	varies[2]		
Volume of Fill Material (core, filter) (cy)	101,900	101,900	101,900
Volume of Riprap (cy)	2,500	2,500	2,500
Volume of Excavated Material (cy)	8,500	8,500	8,500
Site Clearing and Grubbing Below Dike (acres)	6.2	6.2	6.2
Bridge Bay Dikes			
West Dike			
Crest Elevation[1] (feet)	1,081.2	1087.2	1,104.2
Volume of Fill Material (core, drain, filter) (cy)	3,000	7,700	69,000
Volume of Riprap (cy)	200	800	23,600
Volume of Excavated Material (cy)	2,100	5,000	15,300
Site Clearing and Grubbing Below Dike (acres)	0.8	1.4	2.2
East Dike			
Crest Elevation[1] (feet)	1,081.2	1087.2	1,104.2
Volume of Fill Material (core, drain, filter) (cy)	1,000	3,000	40,100
Volume of Riprap (cy)	40	160	7,400
Volume of Excavated Material (cy)	900	2,000	16,900
Site Clearing and Grubbing Below Dike (acres)	0.4	0.6	1.1

Notes:
Volumes include swelling factors.
[1] Elevation based on North American Vertical Datum of 1988.
[2] Railroad embankment crest elevations vary by the proposed railroad alignment.
Key:
- = not applicable
cy = cubic yards

Typical cross sections for homogenous fill dikes for an 18.5-foot dam raise are shown in Plate 22. Cross sections would be similar for 6.5- and 12.5-foot raises. Plate 23 shows typical cross sections of railroad embankments. It is expected that up to 5 feet of organic-rich soil and vegetation would be excavated from the foundation of the dike, and from a shear key on the upstream side of the dike. Ground treatment and/or over-excavation may be necessary in some areas to remove and/or treat pervious material. Riprap would be placed on the upstream face of each dike to the crest of the dike to provide protection from wave run-up and erosion.

For the purposes of this feasibility study, *Reclamation Design of Small Dams* (Reclamation 1987) guidelines were used to generate typical dike cross sections. Currently, all dikes are proposed with homogenous fill, consisting of relatively impervious fill with embankment slopes of 3:1 upstream and 2.5:1 downstream, as shown in Plate 22. A low-permeability core would extend to the

crest of the dike and have upstream and downstream slopes of 2:1. Subsequent phases of geotechnical investigation during final design may lead to revisions of these typical cross sections.

Doney Creek Dike

For the proposed 18.5-foot alternative, the Doney Creek Dike would extend approximately 1,800 feet along the southeastern side of the UPRR embankment to the north of the Doney Creek Bridge, turning to the west underneath the Doney Creek Bridge along the shoreline of Doney Creek, as shown in Plate 20. The purpose of the Doney Creek Dike would be to protect the UPRR embankment to the north of the Doney Creek Bridge from partial inundation when water reached ordinary high water levels as a result of the 18.5- and 12.5-foot dam raise alternatives.

Dike construction would consist primarily of homogenous fill in the flat areas to the south of the existing UPRR embankment. The use of homogenous earth dikes in this area is intended to limit construction costs. A combination of flood walls and zone embankments would be required in areas where construction access would be limited or where natural slopes exceeded the slopes of the embankments. The limited overhead construction space below the Doney Creek Bridge would make constructing an earthen dike infeasible, since the upper lifts of the dike would not be accessible with a compactor. Accordingly, a flood wall would be required at this location. Similarly, the natural slopes of the ravine located north of the Doney Creek Bridge are steeper than the anticipated slopes of the homogenous dikes. A rock fill dike or a dike supporting a floodwall would be required at this location.

Antlers Dike

For the proposed 18.5-foot alternative, the Antlers Dike would extend approximately 200 feet in a northeasterly direction away from Interstate 5. The purpose of the Antlers Dike would be to protect Interstate 5 from partial inundation when water reached ordinary high water levels for the 18.5-foot dam raise. Dike construction would consist of a homogenous fill embankment, which would be the most cost-effective and appropriate for this small dike.

Railroad Embankments

Three railroad embankments, labeled North, South, and Central (see Plate 24), are proposed along the railroad alignment in the Lakeshore area, located between the Doney and Charlie creek arms of Shasta Lake. The purpose of these embankments would be to support the railroad for the adjusted alignment. The North Embankment would extend approximately 1,700 feet from the north shore of Charlie Creek in a northern direction. The South Embankment would be to the north of the first embankment and would extend approximately 1,100 feet along the proposed railroad alignment. The Central Embankment would extend approximately 340 feet along the proposed railroad alignment, terminating at the south shore of Doney Creek.

Bridge Bay West and East Dikes

At the Bridge Bay Marina, a 700-foot long section of UPRR tracks stretches between two railroad tunnels, located downslope from Interstate 5. This section of railroad tracks would be inundated as a result of ordinary high water for all of the dam raise alternatives. Dikes are proposed on either side of the tracks to protect the railroad from inundation both by Shasta Lake and impounded stormwater runoff from the hillside directly east of the tracks, as shown in Plate 25.

Geotechnical analysis of the existing foundation material for the Bridge Bay dikes determined that significant excavation would be required for the west Bridge Bay Dike. To minimize the dike footprint and limit excavation, jet grouting was proposed. The existing unsuitable foundation material for the east Bridge Bay Dike was determined to extend to a maximum depth of 15 feet.

Borrow Material for Dikes

The Lakeshore and Bridge Bay dikes would be constructed as homogenous embankments. Homogenous dikes would consist primarily of low-permeability fill with a small granular drain and filter at the toe of the embankment. Dike slopes retaining water would be armored with riprap. An overview of the borrow material needed for construction of the proposed dikes and description of potential borrow sources is provided in the following paragraphs.

Borrow Material Classification

Dike designs consider embankment fill materials, including homogenous fill, core, riprap, filter, and drain materials. Brief descriptions of these materials are given below.

Core and Homogenous Fill Material Designs of dikes constructed as homogenous embankments would be constructed almost entirely of low-permeability soil. Typically, core fill materials consist of impervious fine-grain materials, such as silts and clays, or coarse-grain materials, such as gravels or sands with significant components of clay or silt.

Riprap Riprap is used to protect embankment slopes subjected to wave erosion. Properly graded riprap is commonly used to provide slope protection. Riprap needs to be placed in a manner to provide a well-integrated mass with minimum void spaces. Generally, riprap consists of a uniform distribution of angular and durable gravel- to boulder-sized rock.

Filter Material Granular filters will be required for each of the proposed embankments in the Lakeshore and Bridge Bay areas. Granular filters are used to minimize the risk of internal erosion at the boundaries of dissimilar fill materials. The filters consist of uniformly graded, free-draining materials with less than 5 percent fines by weight. Granular filters are restricted to a maximum particle size of 3 inches to avoid segregation and bridging of large particles during construction.

Drain Material The proposed homogenous fill embankments would be constructed with toe drains to minimize pore pressures within the embankments. Toe drains can be used in concert with blanket drains to further reduce uplift pressures along embankment foundations. Toe drains must be strong, durable, and free draining. Typically, drain materials consist of sands and gravels with less than 5 percent fine-grained soil.

Borrow Requirements for Dikes

Estimates of the borrow materials needed to construct the proposed dikes are presented in Table 3-14. Proposed dike geometries were developed for engineering and design analyses for this EIS. Accordingly, volumes of core and homogenous fill, riprap, filter, and drain materials are estimates, and may be refined during subsequent phases of design. Borrow sources for proposed dikes are discussed in a later section under "Other Considerations." The required fill volumes are presented in greater detail in the SLWRI *Reservoir Area Dikes and Related Facilities Report* (Reclamation 2012b).

Other Considerations

The following sections discuss other dam raise options considerations relating to Pit 7 Dam, Keswick Dam, probable maximum flood (PMF), borrow sources, and geological and geotechnical information.

Pit 7 Project Facilities

This section presents design and construction information to support the assessment of the Pit 7 Dam, Powerhouse, and related facilities associated with the proposed raise of Shasta Dam. The Pit 7 Dam and Powerhouse, which is owned and operated by Pacific Gas and Electric Company (PG&E), are located on the upper Pit River at the northeast end of Shasta Lake. The complex consists of three main features: a main dam with integral spillway, a two-unit hydroelectric powerhouse immediately downstream from the main dam, and an afterbay dam (see Plate 24). Each main feature, and the impacts of the three Shasta Dam and Reservoir raise options on each feature, is discussed below. Costs are included in the estimates for potential physical impacts to the Pit 7 Powerhouse. Reclamation commits to future studies after Congressional Authorization, the types of studies will be determined in coordination with PG&E.

Pit 7 Dam

The main Pit 7 gravity dam was evaluated to determine the impact of the increased tailwater level caused by a Shasta Dam raise on the uplift pressures under the base of the dam. Normal operating conditions for the three Shasta Dam raise alternatives (6.5, 12.5, and 18.5 feet) were considered in the stability analysis. An extreme loading combination, including seismic loads, was also considered in the analyses. For this evaluation, the computer program CADAM 2000 (Version 1.4.11) was used to calculate factors of safety against sliding and

overturning of the dam. Compressive and tensile stresses were also investigated at the heel and toe of the dam.

Pit 7 Dam Spillway

The spillway was evaluated to determine if a potential modification or raising of the Pit 7 Dam spillway flip bucket would be required because of higher tailwater levels caused by a Shasta Lake raise and concurrent Pit 7 Dam spillway flows. Tailwater levels above the lip of the spillway combined with substantial spillway flows could potentially affect spillway performance and have adverse effects on the dam and adjacent powerhouse.

Backwater conditions above the lip of the spillway could potentially interfere with spillway performance. If the spillway discharge was small enough or if the tailwater was high enough, sweep-out of the flip bucket would not occur and the roughly 85-foot-long flip bucket would function in a manner similar to a stilling basin. If the spillway flows were great enough to cause sweep-out of the flip bucket, a high tailwater level could interfere with the intended trajectory of the spill and cause energy dissipation and potential scour to occur near the terminus of the spillway. This is a condition that should be avoided. At all tailwater levels below the lip of the flip bucket, the flip bucket would either function as a stilling basin for low flows, or when the spillway flow was high enough, the spill would be thrown a distance downstream and energy dissipation would occur at an acceptable distance away from the dam.

The 50-year historical and simulated record does not indicate any spillway discharge events that would likely be damaging because of the potential Shasta Dam raises. Thus, it can be projected that the Pit 7 Dam should not be subjected to damaging flows for the potential dam raise alternatives up to the 1 percent chance of occurrence each year. This is not an indication that damaging conditions at the spillway would not occur for all flood events up to the PMF, but the damage potential from overtopping of the Pit 7 Dam would probably exceed that which could be attributed to spillway performance alone. Therefore, it is recommended that there should be no requirement to raise the Pit 7 Dam spillway as a direct result of the Shasta Dam raise options that are under consideration.

Backwater conditions do have the possibility of creating wave action that could undermine the powerhouse and dam when flows are released over the spillway. It is recommended that both the left and right concrete training walls be increased in height to prevent this from occurring.

Pit 7 Powerhouse

The powerhouse is a semi-outdoor type powerhouse, with two generating units each rated at 56 MW output under approximately 204 feet of net head. The main powerhouse yard/deck, where the generators and generator step-up transformer are located, is at elevation 1,104.25 feet NGVD29. (Note that the following elevations presented in this section are based on the NGVD29

datum). A training wall with top at elevation 1,094 feet separates the dam spillway from the powerhouse. The normal tailwater level under existing conditions is elevation 1,067 feet. A raise of Shasta Dam by 18.5 feet would raise the normal tailwater to elevation 1,087.5 feet. This would still provide 6.5 feet of freeboard to the top of the training wall and 16.75 feet of freeboard to the powerhouse yard/deck. The overall powerhouse would not be inundated, but other effects need to be considered and addressed.

To ensure that proper operation of equipment in the powerhouse, the dewatering capacity of the existing sump pumps will need to be increased to address any additional seepage. This can be achieved with the installation of a new submersible pump.

The Pit 7 Powerhouse is sometimes operated in synchronous or “motoring” mode to balance the power grid if demand drops below available generation. In this condition, the water in the draft tube is lowered to an elevation below the runner while the unit is at synchronous speed. A set of breakers is closed and surplus power from the grid is used to turn the generator similar to a motor without water flowing through the turbine. At the Pit 7 Powerhouse, the normal tailwater is below the bottom of the runners. This enables the Pit 7 Powerhouse to switch to synchronous mode by simply closing the wicket gates and allowing the tailwater to equalize in the draft tubes at the current stream elevation, then closing the breakers to switch to “motoring” mode. With an increased tailwater elevation, it would be necessary to install a tailwater depression system to lower the water level in the draft tubes before the units could be switched to synchronous mode. The tailwater depression system would be sized with enough storage tank capacity to complete the initial blowdown in a few seconds, and a smaller compressor could be used to maintain the draft tube pressure and water elevation over long periods of time.

Another consideration is the static pressure on the turbine head covers and main shaft seals due to the increased tailwater elevation. At the current normal tailwater elevation, the turbine head covers are only under pressure with the wicket gates open and the turbine units running. When the wicket gates are closed, the water in the turbine and draft tube equalizes with the tailwater and relieves the pressure on the head cover. If the tailwater elevation were higher than the turbine head covers, the head covers and associated seals would experience static internal pressures when the wicket gates were closed with the draft tube gates open. A tailwater depression system would maintain the same static pressure under the head covers while the units operated in synchronous mode. The unit centerlines are at elevation 1,073.0, which is 14.5 feet below the new maximum tailwater elevation of 1,087.5 feet for the proposed 18.5 foot dam raise option. The 14.5 feet of static head is much less than the 204 feet of head that the turbines currently operate under. Therefore, the existing seals in the turbines should be capable of withstanding the static head at any of the proposed maximum tailwater elevations. Aside from the decrease in generation

due to the reduced net head, the existing turbines should function properly with the new maximum tailwater elevation.

Reduction in Generation Capacity

Initial estimates of reduced generation at the Pit 7 Powerhouse used the maximum proposed pool elevations for Shasta Lake, but more recent models recognize that the maximum pool would not be maintained for extended periods, and may not even be achieved most years. The most recent estimates of reductions in energy generation at the Pit 7 Powerhouse due to the proposed SLWRI dam raises are indicated in Table 3-15. While the average annual reduction in power remains small (less than 3%), Reclamation realizes that the loss of power is an impact to PG&E. Reclamation commits to deliver in-kind replacement power to PG&E based on real time models. Reclamation, in coordination with PG&E, will develop these real time models before operation of an enlarged Shasta Dam and Reservoir.

Table 3-15. Simulated Average Annual Decrease in Pit 7 Powerhouse Generation for SLWRI Comprehensive Plans

Item	CP 1 (6.5-Foot)	CP 2 (12.5-Foot)	CP 3 (18.5-Foot)	CP 4 (18.5-Foot)	CP 4A (18.5-Foot)	CP 5 (18.5-Foot)
Change in Generation (GWh)	-4	-7	-15	-16	-15	-15
Percent Change (percent)	-1%	-1%	-3%	-3%	-3%	-3%

Key:
GWh = gigawatt-hour
SLWRI = Shasta Lake Water Resources Investigation

Existing Powerhouse Structure

The existing Pit 7 Powerhouse has 4-foot-thick concrete walls. These walls span vertically between the concrete floor slabs to resist lateral soil and hydrostatic loads. A review of the structure's capacity indicates that the existing powerhouse wall would perform satisfactorily when subjected to loading from the maximum proposed tailwater elevation. The existing powerhouse structure would not require modifications to accommodate any of the proposed tailwater elevations.

The existing draft tube gates are fabricated from steel wide-flange beams and steel plate. A review of the gate elements indicates that under the new maximum tailwater elevation, the 11/16-inch-thick skin plate and the 24-inch-deep wide flange beams spanning horizontally that comprise the draft tube gates would perform adequately under the proposed tailwater elevations associated with the three Shasta Dam raise options. Therefore, the existing draft tube gates are considered adequate for continued service under the maximum proposed tailwater elevation. Further detailed review and/or analysis of specific elements

or locations may be required at a later date, when a final tailwater elevation is determined.

Pit 7 Afterbay Dam

The Pit 7 Afterbay Dam consists of two main sections: a rockfill dam with a 550-foot-long crest with elevation 1,060 feet NGVD29 (note that the following elevations presented in this section are based on the NGVD29 datum), and a concrete uncontrolled spillway section 145 feet in length, with a crest elevation that varies between elevation 1,026 feet and elevation 1,058 feet.

Slope stability analyses results for the Pit 7 Afterbay Dam, as modeled under the higher water levels cause by a raised Shasta Dam and Reservoir, show that the factors of safety against slope failures of the rockfill dam are above 2.0 for all the loading cases considered. Although the analyses show that complete failure of the rockfill dam would not occur under seismic loading, local surficial deformations would likely occur on the upstream side and less likely on the downstream reinforced face.

At the time of year when Shasta Lake is at the maximum normal pool, elevation 1,087.5, the rockfill dam is under 27.5 feet of water. The dam would be subjected to both hydrostatic and hydrodynamic forces that are not expected to have any significant impacts to the structural stability of the dam. The weight of water on top of the dam acts against slope failures and would increase the factor of safety. Flow velocities through the dam are not expected to be high enough to cause erosion of the dam. If high velocities were to occur, the steel reinforcement in the dam and on the downstream slope would act against erosion of the dam. Based on this assessment, it is not recommended that any modifications be made to the Pit 7 Afterbay Dam. However, the steel reinforcement should be inspected regularly.

The Pit 7 Afterbay Dam may require the placement of rock dowels and rip rap for slope stability to meet the necessary safety standards. Ancillary facilities will need to be addressed near the Pit 7 Afterbay Dam including relocating the gaging station and cableway that would be inundated by the new high water line, extending the boat barriers, relocating security fences and signs, rehabbing the existing boat ramp, and relocating the warning siren.

Keswick Dam

Keswick Dam is a concrete, gravity-type structure with a spillway over the center of the dam, and is located downstream from Shasta Dam. The spillway has four 50-foot by 50-foot fixed-wheel gates with a combined discharge capacity of 248,000 cfs at full pool elevation (587). It is estimated that no modifications to Keswick Dam would be required for the 6.5-, 12.5-, or 18.5-foot Shasta Dam raise options.

Probable Maximum Flood

An appraisal-level PMF was originally developed by Reclamation for the Shasta Dam Enlargement Studies in April 2001 (Reclamation 2008a), using current Hydrometeorological Report No. 59 (HMR 59) procedures. The 2001 PMF was a general storm with a peak inflow of 633,400 cfs and a 15-day volume of 3,961,700 acre-feet, and was used to develop an appraisal-level hydrologic hazard analysis (HHA). The HHA provided frequency floods with return periods ranging from 100 to 20,000 years. Of note, the 20,000-year frequency flood was the same size (by peak and 15-day volume) as the appraisal-level PMF (Reclamation 2002).

A feasibility-level PMF hydrograph was developed by Reclamation for the dam raise feasibility-level design in January 2008 (Reclamation 2008a), with a peak inflow of 631,806 cfs and a 30-day volume of 6,245,905 acre-feet for a general storm on snow. The peak 15-day volume for the revised PMF was estimated to be 4,970,100 acre-feet. This corresponds closely with the appraisal-level PMF peak inflow, but is significantly greater in 15-day flood volume because of increased contributions from the Pit River Arm of the Shasta Lake drainage basin, and because of a generally larger (and longer duration) 100-year rain-on-snow antecedent flood. The Sacramento, McCloud, and lower Pit River subbasins would contribute the majority of the flow and would be responsible for the PMF peak inflow. The upper Pit River subbasins, with a total area of 3,310 square miles, were shown to contribute only about 2 percent to the peak inflow and 7 percent to the flood volume.

A revised HHA was prepared for the 2008 *Comprehensive Facility Review of Shasta Dam* by scaling the frequency flood hydrographs from the revised PMF (Reclamation 2008c). Table 3-16 summarizes peak discharge and volume estimates for return periods between 100 and 20,000 years. The revised 20,000-year frequency flood has about the same inflow peak and 15-day volume as the revised (feasibility-level) PMF.

Table 3-16. Revised Frequency Flood Peaks and Volumes, Shasta Dam

Return Period (years)	Peak Discharge (cfs)	Flood Volume (acre-feet)				
		1-Day	3-Day	5-Day	7-Day	15-Day
100	259,134	471,474	1,051,291	1,382,661	2,091,844	3,344,938
200	300,152	546,344	1,181,525	1,479,017	2,232,652	3,529,297
500	358,657	653,186	1,399,982	1,720,821	2,442,971	3,789,612
1,000	406,375	740,373	1,577,562	1,921,799	2,619,760	3,999,925
2,000	457,260	833,383	1,766,161	2,140,084	2,811,839	4,222,543
5,000	529,664	965,787	2,033,887	2,448,206	3,088,838	4,536,346
10,000	588,534	1,073,488	2,250,234	2,696,538	3,314,482	4,789,570
20,000	631,800	1,152,666	2,409,440	2,878,272	3,479,689	4,974,552

Key:
cfs = cubic feet per second

Flood routings were performed for both the existing and raised conditions, using an Excel spreadsheet to simulate the Emergency Spillway Release Diagram (ESRD) to properly limit discharges when the RWS is below the top of joint-use storage.

Borrow Areas/Sources

Construction at Shasta Dam for the main concrete dam, right wing dam, left wing dam, spillway, river outlets, power outlets, TCD, and visitor center will require nearly 100,000 cubic yards of concrete, or between 150,000 and 180,000 tons of sand and gravel, and between 20,000 and 25,000 tons of cementitious material (cement and pozzolan). Construction for the UPRR railroad bridges and Pit River Bridge modification will require nearly 23,000 cubic yards of concrete, or approximately 35,000 tons of sand and gravel, and approximately 6,000 tons of cementitious material. Construction for Lakeshore and Bridge Bay area embankments would need more than 300,000 cubic yards of core and homogenous fill, shell fill, riprap, filter, and drain materials.

Potential Dam Area Borrow Sources

Multiple borrow sources are available to meet project needs for shell fill and possibly core material for the wing dam construction. Potential borrow sources were examined at a preliminary level and would need further sampling and testing to determine suitability and to refine quantity estimates. These borrow sources are located on federal property downstream from Shasta Dam, southwest of the Shasta Dam Maintenance Yard, in the downstream area on federal property known as Project City of (Government Camp). Commercial sources for the dam construction materials were also identified. Material availability would vary with market demand and production restrictions, but it is expected that sufficient concrete sand and gravel materials will be available when needed for construction. More details regarding potential local sand and gravel aggregate sources are contained in Reclamation's *Shasta Dam Enlargement – Sand and Gravel Aggregate Sources* (2007d). For projects involving more than 100,000 cubic yards, Reclamation recommends locating five times the material required for construction when evaluating this project to ensure adequate fill materials (Reclamation 1987).

Potential borrow sources and fill materials for construction available at these borrow sources are summarized in Table 3-17. Commercial sources are located within approximately 10 to 30 miles of the Shasta Dam site. Locations of potential reservoir area and commercial borrow sources are identified in Plate 25.

Potential Lakeshore Drive Area and Bridge Bay Marina Borrow Sources

Multiple borrow sources are available to meet project needs for core and homogenous fill, shell fill, riprap, filter, and drain materials of the reservoir area dikes and embankments. Potential borrow sources were examined at a preliminary level and would need further sampling and testing to determine suitability and to refine quantity estimates. These borrow sources could include

areas of the dike construction sites, areas located below the reservoir's inundation zone, and commercial sources.

For the Lakeshore Drive area, potential borrow sources and fill materials for dike construction available at these borrow sources are summarized in Table 3-17. Commercial sources are located at 2 quarries approximately 15 miles from the Lakeshore sites. Locations of potential reservoir area and commercial borrow sources are identified in Plate 25.

For the Bridge Bay Marina area, potential borrow sources and fill materials for dike construction available at these borrow sources are summarized in Table 3-17. Commercial sources are located at quarries within 2 to 30 miles from the Bridge Bay sites. Locations of potential reservoir area and commercial borrow sources are identified in Plate 25.

Table 3-17. Summary of Potential Borrow Resources

Borrow Sources	Core (cy)[1]	Shell (cy)[1]	Drain & Filter (cy)[1]	Riprap (cy)[1]
Shasta Dam Area	0	500,000	N/A	N/A
Lakeshore Drive Area	642,000	553,000	N/A	230,000
Bridge Bay Marina Area	N/A	674,000	N/A	200,000
Material Total	642,000	1,727,000	N/A	430,000

Note:
[1] Some of these volume estimates have not been field-verified by subsurface investigations.
Key:
cy = cubic yards
N/A = not applicable

Additional Borrow Considerations

The top 3 feet of material in all borrow areas are likely to contain organic matter, and be unsuitable for construction purposes. This surface material should be stockpiled and used to restore the sites after borrow activities are completed. A 3-foot increment was subtracted from the estimated depths of borrow materials to estimate volumes for all borrow areas.

Riprap material developed from moderately to slightly weathered basalt can be quarried below a thin soil cover in most locations along the Lakeshore Drive area. It is assumed that if a borrow area is selected for soil materials, this area could also be quarried for the required riprap.

Clean sand required for the proposed filters and drains was not found in any of the borrow locations investigated. Sand may possibly be produced from crushing and processing the basalt. Further study is recommended to evaluate

the feasibility of crushing basalt into sand and gravel to construct drainage and filter elements.

For additional details on potential borrow sources, please refer to Reclamation's *Geology Report 2, Phase 1 Feasibility Geologic Report for Shasta Dam Enlargement Project* (2009b).

Borrow Recommendations

The borrow source evaluation was conducted as part of engineering and design analyses for this EIS and related Feasibility Report. Note that the statements provided herein are based on geotechnical investigations, soil sampling, in field testing, and laboratory testing.

Based on anticipated borrow requirements, and the initial assessment of potential borrow sources, construction of the proposed dam embankment, and Lakeshore and Bridge Bay dikes is generally feasible with respect to the availability of construction materials. Note, however, that the findings in this section are based on engineering and design analyses that may change as the project is developed. Design changes and field investigations may encounter conditions that would modify the evaluations and statements presented in this Engineering Summary Appendix.

It is recommended that subsurface investigations be conducted to better characterize the types and depth of soils at different locations around Shasta Lake. Laboratory testing will be required during final design to determine the physical and strength characteristics of borrow materials.

Geology/Geotechnical

The following sections discuss the regional geology and seismicity of the SLWRI study area.

Regional Geology

The regional geology of the area surrounding Shasta Dam is influenced by the intersection of three tectonic plates, defined as a triple junction (Reclamation 2004b, 2007a). The Mendocino Triple Junction, composed of the Gorda, North American, and Pacific plates, is one of the most seismically active regions of the San Andreas transform system. Since 1983, the region has generated about 80 earthquakes with a magnitude of greater than or equal to 3.0 each year, and historically the region has experienced major quakes. This activity is generated in response to ongoing plate motions among the three plates of the Mendocino Triple Junction, which lies approximately 100 miles east of Shasta Dam (USGS 2013). Three active fault zones make up the tectonic interaction. These faults are the San Andreas Fault Zone, Cascadia Subduction Zone, and Mendocino Fault Zone. Both the San Andreas and Mendocino faults are classified as transform faults, or faults whose motion is normal along the fault trace. The Cascadia Subduction Zone is the result of the Pacific plate being subducted under the North American plate.

The interaction of the three plates of the Mendocino Triple Junction has created varied surface geomorphology, resulting in five major geomorphic provinces in the area of Northern California: the Klamath Mountain Range, Cascade Mountain Range, Great Valley Sequence, Modoc Plateau, and Coastal Mountain Range (Reclamation 2007a). Shasta Dam and Reservoir are located at the southeastern edge of the Klamath Mountains geomorphic province.

The Klamath Mountains geomorphic province is formed from the compressional and uplift forces of the volcanic arc and continental margin sequence (Reclamation 2007a). Surface topography is rugged, with prominent peaks and ridges reaching elevations 6,000 to 8,000. Throughout this mountainous region are thrust faults; structure relates to low-grade metamorphism. Rocks of the Klamath Mountains range in age from Ordovician to late Jurassic, and consist of greywacke sandstones, greenstones, cherts, limestone, and metamorphic equivalents of (the foregoing) rock types, and abundant granitic intrusive and ultramafic sheets.

Geology and subsurface foundation conditions for proposed structure modifications and new construction have been observed by Reclamation. A subsurface investigation performed in 2009 by Reclamation included fifteen boreholes 50 feet to 100 feet deep and fifteen test pits. These boreholes and test pits were located in the Shasta Dam, Lakeshore Drive, and Bridge Bay Marina areas to characterize subsurface foundation conditions within designated areas, document geologic investigations, and identify and characterize borrow sources (Reclamation 2009b). Known foundation conditions have been summarized on a dike-by-dike basis in Chapter 4.

Seismicity

The closest active fault to Shasta Dam is the Battle Creek Fault, located approximately 25 miles to the south. The Battle Creek Fault is a normal fault with a length of 29 kilometers (km), a dip of 75 degrees, and a width of 11 km (USGS 2002). The characteristic magnitude is 6.5, with a recurrence rate of 7.6 E-04/year and a slip rate of 0.5 millimeters (mm) per year.

Since 1973, 1,548 recorded earthquakes greater than magnitude 3.0 have occurred within 200 km of Shasta Dam. This radius includes earthquakes generated by activity in the Mendocino Triple Junction. When the search radius is reduced to 100 km (excluding the Triple Junction), only 224 earthquakes greater than magnitude 3.0 are found. The majority of earthquakes in this region are magnitude 3.0 to 4.0. The largest earthquake near Shasta Dam occurred on November 26, 1998, and was magnitude 5.4 (USGS 2013). This earthquake was not located on the Battle Creek Fault.

Chapter 4
Design Consideration for Reservoir Area Infrastructure Modifications and/or Relocations

Road Relocations

As a result of the proposed Shasta Dam raise, existing reservoir area roads inundated by the increase in full pool elevation would need to be removed and/or relocated. The following sections discuss road relocation construction activities, design criteria and estimated material quantities for each dam raise alternative.

Construction Activities

Roadway construction activities would involve, but not be limited to, demolition of existing roadways as required; clearing, grubbing, and site preparation of work areas, as required; grading road alignments to meet finished grades; placing road subgrade; paving operations; installing storm drain culverts; constructing retaining wall systems; installing road appurtenances such as guardrails; and performing construction-related traffic control.

Replacement roadways would be constructed by excavating the existing up-grade slope to provide fill material for the embankment fill portion of road construction; bench-excavating into the up-grade slope above the existing roadway to establish the new road finished grade; building the new road on an engineered fill embankment from imported borrow material; or building the new road directly above the existing road on an engineered fill embankment from imported borrow material. A road alignment may use either use a single method of construction for the entire alignment, or use all four methods at different locations along an alignment. A graphical representation of the typical road replacement sections can be found in Plate 26.

Estimated work limits depend on the surrounding terrain, and vary from a minimum of 5 feet to 30 feet wide, measured from the extent of earthwork. Where the road would be constructed as an embankment fill against an existing steep hillside, a 5-foot-wide minimum work area would be used. Where the terrain beyond the limit of earthwork was flat enough to be used as work areas for construction equipment, the work limits would range from 15 feet to 30 feet wide.

Design Criteria Basis

Road replacement design criteria were established based on the following documents:

- *A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials* (AASHTO) (1990).
- *Shasta County Development Standards, Shasta County* (1997).

Research was conducted into the road design standards used by the U.S. Forest Service (USFS). Some information was provided by USFS from Chapter 4 of the USFS Road Preconstruction Handbook; however, no specific USFS requirements pertaining to road materials, widths, and construction were obtained. For this level of analysis, the criteria established below, based on AASHTO and Shasta County standards, are sufficient. Further research into USFS road requirements should be conducted before final design of roadways. For additional design and specification information, see the *SLWRI Road Relocations Technical Memorandum* (Reclamation 2007g).

Road Design Criteria

Criteria were established for four typical road replacement scenarios. (Table 4-1 presents the road design criteria. Graphical representation of the typical road replacement sections can be found in Plate 26.)

Nearly all paved roadways to be replaced have a paved width of approximately 18 feet, 20 feet, or 24 feet; therefore, typical paved sections of those dimensions were established. The design intent was to match road replacement widths with those of the existing paved roads to be replaced. The thicknesses used for asphaltic concrete (AC) and aggregate base (AB) are based on Shasta County typical requirements. During final design of the road relocations, geotechnical recommendations should be provided regarding actual AC and AB thicknesses to be used for construction.

Unpaved roads requiring replacement vary in road width and in road material. Some unpaved roads have a gravel finished surface and others are earth with no finish material. For this analysis, it was assumed that all unpaved roads would be replaced with an 8-inch-thick AB section meeting the width of the existing road.

Guardrail would be placed in areas where the existing road has guardrail or in areas where conditions have a higher potential for vehicles to run off the road.

Table 4-1. Typical Road Replacement Scenarios

Criteria	24-foot-wide Paved Road	20-foot-wide Paved Road	18-foot-wide Paved Road	Unpaved Road (AB)
Paved Width	24 feet	20 feet	18 feet	Varies
Shoulder Width	4 feet	4 feet	2 feet	2 feet
Roadside V-Ditch	As required	As required	As required	As required
Cross Slope	3%	3%	3%	3%
AC Thickness	4 inches	3 inches	3 inches	N/A
AB Thickness	8 inches	8 inches	8 inches	8 inches
Traffic Index	6.0	5.0	4.5	N/A
Rolling Terrain Minimum Design Speed	40 mph	30 mph	20 mph	20 mph
Mountainous Terrain Minimum Design Speed	30 mph	20 mph	20 mph	20 mph
Maximum Grade	8%	8%	10%	10%
Minimum Horizontal Curve Radius	50 feet	50 feet	50 feet	50 feet
Minimum Right-of-Way	60 feet	50 feet	50 feet	50 feet
Minimum Freeboard (above elevation 1,090.20 (NAVD88))	3 feet	3 feet	3 feet	3 feet

Key:
AB = aggregate base
AC = asphaltic concrete
mph = miles per hour
NAVD88 = North American Vertical Datum of 1988
N/A = not applicable

Culverts would be placed at low points, as required, based on the road relocation grading designs. In areas where feasible, low points would be filled with embankment fill rather than providing a culvert. The majority of existing culverts in the Shasta Lake area appear to be corrugated metal pipe (CMP); thus, this was the pipe material assumed for the analysis. Minimal analysis was conducted to establish the culvert diameters shown. Acreages of the upstream storm watersheds were estimated, and a culvert diameter was assumed based on these areas. These culvert sizes should be used for feasibility-level cost estimating only. During final design of the road relocations, a complete hydrological analysis should be conducted to size all culverts for the established design storm.

Properly graded riprap is commonly used to provide slope protection. Riprap would be placed on new embankment slopes that would be subject to wave erosion. Riprap would need to be placed in a manner that would provide a well-integrated mass with minimum void spaces. Generally, riprap consists of a uniform distribution of angular and durable gravel- to boulder-sized rock.

In areas where it would not be feasible to make steep hillside excavations or use embankment fill to establish the finished road grades, cast-in-place (CIP) concrete retaining walls, with spread footings, would be used. Wall dimensions

are based on previous retaining wall designs. This detail should be used for cost estimating in this EIS and Feasibility Report only. During final design, the need for retaining walls should be revisited and designed accordingly for construction.

The existing terrain around Shasta Lake varies from rolling to mountainous, depending on the specific area. Slopes of the existing hillside embankments typically range from as steep as 0.25:1 to as flat as 3:1. Slopes of the existing terrain were assessed at each road relocation area during the analysis. For this analysis, it was assumed that the steepest cut slope allowed would be 1:1 and the ideal cut slope would be 2:1. If an existing roadway cut slope appeared to be in good condition, it was assumed that the new road cut slopes in the same vicinity could safely match the existing conditions. The steepest fill slope permitted would be 1.5:1 and the ideal fill slope would be 2:1. Borrow material for road embankment construction would be derived from sources identified in Chapter 3.

Affected Road Segments and Estimated Quantities

Quantities have been generated for each road segment. It is estimated that approximately 4.1 miles of paved roadway and 2.3 miles of unpaved roadway would need to be constructed as a result of the new full pool water surface elevation for the 18.5-foot raise. Table 4-2 summarizes the affected road segments and estimated road relocation quantities and Table 4-3 details the quantities by major road focus areas. Figures 4-1 and 4-2 illustrate realignment of Lakeshore Drive and associated replacement of Doney Creek and Charlie Creek vehicular bridges, UPRR railroad bridges and track realignment, and Lakeshore area dikes. Imported fill borrow areas would be similar to those outlined for dikes and embankments in Chapter 3.

Table 4-2. Summary of Approximate Road Relocation Quantities for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Road Segments Affected	10	21	30
Length (lf)	16,700	28,400	33,100
Paved Area (sf)	319,800	539,500	627,200
Embankment Fill (cy)	235,400	372,500	400,100
Excavation (cy)	65,100	78,300	82,100

Key:
cy = cubic yards
lf = linear feet
sf = square feet
SLWRI = Shasta Lake Water Resources Investigation

Table 4-3. Approximate Road Relocation Quantities by Major Road Focus Area for SLWRI Dam Raise Alternatives

Road Relocation Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Lakeshore Drive			
Number of Road Segments Affected	4	6	8
Length (lf)	8,100	13,100	13,700
Clearing and Grubbing (acres)	4	7	7
Excavation to Embankment (cy)	46,100	55,100	55,500
Embankment Fill (cy)	122,800	171,800	174,900
Closure Expected	No	No	No
Turntable Bay Area			
Number of Road Segments Affected	3	3	3
Length (lf)	6,200	6,200	6,200
Clearing and Grubbing (acres)	2	2	2
Excavation to Embankment (cy)	19,000	19,000	19,000
Embankment Fill (cy)	76,200	76,200	76,200
Closure Expected	Yes	Yes	Yes
Gillman Road			
Number of Road Segments Affected	-	3	3
Length (lf)	-	1,200	1,200
Clearing and Grubbing (acres)	-	1	1
Excavation to Embankment (cy)	-	0	0
Embankment Fill (cy)	-	22,800	22,800
Closure Expected	-	Yes	Yes
Jones Valley and Silverthorn Area			
Number of Road Segments Affected	-	-	3
Length (lf)	-	-	1,600
Clearing and Grubbing (acres)	-	-	1
Excavation to Embankment (cy)	-	-	1,500
Embankment Fill (cy)	-	-	13,200
Closure Expected	-	-	No
Salt Creek Road			
Number of Road Segments Affected	-	4	5
Length (lf)	-	4,300	5,100
Clearing and Grubbing (acres)	-	1	1
Excavation to Embankment (cy)	-	4,100	5,500
Embankment Fill (cy)	-	31,700	33,100
Closure Expected	-	Yes	Yes
Remaining Road Relocations			
Number of Road Segments Affected	3	5	8
Length (lf)	2,500	3,500	5,200
Clearing and Grubbing (acres)	0.4	1	2
Excavation to Embankment (cy)	15	120	600
Embankment Fill (cy)	36,400	70,000	81,000
Closure Expected	Yes	Yes	Yes

Key:
- = not applicable
cy = cubic yards
lf = linear feet
SLWRI = Shasta Lake Water Resources Investigation

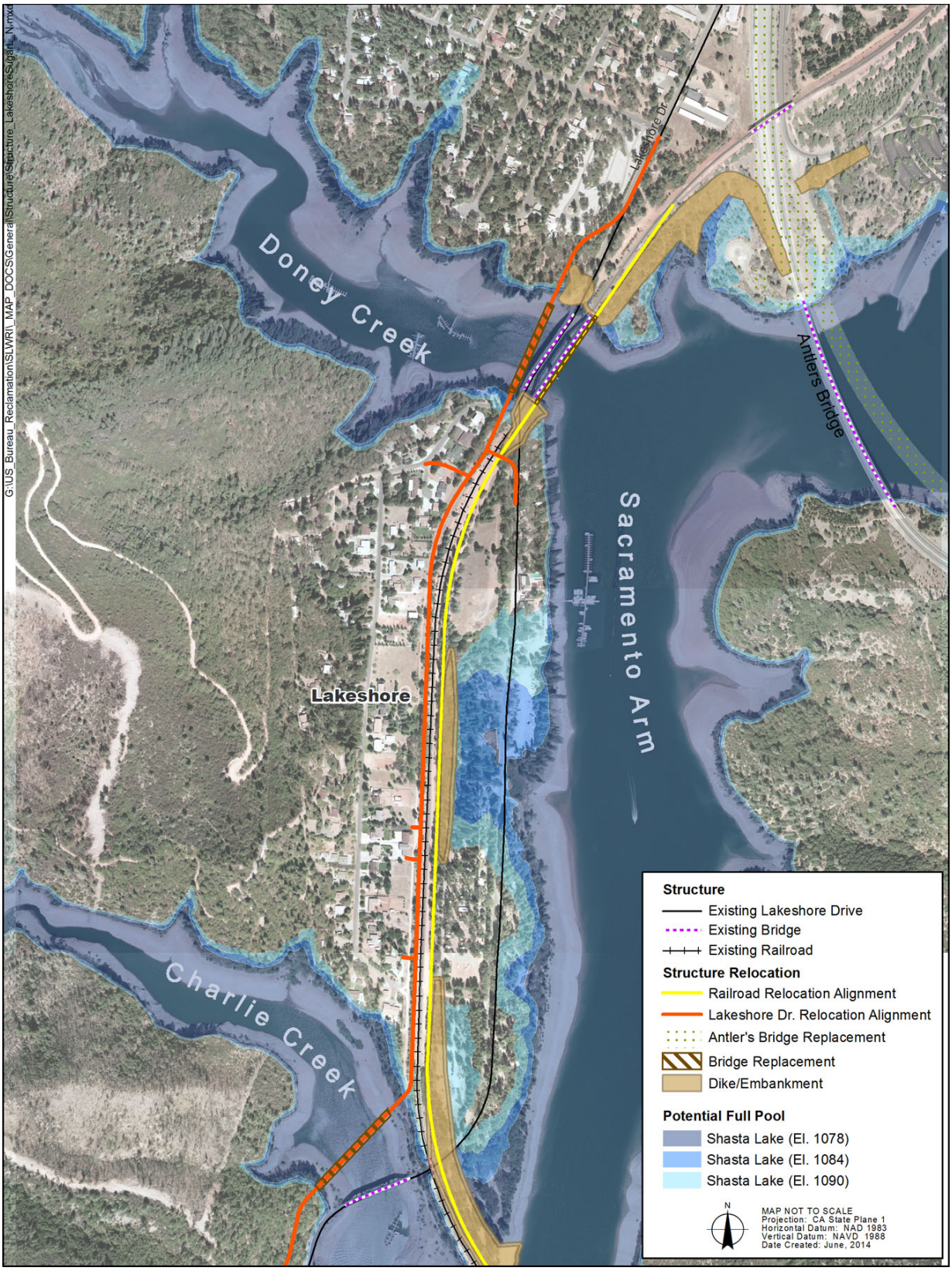

Figure 4-1 Lakeshore Area Roadway, Bridge, and Railroad Relocations for Comprehensive Plans (Antlers to Charlie Creek)

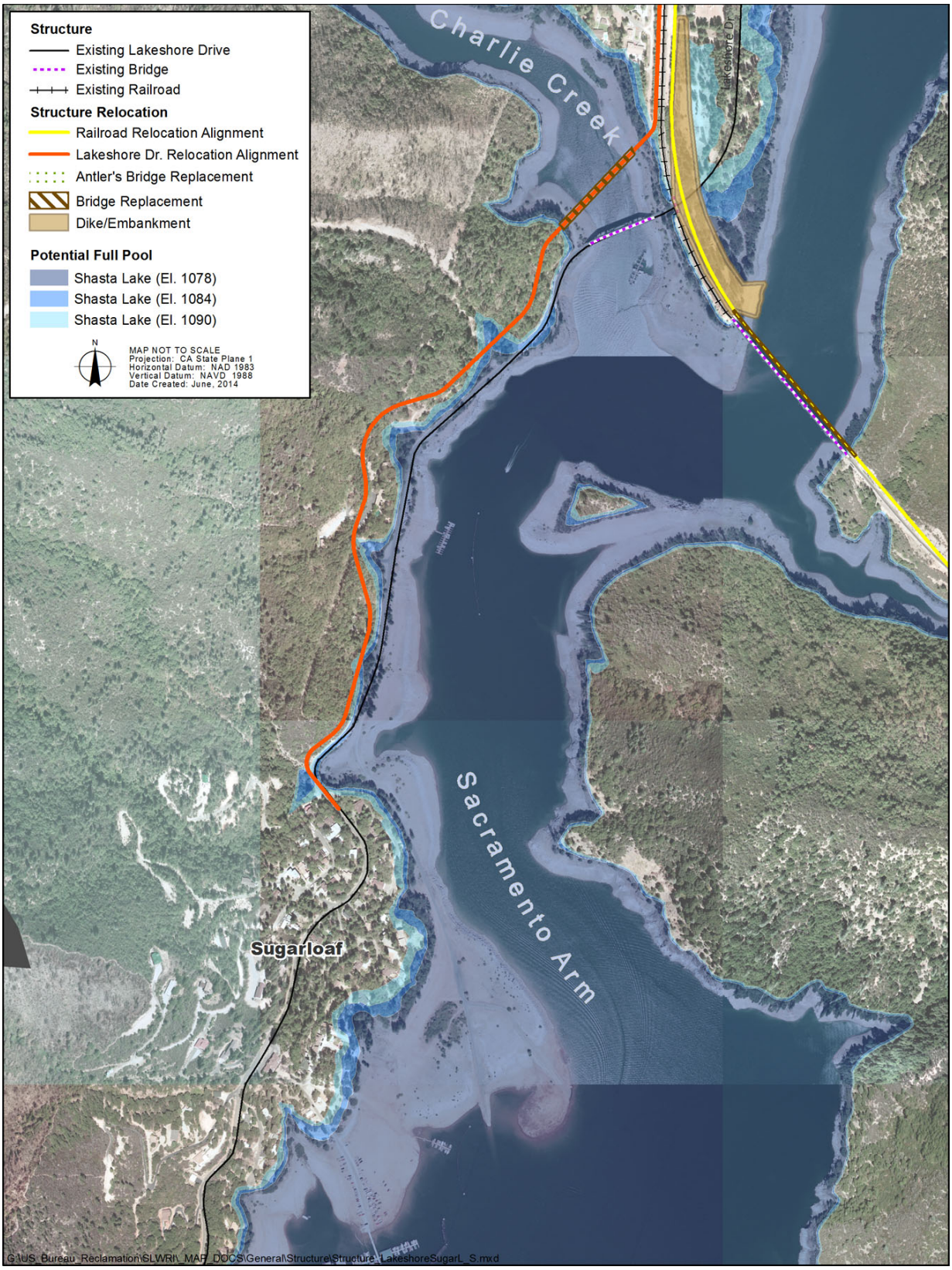

Figure 4-2 Lakeshore Area Roadway, Bridge, and Railroad Relocations for Comprehensive Plans (Charlie Creek to Sugarloaf)

Relocations for 6.5-foot and 12.5-foot Dam Raises

The analyses presented in this document were performed to support evaluations of the 18.5-foot dam raise. However, 6.5- and 12.5-foot dam raise scenarios are also under consideration. As a result of a 6.5- and 12.5-foot Shasta Dam raise, the new reservoir full pool elevations would be 1,078.2 (NAVD88) and 1,084.2 (NAVD88), respectively. Table 4-4 summarizes the road segments that would be inundated by the 18.5-foot dam raise, and continue to be inundated by 6.5- and 12.5-foot dam raises. It is estimated that approximately 1.5 miles of paved roadway and 0.8 miles of unpaved roadway would have to be constructed as a result of a 6.5-foot dam raise; 2.5 miles of paved roadway and 1.5 miles of unpaved roadway would have to be constructed as a result of a 12.5-foot dam raise.

Table 4-4. Impacts from 6.5-Foot and 12.5-Foot Dam Raises

Road Segment ID No.	Description	6.5-Foot Dam Raise Impact (Y or N)	12.5-Foot Dam Raise Impact (Y or N)
32	Unpaved road to waterfront	Y	Y
71	USFS Road 35N17–Conflict Point	N	N
76A	USFS Road 35N08–Lakeshore Drive	Y	Y
76B1	USFS Road 35N08–Lakeshore Drive	N	N
76B2	USFS Road 35N0–Lakeshore Drive	Y	Y
76C	USFS Road 35N08–Lakeshore Drive	N	N
77	USFS Road 35N17–Conflict Point	N	Y
81	USFS Road 35N08–Lakeshore Drive	Y	Y
93	Shasta County Road–Lakeshore Drive	Y	Y
99	Shasta County Road–Lakeshore Drive	N	Y
110	Shasta County Road–Lakeshore Drive	N	Y
109	USFS Road 35N14E–Antlers Road	N	N
34	USFS Road 34N09B–Lower Deck	Y	Y
39	USFS Road 34N09A–Shasta Yacht Club Road	Y	Y
96	USFS Road 35N60D–Hirz Road	N	Y
135	Shasta County Road 7H009–Gillman Road	N	Y
140	Shasta County Road 7H009–Gillman Road (McCloud River Bridge)	N	Y
141	Shasta County Road 7H009–Gillman Road (McCloud River Bridge)	N	Y
144	USFS Road 36N54–Bollibokka Club Road	N	N
174	USFS Road 34N09–Turntable Road	Y	Y
9	USFS Road 33N86–Jones Valley	N	N
20	Shasta County Road 5J050–Silverthorn Road	N	N

Table 4-4. Impacts from 6.5-Foot and 12.5-Foot Dam Raises (contd.)

Road Segment ID No.	Description	6.5-Foot Dam Raise Impact (Y or N)	12.5-Foot Dam Raise Impact (Y or N)
21	Shasta County Road 5J050–Silverthorn Road	N	N
156	South Access Road–Pit River Bridge	Y	Y
41	USFS Road 35N03–Salt Creek Road	N	N
47A	USFS Road 35N03–Salt Creek Road	N	Y
47B	USFS Road 35N03–Salt Creek Road	N	Y
61	USFS Road 35N03–Salt Creek Road (Didallas Creek Bridge)	N	Y
62	USFS Road 35N03–Salt Creek Road (Didallas Creek Bridge)	N	Y
166	USFS Road 35N17–Lower Salt Creek Road	Y	Y

Key:
ID = identification
N = no
USFS = U.S. Forest Service
Y = yes

Conclusions

The major road and road segment feasibility-level designs presented in this Engineering Summary Appendix are potential solutions to the inundation of existing roads as a result of an 18.5-foot dam raise. If an action alternative is authorized by congress, efforts will continue toward a more detailed design of these road modifications. Recommendations for additional analysis during future efforts include:

- Further coordination must be conducted with USFS and Shasta County. Consideration should be given to the need for some of the road segments to be above the new full pool elevation.
- Further coordination must be conducted with UPRR regarding the Lakeshore Drive relocation impacts on the existing and relocated UPRR tracks in the Lakeshore area.
- A current topographical survey for each road segment area would need to be conducted before final design.
- Geotechnical data and recommendations would need to be obtained specific to each road segment area, including, but not limited to clearing and site preparation, slope stability, excavation and shoring, subgrade preparation, embankment fill materials, compaction criteria, retaining wall earth pressures, and pavement sections.
- Additional design refinements and value engineering would need to be evaluated and integrated, as appropriate.

Bridge Relocations

Raising Shasta Dam would affect nine bridges around the reservoir to varying degrees. Some bridges would require complete removal and replacement, while others would require protection of the piers from inundation. The bridges affected by a dam raise were identified as vehicle bridges or railroad bridges.

Vehicle Bridge Replacements

As a result of raising Shasta Dam, the following local vehicle bridges would be replaced:

- Charlie Creek Bridge
- Doney Creek Bridge
- McCloud River Bridge
- Didallas Creek Bridge

Advance planning studies were prepared for the four bridges listed above (refer to Plates 27 through 30). The Second Creek Bridge, which was addressed in the PFR (Reclamation 2007f), is not included in the above list because the relocated replacement structure is anticipated to consist of a small culvert. Relocation costs for this bridge are included in the road relocations cost estimates.

Design Criteria and Assumptions

Criteria and assumptions considered in determining structure type and length for the replacement structures included the following:

1. Structure type based on cost and constructability.
2. Superstructure depth based on depth-to-span ratios of 0.04 for CIP prestressed concrete box girder structures, and .055 and 0.06 for multispan and single-span CIP reinforced-concrete box girder structures, respectively.
3. Four-foot minimum freeboard above full pool elevation 1,087.50 (18.5-foot dam raise, NGVD29).
4. Approach fill height into the river/creek channel limited to approximately 10 feet to minimize reduction of hydraulic opening.
5. Total bridge width of 31 feet, 6 inches, based on two 12-foot lanes with 2-foot shoulders (low volume road) and 1-foot, 9-inch barrier railing widths.
6. Use of driven steel piles and sheet piling for foundations/falsework and cofferdams, respectively.

Bridge Replacement Summary

Based on the above noted design criteria and assumptions, and considering horizontal alignments and profile grades developed for the relocated roadways, Table 4-5 summarizes proposed bridge characteristics for the four vehicle bridges requiring replacement.

Table 4-5. Vehicle Bridge Replacement Summary Table

Bridge Name	Bridge Type	Bridge Length (feet)	Structure Depth (feet-inches)	Bridge Deck Profile Grade Elevation (feet)	Vertical Clearance (freeboard) Above Full Pool (feet)
Charlie Creek Bridge	CIP Prestressed Concrete Box Girder	782	10-0	1,102.0	4.5
Doney Creek Bridge	CIP Prestressed Concrete Box Girder	760	10-0	1,102.0	4.5
McCloud River Bridge	CIP Reinforced-Concrete Box Girder	490	8-3	1,100.25	4.5
Didallas Creek Bridge	CIP Reinforced-Concrete Box Girder	115	7-0	1,099.0	4.5

Key:
CIP = cast-in-place

Construction Quantities

Construction quantities for major items of work are summarized in Table 4 6. Demolition of the four bridges would produce about 9,900 cubic yards of waste material.

Table 4-6. Construction Quantities for Vehicle Bridge Construction

Item Description	Charlie Creek Bridge	Doney Creek Bridge	McCloud River Bridge	Didallas Creek Bridge
Demolished Material (cy)	3,500	3,300	2,300	800
Excavation (cy)	1,200	550	820	440
Backfill (cy)	480	400	530	180
Number of Piers	4	4	4	0
Pier Diameter (lf)	14	14	6	N/A
CIP Structural Concrete (cy)	3,530	3,320	2,320	760
Bar Reinforcing Steel (lbs)	1,124,000	1,006,000	757,000	208,000

Table 4-6. Construction Quantities for Vehicle Bridge Construction (contd.)

Item Description	Charlie Creek Bridge	Doney Creek Bridge	McCloud River Bridge	Didallas Creek Bridge
Prestressing Steel (lbs)	26,000	25,000	N/A	N/A
Class 140 Piles (each)	24	24	24	24
Class 140 Piles (lf)	1,080	1,080	1,080	1,080
24-inch Cast-In-Steel-Shell Piles (each)	72	72	32	N/A
24-inch Cast-In-Steel-Shell Piles (lf)	3,600	3,600	1,600	N/A

Key:
CIP = cast-in-place
cy = cubic yard
lbs = pounds
lf = linear feet
N/A = not applicable

Construction Activities

Most of construction would take place during the low-water season, and is expected to last about 12 months. The waterway would remain clear for navigation during construction. Bridge construction would begin with piers and abutments. To allow underwater construction of pier foundations, steel pile shells would be driven into the lake bed to create a temporary cofferdam. It may be necessary to dewater the shells during drilling if water seeps in. A hole would then be drilled to the specified foundation depth. Reinforcing steel would be installed within the shells before concrete was poured. After completion of the piers and abutments, construction of the superstructure and bridge deck would begin via the balanced cantilever method. This process entails forming and constructing the horizontal structure outward from the piers in each direction, in equal (balanced) proportions, until the superstructure/deck segments meet at midspan.

Traffic would continue on the existing bridges during construction. It is likely that barges would be used extensively for bridge foundation construction, bridge assembly, transport of materials, workers, and equipment, and demolition of the existing bridges. Concrete would be poured from barges. A staging area would be required on the lakeshore, from which barges could be loaded and unloaded.

Fender's Ferry Bridge Modifications

The Fender's Ferry Bridge is a three-span structure comprising a steel plate girder superstructure supported on riveted steel tower bents and reinforced-concrete piers with spread footings. As a result of differences in West River and East River bank topography, the Pier 3 steel tower is supported at a much lower

elevation than the Pier 2 tower. Thus, considering a full pool elevation of 1,087.50 NGVD29, the Pier 3 steel tower would be inundated.

Proposed Modifications

A preliminary modification concept previously proposed consisted of constructing a concrete box extension to protect the existing steel tower (Reclamation 2004a). However, considering the narrow geometry of the concrete pier and steel tower, construction of a concrete box around the existing steel tower would preclude adequate future inspections and likely result in maintenance problems. Thus, it was recommended that the existing reinforced-concrete pier and footing be enlarged and extended, and the existing steel tower be modified to prevent inundation as a result of the higher joint-use pool level Proposed modifications would include the following:

- Enlargement of the existing reinforced-concrete footing
- Enlargement and extension of the existing reinforced-concrete columns and pier wall to elevation 1,096.16 NGVD29
- Removal of approximately 24 feet of the lower portion of the Pier 3 steel tower (based on location of existing cross bracing)
- Reuse of the existing steel bearing assemblies

Construction activities would likely be completed from the existing embankment without the need to construct cofferdams around the pier because the average water surface elevations are below the existing Pier 3 bottom of footing elevation for all months, with the exception of April and May. Construction of temporary bents to support the superstructure would be necessary to facilitate construction of the pier modifications. During construction activities, temporary traffic controls may be needed to facilitate delivery of materials and construction of temporary support bents. Refer to Plate 31 for the Advance Planning Study illustrating the proposed modifications.

Construction Quantities

Construction quantities for major items of work are summarized in Table 4 7.

Table 4-7. Fender's Ferry Bridge Construction Quantities

Item Description	Quantity
Excavation (cy)	75
Temporary Superstructure Support (lump sum)	1
Concrete Surface Preparation (sf)	2,150
Drill and Bond Dowels (each)	540
Structural Concrete (cy)	230
Bar Reinforcing Steel (lbs)	66,400
Removal of Portion of Existing Steel Tower (lump sum)	1
Structural Steel (lbs)	130
Lead Paint Containment (lump sum)	1

Key:
cy = cubic yard
lbs = pounds
sf = square feet

Union Pacific Railroad Bridge Replacements

As a result of the raising of Shasta Dam, the following UPRR bridges would need modification or replacement:

- Pit River Bridge (modification)
- Sacramento River 2nd Crossing Bridge (replacement)
- Doney Creek Railroad Bridge (replacement)

Pit River Bridge Pier Modification

The existing bridge was designed and built by Reclamation in 1938 as part of the relocated highway and railroad facilities required for the construction of Shasta Dam. The bridge is still owned by Reclamation. Plate 32 is a copy of the original design drawing showing the bridge plan, elevation, and sections. The bridge is a multipurpose structure, carrying both UPRR and Interstate 5 traffic. The bridge is both a steel-through truss and a deck truss. UPRR and Caltrans have joint operation and maintenance responsibility. The bridge main structure is approximately 2,754 feet long; including the approach spans, it is approximately 3,588 feet long. The new top of full pool elevation was set based on providing a minimum 4-foot freeboard below the existing truss bridge low chord near Abutment 2.

The elevation at the top of existing Pier 3 concrete is 1,069.67 (NAVD88). (Note that elevations presented in this section are based on the NAVD88 datum, unless otherwise noted). This elevation matches the existing top of joint-use (full pool) elevation of 1,069.67. The elevation at the top of existing Pier 4 concrete is 1,072.19, which is 2.52 feet above the existing top of joint-use (full pool) elevation. The new top of joint-use (full pool) elevation will be 1090.2, which would inundate the existing bridge bearings and low-chord steel truss members at both piers 3 and 4. To keep the existing steel bearings and lower portions of the steel truss members from being submerged, a watertight concrete

tub structure would be required. Elevations for the top of the bearing protection structure and major construction quantities for Pit River Bridge modifications under each proposed dam raise are shown in Table 4-8. The remainder of the Pit River Bridge structure would not be affected by the proposed dam raise. This reinforced-concrete structure would be attached to the top of the existing concrete Piers 3 and 4, as shown in Plate 33. The structure footprint is rectangular and is approximately 151 feet long by 52.5 feet wide. From the edge of the existing pier, the interior base of the tub extends 8 feet and the side slopes approximately match the slope of the existing steel truss members. Structure thickness varies from 2 feet to 8 feet. The top of the concrete structure is set to be 4 feet above the new full pool elevation. Four-inch-diameter holes would be drilled through the existing concrete for installation of bundled No. 11 bars to anchor the structure to the existing piers.

Table 4-8. Bearing Protection Structure Physical Features for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Top of Bearing Protection Structure Elevation (feet)[1]	1082.2	1088.2	1094.2
Concrete (cy)	2,100	2,900	4,000
Reinforcing Steel (lbs)	618,000	876,000	1,200,000
Core Drilling (lf)	2,200	2,200	2,200

Note:
[1] Bearing protection structure elevations are based on the North American Vertical Datum of 1988
Key:
cy = cubic yard
lbs = pounds
lf = linear feet
SLWRI = Shasta Lake Water Resources Investigation

Piers 3 and 4 Protection Sump Pumps Since the existing bridge superstructure and top of piers are exposed to the elements, a structure cover would not be required; however, sump pumps would be installed that would keep any water away from the bearings. The following assumptions have been made:

- Existing highway drains would be redirected away from the sump
- 120-volt (V) alternating current would be available
- Telephone line would be available for the requested alarm system
- Railroad tracks would be built on open style supports that would allow passage of water
- Two 2.5-by-2.5-foot sumps in the concrete would be provided

Two submersible sump pumps would be used to keep the water level in the new concrete protective structure from rising near the bearings. Each pump would discharge into 2-inch-diameter copper tubing, and the two lines would tee into a 2.5-inch-diameter line that would follow the slope upward to the discharge point. Check valves and ball valves would prevent pumped water from draining out of the line back into the sump, and would isolate the sump. Protective grates would prevent large objects from entering the sump area. A high-water alarm would be used to alert personnel someone if the pumps did not function properly. An electrical engineer would provide power and alarm designs. Brief research showed a 2006 peak rainfall in Redding, California, of 5 inches per hour. The pumps were sized for this peak level even though the tub structure would be partially covered because winds and other drainage problems could cause larger amounts of water to enter the sump. It was assumed that the current bridge drains would be redirected to discharge outside the protective structure. If the bridge drains cannot be redirected, larger pumps may be needed.

Union Pacific Railroad Sacramento 2nd Crossing and Doney Creek Bridge Replacement

The existing Sacramento River 2nd Crossing and Doney Creek railroad bridges were designed and built by Reclamation, and are operated and maintained by UPRR. The bridge superstructures consist of deck truss bridges with a single track, and the piers and abutments were designed to accommodate a future parallel single-track superstructure. Portions of both bridges would be submerged for any reservoir raise and would need to be replaced with new higher superstructures. Structural analyses of the existing bridge piers under design earthquake loads indicated that new bridge piers would be required. Therefore, the existing bridges will be removed and replaced with new bridges. The feasibility-level designs would permit uninterrupted rail service during construction.

New bridge superstructures and substructures were designed to accommodate a single track according to the American Railway Engineering and Maintenance of Way (AREMA) code (2007). The UPRR office in Omaha, Nebraska, indicated a preference for a deck girder superstructure rather than a through-truss or girder for both replacement bridges. The proposed new bridge superstructure would be a composite superstructure consisting of steel plate girders and a reinforced concrete deck. In general, the bridge superstructures would be designed to be continuous over the piers. However, with a requirement for 16 feet of vertical clearance underneath Span 2 for the Sacramento River 2nd Crossing Bridge, with a minimum width of 30 feet, to allow for the passage of houseboats, Span 2 is a simply supported span. No minimum clearance for houseboat traffic would be required for the Doney Creek railroad bridge. Large-diameter concrete columns with drilled shafts would support the superstructure and be founded on bedrock. The Sacramento River 2nd Crossing railroad bridge would require nine spans with a total length of 982 feet between concrete abutments (see Plates 34 and 35). The Doney Creek railroad bridge would require five spans with a total length of 537.5 feet

between concrete abutments (see Plates 36 and 37). Construction quantities for major items of work for these features are summarized in Table 4 9.

Table 4-9. Railroad Bridge Construction Quantities

Item	Sacramento River 2nd Crossing Bridge Quantities	Doney Creek Bridge Quantities
Steel Truss Bridge Removal (lbs)	3,300,000	2,000,000
Concrete Removal (cy)	15,310	4,570
Excavation (cy)	2,100	630
Backfill (cy)	1,900	2,200
Concrete , including Shafts (cy)	11,700	7,080
Reinforcing Steel (lbs)	3,420,000	1,760,000
Drilled Shafts, 6-foot diameter (lf)	130	230
Drilled Shafts, 8-foot diameter (lf)	110	N/A
Drilled Shafts, 12-foot diameter (lf)	120	N/A
Drilled Shafts, 14-foot diameter (lf)	N/A	416
Drilled Shafts, 16-foot diameter (lf)	280	N/A
Structural Steel in Girders (lbs)	4,750,000	2,250,000

Key:
cy = cubic yard
lbs = pounds
lf = linear feet
N/A = not applicable

The proposed relocation of the railroad bridges would require realigning the railroad tracks between the two bridges. This realignment would parallel the existing tracks with a 25-foot offset to the east. Proposed horizontal and vertical alignments for the new railroad tracks between the two new railroad bridges are shown in Plate 38. Construction quantities for major items of work for the railroad realignment between the UPRR bridges are summarized in Table 4-10.

Table 4-10. Railroad Realignment Construction Quantities

Item	Railroad Realignment Between Bridges
Length of Track Realignment (lf)	8,400
Removal of Existing Railroad Track (tons)	370
Ballast Removal (tons)	6,400
Excavation (cy)	35,000
Compacted Backfill (cy)	7,500
Railroad Track (tons)	390
Concrete Railroad Ties (each)	4,200
Ballast (tons)	26,500

Key:
cy = cubic yard
lf = linear feet

Utilities and Miscellaneous Minor Infrastructure

As a result of the proposed Shasta Dam raise, existing infrastructure inundated by the increase in full pool elevation would need to be removed and/or relocated. The following sections discuss existing reservoir area utilities, design criteria, and relocations approach.

Existing Utilities and Minor Infrastructure Description

As previously stated, infrastructure was inventoried around the perimeter of the reservoir that would be impacted by the proposed 18.5-foot dam raise (Reclamation 2003a, 2007i). This 18.5-foot dam raise corresponds to a 20.5-foot raise in the full pool because of associated modifications in operation of the dam (new full pool elevation 1,090.2, NAVD88). The identified inventory items included bridges, buildings, dams, gas/petroleum facilities, hazardous materials, miscellaneous objects, parking areas, power towers, railroads, and roads. Also on the inventory are potable water, power distribution, telecommunication, and wastewater facilities.

A majority of the infrastructure adjacent to Shasta Reservoir is located along the Interstate 5 corridor (see Plates 1 and 2). The largest potentially impacted residential developments near the reservoir are in the Lakeshore and Sugarloaf areas in the northern part of the Sacramento River arm (see Plate 2). The main facilities in the Pit River arm are at Bridge Bay Marina and in the Jones Valley and Silverthorn areas. The upper Pit River arm is very remote; the only significant infrastructure is the Fender Ferry Bridge and Pit 7 Dam at the upstream end. Main development along the McCloud River arm includes several USFS campgrounds and a marina, the Bollibokka Club, and some summer-use cabins. The Squaw Creek Arm has the least infrastructure, with the old Bully Hill Mine and a few cabins.

Only impacts to gas/petroleum, potable water, power distribution, telecommunications, and wastewater facilities will be discussed in this Engineering Summary Appendix; other types of facilities may be listed in the tables for completeness but are not discussed in detail. Following is a description of existing facilities and a discussion of their distribution around the perimeter of the lake.

Gas/Petroleum Facilities

The inventory concluded that no natural gas facilities are present in the inventory area (Reclamation 2007i). Home heating and cooking gas used in the area are exclusively propane. Propane tanks for homes and businesses were not included in the inventory because they are portable and also may be leased. The gas/petroleum facilities that were identified were primarily gasoline and diesel fuel storage tanks. The majority of the tanks were used to store fuel for boats. The tanks varied in size from approximately 1,000 gallons to 4,000 gallons.

Potable Water Facilities

Potable water is provided in one of three ways in the inventory area: (1) water may be provided by Shasta County through county service areas (CSA); (2) by mutual water companies; (3) by individual residence or group wells. The two CSAs in the inventory area are CSA 2, which operates in the Sugarloaf community, and CSA 6, which provides water to the Silverthorn summer homes. Mutual water companies are cooperative or mutual associations that furnish water to a resort or development. Fifteen mutual water companies were identified in the inventory area. Wells serving groups of homes or resorts were also identified in the inventory (Reclamation 2007h). Individual homes or businesses that were not confirmed to be associated with CSAs, mutual water companies, or group wells were assumed to have an individual well.

Power Distribution Facilities

All electric power service in the inventory area is provided by PG&E. Power lines are typically routed overhead on poles or towers, although a portion of the lines serving individual businesses, homes, and cabins is routed underground. Power lines are also frequently attached to bridges when routed over rivers and lake inlets. Voltage of local distribution lines is typically 12 kilovolts (kV) while the voltage of high-voltage transmission lines is typically 60 kV to 230 kV. Service to individual homes and businesses is typically 120 to 480V.

Telecommunications Facilities

Telecommunication services in the inventory area are primarily provided by American Telephone and Telegraph (AT&T). Qwest Communications was listed with AT&T on one line but the continued ownership was not confirmed. One cable television operator, DCA Cable, was reported to have facilities in the inventory area but this was not confirmed and these facilities were not located. Telecommunication lines in the area are either copper wire or fiber optic cable, which, similar to power lines, may be overhead, underground, or attached to bridges. It should be noted that no cell phone towers were identified in the inventory area (Reclamation 2007h). Also, AT&T confirmed that there were no transcontinental fiber-optic lines in the inventory area.

Wastewater Facilities

No large wastewater collection or treatment systems are located in the inventory area. Wastewater treatment is accomplished using septic tank/leach field systems or vault/pit toilets. At several larger resorts, three to five cabins or buildings were routed to a single septic system. In all other cases, individual homes, cabins, or businesses were routed to individual septic systems. Campgrounds and public restrooms were either septic tank/leach field systems or vault/pit toilets (Reclamation 2007h).

Design Criteria

The following sections discuss the demolition and design criteria for relocated utilities and minor infrastructure within the SLWRI study area.

Demolition Criteria for Existing Utilities and Minor Infrastructure

A set of criteria was established for each category of utilities to determine whether or not the utilities would need to be demolished.

Buildings Knowledge of the relocation status of all potentially impacted buildings is critical to accurately assessing the extents of utilities and minor infrastructure that would require removal or relocation. In addition, an accurate accounting of the extent of relocated utilities and minor infrastructure cannot be determined unless the ultimate location of the relocated buildings is known.

Demolition Criteria

Nonrecreation Structures Under all proposed dam raise alternatives, nonrecreational residential and commercial structures affected by inundation would require demolition. Any structure that is inundated or within 3 vertical feet of the inundation line would be demolished along with its associated utilities unless otherwise specified. Demolished residences would not be relocated. Table 4-11 shows the total volume of demolished material for nonrecreational structures by each dam raise alternative.

Table 4-11. Nonrecreation Structures Demolition Quantities for SLWRI Dam Raise Alternatives

Demolition	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Structure Demolition (square feet)	8,700	21,500	27,000
Total Volume of Material (cubic yards)	1,300	3,200	4,000

Key:
SLWRI = Shasta Lake Water Resources Investigation

Recreation Structures Any recreation building that is inundated or within 3 vertical feet of the inundation line would be demolished along with its associated utilities. All demolished recreation buildings and their associated facilities would be relocated, with the exception of recreation facilities that would be abandoned. More detail on these requirements is discussed in a later section, “Recreation Facilities.”

Demolition Practices If buildings are inundated, structures would be demolished by appropriately licensed contractors. All utilities would be disconnected, capped, and/or removed per permit requirements and governing utility standards. The structure and foundation would then be demolished. Asbestos material, if discovered, would be removed and taken to an approved landfill for disposal per permit requirements. General demolition waste would also be removed and trucked to an approved landfill.

A typical structure demolition crew would include an excavator with operator, a 50- to 70-yard end-dump truck with operator, a bobcat or similar small front-loader with operator, and two laborers. A typical house would reduce to about 3

to 4 feet high (5 to 6 feet for two-story houses) of fluffed material within the foundation footprint. Typical foundation construction is assumed to be a concrete stem wall around the perimeter of a structure with an overall height of 5 feet and thickness of 1 foot. Costs associated with nonrecreation structures demolition are included as part of the utilities and miscellaneous minor infrastructure cost estimate discussed in Chapter 5. Costs associated with recreation structures demolition are included as part of recreation facilities cost estimate also discussed in Chapter 5.

All structures subject to demolition must file a Demolition Declaration with the Shasta County Department of Resource Management's Building Division, pursuant to Section 19827.5 of the State Health and Safety code. Structure demolitions associated with this public project would require filing an Asbestos National Emission Standards for Hazardous Air Pollutants (NESHAP) Notification of Demolition and Renovation. An asbestos survey must be completed by a licensed and appropriately registered contractor, and the completed Asbestos NESHAP Notification must be sent to the U.S. Environmental Protection Agency (EPA). Any asbestos abatement would be as required by the agency. A copy of the Asbestos NESHAP Notification must be attached to the Demolition Declaration filed with Shasta County.

Grading or excavating activities associated with the structure demolitions for public works projects are typically exempt from the Shasta County Department of Resource Management's Environmental Health Division (EHD) Grading Permit under Shasta County Code 12.12.050. An Application for Grading Permit, however, must be filed with EHD to indicate the exemption.

Septic Systems

Demolition Criteria The Shasta County Development Standards state the following (Shasta County 1997):

Disposal area shall not include:

> *Land closer than 200 feet to a lake or reservoir, measured from the high water line or 100 feet if down slope from the lake or reservoir.*

These criteria would be applied to the septic system demolition criteria, indicating that septic systems within 200 feet of the new full pool waterline or 100 feet downslope of the new full pool waterline would be demolished.

Demolition Practices

Wastewater Pipes Abandon in place wastewater pipes 6 inches in diameter and smaller. Fill pipes larger than 6 inches with sand and abandon in place per Shasta County Public Works Department requirements (Shasta County 1997).

Septic System and Vaults/Pits Pump out septic tank, fill with sand, and abandon in place per Shasta County EHD requirements (Shasta County 1997). Pump out vaults/pits, fill with sand, and abandon in place. Abandon leach fields in place. Demolish associated restroom building and contents and take to an approved landfill. A Shasta County permit is required.

Water System

Demolition Criteria The water systems affected by the inundation line consist of either wells or waterlines.

Wells Several wells do not fall within the inundation line but are close to the shoreline at the new full pool. If these wells appear to be associated with buildings that would be demolished, they would also be demolished. If these wells are associated with a water system or with buildings that would not be demolished, they would remain in place.

Waterlines Waterlines that would be relocated would be moved to a minimum of 20 feet from the shoreline at the new full pool. Several waterlines do not fall within the inundation line but are close to the shoreline at the new full pool and are located at a depth below the water level. These water lines would remain in place.

Demolition Practices

Water Pipes Abandon in place water pipes 6 inches in diameter and smaller. Fill pipes larger than 6 inches with sand and abandon in place per Shasta County Public Works Department requirements (Shasta County 1997).

Wells Fill wells with sand and abandon in place per Shasta County EHD requirements (Shasta County 1997). A Shasta County permit is required.

Pump/Lift Station Demolish building and contents and take to an approved landfill. Abandon associated underground piping in place. Reseed area.

Power and Telecommunication Facilities

Demolition Criteria Most power lines and telecommunication lines are along the same alignment because they typically use the same power pole. The majority of the power lines and telecommunication lines are overhead with a few underground lines.

Any low-voltage power lines, telecommunication lines, or power poles that are inundated or within 50 feet from the new full pool elevation would be relocated a minimum of 50 feet from the new full pool elevation.

Any high-voltage power lines or power towers that are inundated or within 100 feet from the new full pool elevation would be relocated a minimum of 100 feet from the new full pool elevation.

Demolition Practices

Power and Telecommunication Lines Demolish power and telecommunication lines in accordance with the National Electrical Safety Code (NESC) and California Public Utilities Commission General Order 95 (CPUC GO 95) requirements. Remove all poles and wires and dispose of at an approved landfill. Excavate and remove connection point to underground wires to 30 inches below grade and abandon remaining underground wires in place.

Gas/Petroleum Facilities and Miscellaneous Objects

Demolition Criteria Demolish and relocate any gas/petroleum facilities and/or miscellaneous objects that are inundated.

Demolition Practices

Fuel Tanks Excavate and remove existing underground tanks and all associated piping. Perform hazardous material testing and removal, as required, in accordance with Title 23 of the California Code of Regulations, Division 3, Chapter 16, Underground Tank Regulations (State of California 2005), and in accordance with Shasta County EHD requirements (Shasta County 1997). A Shasta County permit is required.

Design Criteria and Assumptions for Relocated Utilities and Minor Infrastructure

Facilities to be relocated would be designed and constructed in accordance with all applicable Federal, State, and local codes and requirements. Demolished facilities would not be reused to construct relocated facilities. Relocated facilities would be of the same types, sizes, and materials as the existing facilities to be replaced, where in compliance with applicable codes and requirements. Additional criteria for specific facilities are discussed in the following sections.

Gas/Petroleum Facilities Relocated fuel storage tanks would be designed and constructed in accordance with Title 23 of the California Code of Regulations, Division 3, Chapter 16, Underground Tank Regulations (State of California 2005); the Uniform Fire Code (NFPA 2006); California Air Resources Board, Shasta County Development Standards, Section 6.7, and Shasta County EHD requirements (Shasta County 1997).

Potable Water Facilities Relocated potable water facilities would be designed and constructed in accordance with Shasta County Development Standards, Chapter 7, and the following:

- Relocated wells would acquire and would meet conditions of a Shasta County EHD Well permit.
- For cost estimating purposes, wells would be assumed to be 200 feet deep and produce 15 gallons per minute (gpm).

- Water main piping smaller than 4 inches in diameter would be American Society for Testing and Materials (ASTM) 1785 Schedule 40 PVC. Water main piping 4 inches in diameter and larger would be PVC – American Water Works Association (AWWA) C900, Class 150, standard dimension ratio (SDR) 18, or Ductile Iron – AWWA C151, Class 51 or 50.

- Water main piping serving fire hydrants would be a minimum of 6 inches in diameter, or as required.

- Water main piping serving only service connections would be a minimum of 2 inches in diameter, or as required.

- Individual service connections are assumed to be 0.75-inch- or 1-inch-diameter pipe.

- Blowoffs would be provided at all low points and on any main with dead-ends more than 10 feet past a fire hydrant.

- Combination air valves would be installed on all high points. Valves would be a minimum of 1 inch in diameter or as required.

- Minimum depth of cover would be 3 feet for water mains.

Power Distribution Facilities All safety and operational requirements for relocated power lines would comply with NESC, CPUC-GO 95, CPUC-GO 131(d) regulations. Underground lines would have a minimum of 30 inches of cover and comply with CPUC-GO 128.

Telecommunications Facilities All safety and operational requirements for relocated telecommunication lines would comply with NESC and CPUC-GO 95 regulations. Underground lines would have a minimum of 30 inches of cover and comply with CPUC-GO 128.

Wastewater Facilities Relocated wastewater facilities would be designed and constructed in accordance with Shasta County Development Standards, Chapter 5 (Shasta County 1997), and the following:

- Relocated septic systems would acquire and meet conditions of a Shasta County EHD Sewage Disposal System Permit.

- For cost estimating purposes, septic tanks would be assumed to have a 1,100-gallon capacity, and leach fields would be assumed to be 100 feet long and 3 feet deep by 3 feet wide. Septic tanks would have a minimum of two compartments.

- Pipe would be PVC ASTM 3034, SDR 35 with Ring-Tite or Fluid-Tite joints, and would be a minimum of 6 inches in diameter, or as required.

General Facility Relocations Approach

The following sections discuss the general facility demolition and design criteria for relocated utilities and minor infrastructure within the SLWRI study area. Relocation quantities of utilities and minor infrastructure are shown for each proposed dam raise in Table 4-12.

Table 4-12. Utilities and Minor Infrastructure Relocation Quantities for SLWRI Dam Raise Alternatives

Utility Type	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Potable Water Facilities			
Length of Waterlines Relocated (lf)	7,200	8,500	11,000
Wells/Tanks Relocated (number)	12	13	10
Pump Stations Relocated (number)	2	2	3
Length of Waterline Demolished (lf)	8,900	11,200	14,800
Wells/Tanks Demolished (number)	16	28	25
Pump Stations Demolished (number)	2	2	3
Gas/Petroleum Facilities			
Tanks Relocated (number)	7	10	10
Tanks Demolished (number)	7	10	10
Wastewater Facilities			
Septic Systems Relocated[1] (number)	14	19	19
Vault/Pit Toilets Relocated (number)	2	2	2
Pump Stations Relocated (number)	1	1	1
Length of Wastewater Pipe Relocated (lf)	400	400	430
Septic Systems Demolished[2] (number)	211	239	266
Vault/Pit Toilets Demolished (number)	2	2	2
Pump Stations Demolished (number)	2	2	2
Length of Wastewater Pipe Demolished (lf)	2,300	2,300	2,400
Package Wastewater Treatment Plants[3] (number)	Up to 6	Up to 6	Up to 6
Power Distribution Facilities			
Power Lines Relocated (lf)	34,520	40,565	42,050
Power Towers Relocated (number)	11	11	11
Power Lines Demolished (lf)	33,227	40,565	43,045
Power Towers Demolished (number)	26	26	26

Table 4-12. Utilities and Minor Infrastructure Relocation Quantities for SLWRI Dam Raise Alternatives (contd.)

Utility Type	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Telecommunications			
Copper Wire Relocated (lf)	27,900	30,200	33,400
Fiber-Optic Cable Relocated (lf)	4,300	5,800	5,800
Copper Wire Demolished (lf)	23,600	27,800	31,200
Fiber-Optic Cable Demolished (lf)	3,600	5,200	5,200

Notes:
[1] Does not include septic systems replaced with new sewer connections.
[2] Includes demolition of septic systems to be relocated, replaced with new sewer connections, and removed without relocation or replacement.
[3] Includes additional lift stations, force main, laterals, and holding tank pumps/valves not shown.
Key:
lf = linear feet
SLWRI = Shasta Lake Water Resources Investigation

Fuel Storage Tanks

Relocated fuel tanks would be designed and constructed in accordance with Title 23 of the California Code of Regulations, Division 3, Chapter 16, Underground Tank Regulations (State of California 2005); Uniform Fire Code (NFPA 2006); California Air Resources Board; Shasta County Development Standards, Section 6.7; and Shasta County EHD requirements, as noted in Section C (Shasta County 1997). The tanks would be located in cleared areas with code-mandated clearances from other facilities. For reference, 4,000-gallon capacity tanks may be assumed to be approximately 8 feet in diameter and 15 feet long.

Potable Water and Wastewater Piping

Relocated piping for potable water and wastewater facilities would follow the design criteria previously described and would typically be located within established roadways consistent with Shasta County Development Standards (Shasta County 1997). Pipe trench sections would meet Shasta County Development Standards (Shasta County 1997). Typical construction characteristics for potable water and wastewater piping are also described in the SLWRI Utilities and Miscellaneous Minor Infrastructure Technical Memorandum (Reclamation 2007h).

Potable Water Wells

Potable water wells would be designed and constructed per Shasta County EHD requirements (Shasta County 1997). Wells would be sited with the required separation from septic systems, would be drilled to an approximate depth of 200 feet, and would have a capacity of approximately 15 gpm. The actual depth and capacities of specific wells would depend on groundwater table elevation and

soil permeability characteristics at the particular site. Residential wells would typically include a bladder tank and a small well pump.

Wastewater Treatment Facilities

An expanded discussion of the approach and methodology for relocation of wastewater treatment facilities is presented below.

General Considerations With the proposed full pool water surface raised approximately 20.5 feet to elevation 1,090.2 (NAVD88), a number of wastewater facilities, primarily septic systems, would be directly inundated. In addition, some existing septic systems would no longer meet Shasta County EHD requirements for separation from the lake (Shasta County 1997). This is significant because homes and businesses without permitted septic systems cannot be occupied and would require abandonment and demolition.

The approach to relocation of wastewater treatment facilities in the project area is to either construct new septic systems on the property of an impacted home, where feasible, or to define a possible wastewater treatment plant alternative to abandoning homes that do not meet Shasta County requirements for septic system separation from the lake. New septic systems would be constructed per Shasta County Development Standards (Shasta County 1997). Tanks would have two compartments and would be approximately 11 feet long, 5 feet high, and 5 feet wide, and buried with about 3 feet of cover. Leach fields would typically be 100 feet long and 3 feet wide by 3 feet deep. The actual size of specific septic tanks and leach field systems would depend on the size of the homes or businesses and the percolation characteristics of soils in the leach field area.

The locations where the possible wastewater treatment plant approach would be implemented are described in Section E of the *SLWRI Utilities and Miscellaneous Minor Infrastructure Technical Memorandum* (Reclamation 2007h). The general wastewater treatment plant concept includes a pressurized sewer collection system to transport wastewater flows to a number of centralized package wastewater treatment plants.

Plant Siting Considerations The following discussion defines wastewater treatment plant siting considerations, one package wastewater treatment plant alternative, other possible alternatives, and various assumptions that were made. Treatment plant siting is generally based on the following factors:

- Distance from the effluent discharge location. Locations as close to the effluent discharge location as possible are desirable.
- Treatment plant equipment layout (size of lot needed).
- Method of wastewater collection (gravity versus pumped). Maximizing gravity flows to minimize the pumping requirements is desirable.

- Environmental impacts to the potential site. Environmental impacts to the receiving water body, especially how the water quality management plan of the area is affected.
- Availability of power and other utilities.
- Accessibility to roads.
- Flooding potential and earthquake fault locations.
- Construction costs of building at a particular site.
- Site maintenance, including parking.
- Operator safety and neighborhood safety.

Specific plant siting issues applicable to the proposed project are described in this paragraph. It is generally assumed that most of the wastewater collection system (including individual laterals to homes) would need to be pumped because of the mountainous terrain and the likelihood that few sites suitable for pump stations or wastewater treatment facilities are located near Shasta Reservoir. If suitable sites are available near Shasta Reservoir, this would decrease pumping costs. No attempt has been made to evaluate the water quality impacts of wastewater treatment effluent discharge to Shasta Reservoir.

Odor control is another important factor to consider for plant siting. Odors from the wastewater facilities have the potential to affect nearby residents. Buffer zones are often used to deal with this problem. A buffer zone is a defined distance from wastewater facilities to the closest neighbor. This distance is determined by performing odor studies that take into account an odor source and strength, meteorological/dispersion conditions, and type of surrounding development. Buffer zones can be as large as 1,500 feet. Physical/mechanical methods may also be used to control odors. These methods would typically include carbon air filters combined with air blowers. If no physical/mechanical odor control is included in wastewater treatment design, this will increase the land area required. The approximate amount of land area required for each of the assumed treatment plants is about 0.25 acres. If a 1,500-foot-wide buffer zone were required, this area would increase to about 40 acres.

Wastewater Treatment Process The wastewater treatment process assumed in the current analysis is shown in Figure 4-3.

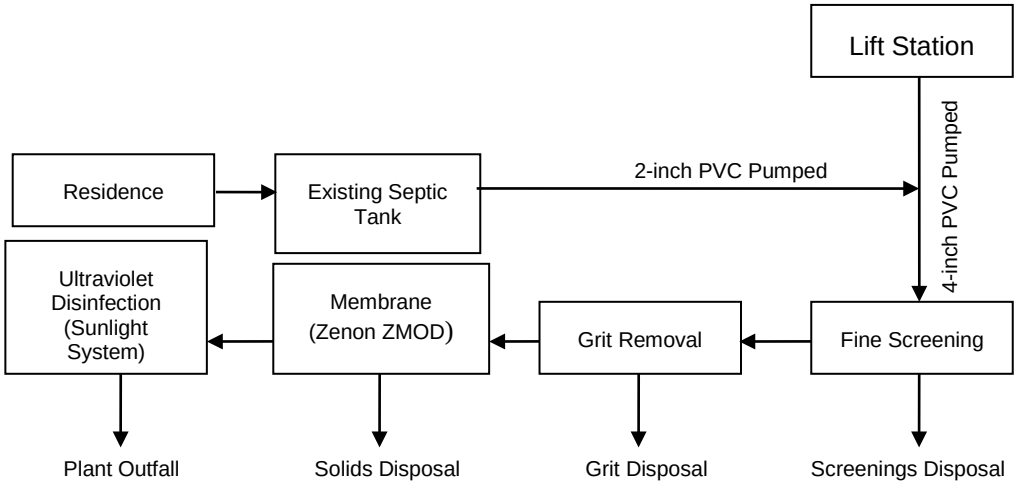

Figure 4-3. Wastewater Treatment Process Flow Schematic

The wastewater treatment process shown in Figure 4-3 is described in this paragraph. It is assumed in the proposed plan that the existing septic tanks at each residence can be reused. The tank discharge pipe to the disposal field would be capped off and the disposal field would become inactive. Sewage ejector pumps would be installed in each septic tank and the contents of the septic tank would be pumped via a 2-inch PVC line into a 4-inch PVC force main (pressurized sewer line). The 4-inch PVC force main for each system is assumed to be a common collection force main that would be installed in the existing roadways. It is assumed that lift stations would be required to pump all wastewater because of the mountainous terrain. Each lift station would consist of a 4 foot-diameter manhole with two grinder pumps. The footprint area required for each lift station would be approximately 15 feet by 15 feet. Two pumps would be required to provide redundancy in case one of the pumped stops operating. The 4-inch PVC force main contents would be pumped to the wastewater treatment plant. The wastewater treatment plant would require a fine screen (2 mm openings) to screen out all large solids to prevent damage to the proposed membrane system. Grit removal would follow the fine screens to remove small abrasive materials (e.g., sand) that can also damage the membrane system. Flow after these two preliminary treatment processes would then be directed to the secondary treatment process, which is an ultrafiltration membrane. This is basically a biological filter that removes smaller particles and organics. The last step in the treatment process would be ultraviolet (UV) disinfection, which is used to destroy disease-causing organisms before discharge. Treated water from this treatment train would then be discharged to Shasta Reservoir (pending permit approval). It has been assumed that this would be accomplished via gravity, although the mountainous terrain may require effluent to be pumped to Shasta Reservoir.

It is assumed that the system described above would be used at several locations around the lake. Various issues should be understood when considering a small package treatment plant. Wastewater treatment in small communities is relatively expensive because the same level of treatment is usually required for small communities, without the financial advantage of the economy of scale of a larger community. Smaller communities are generally more spread out, which also increases the wastewater collection system cost. In the case of Shasta Reservoir, the mountainous terrain would increase the per capita cost even more. In addition, operation and maintenance costs that currently are not incurred would be required for the wastewater treatment system shown in Figure 4-3, further increasing the overall cost. Another issue is odor control. As discussed previously, buffer zones are often used to mitigate odor problems, and this has been assumed in the wastewater treatment process described above. If physical/mechanical odor control facilities would be required, this would increase a wastewater treatment facility's capital cost and operation and maintenance costs.

Other Wastewater Treatment Alternatives It should be noted that other alternatives could be considered during final design, as described below.

Centralized Septic System This type of system would use existing septic tanks for solids separation, and then all septic tanks would pump septic tank effluent to a centralized septic field. The size of the septic field would be based on many different factors, including soil type and trench capacity. Trench capacity can include sidewalls or just the trench bottom. A rough calculation with no site-specific data, and the assumption of a wastewater flow capacity of 25,000 gallons per day (gpd), yields a septic field size of about 30 acres. If sidewalls are included in the calculation, the required area may be reduced to about 25 percent of the trench-bottom-only area.

Recirculating Granular-Medium Filter In these systems, septic tank effluent is pumped to a sand filter multiple times before being discharged to a plant outfall or septic field. Disinfection is required if discharging to surface waters directly from the sand filter.

Other Package Treatment Plant Alternatives Many other package wastewater treatment plant alternatives could be suitable.

Power Distribution Facilities

An expanded discussion of the approach and methodology for relocating power distribution facilities is provided below.

General Considerations With a dam raise of 18.5 feet, several transmission and distribution lines would either be inundated or in close proximity to the reservoir. All transmission towers, power poles, and underground power lines that would be inundated would be relocated. There are no regulations pertaining to how far power lines need to be located from the inundation line.

Underground power lines, transmission towers, and power poles merely need to be located in dry areas. It is assumed that areas 100 feet inland from the inundation line would be dry enough for the transmission towers, while areas 50 feet inland from the inundation line would be suitable for underground power lines and power poles. If a transmission line is within 100 feet of the inundation line, it would be relocated. If a distribution line is generally within 50 feet of the inundation line, it would be relocated. If a home is within 50 feet of the inundation line, and is not demolished because of other criteria, the local distribution line to the house would be retained.

Inventory of Existing Transmission and Distribution Lines in Project Area
An initial inventory of and data collection for the existing transmission and distribution lines near the reservoir, or subject to be inundated, was carried out to identify the volume of work that would be generated by the project. There are six locations where the transmission lines cross Shasta Lake: Antlers, three times in the Bailey Cove area, Turntable Bay, and the South Crossing near the Pit River Bridge.

As many as 28 structures ranging from single circuit wood structures to double circuit steel structures would need to be removed due to inundation or inadequate clearances. They would be replaced by 11 double circuit dead-end or suspension towers, depending on location, and vary from 70-feet to 220-feet in height. Approximately 12,000 feet of new conductor would be used for the replacement.

For the main distribution lines, about 23,300 feet would be demolished and relocated. An average distance of 75 feet was assumed for the distance between a home and main distribution line. Approximately 8,000 feet of local distribution lines would be demolished and relocated.

Selection of New Power Line Routes Route selection is a critical step in the design process for a transmission line. Any route selected would have some impact on the land and its uses. Therefore, it is important to analyze all possible alternatives and choose a route that would minimize those impacts, and allow construction, and facilitate utility personnel in easily building or accessing the routes.

From an engineering perspective, several factors associated with relocating power lines are typically addressed in a route selection study. These factors are economics, reliability, and environmental impacts. The power towers preferably would be located in dry areas where foundations are above the water table level and soils are capable of sustaining the foundations. If wetlands or severe terrains cannot be avoided, costly foundations and/or special construction equipment or techniques would be required. Also, crossing heavily forested areas that would require extensive clearing would be avoided, as well as hunting grounds with a high probability of gunshot damage to insulators. These are a few aspects to be considered when planning a new route.

Clearances Clearances for transmission lines are those required to provide safety to the public and those required to provide reliable operations. Clearances required for safety and, to some extent, for operations, are stated in the NESC. These include clearances above the ground, streets, railroads, etc. For transmission lines of 230 kV and below, NESC clearances would generally provide for reliable operations as well as safety. These clearances are based on the voltage between the phase conductor and ground (L-G voltage). When considering phase voltage, a multiplier of 1.05 should be applied to the nominal voltage to determine maximum L-G voltage. Structure clearances are concerned with the air gap clearance between an energized conductor and the supports to prevent lightning and switching surge flashovers. Table 4-13 shows clearances between a restrained conductor and supporting structure. If conductor support is not restrained, clearance would be adjusted according to the maximum design range of swing of the insulator string. Any additional clearance to allow workers movement during live-line maintenance work should be added to determine the minimum tower-to-conductor clearance.

Table 4-13. Restrained Conductor Clearances

Voltage (L – L)	Phase to Ground Voltage	Minimum Structure Clearance (feet)
69 kV and below	41 kV	1.3
138 kV and below	84 kV	2.5
230 kV and below	140 kV	4

Key:
kV = kilovolt
L – L = line to line

Clearances not covered by the NESC that should be considered are phase-phase clearance, for very long spans, galloping, and leakage current limitation.

At the start of the design of a line, it is important to develop a table of clearances as part of the design criteria to be used throughout the design. The table would include not only phase-to-ground and phase-to-phase structure clearances, but also phase-to-ground or crossing, or to the edge of right-of-way (ROW) clearances.

Also, various clearance requirements would need to be implemented from CPUC-GO 95, and CPUC-GO 128. Since PG&E owns the power lines and ROW, PG&E criteria would also need to be met.

Rights-of-Way When considering a new line, it is always necessary to determine ROW width. It is known that transmission lines generate electric and magnetic fields, but no clear evidence has been found of any significant environmental and health effects resulting from the operation of these lines. However, some states have established regulatory limits on the strength of electric and/or magnetic fields from power lines. Therefore, a ROW easement obtained for transmission lines generally prohibits the installation of any

buildings or facilities within the ROW, but would allow buildings or structures at the edge of a ROW. Therefore, the first condition for ROW width is to provide NESC horizontal clearances to buildings for the longest span in the transmission line, remembering that the clearance must be maintained with a 6-pound wind on the conductor and structure. Therefore, conductor swing and structure deflection must be considered when calculating the clearance. The minimum clearance under these conditions can be based on the basic impulse level (BIL) flashover distance rather than the NESC safety distance.

Table 4-14 presents typical minimum ROW widths for transmission lines with voltages (phase to phase) of up to 230 kV. However, ROW widths would need to be calculated based on site-specific data for any particular line.

Table 4-14. Minimum Right-of-Way Widths

Voltage (L – L)	BIL Flashover	Minimum Right-of-Way Width (feet)
68 kV and below	350 kV	40
138 kV and below	550 kV	60
230 kV and below	750 kV	75

Key:
BIL = basic impulse level
kV = kilovolt
L – L = line to line

Plan and Profile, Structure Spotting Plan and profile information is essential to determine structure locations. These drawings generally consist of a plan on half of a drawing and an elevation of a transmission centerline on the other half of the drawing. Such information is obtained by performing a survey along a transmission line corridor. This survey may consist of a ground survey or an aerial survey. Generally, short lines (such as the lines to be relocated by this project) use a ground survey, while long lines use aerial surveys.

When plan and profile information is prepared, it would include plan information and centerline elevations, as well as the following information:

- Section line locations
- Property line locations
- Property owners
- Road and street ROW
- Railroad ROW
- Wire crossings (e.g., transmission lines, telephone)

- Elevation of wire crossing
- Underground facilities (e.g., pipelines, cables)

Poles and Structures Poles can be of wood or steel, and used as a single support, or as a framed structure, such as an H-frame steel pole, unlike wood poles can be fabricated to almost any required strength and are therefore more versatile for longer span applications.

Regarding structures, even though some can be of wood, steel is the most common material, particularly for structures subjected to high mechanical loads. Lattice steel structures have been used since the earliest transmission lines, but more recently tubular steel poles have become common.

Foundations Wood pole or steel pole foundations can be directly embedded in the ground with crushed rock or concrete backfill, or installed using reinforced-concrete caissons and anchor bolts. The direct-embedment type foundation is acceptable for tangent and small-angle structures, but concrete caisson foundations would be required for large angle and dead-end structures.

Foundations for lattice steel structures are typically concrete caissons or earth grillages.

Permits A series of permits would need to be obtained from Federal and State agencies, and also from local governments for relocating power lines. As a minimum, the following agencies would be contacted and/or permits would be required:

State

- California Public Utilities Commission (CPUC)
- California Department of Fish and Wildlife (CDFW)
- Caltrans
- Road crossing permit
- Railroad crossing permit

Municipal

- Neighborhood plan review from each town or community where a power line would cross a roadway
- Local permits for construction
- Local zoning permits or conditional use permits

Please see Draft Environmental Impact Statement, Chapter 26, for additional information on compliance with applicable laws, policies, and plans.

Telecommunication Facilities

Relocation of telecommunication lines would comply with all NESC and CPUC-GO 95 requirements. Telecommunications lines would typically be attached to power poles at a height lower than the power lines, typically 18 feet off the ground. Buried lines would typically be routed along roadway shoulders and direct-buried with a minimum of 30 inches of cover.

Recreation Facilities

The Whiskeytown-Shasta-Trinity NRA was established November 8, 1965, by Congress to provide for public outdoor recreation use and enjoyment, and conserve scenic, scientific, historic and other values contributing to public enjoyment of such lands and waters. The NRA offers a variety of outdoor activities, including boating, water-skiing, swimming, fishing, camping, picnicking, hiking, and hunting. Shasta Dam and Reservoir are located in the Shasta Unit of the NRA. Shasta Reservoir and is the largest man-made reservoir in California, with approximately 420 miles of shoreline, and a surface area of 29,600 acres, making the lake ideal for recreation.

Any raise of Shasta Dam would have some effect on the many recreation features found along the reservoir shoreline. These features include marinas/boat ramps, resorts, campgrounds/day use areas, trails, and USFS facilities. Reclamation would protect such facilities from inundation, modify existing facilities to replace affected areas (i.e., relocate facilities on site) or abandon existing facilities and replace them at other suitable sites (i.e., relocate facilities off site).

Although USFS has not approved relocation sites or recreation site plans, preliminary plans for effects of a dam raise on Shasta Lake recreation facilities have been developed with the cooperation of USFS. Plate 39 details the location of existing and potential recreation areas (referred to as windows) with proposed site modification, expansion, or relocation associated with an 18.5-foot dam raise; and proposed new recreation sites. Table 4-15 details recreation facility modifications and relocations for the 18.5-foot dam raise. After authorization of the project, further detailed designs would need to be developed. The primary goal of the relocation plans is to verify that with any dam raise, the existing recreation capacity could be maintained. Reclamation has identified more capacity than is required for to maintain current recreational capacity, but the cost estimates only represent replacement of lost capacity due to inundation. Reclamation and USFS will continue to work together to revise a recreation plan that is suitable for the NRA.

Decisions about whether individual affected facilities would be modified or relocated would be addressed in conjunction with USFS, based on overall effects on the features of individual facilities as well as operational needs. While the preference would be to modify or relocate within the immediate vicinity, some relocated facilities may be consolidated within other existing facilities, rather than being relocated at a currently undeveloped area. All plans for replacing of facilities would be evaluated and approved by USFS.

Where feasible, Reclamation would protect recreation facilities from seasonal high-water levels by installing retaining walls or similar structures to prevent inundation. The surface level of affected paved and unpaved areas (most used for parking) would be raised if that would prevent inundation. In areas where this would not be feasible or would be impractical, new facilities to replace lost parking areas would be constructed in adjacent unaffected areas.

All capacity of recreation facilities (e.g., boat launching, campsites, picnic sites, marina moorage and related services, resort lodging) lost as a result of inundation would be replaced. Reclamation would seek to maintain the quality of visitor experiences by replacing affected recreation facility capacity with facilities providing equivalent visual resource quality, amenities, and access to Shasta Lake and terrestrial natural resources.

Inundated recreation facilities and associated utilities would be relocated before demolition, with the exception of facilities identified for abandonment. Proposed dam raise alternatives would, at minimum, maintain the existing recreation capacity at Shasta Lake. A summary of recreation facilities to be modified or relocated under SLWRI proposed Comprehensive Plans can be found in Table 4-16. Construction-specific information regarding relocation and demolition of recreation facilities is under development and will be completed after the SLWRI is authorized. Estimated quantities of demolition and construction materials associated with modification and relocation of recreation facilities are listed in Table 4-17.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise

Facility	Land Owner	Arm	Description
Public Boat Ramps	**Maintain public boat ramp capacity. Modify up to six public boat ramps in-place and potentially expand two public boat ramps.**		
Antlers Boat Ramp	Federal	Sacramento River	Modify and/or Expand Existing Facilities: Extend existing boat ramp in place and tie in new parking area to existing grade and potentially expand. Affected structures to be demolished and relocated onsite.
Bailey Cove Boat Ramp	Federal	McCloud River	Modify Existing Facilities: Extend existing boat ramp in place, and raise parking area in place on fill. No structures are to be demolished.
Centimudi Boat Ramp	Federal	Sacramento River	Modify Existing Facilities: Extend existing boat ramp in place, and reconstruct parking area upslope on fill. No structures are to be demolished.
Hirz Bay Boat Ramp	Federal	McCloud River	Modify Existing Facilities: Raise top parking lot on fill, and construct new high-water boat ramp from top parking lot. Affected structures to be demolished and relocated onsite.
Jones Valley Boat Ramp	Federal	Pit River	Modify Existing Facilities: Extend existing boat ramp in place upslope and realign access road to new boat ramp section. No structures are to be demolished.
Packers Bay Boat Ramp	Federal	Pit River	Modify and/or Expand Existing Facilities: Extend existing boat ramp in place. Reconstruct parking area upslope on fill; potentially expand area north of existing site. Affected structures to be demolished and relocated onsite.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
Marinas	**Modify and/or relocate up to nine marinas, with preference of modifying marinas in place. If in place modification is not possible, new marina sites are identified to maintain recreation capacity.**		
Antlers Resort and Marina (Concession Area)	Federal	Sacramento River	Modify Existing Facilities: Affected structures to be demolished and relocated upslope at existing site.
Bridge Bay Marina	Federal	Pit River	Modify Existing Facilities: Extend existing boat ramps, and reconstruct parking areas in place, on fill, with retaining walls. Demolish affected structures and relocate up to 50% of demolished square footage as floating facilities.
Digger Bay	Federal	Sacramento River	Modify Existing Facilities: Marina facilities unaffected, modify existing boat ramp for continued use.
Holiday Harbor Marina	Federal	McCloud River	Modify and/or Expand Existing Facilities: Extend boat ramp upslope, reconstruct parking area upslope, on fill, and potentially expand. Demolish affected structures and relocate up to 50% of demolished square footage as floating facilities. Potentially expand parking area.
Jones Valley Marina	Federal	Pit River	Modify Existing Facilities: Extend existing boat ramp and reconstruct parking areas in place, on fill. Demolish affected structures and relocate up to 50% of square footage to floating facilities.
Packers Bay Marina	Federal	Pit River	None: Maintain marina. Access to be maintained through modifications at Packer Bay Public Boat Ramp. No structures to be demolished.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
Shasta Marina	Federal	Sacramento River	Modify Existing Facilities: Extend existing boat ramp and reconstruct parking areas in place, on fill. Demolish affected structures and relocate up to 50% of square footage to floating facilities.
Silverthorn Marina	Federal	Pit River	Modify Existing Facilities: Extend existing boat ramp and reconstruct parking areas in place, on fill, with retaining walls. Demolish affected structures, and relocate up to 50% of square footage to floating facilities.
Sugarloaf Marina	Private/Federal	Sacramento River	Modify Existing Facilities: Extend existing boat ramp and reconstruct parking areas in place, on fill. Demolish affected structures, and relocate up to 50% of square footage to floating facilities.
Turntable Bay Area New Marina	Federal	McCloud River	Potential Marina Relocation Site: Develop a new marina site on the north ridge of Turntable Bay. This site to be used to offset loss of recreation capacity if existing marinas cannot be modified in place.
Silverthorn Area New Marina	Federal	Pit River	Potential Marina Relocation Site: Develop new marina site on ridge adjacent to existing Silverthorn Marina. This site to be used to offset loss of recreation capacity if existing marinas cannot be modified in place.
Family/Group Camping &Day Use Areas	**Maintain family/group camping and day use capacity through modification and expansion of existing camping/day use area sites.**		
Antlers Campground	Federal	Sacramento River	Expand Existing Facilities: Expand existing campground by developing new campsites.
Bailey Cove Campground and Day Use Area	Federal	McCloud River	Modify Existing Facilities: Relocate up to seven picnic sites affected by the parking lot raise, and realign access road to campground.
Dekkas Rock Campground and Day Use Area	Federal	McCloud River	Modify and Reuse Facilities: Relocate Dekkas Rock Group Campground to adjacent day use area. Relocate day use area to new site.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
Ellery Creek Campground	Federal	McCloud River	Reuse Existing Facilities: Relocate campground, and modify to allow reuse of unaffected portion of site for development of day use area. Demolish up to 19 campsites and develop new picnic sites.
Fisherman's Point Day Use	Federal	Sacramento River	Modify Existing Facilities: Modify existing picnic sites affected by the new left wing dam.
Gregory Creek Campground	Federal	Sacramento River	Reuse Existing Facilities: Modify to allow use of unaffected portion of facility to support day use and undeveloped shoreline camping. Developed camping to be relocated. Demolish existing restroom and up to 18 campsites and develop new picnic areas.
Hirz Bay Campground	Federal	McCloud River	Expand Existing Facilities: Expand existing campground by developing new campsites. Potential for replacing group camping with new family camping sites.
Jones Valley Campground – Lower	Federal	Pit River	Modify Existing Facilities: Demolish and relocate campground buildings. Modify existing campsites to maintain capacity.
Lakeshore East Campground	Federal	Sacramento River	Highly Impacted – Site Abandoned: Access road and facility mostly inundated. Relocate facilities off site.
McCloud Bridge Campground and Day Use Area	Federal	McCloud River	Modify and/or Expand Existing Facilities: Abandon existing campground and day use area for new adjacent campground and day use area. Demolish up 5 picnic sites and up to 17 new campsites. Develop new picnic sites and campsites.
Moore Creek Campground	Federal	McCloud River	Modify Existing Facilities: Lower portion of loop road and shoreline campsites appear to be affected. Minor modification of up to 6 campsites may be required.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
Nelson Point Campground	Federal	Sacramento River	Highly Impacted – Site Abandoned: Small facility mostly inundated. Abandon and consolidation of facilities is preferred.
Pine Point Campground	Federal	McCloud River	Modify Existing Facilities: Potential that some shoreline campsites are affected. Minor modifications of up to 4 campgrounds may be required.
Oak Grove Campground	Federal	Sacramento River	Modify and/or Expand Existing Facilities: Minor modifications to expand existing facilities. Demolish and replace campground facilities and develop new campsites.
Upper Salt Creek Day Use Area	Federal	Sacramento River	Highly Impacted –Site Abandoned: Demolish facilities within the inundation pool. No rehabilitation of day use or group camps at site.
Boat-In Campgrounds	**Maintain boat-in campground capacity through modification and expansion of existing boat-in sites and new sites.**		
Arbuckle Flat Boat-In Camp	Federal	Pit River	Modify Existing Facilities: Several campsites inundated and to be redeveloped upslope. Demolish up to 11 campsites.
Green's Creek Boat-In Camp	Federal	McCloud River	Modify Existing Facilities: Several campsites inundated and to be redeveloped upslope. Demolish up to 9 campsites.
Monday Flat Boat-In Camp	Federal	Squaw Creek	Modify and/or Expand: New mitigation site for boat-in site recommended by USFS. Boat-in camp area to mitigate for impacts to Arbuckle Flat and Green's Creek Boat-in Camps. New campsites to be developed.
Ski Island Boat-In Camp	Federal	Pit River	Modify Existing Facilities: Modify up to 23 campsites by relocating upslope.
Gooseneck Boat-In Camp	Federal	Sacramento River	Modify Existing Facilities: Modify up to 8 campsites by relocating upslope.
Former Lakeview Marina	Federal	McCloud River	Potential Boat-in Camp Relocation Site: Develop new boat-in camp sites on eastern ridge.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
Resort Areas & Other Non-Marina Commercial Recreation	**Maintain resort and non-marina commercial recreation capacity through modification and expansion of existing sites.**		
Antlers RV Park and Campground (Concession Area)	Federal / Private	Sacramento River	Modify and/or Expand Existing Facilities: Demolish and relocate two structures upslope and add potential new family camping and RV resort area north of site. Site would include up to 19 new campsites, 88 RV sites, and 14 cabins to replace lost capacity.
Holiday Harbor RV Park/Campground (part of Holiday Harbor Marina)	Federal	McCloud River	Modify Existing Facilities: Raise existing RV park/campground. Demolish and relocate restroom, campground buildings, and up to 28 RV sites.
Lakeshore Inn and RV Resort	Federal / Private	Sacramento River	Highly Impacted – Site Abandoned: Facility partially inundated flat topography and high water table constrain use of adjacent area for mitigation. There are also unsafe access issues due to the relocation of the railroad and road. Relocate 2 buildings and cabins to new Antlers Concession Area. Relocate up to 38 RV sites to another site.
Shasta Lake RV Resort and Campground	Private	Sacramento River	Highly Impacted – Site Abandoned: Access road inundated, and unsafe access issues with relocation of railroad and road. Demolish and relocate facilities and cabins to the new Antlers Concession Area. Relocate up to 50 RV sites and up to 19 campsites to another area.
Sugarloaf Cottages	Private	Sacramento River	Modify Existing Facilities: Demolish and relocate cottage facilities on adjacent land.
Tsasdi Resort	Private	Sacramento River	Modify Existing Facilities: Demolish and relocate up to 6 resort structures at the existing site.
Kamloops Kamp	Federal	McCloud River	Modify Existing Facilities: Demolish affected structure and relocate upslope at existing site.
Shasta Caverns Landing - East	Federal	McCloud River	Modify Existing Facilities: Modify boat landing facilities at existing site.
Shasta Caverns Landing - West	Federal	McCloud River	Modify Existing Facilities: Modify boat landing facilities at existing site.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
USFS Fire/Ranger Facilities	**Modify one facility in-place and relocate one facility.**		
USFS Lakeshore Fire Station	Federal	Sacramento River	Highly Impacted – Existing Site Demolished/Relocate to New Site: Demolish fire station and administration facilities on Lakeshore Drive, and relocate all facilities to site adjacent to I-5 Lakehead exit.
USFS Turntable Bay Maintenance Station	Federal	McCloud River	Modify Existing Facilities: Demolish up to four facility structures and relocate structures and parking area on fill.
Recreation Residence Tracts	**Demolish impacted cabins.**		
Campbell Creek Recreation Residence Tract	Federal	McCloud River	Impacted Cabins – No Relocation Potential: Demolish and do not relocate inundated cabins.
Didallis Recreation Residence Tract	Federal	Squaw Creek	Impacted Cabins– No Relocation Potential: Demolish and do not relocate inundated cabins.
Salt Creek Recreation Residence Tract	Federal	Sacramento River	Impacted Cabins – No Relocation Potential: Demolish and do not relocate inundated cabins
Trails	**Maintain trail/trailhead capacity through modification and expansion of existing sites.**		
Bailey Cove Trail	Federal	McCloud River	Modify Existing Facilities: Impacted trail sections to be relocated upslope. Trailhead replaced along with Bailey Cove Day Use area construction.
Clikapudi Trail	Federal	Pit River	Modify Existing Facilities: Impacted trail sections to be relocated upslope. Trailhead will be replaced.
Dry Fork Creek Trail	Federal	Sacramento River	Modify Existing Facilities: Impacted trail sections to be relocated upslope. Inundated road will be realigned during right wing dam construction. Trailhead will be replaced.
Fisherman's Point Trail	Federal	Sacramento River	Modify Existing Facilities: Impacted trail sections to be relocated upslope. Trailhead will be replaced along with Centimudi Public Boat Ramp construction.
Hirz Bay Trail	Federal	McCloud River	Modify Existing Facilities: Impacted trail sections to be relocated upslope.

Table 4-15. Recreation Facility Relocations and Modifications for the 18.5-foot Dam Raise (contd.)

Facility	Land Owner	Arm	Description
Packers Bay Trail	Federal	Pit River	Modify Existing Facilities: Impacted sections of Packer's Bay trails; East Side, Fish Loop, and Water Gulch (3 out of 4) to be relocated (primarily upslope). Trailhead will be replaced along with Packers Bay Public Boat Ramp construction.
Samwel Cave Nature Trail	Federal	McCloud River	Modify Existing Facilities: Impacted trail sections to be relocated upslope.

Table 4-16. Summary of Recreation Facilities to be Modified or Relocated Under SLWRI Comprehensive Plans

Recreation Facilities	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3, CP4, and CP4A (18.5-Foot)	CP5 (18.5-Foot)
Marinas/Public Boat Ramps				
Number of Affected Facilities (marinas/boat ramps)	9/6	9/6	9/6	9/6
Relocation Needed[1] (acres)	8.5	8.5	8.5	8.5
Replacement Structures (sf)	49,900	49,900	49,900	49,900
Campsites and Day-Use Sites				
Number of Affected Facilities (campsites and day-use sites)	202	261	328	328
Relocation Needed[1] (acres)	32	34	39	39
Replacement Structures (sf)	6,200	6,200	6,200	6,200
Resorts				
Number of Affected Facilities (resorts)	6	6	6	6
Relocation Needed[1] (acres)	14	14	14	14
Replacement Structures (sf)	27,100	38,900	55,000	55,000
USFS Facilities				
Number of Affected Facilities (USFS facilities)	2	2	2	2
Relocation Needed[1] (acres)	5	5	5	5
Replacement Structures (sf)	13,900	13,900	13,900	13,900

Table 4-16. Summary of Recreation Facilities to be Modified or Relocated Under SLWRI Comprehensive Plans (contd.)

Recreation Facilities	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3, CP4, and CP4A (18.5-Foot)	CP5 (18.5-Foot)
Trailheads/Trails				
Number of Affected Facilities (trailheads/trails)	2/9	2/9	2/9	2/9
Relocation Needed[1] (miles)	8.1	9.9	11.6	11.6
Recreation Enhancement[2] (trailheads/trails[miles])	-	-	-	6/18

Notes:
[1] Does not include on-site modification of facilities.
[2] Additional recreation facilities for Alternative CP5 only.
Key:
- = not applicable
CP = Comprehensive Plan
sf = square feet
SLWRI = Shasta Lake Water Resources Investigation
USFS = U.S. Department of Agriculture, Forest Service

Table 4-17. Recreation Demolition and Construction Material Quantities for SLWRI Comprehensive Plans

Material	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3, CP4, CP4A, and CP5 (18.5-Foot)
Recreation Facilities			
Imported Fill (cy)	236,200	384,200	552,800
Excavation to Waste (cy)	592,300	430,600	315,400
Structure Demolition (sf)	130,700	146,700	164,200
Demolition Waste (cy)	99,200	102,100	105,200

Key:
CP = Comprehensive Plan
cy = cubic yard
sf = square feet
SLWRI = Shasta Lake Water Resources Investigation

Marinas

Several marinas around Shasta Lake would be affected by raising Shasta Dam. Typically, marinas consist of a parking area, a boat ramp, various structures (e.g., retail, restrooms, maintenance facilities, storage, administration), and utilities (power, water, and septic). Most of the effects of the dam raise would result from the inundation of boat ramps, parking lots, structures, and utilities. Boat ramps would be modified in place on fill, where possible. Modifications to parking areas would include replacing them on fill, or relocating them above the new reservoir elevation. Existing structures that would be inundated would be demolished, and either replaced above the reservoir elevation (upslope or on placed fill), or moved to a floating structure on the water to provide better

access for recreational users. Any access roads would be relocated above the new full pool to continue to provide access around the marinas. Existing septic systems that would be inundated would be demolished and removed from the area or relocated. New facilities could also be connected to new localized wastewater treatment facilities. Power lines would be installed to accommodate new structures.

To maintain shoreline accessibility and facility distribution around the lake, each affected marina would be relocated in the immediate vicinity of its existing location. Relocation of marinas in their existing location is the most cost effective approach to maintaining marina-related recreation capacity at Shasta Lake. If unforeseen circumstances prevent affected marinas from being maintained in their current location, relocating or consolidating with other marinas would be reconsidered. Although not anticipated, potential new or expanded areas that could be used include:

- Silverthorn Marina Area
- Turntable Bay Area
- Holiday Harbor Marina Area

See Plate 39 for locations of these potential recreation areas.

Public Boat Ramps

Six public boat ramps that could be inundated would be modified or relocated in the immediate vicinity of the existing facility. Public boat ramps that could not be modified in place would be relocated to adjacent areas that can provide the necessary grade and access for ramps. To maintain current recreation capacity of public boat ramps the following potential expanded areas could be used:

- Antlers Public Boat Ramp Area
- Packers Bay Public Boat Ramp Area

Campgrounds/Day Use Areas

Several undeveloped areas have been identified as potential campgrounds to replace capacity lost because of inundation. While some inundated campgrounds would be relocated on fill at their existing location, others would be moved around the reservoir to new locations identified as potential campground sites. As much as 39 acres of expanded, or new, campground area would be needed for the 18.5-foot dam raise to maintain current recreation capacity of campgrounds, boat-in campgrounds, and day-use areas. The following areas could be used to meet the need for campgrounds:

- Antlers Campground

- Oak Grove Campground
- Hirz Bay Campground
- McCloud Bridge Area

The following areas could be used to meet this need for boat-in campgrounds:

- Former Lakeview Marina Area
- Monday Flat Boat-In Camp

The following areas could be used to meet this need for day-use areas:

- Ellery Creek Campground
- Gregory Creek Campground
- McCloud Bridge Area

See Plate 39 for locations of these potential relocation areas.

Resorts

Raising Shasta Dam would affect approximately six resorts around the reservoir to some degree. Inundated structures, and those within 3 feet of the new full pool, would be demolished. Associated septic systems would also be demolished, and the remaining structures would either connect to new localized wastewater treatment facilities or be relocated to other septic systems. As much as 14 acres of expanded, or new, resort land use would be needed to maintain current recreation capacity. The Antlers Concession Area is a potential area that could be used to meet this need.

USFS

Recreation within the NRA is managed by USFS, which has several facilities located throughout the reservoir area. USFS facilities consist of various storage and maintenance buildings and equipment, fire protection equipment, customer service facilities, office space, and employee living facilities. Two USFS facilities would be inundated at all dam raise heights, and require relocation or replacement: Lakeshore Fire Station and Turntable Bay Station. Lakeshore Fire Station would be relocated to an area above the new full pool just west of the Antlers Campground expansion area, providing necessary access to Interstate 5 and minimizing potential conflicts with adjacent recreation, residential, and commercial areas. The new facility would contain all of the features that exist at the current facility. The inundated facility would be demolished, and hauled to waste. Additional space at Turntable Bay Station would allow this facility to be relocated on fill in its current location.

Recreation Trails

Portions of most Shasta Lake trails would be affected by any dam raise. Affected segments of hiking and biking trails would be relocated upslope to restore the continuity of affected trails. In addition, CP5 includes construction and/or modification of existing facilities at various locations to provide for 18 new miles of trails and 6 trailheads to enhance recreation opportunities at Shasta Lake.

Access Roads

Reclamation's modification and/or relocation plans for recreation facilities include project effects on roads and bridges (as described in the preceding discussion of roadway relocations), many of which are used to access recreation facilities. Facility access roads may be relocated, raised, or abandoned. If abandoned roads serve a substantial recreation-access purpose, relocation may take the form of upgrading alternative access routes that serve the same areas.

Ecosystem Restoration

CP4, CP4A, and CP5 include ecosystem restoration measures around Shasta Lake and along its tributaries, as well as downstream from Shasta Dam along the upper Sacramento River.

Reservoir Area

Shoreline enhancement and tributary aquatic habitat enhancement are only considered reservoir area ecosystem restoration measures for CP5.

Shoreline Enhancement

The ecosystem enhancement goal for the shoreline environment of Shasta Lake is to improve the warm-water fish habitat associated with the transition between the reservoir's aquatic and terrestrial habitats. Shoreline enhancement entails the range of enhancement opportunities along the Shasta Lake shoreline below the full-pool elevation of 1,090.2 (NAVD88) that would occur with an 18.5-foot dam raise. This area is typically between 0.1 and 1.5 miles upslope from the current full-pool elevation of 1,069.7 (NAVD88). The shoreline is defined as the area encompassing nearshore aquatic habitat within the reservoir itself and vegetation and other habitat components adjacent to the reservoir.

Two categories of potential nearshore warm-water fish habitat enhancement activities are discussed below: (1) *structural enhancements*, which entail construction and placement of artificial structures in Shasta Lake's littoral zone; and (2) *vegetative enhancements*, which entail planting and seeding to provide submerged and partly submerged vegetative cover when the reservoir is at full-pool capacity during the winter/spring months.

Structural enhancements associated with CP5 include placement of brush structures constructed from whiteleaf manzanita (*Arctostaphylos manzanita*) in

Shasta Lake's littoral zone. Because of manzanita's density, installation does not require using anchor or cabling techniques that could result in ancillary negative impacts (e.g., maintenance, hazards to boaters). The brush structures would be assembled in the drawdown zone of the reservoir in an area that would be inundated as the reservoir surface elevation rises in fall. The brush structures are expected to be about 1,800 cubic feet in size. The establishment period would be the first year after construction; life span of the brush structures is projected to be 10 years.

Table 4-18 identifies the general area, number, and size of proposed structural enhancement locations for the main body of Shasta Lake, and the Pit, Sacramento, McCloud, Big Backbone, and Squaw arms. Selection of specific locations has been deferred so that enhancement locations would be consistent with other objectives of the SLWRI. The level of proposed treatment is based on the proportion of available manzanita surrounding Shasta Lake. In general terms, these locations would incorporate available material at locations with preferred topographic features; preferred locations are coves that offer steep drawdown areas during the primary use period (spring, early summer).

Table 4-18. Proposed Structural Enhancement of Lake and by Arm Under Comprehensive Plan 5

Area	Area Treated (acres)	Number of Locations
Lake Main Body	17	595
Pit Arm	12	420
Sacramento Arm	43	1,505
McCloud Arm	8	280
Big Backbone Arm	3	105
Squaw Arm	17	595
Total	**100**	**3,500**

Vegetative enhancements associated with CP5 include planting willows (Salix) to enhance nearshore fish habitat, and aerial and hand seeding of annual cereal grains to treat shoreline areas at Shasta Lake. More than 30 acres could be available to enhance willow recruitment adjacent to Shasta Lake. Rooted willows would be planted in draws and other moist sites, such as springs, to provide long-term live cover. The establishment period for willows would be the first year after construction; life span is projected to be 5 to 50 years. The establishment period for cereal grains would also be the first year of construction, with the life span projected to be 1 to 3 years. This approach requires native seed and nursery stock; several years of advanced preparation would be needed before planting could take place. Table 4-19 identifies the general area, number, and size of proposed vegetation enhancement locations for the main body of Shasta Lake, and the Pit, Sacramento, McCloud, Big Backbone, and Squaw arms.

Table 4-19. Proposed Vegetation Enhancement of Lake and by Arm Under Comprehensive Plan 5

Area	Willow Planting (acres)	Native Grass Seeding (acres)
Lake Main Body	1	2
Pit Arm	1	4
Sacramento Arm	7	4
McCloud Arm	1	2
Big Backbone Arm	3	2
Squaw Arm	1	2
Total	**14**	**16**

Tributary Aquatic Habitat Enhancement

The quantity and quality of aquatic habitat in the tributaries of Shasta Lake are influenced primarily by the presence of road crossings and culverts, although in some cases, other structures or grade controls (e.g., transitional deltaic deposits) may constitute barriers to aquatic connectivity, including fish passage.

Barriers to fish passage in the watersheds above Shasta Lake are primarily associated with culverts or other types of stream crossings. Typical passage problems created by culverts and other road crossings include the following:

- Excessive drop at the downstream end of a crossing (perched outlet)
- Water velocities within a crossing that are too fast to allow fish to swim upstream
- Constriction of flow as it enters a crossing, causing excessive water velocities and turbulence at an inlet
- Lack of sufficient water depth in a culvert for the fish to swim
- Debris accumulation across an inlet or within a culvert

Surveys have identified opportunities to restore and/or enhance 14 perennial and intermittent stream crossings to improve fish passage. Based on information obtained in the surveys, these crossings meet one or more of the criteria for impaired fish passage. Table 4-20 identifies the sites by road section, the watershed in which they occur (arm of Shasta Lake), and the type and size of crossing, and characterizes problems identified at these sites.

Table 4-20. Culvert Replacement on Perennial and Intermittent Streams Under Comprehensive Plan 5

Road/Site No.	Watershed	Type/Size of Crossing	Problems
FS 35N08 Sugarloaf Creek (Site 1)	Sugarloaf Creek	Culvert / 13.5-foot-diameter	Undersized, misaligned culvert, velocity/gradient barrier, eroding fill slope
FS 35N60 (Site 3)	McCloud	Culvert / 48-inch-diameter	Undersized culvert, velocity/gradient barrier, plunge pool, fill slope erosion
FS 35N60 (Site 4)	McCloud (Ellery Creek)	Culverts / 3 culverts 5-foot-diameter	Multiple culverts, velocity/gradient barrier, plunge pool, fill slope erosion
FS 35N60 (Site 5)	McCloud (Moore Creek)	Culvert / 72-inch-diameter	Culvert damaged, undersized, fill slope erosion
FS 35N17 (Site 6)	Salt Creek	Culvert / 36-inch-diameter	Undersized, shotgun outlet, velocity/gradient barrier, eroding fill slope
FS 35N17 (Site 7)	Salt Creek	Culvert / 24-inch-diameter	Undersized, shotgun outlet, velocity/gradient barrier, eroding fill slope
FS 35N08 (Site 11)	Sugarloaf Creek	Culvert / 48-inch-diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 12)	McCloud Arm	Culvert / 24-inch-diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 13)	McCloud Arm	Culvert / 24-inch-diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 14)	McCloud Arm	Culvert / 18-inch-diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 15)	McCloud Arm	Culvert / 18-inch-diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 16)	McCloud Arm	Culvert / 18-inch-diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 17)	McCloud Arm	Culvert / 36-inch-diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 18)	McCloud Arm	Culvert / 24-inch-diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion

Key:
FS = U.S. Forest Service Road

Downstream from Shasta Dam

Gravel augmentation and side channel restoration are two proposed ecosystem restoration measures for CP4, CP4A, and CP5 downstream from Shasta Dam.

Gravel Augmentation

Gravel suitable for spawning has been identified as a significant influencing factor in the recovery of anadromous fish populations in the Sacramento River. As part of CP4, CP4A, and CP5, spawning-sized gravel would be placed at multiple locations along the Sacramento River between Keswick Dam and the RBPP.

Gravel augmentation would occur at one to three locations every year, for a period of 10 years, unless unusual conditions or agency requests precluded placement during a single year. This program, in combination with the ongoing Central Valley Project Improvement Act (CVPIA) gravel augmentation program, would help address the gravel debt in the upper Sacramento River, but the reach may continue to be gravel-starved into the future. Therefore, the gravel augmentation program proposed herein would be reevaluated after the 10-year period to assess the need for continued spawning gravel augmentation, and to identify opportunities for future actions or programs to do so.

Fifteen preliminary locations for spawning gravel augmentation were identified in the Sacramento River between Keswick Dam and Shea Island, and were selected based on potential benefits to anadromous fish and site accessibility. Each location would be eligible for gravel placement one or more times during the 10-year program. Gravel placement would provide either immediate spawning habitat or long-term recruitment.

Although preliminary sites have been identified, specific gravel augmentation site(s) and volume(s) would be selected each year in spring or early summer through discussions among Reclamation, the U.S. Fish and Wildlife Service, CDFW, and the National Marine Fisheries Service. The discussions would include topics such as avoiding redundancy with planned CVPIA gravel augmentation activities in a given year; identifying hydrology or morphology issues that could impact the potential benefit of placing gravel at any particular site; identifying changes in spawning trends due to previous years' gravel augmentation activities; evaluating potential new sites; and are appropriately distributing selected gravel sites along the river reach(es).

Construction Activities On average, 5,000 to 10,000 tons of gravel would be placed each year, although the specific quantity of gravel placed in a given year may vary from that range. Gravel would be obtained as uncrushed, rounded river rock, free of debris and organic material, from local, commercial sources. To maximize the benefit to anadromous fish, gravel would be washed and sorted to meet specific size criteria. To minimize impacts to salmonid spawning activity, gravel applied to active river channels would be placed between

August and September each year, consistent with the time frame for the ongoing CVPIA gravel augmentation program.

Construction activities would vary significantly by location, but generally would include clearing, grubbing, and some grading of new access routes to allow construction vehicles to access the river. At several locations, clearing and grubbing of the riverbank would be required to allow gravel to be placed on the bank for recruitment. Gravel would be delivered to the locations by dump trucks. In most cases, gravel would be stockpiled in a staging area and moved with bulldozers, loaders, and/or excavators. Dust control trucks would be present during all construction activities.

Several locations would require in-water construction work. Generally, this involves building gravel out into the river channel "step-wise," meaning that gravel is dumped and leveled, and the leveled area serves as a working platform for the next step of construction. This practice is common for spawning gravel placement, and minimizes the extent to which construction vehicles drive directly through an active river channel. One or two locations, however, would require construction activity in the active river channel, where construction vehicles would deposit gravel and raise the grade of the river near existing riffles.

Restore Riparian, Floodplain, and Side Channel Habitat

Under CP4, CP4A, and CP5, riparian and floodplain habitat restoration would be constructed at a suitable location along the Sacramento River. Several potential sites exist along the upper Sacramento River between Keswick Dam and RBPP that would be fit for restoration measures to benefit anadromous fish. Table 4-21 lists the potential restoration site and type of habitat enhancement. Figure 4-4 is an overview map of the potential restoration sites along the upper Sacramento River. These sites were evaluated for possible inclusion in CP4, CP4A, and CP5 based on their geologic, hydrologic, and ecologic restoration potential through floodplain, side channel, and riparian habitat enhancement. Additional considerations included site accessibility and immediate availability for restoration activities. The sites described in this section are described in the order that they are located along the Sacramento River from upstream to downstream. Additional detail on the evaluation of potential riparian, side channel, and floodplain restoration site can be found in the SLWRI Upper Sacramento River Potential Restoration Sites Technical Memorandum (Reclamation 2012c).

Currently, the exact size, scope, and location of a desired and suitable restoration site is still under development. Not all of these sites will be included in the final alternatives so the following should be considered as examples of construction measures proposed for restoration of riparian, floodplain, and side channel habitat. However, for this stage in the planning process restoration activities anticipated under CP4, CP4A, and CP5 are expected to be similar in

size and scope of restoration at Reading Island (described below), and of which is used as a proxy for anticipated costs.

Table 4-21. SLWRI Potential Restoration Sites in the Upper Sacramento River by Type of Habitat Enhancement

Site Name	Spawning Habitat Enhancement	Rearing Habitat Enhancement
Henderson Open Space	x	
Tobiasson Island	x	
Shea Island Complex	x	
Kapusta Island	x	
Anderson River Park		x
Reading Island	x	x

The HEC-RAS hydraulic model developed by the California Department of Water Resources (DWR), Division of Planning and Local Assistance, Northern District was used to estimate river stages at different flow rates for the potential restoration sites. Steady flow data for a 50 year flood event was scaled down uniformly to generate 15 different flow profiles ranging from an average flow of 4,000 cfs to 20,000 cfs in the Sacramento River. Critical depth for each flow profile was set equal to the downstream boundary condition for the hydraulic model.

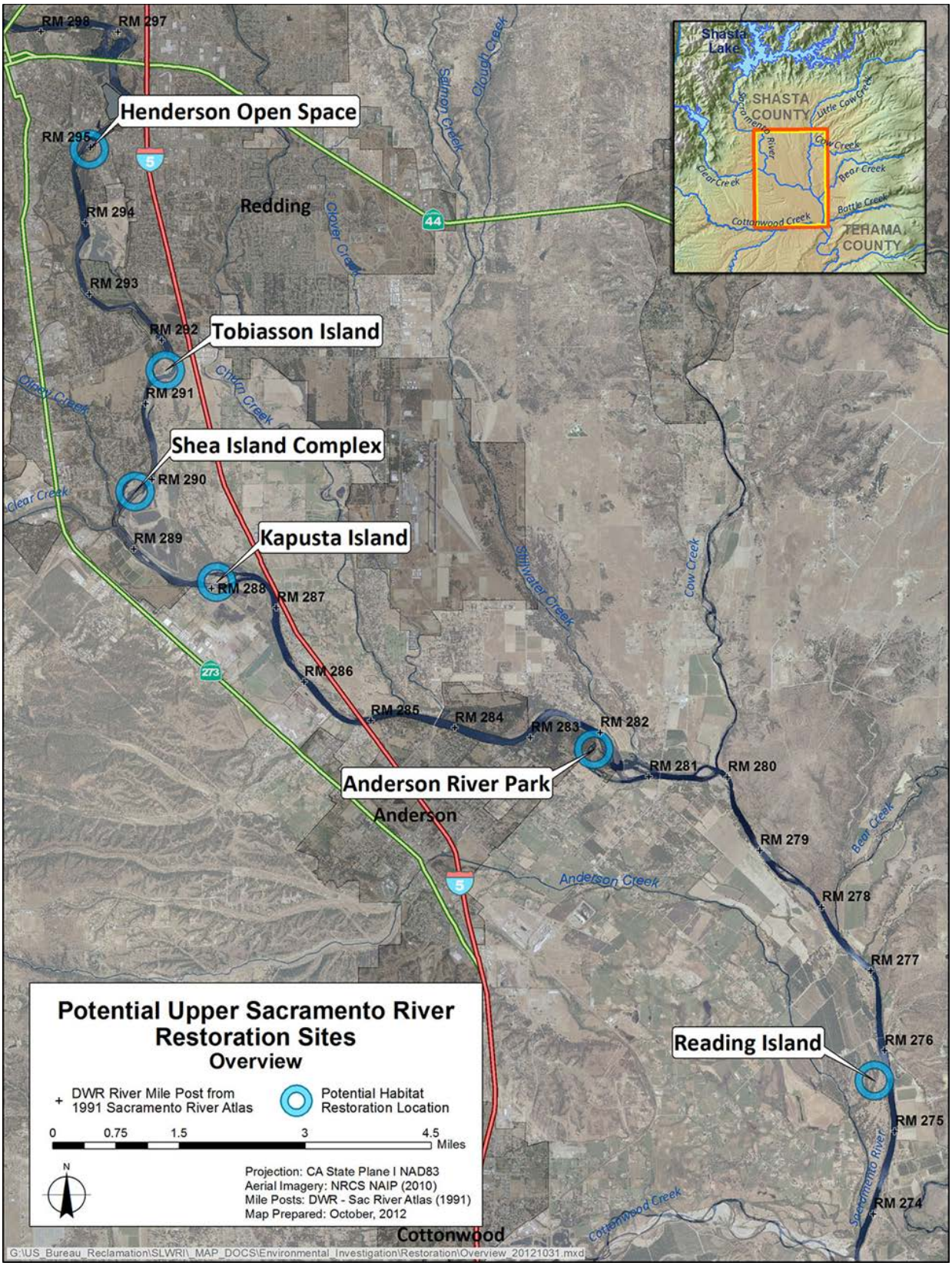

Figure 4-4. Overview of Locations of Potential Restoration Sites Along Upper Sacramento River as Part of the SLWRI

General Construction Activities Construction activities for riparian, floodplain, and side channel habitat restoration would vary depending on the location or locations and type of restoration measure to be implemented at the site. Table 4-22 summarizes the estimated construction quantities for each the potential sites. In general, construction activities would include earth moving activities with bulldozers, loaders, excavators, and/or compactors. Sites proposing channel excavation would typically follow a trapezoidal 3:1 cut with a 25-30' wide base. Excavated materials would either be reused on site, or be taken off site to commercially available, approved locations for safe storage, use, and/or disposal. Access to some sites may be achieved through public and private access and include construction of temporary bridges to allow construction vehicles to cross existing side channels. Embankment bridges would be constructed with appropriately sized spawning gravels which could then be used for gravel augmentation purposes. Vegetation removal may be necessary at some sites, either for channel deepening/widening, or where water with aquatic vegetation is present in a channel pending modification. Revegetated areas are expected to develop into self-sustaining riparian habitats within 1 to 4 years of initial planting, based on results of previous riparian restoration projects along the Sacramento River.

Special precautions for restoration at these sites will primarily involve:

- maintaining the active spawning areas in proximity to the site
- avoiding the creation of habitat for predacious fish
- minimal disruptions to navigability of the river
- prevent the spread of invasive, non-native plant species
- insuring the safety of homes located on the Sacramento River downstream from the sites

Table 4-22. Construction Quantities for Potential Restoration Sites Along the Upper Sacramento River

Item	Henderson Open Space	Tobiasson Island	Shea Island Complex	Kapusta Island	Anderson River Park	Reading Island
Modified Channel Length (lf)	1,900	1,300	700	1,600	2,600	4,300
Vegetation Removal (acres)	2.6	3.2	0.9	3.1	9.4	2.9
In-River Gravel Placement (cy)	-	3,100	4,700	3,100	-	-
Excavation (cy)	14,700	37,300	3,400	25,900	17,900	23,500
Riparian Vegetation Planting (acres)	1.2	1.4	0.4	1.4	4.2	2.3
Temporary Irrigation and Site Fencing	Yes	No	No	No	Yes	Yes
Relocation of Power Lines (lf)	1,100	-	-	-	-	-

Key:
cy = cubic yard
lf = linear feet

Henderson Open Space The City of Redding Henderson Open Space area is located south of Cypress Bridge on the east side of the Sacramento River at River Mile 295. Riparian and side channel restoration at the Henderson Open Space site as shown in Figure 4-5 could consist of the enhancement of an existing side channel to activate the frequency and duration of flows for Chinook salmon spawning habitat throughout the side channel. This potential modification would create up to 2,000 more linear feet of spawning habitat in close proximity to areas of the Sacramento River that are actively used by anadromous fish for spawning.

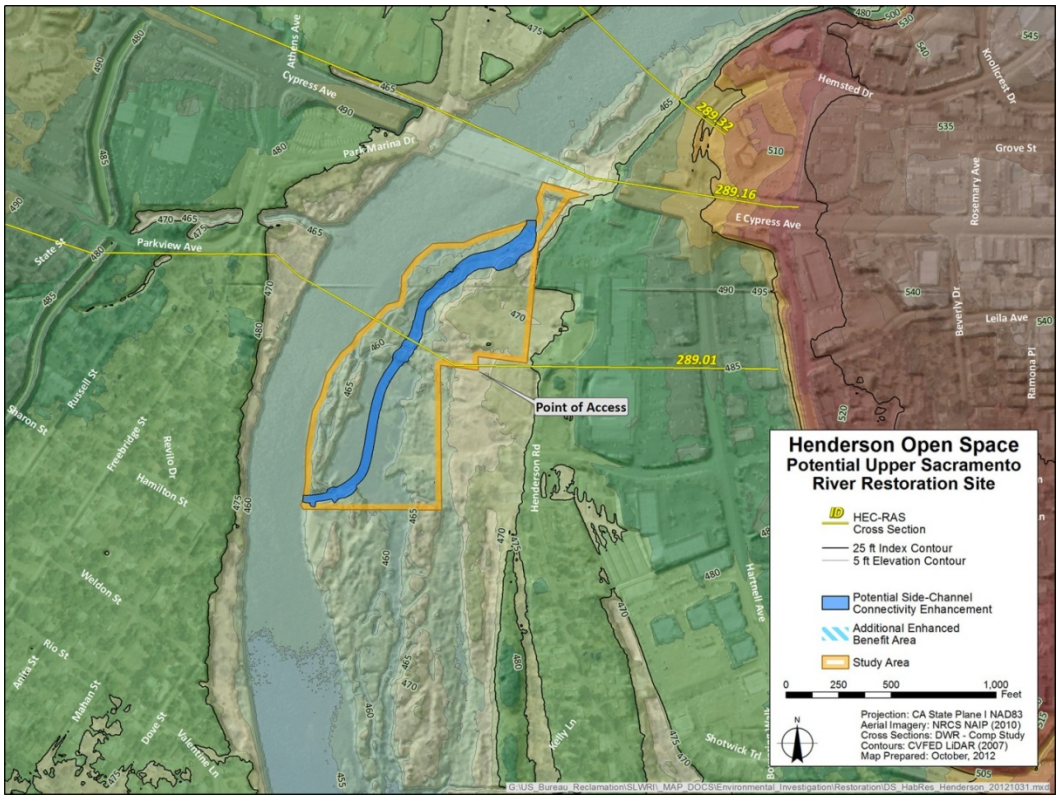

Figure 4-5. Henderson Open Space Potential Restoration Site

The enhancement of an existing side channel to activate the frequency and duration of flows for Chinook salmon spawning habitat throughout a portion Henderson Open Space Park would involve modifying the northern opening to the existing side channel from the main stem of the Sacramento River and restore connectivity with the Sacramento River at flows greater than 8,000 cfs. Additionally, minor grading and channel slope modification of the existing (sometimes inundated) channel to a point at which flows may be activated for spawning habitat would be necessary. The existing power poles and low frequency power lines on the site would potentially need to be relocated and replaced. Access to Henderson Open Space for habitat restoration would be achieved via public road.

Currently, the existing Henderson Open Space side channel is heavily vegetated. Floodplain terraces and adjacent riparian areas would be replanted with native vegetation following the completion of earth moving activities. Native riparian vegetation planting mix, composition, and density would be determined by a more detailed site analysis. To varying degrees, temporary fencing and irrigation would be necessary to protect and sustain newly established riparian vegetation.

Tobiasson Island Tobiasson Island is located downstream from South Bonnyview Bridge in the center of the Sacramento River at River Mile 292.

Riparian, floodplain and side channel habitat enhancement at this site would include the enhancement of the island to allow for a regularly flowing side channel to increase spawning habitat for all runs of Chinook salmon as shown in Figure 4-6. This would include excavation of a trapezoidal shaped channel to allow flows to enter the side channel and hydraulically connect the side channel to the Sacramento River at flows of 5,000 cfs or greater. If created, this new side channel would add approximately 1,300 linear feet of spawning habitat to this section of the Sacramento River. This process would also include the establishment of new floodplain habitat and riparian vegetation along the course of the side channel.

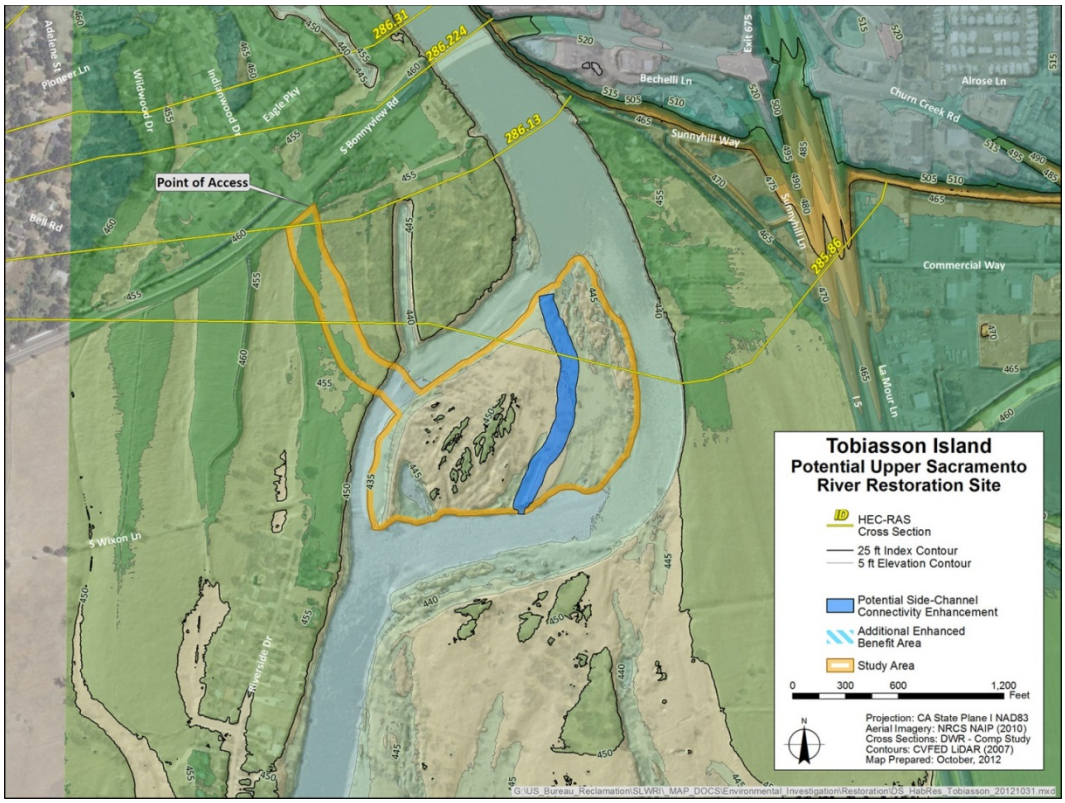

Figure 4-6. Tobiasson Island Potential Restoration Site

The earth material on site consists of optimally sized salmonid spawning gravel, and could be disposed of on site or reused for gravel augmentation projects in the upper Sacramento River. Upon completion of earth moving activities, it would be necessary to establish native vegetation throughout the side channel on the newly created floodplain terraces. Riparian vegetation planting mix, composition, and density would be determined by a more detailed site analysis. Temporary irrigation and fencing for vegetation planting at this site is not feasible due to a lack of electricity at the site. Access to Tobiasson Island could be accomplished by accessing the site at low flows or via a temporary constructed gravel bridge from adjacent private property.

Shea Island Complex The Shea Island Complex is located on the west side of the Sacramento River upstream from the river's confluence with Clear Creek at River Mile 291. Restoration at the Shea Island Complex to improve side channel, riparian, and floodplain habitat would include enhancing a major side channel through the site to keep the side channel hydraulically connected with the main stem of the Sacramento River at a broader range of flows as shown in Figure 4-7.

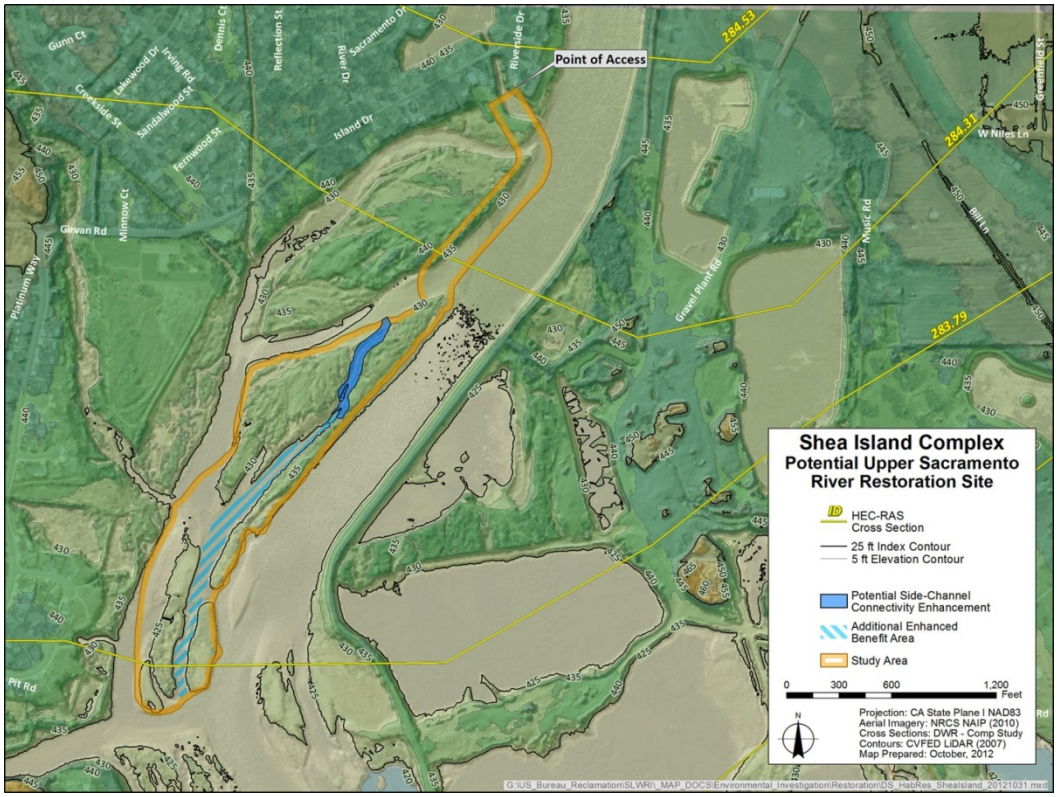

Figure 4-7. Shea Island Complex Potential Restoration Site

Restoration would include lowering a section of the upstream end of the major side channel to keep water more continuously moving through the channel at Sacramento River flows of 10,000 cfs to enhance salmonid spawning habitat. This potential modification would not only create up to 700 more linear feet of spawning habitat in close proximity to areas of the Sacramento River that are actively used by anadromous fish for spawning, but would also add channel complexity and enhance spawning habitat up to an additional 1,900 linear feet because of the connectivity with an existing side channel south of the modified channel. Additionally, vegetation and debris removal would be necessary in the excavated portion of the channel, as well as other portions of the channel to insure connectivity of flows. Minor grading activity would increase channel complexity along the length of the corridor. Upon completion of earth moving activities, it would be necessary to establish native vegetation throughout the side channel on the newly created floodplain terraces. Riparian vegetation

planting mix, composition, and density would be determined by a more detailed site analysis. Temporary irrigation and fencing for vegetation planting at this site is not feasible due to a lack of electricity at the site.

Access to the site would be achieved through private property at the north end of the complex, potentially via a constructed gravel travel way, if needed. As the substrate of the Shea Island Complex appears to consist of optimally sized spawning gravels, earthen materials could be disposed of on or off of site, and are potentially available for use as gravel augmentation substrate.

Kapusta Island Kapusta Island is located adjacent to the Kapusta Open Space area upstream from the I-5 crossing of the Sacramento River at River Mile 288. Restoration of riparian, side channel and floodplain habitat at Kapusta Island would include the enhancement an existing side channel by allowing it to carry water at a greater spectrum of flows specifically to increase winter-run and spring-run Chinook salmon spawning habitat as shown in Figure 4-8.

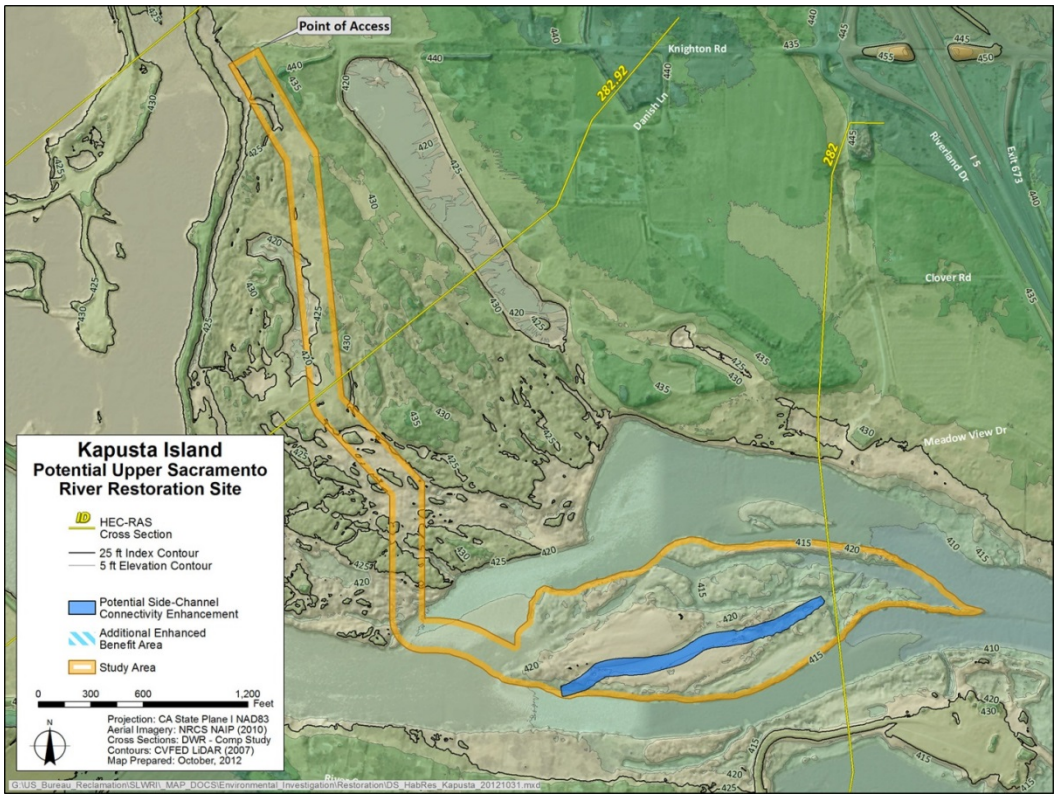

Figure 4-8. Kapusta Island Potential Restoration Site

The enhancement of an existing side channel on Kapusta Island to increase spawning habitat for winter-run and spring-run Chinook salmon in the Sacramento River would involve lowering the channel bed so that the channel may be hydraulically connected to the Sacramento River when it is flowing in excess of 10,000 cfs. Allowing flow through the island, and increasing

floodplain habitat would increase spawning habitat potential in his area of the river by about 1,600 linear feet.

Excavated material would need to be disposed of onsite due to difficulty of access at this point in the river. Vegetation and debris would also need to be removed from the infrequently inundated side channel. Upon completion of earth moving activities, revegetating floodplain terraces and adjacent riparian areas with native plants would be necessary. Riparian vegetation planting mix, composition, and density would be determined by a more detailed site analysis. Temporary fencing or irrigation at this site for newly established riparian vegetation is highly infeasible and a planting mix with this limitation in mind will need to be selected.

Access to the site could be achieved from several publically owned access points as Kapusta Island is located to the south of U.S. Department of the Interior, Bureau of Land Management's Riverland Drive property and north of the Kapusta Open Space Park. Access across the river could be accomplished in any of several ways, including gravel bridge, pontoon, or helicopter with consideration for deep pools and high flows in the river at this site. Special precautions for restoration at this island site primarily involve access to the site at a point in the Sacramento River with high, fast moving flows.

Anderson River Park Anderson River Park is an open space area on the south bank of the Sacramento River downstream from Churn Creek, and upstream from the Deschutes Road crossing at River Mile 283. Restoration at this site would be to hydraulically reconnect a remnant Sacramento River side channel with the Sacramento River as shown in Figure 4-9. Regularly flowing water throughout the length of this side channel would increase anadromous fish rearing habitat in this section of the river.

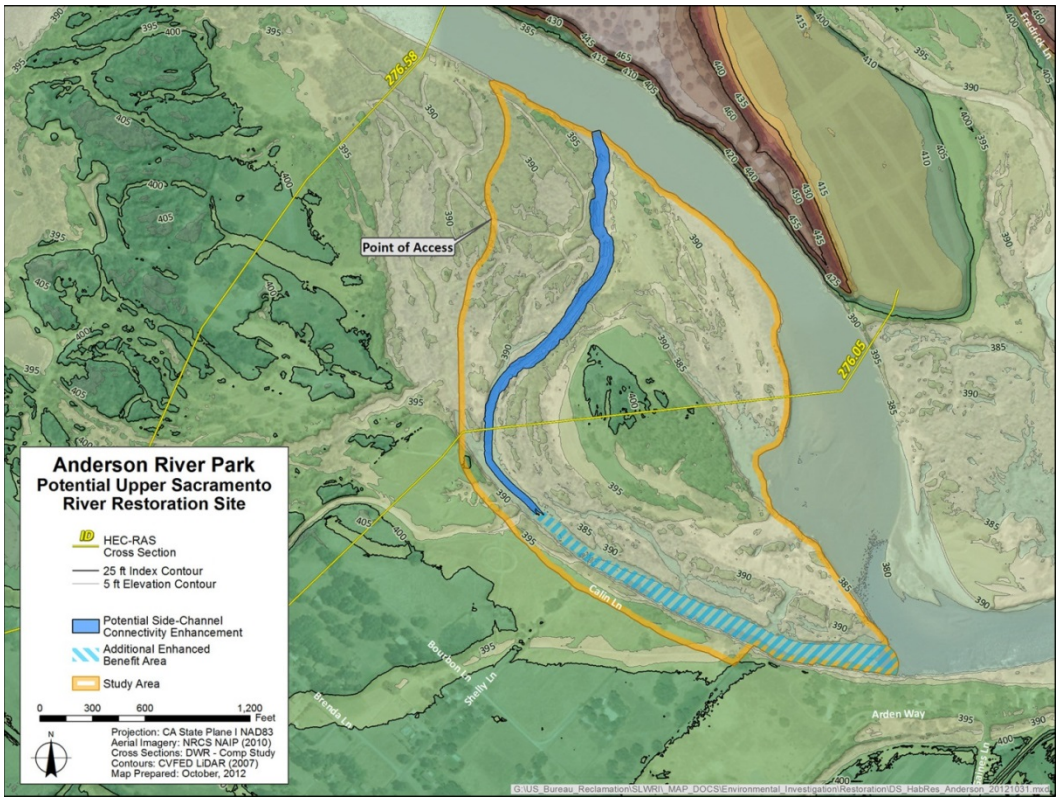

Figure 4-9. Anderson River Park Potential Restoration Site

Floodplain, riparian, and side channel habitat restoration at Anderson River Park would involve altering a relic Sacramento River side channel located in the southeastern portion of the park to function at Sacramento River flows of, or above 8,000 cfs. This type of side channel alteration would create rearing habitat for anadromous fish along 4,800 feet of side channel (including the unmodified portion). Excavated materials would either be reused on site, or be taken off site to commercially available, approved locations for safe storage, use, and/or disposal. Riparian vegetation and appurtenant biota are well established at this site; therefore removal of vegetation to lower the channel bed would be necessary, followed by replanting of native riparian vegetation post-excavation.

Access to Anderson River Park would be achieved via public roads and trail corridors throughout the park. Special precautions at this site to consider are to insure human safety in the park and temporary fencing around the construction and revegetated areas as a safety precaution in this highly recreated area.

Reading Island Reading Island lies along the Sacramento River just north of Cottonwood Creek at River Mile 274 (Figure 4-10). At the Reading Island site, a historic Sacramento River side channel drains into the present-day Anderson Creek, a remnant Sacramento River side channel. The Anderson Creek Slough, into which Anderson Creek empties, was blocked at the upstream end in the

early 1970s by construction of a levee on the adjoining private property. Before levee construction, the Anderson Creek Slough captured a portion of the Sacramento River flow and functioned as side channel habitat, supporting rearing habitat for winter-run Chinook and spawning habitat for Central Valley steelhead. Riparian, floodplain, and side channel restoration on Reading Island would be to restore flows in Anderson Creek and through Anderson Slough by removing the levee on Reading Island and lowering the channel bed.

Preliminary analysis indicates that breaching the levee, and channel clearing and excavation would be necessary to restore connectivity with the Sacramento River at flows ranging between 4,000 to 6,000 cfs. This would include vegetation and debris removal and deepening of the existing channel. These activities, alongside invasive aquatic vegetation removal in the channel and reestablishing riparian vegetation would aid in restoring the juvenile salmonid spawning and rearing habitat that once existed in Anderson Creek, potentially increasing spawning habitat along 7,100 feet (including the unmodified portion) of channel in this area of the river.

Excavated materials would be taken off site to commercially available, approved locations for safe storage, use, and/or disposal. Post-excavation, revegetating floodplain terraces and adjacent riparian areas with native plants would be necessary. This would require temporary irrigation and fencing to sustain plantings and keep livestock off site. Planting mix, composition, and density would be determined by a more detailed site analysis. Reading Island is both privately and publically owned, the potential restoration area is accessible by public road (Adobe Road) via a U.S. Department of the Interior, Bureau of Land Management day-use area.

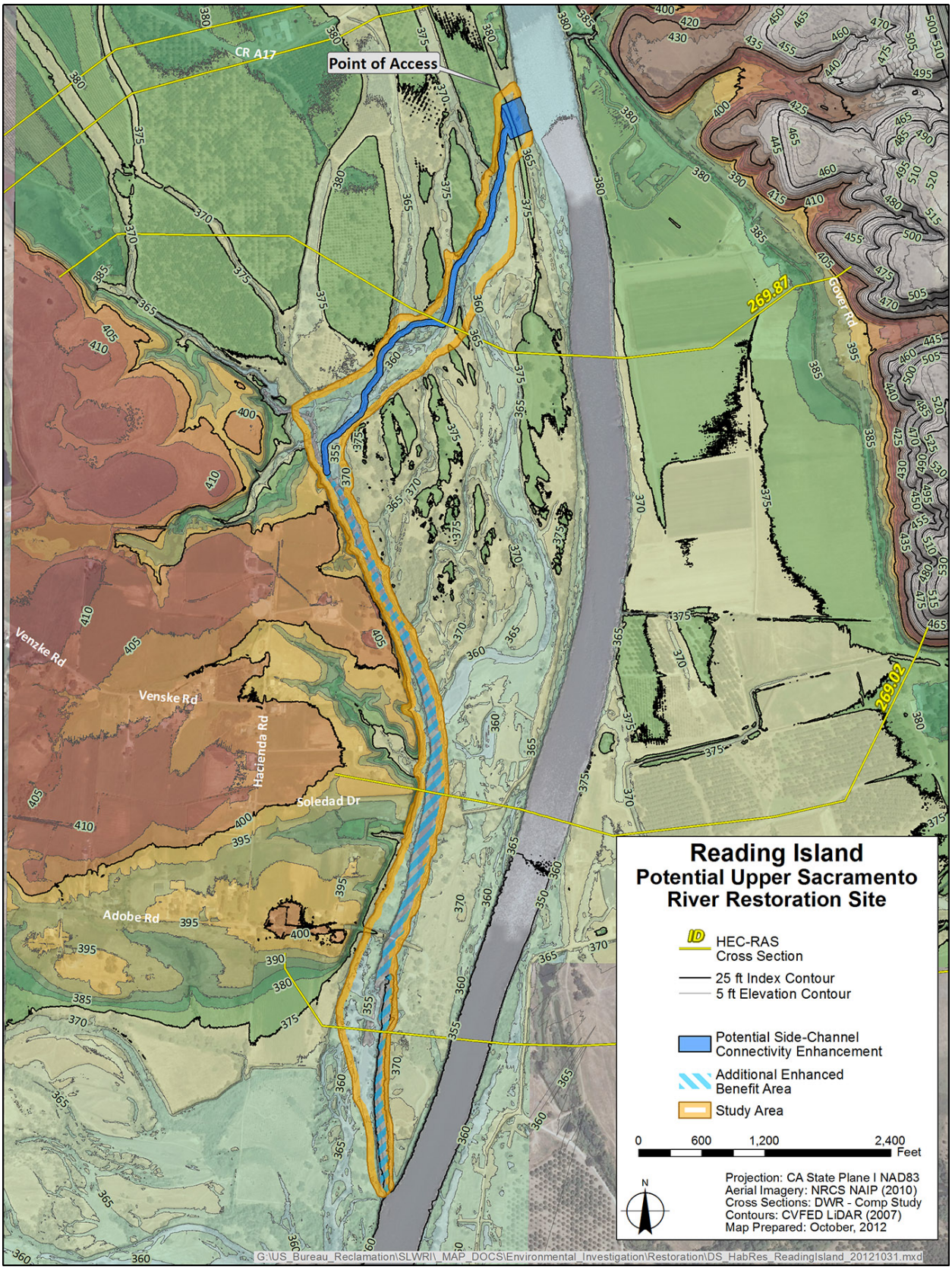

Figure 4-10. Reading Island Conceptual Study Area

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Chapter 5
Opinion of Probable Construction Cost

Most-probable construction cost estimates for the Shasta Dam and Reservoir raise include 3 dam raise alternatives, resulting in six Comprehensive Plans with 19 to 23 separate features. The three dam raise alternatives considered raises of 6.5 feet, 12.5 feet, and 18.5 feet, respectively. Significant features were included separately related to the dam and reservoir raise. The cost estimates were intended to capture the most current pricing for materials, wages and salaries; accepted productivity standards; and typical construction practices, procurement methods, current construction economic conditions, and site conditions for the current level of design. The cost estimates were prepared with less than complete designs and have inherent levels of risk and uncertainties. The cost estimates are intended to be a basis for budget authorization, appropriation, and funding.

Cost Estimates

Cost estimates are based on information and data obtained during design investigations. These investigations provide sufficient information to permit the preparation of preliminary layouts and designs from which approximate quantities for each kind, type, or class of material, equipment, or labor may be obtained. These estimates will be used to assist in the selection of a preferred alternative and to support seeking construction authorization from Congress. At minimum, appraisal-level cost estimates have been developed for all features for the 6.5-foot and 12.5-foot dam raises (CP1 and CP2); some features for the 6.5-foot and 12.5-foot dam raises are at feasibility-level. Feasibility-level cost estimates have been developed for all features for the 18.5-foot dam raises (CP3, CP4, CP4A, and CP5).

Unit prices were developed using a semi-detailed method. Specific construction activities were identified for major cost drivers. Costs for labor, equipment, materials, and other resources were developed. Production rates, overhead, and taxes were applied to develop applicable unit prices. Vendor quotations were obtained for major equipment, supplies, and other items. Minor cost items were developed using historical bid and industry standard reference cost data.

Major Cost Estimate Components and Assumptions

The assumptions listed for direct cost line items, and specifically factors used to determine indirect costs, are critically important to the overall accuracy of the estimate, and should be reviewed and understood by all parties.

Competitive Market Conditions at Time of Bid Tender

Estimates assume that Builder's Risk Insurance would be available to the contractor. If Builder's Risk Insurance is not available to the contractor because of the scope, security implications, or magnitude of the project, increased bid margins can be expected because the contractor would need to assume additional risks.

Price Level

For the majority of features, cost estimates were developed at April 2010 price levels for the SLWRI Preliminary Draft EIS (DEIS) (2011c). For this EIS, costs were indexed for those features to January 2014 price levels using Reclamation's Construction Cost Trends (Reclamation 2014a). Several features were refined between the Draft EIS and the Final EIS, cost estimates for these features were developed at January 2014 price levels.

Cost Estimate Components and Allowances

Depending on the level of study, it is often impractical to identify all items associated with a project. Accordingly, appraisal, feasibility, and partial design estimates should contain a percentage allowance shown as a separate line item for unlisted items. This unlisted items allowance represents the amount required to achieve comparability between preliminary estimates and prevalidation estimates. In general, the less refined the estimate, the higher the percentages used. As more details are developed to refine a specific cost estimate, the number of direct cost line items increases, the accuracy of the quantity takeoffs increases, and the allowance for unlisted items decreases.

Field Cost

Field cost is an estimate of capital costs of a feature or project from award to construction closeout. Allowances for mobilization, design contingencies, allowance for procurement strategies (APS), and construction contingencies are included in field costs.

Mobilization Mobilization costs include contractor bonds, and mobilizing contractor personnel and equipment to the project site during initial project setup. A value of 3-10 +/- percent was used for mobilization for most features. This is based on past experience of similar projects.

Design Contingency Design contingencies are intended to account for three types of uncertainties inherent as a project advances from the planning stage through final design, which directly affects the estimated cost of the project. These include (1) minor unlisted items, (2) minor design and scope changes,

and (3) minor cost estimating refinements. Based on the completeness of the listed items that the detail provided, the design contingency was set at 10-25 +/- percent of the listed items for this project, depending on the feature.

Allowance for Procurement Strategies A line item for APS may be included in cost estimates to account for additional costs when solicitations will be advertised and awarded under other than full and open competition. These include solicitations that will be set aside under socioeconomic programs, along with solicitations that may limit competition or allow award based on technical considerations. For SLWRI, APS was set at 2 percent. SLWRI estimates assume full and open competition, receipt of sealed bids, with award to the lowest responsive and technically responsible bidder.

Construction Contingency Cost estimates include a percentage allowance for construction contingencies as a separate item to cover minor differences in actual and estimated quantities, unforeseeable difficulties at the site, changed site conditions, possible minor changes in plans, and other uncertainties during the construction period. A value of 8-20 +/- percent was used for construction contingencies for the majority of the features. The bridge features used a slightly higher value of 25 +/- percent. The allowance is based on engineering judgment of the major pay items in the estimate, reliability of the data, adequacy of the projected quantities, and general knowledge of site conditions.

Non-Contract Costs

Construction cost is the sum of the feature field costs plus non-contract costs. Non-contract costs refer to costs of work or service provided in support of the feature construction, and other work that can be attributed to the feature as a whole, known as distributed costs, which include facilitating services, investigations, design and specifications, construction management, environmental compliance, and archeological considerations.

Non-contract costs were estimated to be 34.5 ± percent of the total field costs based on analysis of tasks required for the categories described below.. Land acquisition or relocation of property by others, and water use conservation actions are not included in this percentage.

Non-contract costs were divided into five categories for SLWRI and are as follows (this list is not all-inclusive):

- **Planning, Engineering, Design, and Construction Management** – This includes collection, assembly, analysis of data, and preparation and review of additional planning studies, including environmental compliance and permitting. This also includes construction designs and specifications, construction engineering and management, other costs such as general office salaries, supplies and expenses, general transportation expenses, security, environmental oversight, and legal services. The planning, engineering design, and construction

management non-contract cost was estimated at 22.5 percent of the total field cost.

- **Land Acquisition** – This includes lands to be acquired in fee for inundated lands; in fee and by permanent easement for reservoir area facility relocations such as roads, recreation facilities, dikes, utilities, and bridges; and by temporary use agreement for staging and construction activities. See the Real Estate Appendix for detailed analysis on land acquisition non-contract cost.

- **Environmental Mitigation** – This includes additional refinement and implementation of environmental mitigation. The environmental mitigation non-contract cost was estimated at 10 percent of total field cost excluding environmental restoration.

- **Cultural Resources Mitigation** – This includes coordination with California State Historic Preservation Office, compliance documentation, and mitigation. Cultural resources mitigation non-contract cost was estimated at 2 percent of the total field cost.

- **Water Use Efficiency Actions** – This includes funding for an additional water conservation program for new water supplies created by the project, to augment current water use efficiency practices (see EIS, Chapter 2, for more detail on the program). The program is estimated to be included over 10 years at a cost of $5 per year per acre-foot of increased average annual CVP and SWP deliveries.

Total Capital Costs

Total capital cost is the sum of the construction costs and interest during construction (IDC). IDC is interest that accrues on a loan that finances the construction of an alternative. It is applied over the construction period and/or until the debt is begun to be served. For this evaluation, IDC was applied over the time until the debt is begun to be served, which was estimated at 5 years for all of the Comprehensive Plans, at the current Federal discount rate of 3.5 percent. 5 years is the period from the Notice to Proceed milestone to when the reservoir can start filling and claim benefits.

Annual Operations and Maintenance Costs

Anticipated operations and maintenance (O&M) costs for each comprehensive plan include three major components:

- Increased O&M requirements of dam and reservoir area facilities

- O&M requirements of the localized wastewater treatment plants

- Increased pumping requirements of CVP and SWP facilities for delivery of increased water supplies (i.e., increased pumping at CVP and SWP pump stations)

- Reduced energy generation at Pit 7 Dam and Powerhouse, and related Reclamation in-kind power replacement to PG&E

An increase in O&M costs for the dam and appurtenances is considered to be minimal because most of the infrastructure is only being modified. For example, an enlarged Shasta Dam is expected to require very minimal increased O&M related to dam and powerhouse. The majority of the new facilities/features around the reservoir shoreline (e.g., roads, bridges, boat ramps, parking areas) would have similar O&M requirements. Some shoreline facilities (e.g., vehicular bridges) are near the end of their useful life and would potentially have reduced O&M requirements. Annual O&M costs for increased O&M requirements of dam and reservoir area facilities were estimated at 0.2 percent of the total field cost.

Annual operation costs associated with the increase in CVP/SWP pumping energy use were estimated based on monthly simulated increases in pumping and forecast power market prices. Average monthly on-peak and off-peak CVP/SWP pumping was estimated through post processing CalSim-II outputs using the power tools LongTermGen (LTGen) and State Water Project Power (SWPPower). Average monthly on-peak and off-peak energy prices were estimated using the PLEXOS® Integrated Energy Model (PLEXOS) to forecast power market prices for the year 2020 (indexed to a 2012 price level) when the 33% Renewable Portfolio Standard (RPS), mandated by California law, will have been implemented. It was assumed that power market prices would stabilize once the RPS is achieved. The power market value was based on the shadow price (i.e., marginal value) on an hourly basis for North of Path 15 (NP15), which is the Northern California area of the California Independent System Operator (CAISO). Since the shadow prices are initially based on the incremental cost of the marginal generating units, the “market price” represents a conservative estimate of the energy value, as no bid mark-ups or market power is assumed. For the SLWRI, Consumer Price Indices were used to index the power market price to a January 2014 price level (BLS 2014). The costs for increased pumping were estimated by applying the forecast average monthly on- and off-peak power market values to the simulated increases in average monthly on- and off-peak CVP/SWP pumping. Table 5-1 summarizes the total increase in average annual pumping energy required by each comprehensive plan.

A similar methodology was used for estimating costs for providing in-kind power to PG&E to offset the decreased generation at the Pit 7 facility. Average monthly on- and off-peak decreases in Pit 7 facility generation were estimated based on simulated average monthly decreases in Pit 7 facility generation and average monthly on- and off-peak generation ratios from the PLEXOS model.

Costs for in-kind power were then estimated by applying the average monthly on- and off-peak 2020 power market prices (as described above for CVP/SWP pumping cost estimates, indexed to January 2014 price levels) to the average monthly on- and off-peak decreases in Pit 7 facility generation.

Changes in CVP and SWP system generation (e.g., increased generation at dams/power plants) is not included in these O&M costs, but instead as part of the benefits analysis (not discussed in this appendix). Chapter 23 of the EIS details the impacts associated with the CVP and SWP system pumping energy generation and use for each comprehensive plan.

Table 5-1. Summary of O&M Related Energy Requirements for Comprehensive Plans[1]

Item	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3 (18.5-Foot)	CP4 (18.5-Foot)	CP4A (18.5-Foot)	CP5 (18.5-Foot)
Increase in CVP System Pumping Energy Use (GWh)[2]	7	10	26	7	10	16
Increase in SWP System Pumping Energy Use (GWh)[2]	47	73	-16	47	73	86
Total Increase in Pumping Energy Use (GWh)[2]	54	83	10	54	83	106
Decrease in Pit 7 Powerplant Energy Generation (GWh)[1]	4	7	15	16	15	15

Notes:
[1] Average annual values provided for comparison purposes only. Cost Estimates for annual O&M related to increase CVP and SWP pumping and decreased Pit 7 generation are based on average monthly energy estimates and associated and corresponding monthly on-peak and off-peak pricing.
[2] Load center generation and pumping values (accounting for transmission losses) were used to estimate potential benefits and costs of increased hydropower generation and pumping under comprehensive plans.
Key:
CP = Comprehensive Plan
CVP = Central Valley Project
GWh = Gigawatt-Hour
SWP = State Water Project

Total Annual Costs

Total annual costs for each alternative were estimated by interest and amortization of the capital cost over 100 years and at the current Federal discount rate of 3.5 percent.

Major Cost Estimate Exclusions

The cost estimates do not include costs associated with the following:

- Impacts due to multiple construction contracts, market conditions, and number of bidders
- Escalation from January 2014 values to Notice to Proceed date

- Above normal seasonal water levels. Cost estimates assume certain features would be constructed in the late fall when water levels are low and would not require underwater work

Contractor Risks

Several risk items have been identified below in an effort to alert decision-makers to important issues that could impact contractor operations and costs:

- Wing dam and spillway modifications relative to fluctuating lake levels
- Schedule slippage due to security concerns
- Schedule delays for bird nesting restrictions
- Blasting operations at or near dam facilities
- Stringent classification of materials to meet specification requirements
- Material transport restrictions and safety concerns
- Processing areas that are identified as not sufficient to meet required production goals
- Insurance issues in relation to dam significance
- Seasonal work restrictions imposed by phased spillway gate and lower tier outlet gate replacement schedule
- Long contract periods that expose liabilities
- Contractual risk transfer
- Minority business enterprise and miscellaneous flow down provisions
- Environmental and/or cultural delays

Escalation

An allowance for escalation from the January 2014 price level to the Notice to Proceed milestone was not included in the estimate. For projects that are to be developed over an extended period of time, or at some distant time in the future, it is prudent to consider the time value of money. Two distinct periods of time must be considered with escalation: (1) the period from the published price level until Notice to Proceed, and (2) the duration of the construction contract. The cost estimates only include escalation from notice to proceed to midpoint of construction, which is incorporated into the unit prices.

Since escalation through Notice to Proceed was not included in the cost estimates for any of the comprehensive plans, the legislation authorizing the

construction of this project should contain appropriate language to provide Reclamation the authority to adjust the appropriation ceiling by indexing to reflect future changes in costs.

As mentioned, this estimate includes only first costs (without escalation from published price level to Notice to Proceed); however, escalation would be a very significant cost driver for the project. For economic analysis and future project budgeting, a preliminary escalation rate of 3 percent per year is recommended to be used.

The preliminary escalation rate is based on reliance of cost escalation data supplied by the Caltrans Price Index (Caltrans 2010). The Caltrans Price Index demonstrates that California experienced a significant downturn in prices for highway and heavy civil construction infrastructure work. Figure 5-1 shows Caltrans highway construction price trends from 1972 through April 2010, San Francisco City Cost Index trends from 1978 to April 2010 (Engineering News-Record 2011), and Caltrans highway construction price trends from 1972 through the present. From Caltrans Price Index data, expected long-term price trends have been projected through 2020.

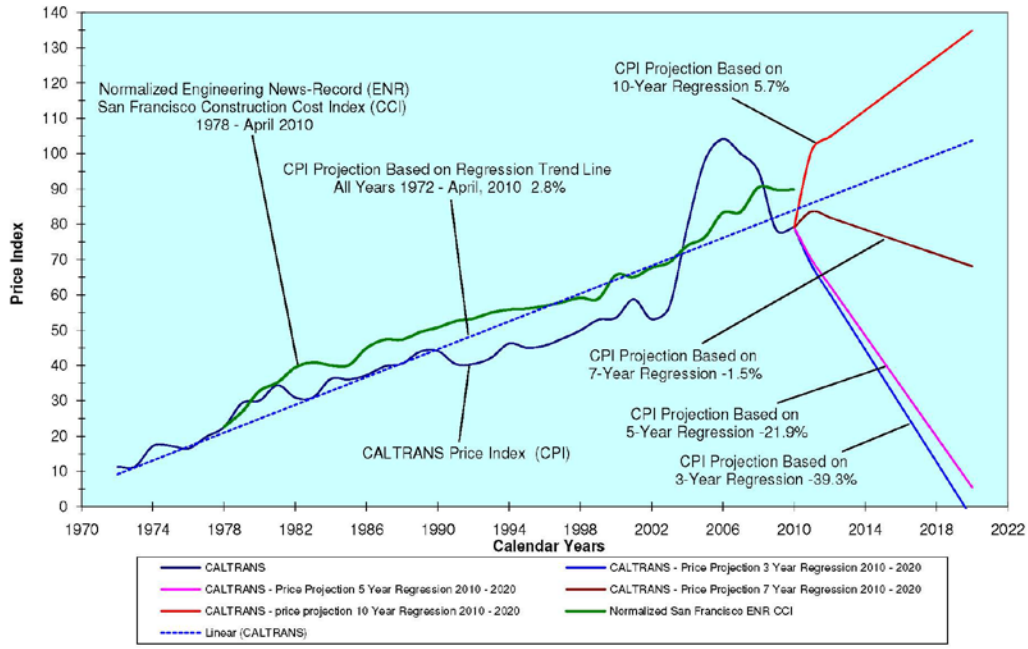

Figure 5-1. California Construction Price Trends

The construction market has experienced extreme price volatility in the last several years. A significant market anomaly occurring from 2002 through 2009 skews the calculation of forward cost trends using short-term linear regression techniques. Of note, the Caltrans Price Index decreased over 17 percent for the calendar year of 2008, and the Caltrans Price Index projection based on the 3 year regression indicates a negative average growth rate of almost 40 percent

per year. Although the economic downturn has resulted in price decreases, it is expected that prices will continue to escalate over the long-term. While future inflation trends are difficult to predict, new market forces (e.g., higher material commodity pricing, energy costs, lack of competition) will likely continue to have significant impacts on heavy civil infrastructure construction costs for the foreseeable future. Because of uncertainty and variability among the short-term regressions, a longer view of the market is preferred. Consequently, while forward cost trends are always difficult to predict, there is some basis to believe that cost escalation is normalizing back to historical levels at approximately 3 percent per year.

Program Cost Drivers

Although not included in the estimates of first costs, escalation is a significant cost factor for the program and should be included for economic studies and future project budgeting. Total contingency is another significant cost driver. As explained previously, contingency consists of three separate components: estimating contingency, risk provision supported by probability theory, and unlisted items allowance.

Risk and Uncertainty

With each aspect of this report, certain assumptions were made based on engineering and scientific judgment. Careful consideration was given to the methodologies and evaluations for hydrology and system operations, cost estimates, and biological analyses. Analyses were developed with advanced modeling and estimating tools using historical data and trends. While this is an effective way to help predict outcomes for future operations, biological conditions, and costs, many uncertainties could affect the findings of this Engineering Summary Appendix.

All cost estimates, even at a feasibility-level, have inherent risks and uncertainties. In development of cost estimates for the alternatives, Reclamation has no control over the costs of labor, materials, competitive bidding environments, unidentified field conditions, financial and/or commodity market conditions, or any other factors likely to affect the cost estimates of the alternatives, all of which are and will unavoidably remain in a state of change, especially in light of high market volatility attributable to Acts of God and other market forces or events beyond the control of the parties. As such, these cost estimates are based on normal market conditions, defined by stable resource supply/demand relationships, and do not account for extreme inflationary or deflationary market cycles. These estimates are a "snapshot in time" and their reliability will degrade over time. No warranty, promise, guarantee or representation, either expressed or implied, is given that proposals, bids, project construction costs, or cost of O&M functions will not vary significantly from these cost estimates.

Cost Estimates for Alternatives

Estimated total construction costs for each of the Comprehensive Plans are summarized in Table 5-2. Total capital and annual costs and more detailed cost estimate worksheets and supporting information are included in the following attachments to this appendix:

- **Attachment 1** – Summary Cost Estimates for Comprehensive Plans
- **Attachment 2** – 6.5-Foot Raise and Reservoir Area Infrastructure Cost Estimates (Appraisal-and feasibility-level)
- **Attachment 3** – 12.5-Foot Raise and Reservoir Area Infrastructure Cost Estimates (Appraisal-and feasibility-level)
- **Attachment 4** – 18.5-Foot Raise and Reservoir Area Infrastructure Cost Estimates (Feasibility-level)
- **Attachment 5** – Preliminary Construction Schedule and Work Packages
- **Attachment 6** – CP4A Crystal Ball Estimate
- **Attachment 7** – Construction Cost Estimate and Project Cost Estimate

Attachments 2 through 4 are the detailed cost estimates for the 6.5, 12.5, and 18.5-foot dam raise alternatives, respectively. Attachment 7 contains the initial Construction Cost Estimate and Project Cost Estimate which will be used in future budgetary and construction implementation activities.

The estimates of construction costs shown, and any resulting conclusions on the project's financial requirements, economic feasibility, or funding requirements, have been prepared from the best information available at the time the estimate was performed. Final project costs and resulting feasibility would depend on actual labor and material costs, competitive market conditions, and other variable factors, and should include escalation from the published price level to Notice to Proceed. Accordingly, the final project cost would vary from the estimate.

Table 5-2. Estimated Total Construction Costs for Comprehensive Plans

Item	CP1 6.5 Feet ($ million)	CP2 12.5 Feet ($ million)	CP3 18.5 Feet ($ million)	CP4 18.5 Feet ($ million)	CP4A 18.5 Feet ($ million)	CP5 18.5 Feet ($ million)
Field Costs						
Relocations						
Vehicular Bridges	$34	$34	$54	$54	$54	$54
Doney Creek Railroad Bridge	$56	$56	$56	$56	$56	$56
Sacramento River Railroad Bridge, Second Crossing	$116	$116	$116	$116	$116	$116
Pit River Bridge Modifications	$17	$23	$31	$31	$31	$31
Railroad Realignment	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2
Roads	$17	$26	$37	$37	$37	$37
Local Utilities	$24	$24	$30	$30	$30	$30
Transmission Lines	$19	$19	$19	$19	$19	$19
Buildings/Facilities - Recreation	$133	$150	$166	$166	$166	$166
Dams and Reservoirs						
Main Dam	$54	$64	$76	$76	$76	$76
Outlet Works	$27	$27	$27	$27	$27	$27
Spillway	$126	$131	$131	$131	$131	$131
Temperature Control Device	$28	$30	$31	$31	$31	$31
Powerhouse and Penstocks	$1.3	$1.3	$1.3	$1.3	$1.3	$1.3
Right Wing Dam	$4.6	$5.7	$6.9	$6.9	$6.9	$6.9
Left Wing Dam	$13	$18	$26	$26	$26	$26
Visitor Center	$8.4	$8.8	$9.1	$9.1	$9.1	$9.1
Dikes	$14	$16	$27	$27	$27	$27
Reservoir Clearing	$4.5	$7.2	$21	$21	$21	$21
Pit 7 Dam and Powerhouse Modifications	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2
Environmental Restoration	-	-	-	$6.2	$6.2	$18.2
Recreation Enhancement	-	-	-	-	-	$1.3
Total Field Costs	$713	$773	$881	$887	$887	$901

Table 5-2. Estimated Total Construction Costs for Comprehensive Plans (contd.)

Item	CP1 6.5 Feet ($ million)	CP2 12.5 Feet ($ million)	CP3 18.5 Feet ($ million)	CP4 18.5 Feet ($ million)	CP4A 18.5 Feet ($ million)	CP5 18.5 Feet ($ million)
Planning, Engineering, Design and Construction Management	$160	$174	$198	$200	$200	$203
Lands	$30	$47	$69	$70	$70	$70
Environmental Mitigation	$71	$77	$88	$88	$88	$88
Cultural Resource Mitigation	$14	$15	$18	$18	$18	$18
Water Use Efficiency Actions	$1.6	$2.6	$3.1	$1.6	$2.6	$3.8
Total Construction Cost	**$990**	**$1089**	**$1,257**	**$1,264**	**$1,265**	**$1,283**

Note:

Cost estimate is in January 2014 dollars and subject to change in the future. Escalation from published price level to notice to proceed is excluded. Estimates may include discrepancies due to rounding. For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03 (2007c).

Key:
$ million = million dollars
- = not applicable
CP = Comprehensive Plan

Chapter 6
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