Shasta Dam and Reservoir Enlargement

Appraisal Assessment of the Potential for Enlarging Shasta Dam and Reservoir

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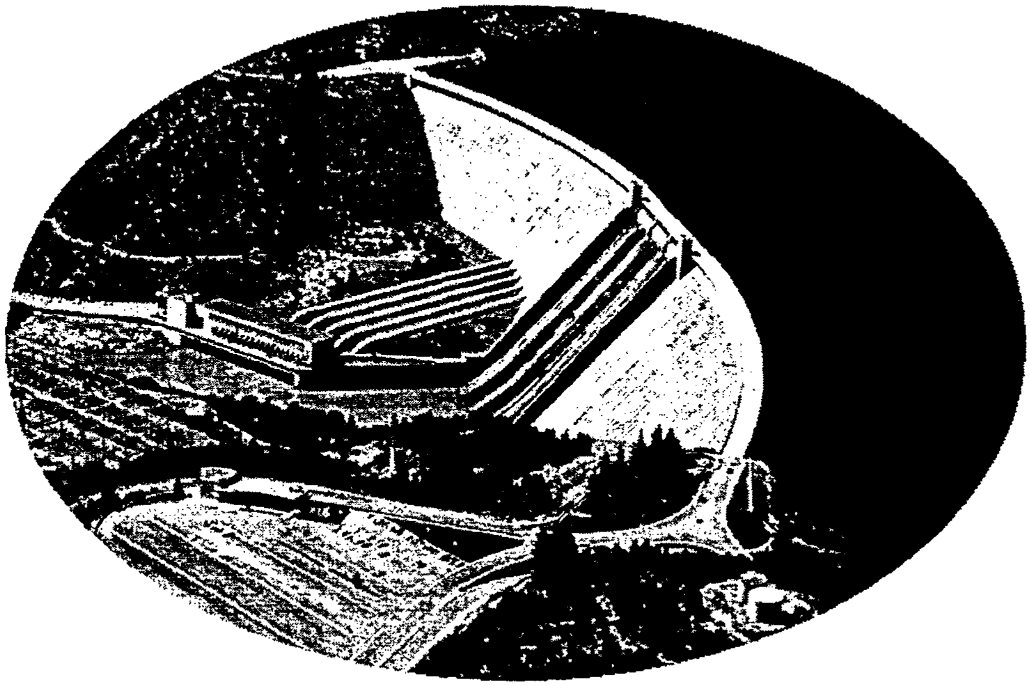
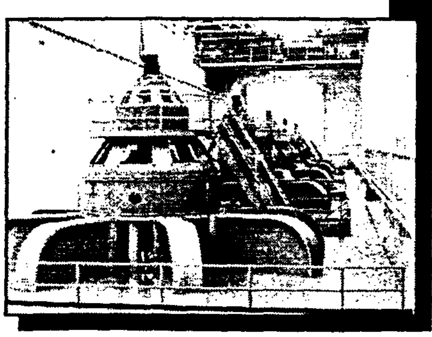


U.S. Department of the Interior
Bureau of Reclamation
May 1998



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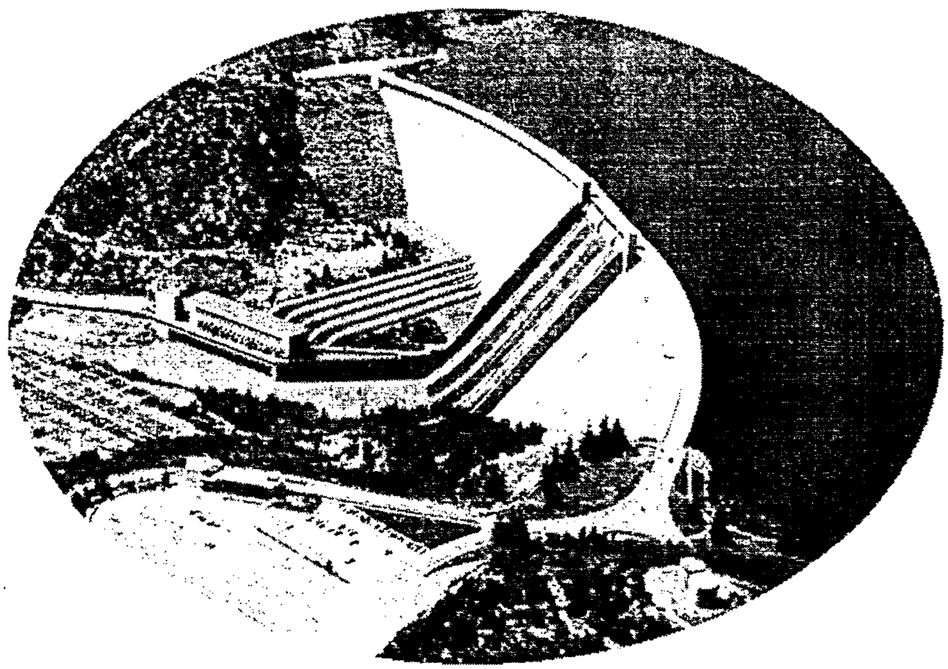

U.S Department of the Interior
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May 1998

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EXECUTIVE SUMMARY

Increasing demands for clean, reliable water in the Central Valley are prompting water agencies to consider methods which could be used to increase water supplies. One project that could increase water supply would be the enlargement of Shasta Dam.

This appraisal level study investigated three enlargement options to illustrate the potential costs, technical issues, and impacts associated with dam raises of 6, 100, and 200 feet. No engineering or geologic conditions were identified that preclude the modification of the existing dam for a raise up to 200 feet. Implementing the options would provide from about 300,000 to 9,000,000 acre-feet of additional storage space in the reservoir, inundating between 2,000 and 30,000 additional acres.

The Investigation of enlargement options included consideration of the following:

- Spillway Modifications
- Outlet Works Modifications
- Temperature Control Device Modifications
- Existing Penstock and Powerplant Modifications
- Development of a New Powerplant and Penstocks
- Existing Switchyard Modifications
- Development of New Switchyards
- Reservoir Dikes
- Relocation of Interstate 5 - Union Pacific Railroad Bridge at Bridge Bay
- Other Road and Bridge Relocations
- Recreation Facility Relocations
- Community Relocations
- Keswick Dam and Powerplant Modifications
- Current and Potential Modifications to Water Operations
- Water Rights Issues
- Technical Issues Associated with Construction
- Scheduling and Sequencing of Construction
- Potential Environmental Affects and Opportunities
- Identification of Potential Flood Control, Water Supply, Hydropower, and Environmental Benefits

Significant flood control benefits and greatly enhanced flexibility to maintain downstream instream flows and water quality could be derived from this additional storage. Costs of options range from about $122 million for a six foot raise, to $5.8 billion for a 200 foot raise. The cost per acre-foot of storage ranges from about $422 to $992. Table ES-1 summarizes potential enlargement options.

Further feasibility studies examining the opportunities for enlarging Shasta Dam and reservoir would be very valuable. Through more advanced studies engineering considerations and cost savings measures can be refined, operational opportunities can be further defined in the context of statewide water issues and programs, benefits can be optimized in relation to meeting multiple demands, and a determination of the optimal height of enlargement can be completed.

Table ES-1 Summary Table - Enlargement Option Features

FEATURE	EXISTING DAM	HIGH OPTION	INTERMEDIATE OPTION	LOW OPTION
Dam Crest Elevation (ft)	1,077.50	1,280	1,180	1,084
Dam Crest Length (ft)	3,460	4,930	4,590	3,660
Height Raise (ft)	None	202.5	102.5	6.5
Joint Use and Top of Gates Elevation (ft)	1,067	1,273.50	1,173.50	1,077.50
Total Reservoir Capacity (MAF)	4.5	14	8.5	4.9
Increase in Capacity (MAF)	None	9.5	4	0.4
Spillway Crest Elevation (ft)	1,037	1,246	1,146	1050
Spillway Gates	three 28' by 110' drum type	six 27.5- by 55-foot radial	six 27.5- by 55-foot radial	six 27.5- by 55-foot radial
Outlet Works	18 outlets in 3 tiers at elev. 950 (six 96" tubes), 850 (eight 96" tubes), and 750 (four 102" tubes)	Replace all 14 existing outlet tubes to handle increased head	Replace outlets in two lower tiers of existing dam (upper tier can accommodate increased head from raise)	Replace 4 tube valves on lower tier outlets for greater reliability and discharge capacity
Relocations				
Interstate 5-Union Pacific Railroad Bridge- Bridge Bay	Not applicable	Yes	Yes	No
Recreation Facilities	Not applicable	Yes	Yes	Minor
Resort Facilities	Not applicable	Yes	Yes	No
Communities	Not applicable	Yes	Yes	No
Hydropower Features				
Temperature Control Device	250' by 300' shutter structure and 125' by 170' with operating range between elev. 840 and 1065.low level intake structure	Raise operating controls	Raise operating controls	Raise operating controls
Existing Penstocks and Penstock Intakes	Five 15' diameter steel penstocks at elev. 815	New 16' by 25' gates, Replace existing pipes with thicker walled steel pipes, strengthen exposed pipe supports	New 16' by 25' gates, Replace existing pipes with thicker walled steel pipes, strengthen exposed pipe supports	Strengthen exposed pipe supports
New Penstocks and Penstock Intakes	Not applicable	Five new 20' diameter penstocks and intakes at elev. 970 on left abutment	Five new 20' diameter penstocks and intakes at elev. 880 on left abutment	None
Existing Powerplant	Currently rated at 578 MW with ongoing uprating program to increase generation to 676 MW. Operation level between elev. 840 and 1065.	No modifications for existing powerplant to upgrade power generation.Upstream isolation valves required to protect existing spiral cases for reservoir elevations above 1186 feet.	No modifications for existing powerplant to upgrade generation. New upstream isolation valves not required.	No modifications for existing powerplant to upgrade generation. New upstream isolation valves not required.
New Powerplant	Not applicable	Five 260 MW turbine/generator units (combined capacity of 1,300 MW) for operation between elevations 980 and 1,280 feet.	Five 215 MW units (combined plant capacity of 1,075 MW) operating between elevations 890 and 1180.	None
Switchyard	Existing switchyard located at left abutment.	Replace the existing switchyard with a new 230kV switchyard (required space 1,250' by 400') at a downstream location. Develop a new 525 kV switchyard (required space 700' by 500')along left abutment.	Replace the existing switchyard with a new 230kV switchyard (required space 1,250 by 400') at a downstream location. Develop a new 525 kV switchyard (required space 350' by 500') along left abutment.	None
Reservoir Dikes				
Centimundi	No	Yes	No	No
Bridge Bay	No	Yes	No	No
Jones Valley	No	Yes	Yes	No
Clickapudi Creek	No	Yes	Yes	No
Other				
Keswick Dam and Powerplant	Not applicable	Enlargement required up to 25 feet to accommodate increased releases from new powerplant.	Enlargement required up to 25 feet to accommodate increased releases from new powerplant.	None
Scheduling/Sequencing	Not applicable	8 to 10 year construction period	8 to 10 year construction period	4 year construction period
Total Investment Cost	Not applicable	$5,810,927,000	$3,889,729,000	$122,281,000

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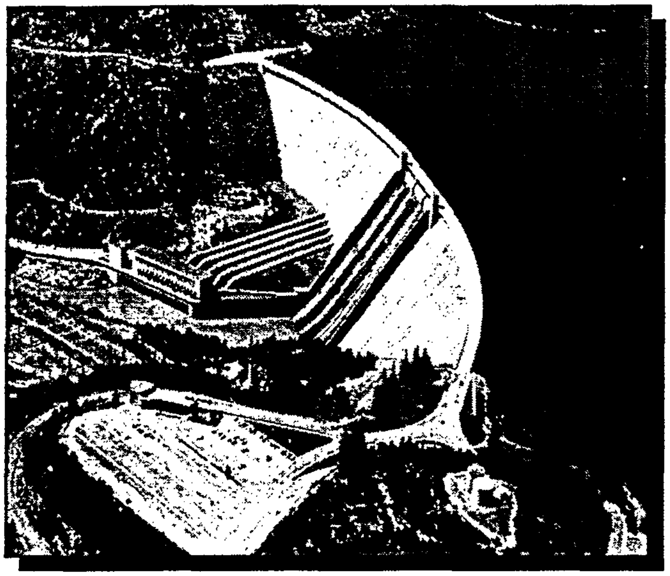
FIGURES

APPENDIXES



Water management in the State of California faces many unique challenges in meeting current and future demands. One of these, increasing pressure to maintain and improve water supplies for environmental, urban, and agricultural uses, may require that additional water storage be developed.

Accordingly, several key water resource management efforts are currently underway in California which will significantly influence water resource management into the next century. These include the CALFED Bay-Delta Program, Central Valley Project Improvement Act actions, and development of the Bay-Delta Water Quality Control Plan. These programs or efforts will significantly influence State water demands. Many stakeholders participating in these activities believe the only method of meeting all future demands for water is through a combination of improving water use efficiency and development of additional storage. In general, the most viable options for development of additional storage are considered to be at offstream storage sites, where environmental impacts may be less, or through enlargement of existing facilities in high precipitation regions where hydrologic conditions can sustain additional storage, and environmental affects are reduced because of the facilities that already exist.

Shasta Dam, a critical component in the existing water management system, is particularly important and unique in its ability to meet water quality, and other environmental resource management goals of the Sacramento River and the Sacramento-San Joaquin Delta. Shasta Dam, located in the upper Sacramento River Basin, has geographic and basin hydrological characteristics that give it a unique ability to meet water demands.

To facilitate a greater understanding of one water storage proposal, the Bureau of Reclamation has prepared this assessment of the potential for enlarging Shasta Dam. This is considered an appraisal level study that is to be used to identify the scope of any project plan and to determine if more detailed feasibility studies are warranted. The primary purpose of this assessment was twofold. First, the purpose was to determine the costs of a wide range of potential enlargements. Second, the purpose was to identify critical issues that potentially affect project feasibility. The following chapters summarize the results of the assessment.

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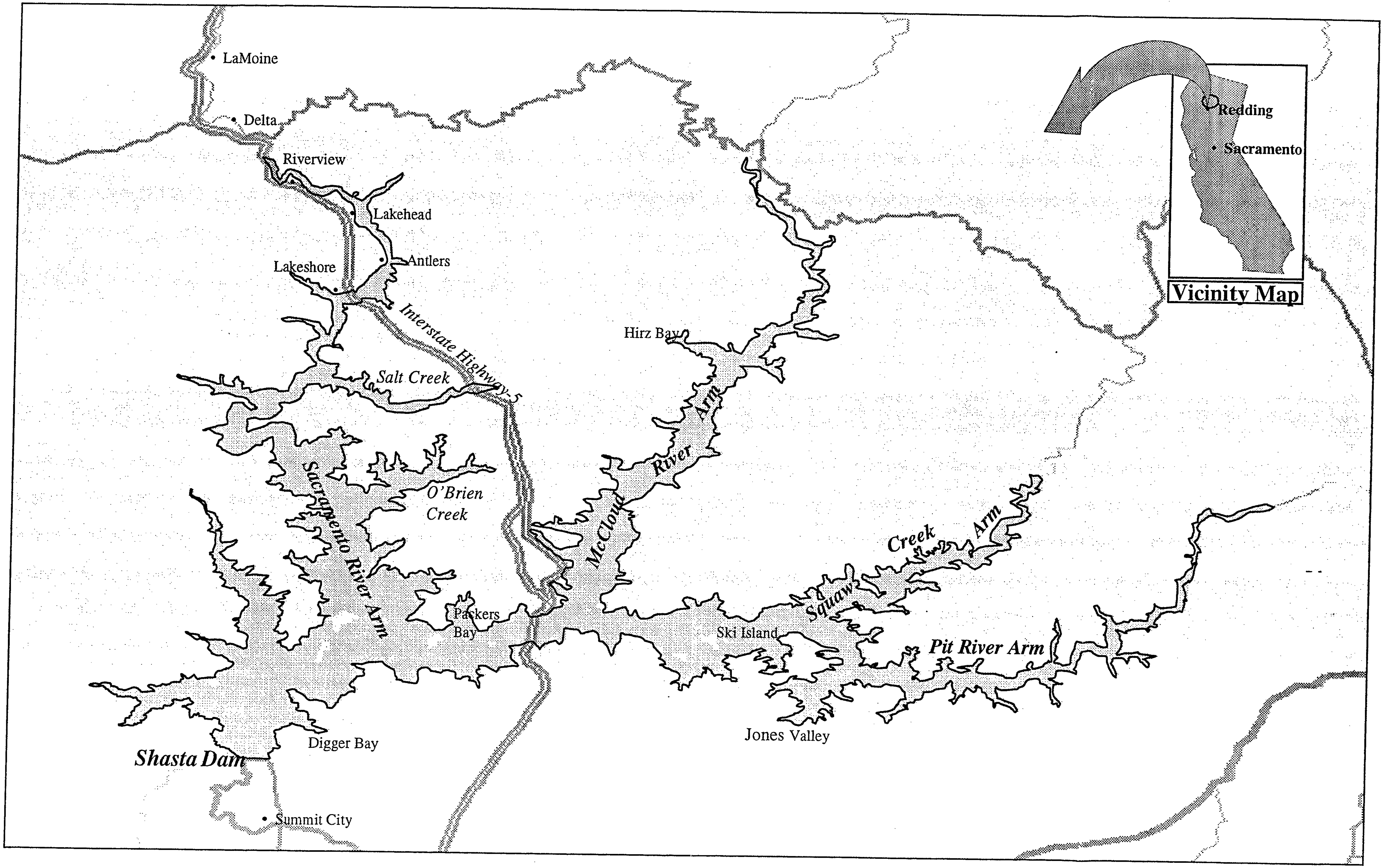
Specifications of Existing Dam

Total Drainage Area	6,421 sq. miles
Dam Type:	Concrete Gravity
Storage:	
With drum gates raised to elevation 1065.0	4,492,742 acre-feet
With 2-foot flashboards lowered to top of drum gates (maximum storage excluding surcharge space; elev. 1067)	4,552,000 acre-feet
At Maximum Storage(Elev. 1067):	
Reservoir Length	35 miles
Surface Area	29,605 acres
Shoreline	365 miles
Crest Length	3,460 feet
Crest Elevation	1077.5 feet
Crest Width	41 feet 5 inches
Structural Height (includes foundation)	602 feet
Height above Streambed at Dam Axis	533 feet
Spillway:	
Width	350 feet
Gates	Drum Type (3) ea. 110 feet x 28 feet
Spillway Outlets:	
Elevation 950	Six 96-inch tubes
Elevation 850	Eight 96-inch tubes
Elevation 750	Four 102-inch tubes

Powerplant:
Five main units
Five 15-foot diameter plate steel penstocks
Two station service turbines

Shasta Dam and lake is located about nine miles northwest of Redding, California on the Sacramento River. The dam was built over an eight year period between 1938 and 1945. The dam is a 533 feet high concrete gravity dam, which provides flood control, power, and water supply benefits. It is a key facility in the Federal Central Valley Project, representing about 41 percent of the total reservoir storage capacity of the entire Central Valley Project. Figure 1 shows the reservoir area.

Three increases in dam heights were evaluated in this appraisal evaluation. These alternative heights, the High, Intermediate, and Low Options, were used to define cost curves and increased storage capabilities for the full range of elevations between the Low and High Options. The elevations of the three options were strategically selected based upon engineering considerations that primarily defined breaks in the cost versus elevation curve. The elevation, storage, and reservoir surface area relationships of the full range of potential height increases are shown in Figure 2. Appendix 1 gives a tabular listing of the storage-area-elevation relationships. The direct actions which may be required in any potential enlargement can be categorized into five different categories: 1) Structural dam and abutment modifications; 2) Relocations; 3) Keswick Dam modifications; 4) Reservoir area saddle dike construction; and 5) Power facility improvements and additions. Additional actions may also be required as a result of mitigation or operations requirements. The



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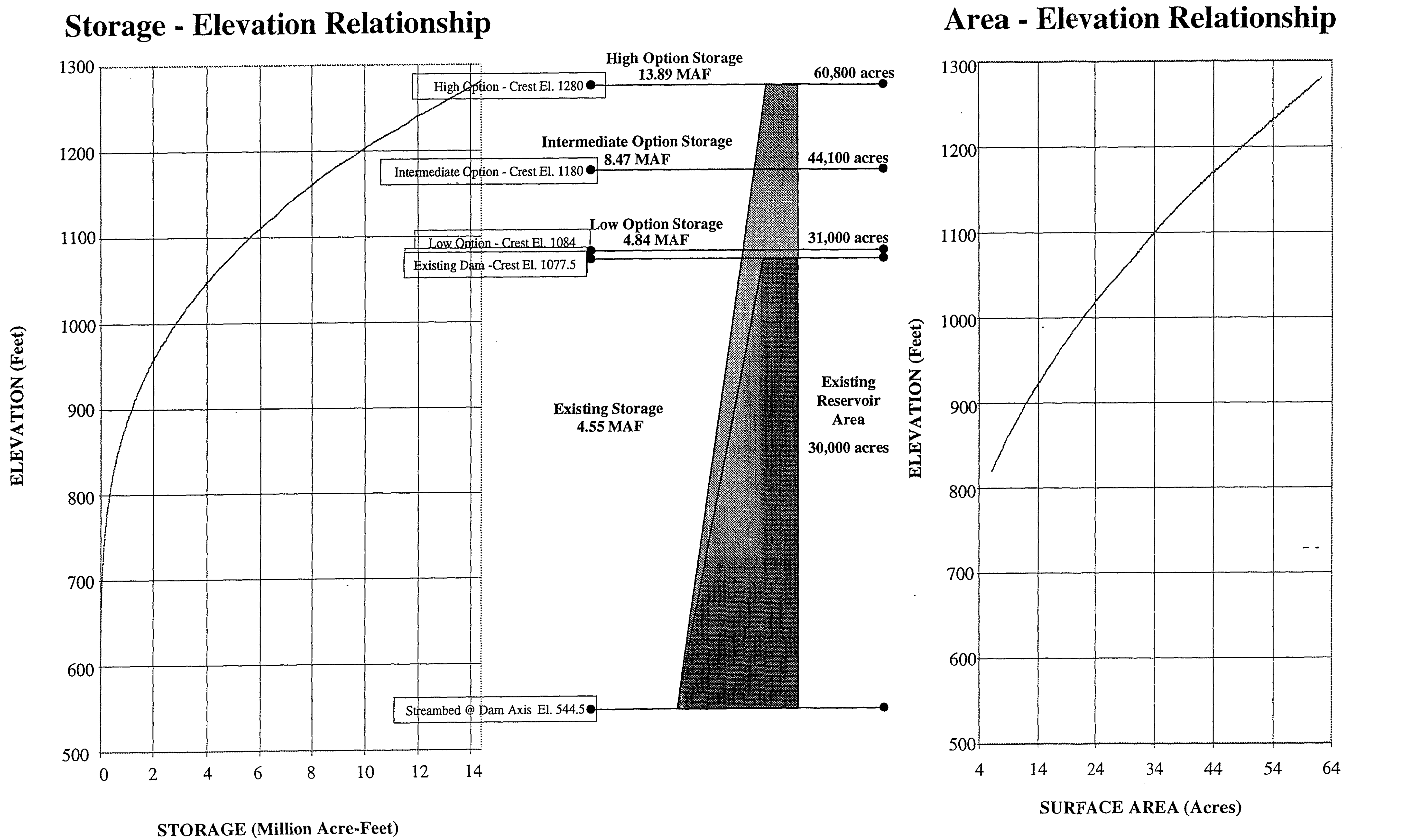


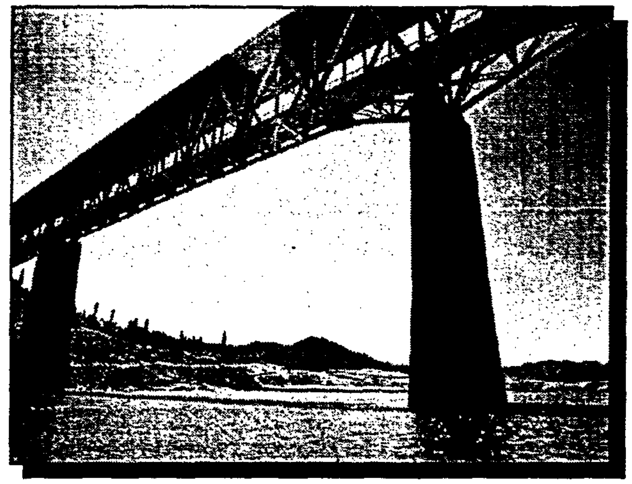
Figure 2 Storage - Area - Elevation Relationships of Shasta Reservoir

Low, Intermediate, and High Options are described in more detail below.

Low Option

The Low Option evaluates a dam raise with a new crest elevation at 1084 feet. The existing dam has a crest elevation at 1077.5 and an elevation of 1067 for the maximum water surface for joint use storage space. The Low Option crest elevation of 1084 represents a structural raise of 6½ feet to the crest height of the existing dam and has a new top of joint use storage space at elevation 1075.5, an additional 8½ feet of water in the reservoir. The total capacity of this new reservoir would be 4.84 million acre-feet, an increase of 290,000 acre-feet above the existing available storage.

The dam raise will be limited to the existing dam crest only, with mass concrete placed in blocks on the existing concrete gravity section and precast concrete panels used to retain compacted earthfill placed on the embankment sections. A new spillway crest section would be developed within the raised structure. Construction is assumed to require the removal of selected features from the existing dam crest, including the gantry crane and rails, the spillway bridge, the sidewalks and parapet walls, and miscellaneous concrete on both abutments. The spillway drum gates and control equipment, and the concrete cantilever support walls, would also be removed to accommodate the higher reservoir levels. Control features of the existing temperature control device would be extended up to the new crest elevation. The temperature control device itself would remain in place. It is assumed that personnel access can be provided to the existing elevator towers.



The Pit River Bridge carries traffic of Interstate Highway 5 on its upper deck and extensive railroad traffic on its lower deck. Relocation of this feature is not required in the Low Option raise to elevation 1084.

Although the raised dam crest construction would remain above the new top of joint-use storage, and provide for flood surcharge only, waterstops and other seepage control measures would be provided.

This option maximizes storage without relocating the Interstate Highway 5 and Union Pacific Railroad Pit River Bridge at Bridge Bay, and minimizes any relocations of recreational facilities within the reservoir area. The option also avoids the construction of additional saddle dikes in the reservoir area. Modifications to the existing power facilities and Keswick dam are not required, nor are any new power facilities developed under this option.

Intermediate Option

The Intermediate Option evaluates a dam raise with a new crest elevation at 1180 feet. This represents a structural raise of 102½ feet to the height of the existing dam. The new top of joint use storage space would be elevation 1171.5. This allows the storage of

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an additional 104½ feet of water in the reservoir above the existing joint use storage pool elevation. The total capacity of this new reservoir would be 8.47 million acre-feet, an increase of 3.92 million acre-feet above the existing available storage.

For the intermediate dam raise the existing concrete gravity dam section would be raised using a mass concrete overlay on the main section of the dam with roller compacted concrete wing dams constructed on both abutments. The left wing dam would extend approximately 1,380 feet, and the right wing dam would extend approximately 420 feet. The mass concrete overlay on the downstream face of the existing dam in the main section would extend from elevation 1180 down to the foundation contact at the downstream toe on a 0.7:1 slope. The overflow (or spillway) section will be made thicker to accommodate the gated spillway crest. The mass concrete overlay for the intermediate dam raise option will be significantly thinner than for the high dam raise option.

A new crest roadway and spillway bridge would be constructed. In addition, new elevators and gantry crane would be required along with all the associated mechanical equipment required for operating the various outlet gates, temperature control device, and other features.

This option halves the number of saddle dikes required within the reservoir area to close off the upper basin watershed allowing storage without spilling onto adjacent watersheds. Two saddle dike, at Jones Valley and Clickipudi Creek, are required in this option, but this is half of those needed in the high option.

Relocation of the Pit River Bridge at Bridge Bay is required in this alternative. In addition most recreational facilities require relocation. New power facilities are also developed in this alternative. These power facilities include a new power plant below the left abutment, improvements to the existing penstocks, and a new switchyard. New facilities (raised dam and modified power facilities) at Keswick would also be required.

While the existing powerplant would continue to be operated within its operating range under this enlargement option, no new upgrading modifications to the existing powerplant were considered in this appraisal level study (ongoing generator rewind uprating programs were assumed to occur). Given the increased reservoir elevations in this alternative, and in the High Option, there may be a potential requirement for major modifications to the existing structure to accommodate new units and overhead cranes. Evaluation of these requirements was beyond the scope of this appraisal study. In addition, major modifications may be required for the temperature control device to accommodate higher design discharges. Further studies are needed to evaluate alternatives to modifying the existing powerplant and to determine the most economic way of optimizing its generating capacity under any potential enlargement.

High Option

The High Option evaluates a dam raise with a new crest elevation at 1280 feet. This represents a structural raise of 202½ feet to the height of the existing dam. The new top of joint use storage space would be elevation

1271.5. This allows the storage of an additional 204½ feet of water in the reservoir. The total capacity of this new reservoir would be 13.89 million acre-feet, an increase of 9.34 million acre-feet above the existing available storage.

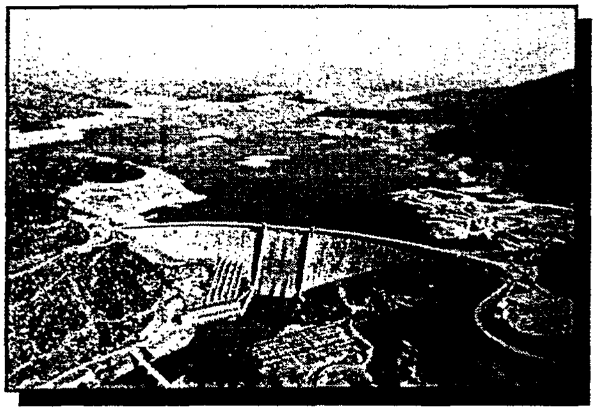
The high option represents the highest feasible raise of Shasta Dam. Enlargements beyond this point begin to experience significant geological foundation problems and significant relocation requirements of upstream Pacific Gas & Electric reservoirs and powerplants.

The existing concrete gravity dam section will be raised using a mass concrete overlay on the existing dam crest and downstream face. The upstream face within the curved nonoverflow sections will extend vertically to the new dam crest at elevation 1280, and the downstream face will have a 0.7:1 slope to the downstream toe. The dam crest will be completed with a crest cantilever for the roadway surface, sidewalks, and parapet walls. The existing elevator shafts will be extended to the new dam crest, and new elevator towers will be provided.

The overflow (or spillway) section will require a thicker section to accommodate the gated spillway crest (similar to the profile for the existing spillway).

The new dam crest would include a crest roadway and spillway bridge, passenger and freight elevators, and three gantry cranes sized to handle mechanical equipment located at the upstream face for the river outlets in the spillway section (60-ton capacity), and for the penstocks for both the existing powerplant (125-ton capacity) and the new powerplant (175-ton capacity). The proposed configuration of the dam modifications would permit retention of the Upper Vista House and parking lots.

Four saddle dikes to close off the upstream watershed are required in this option. A new powerplant and associated switchyard facilities are included on the left abutment. The existing powerplant would continue to be operated within its operating range. The existing penstocks on the right abutment would also be upgraded. New facilities at Keswick (raised dam and modified power facilities at Keswick) would also be required to accommodate the new powerplant.



This chapter documents the current technical engineering studies based on dam crests at elevation 1280 (high), elevation 1180 (intermediate), and elevation 1084 (low), utilizing mass concrete gravity sections with roller compacted concrete gravity wing dams where required. The current appraisal-level designs for enlargement of Shasta Dam address new spillways, river outlets, reservoir dikes, and hydropower features. These features are discussed below along with a brief discussion of diversion features, and associated Keswick Dam modifications.

Site Geology

Shasta Dam is located in the foothills near the northern end of the Sacramento Valley, in the southern Klamath Mountain Geomorphic Province. Tectonic activity associated with the interactions between the North American, Pacific, and Gorda crustal plates (Mendocino triple junction) where they join about 100 miles west of the dam, has influenced regional geomorphic features. Eruptions at Mt. Shasta, a dormant volcano located about 56 miles northeast of the dam, and at Mt. Lassen, a dormant volcano about 50 miles to the southeast, are attributed to heat developed near the interface between the Gorda and the overriding North American plate. Forces generated by the impact and jostling of these plates are believed largely responsible for the faults and the jointed, crushed, and sheared zones that are common to this region, as well as for continuing seismic activity.

Shasta Dam is in an area of historically low-level seismicity in which no Quaternary faults are known to exist (USBR, July 1986). Activity increases to the east in the Lassen Peak area, and to the west in the area of the Mendocino triple junction. The dam may be subjected to the effects of moderate to large earthquakes that might originate in these adjacent, more seismically active regions to the west and east. Most recently (1991/1992), earthquakes with magnitudes between M 6.0 and 7.1 were located neat the Mendocino triple junction (CDMG, March/April 1992). These earthquakes were felt throughout much of northern California and southern Oregon. Earthquakes of magnitude 6.0, 6.5, and 7.1 occurred on April 25 and 26, 1992.

Studies performed by the University of California Seismograph Station personnel indicate that the rate of local seismicity that occurred during the initial filling of Shasta Lake in 1943 was not significantly different from that documented during the 1953-1964 period. In addition, an annual periodicity correlating to seasonal changes in reservoir levels was not evident in the seismicity data for that period. Therefore, future reservoir-induced seismicity does not appear to be likely at the existing Shasta Lake. Further review of the potential for reservoir induced seismicity would be conducted in feasibility studies for any potential enlargement project.

The foundation of Shasta Dam consists of the Copley Formation, a sequence of volcanic rocks which has been metamorphosed to produce a rock type more commonly called greenstone. In the foundation, this rock is fresh and hard where unbroken; however, its integrity has been disturbed by numerous seams consisting of weathered joints, shears, and zones of crushed rock.

All rock on the left abutment is a metavolcanic greenstone of the Copley Formation. Drill hole investigations conducted in 1984 for previous dam enlargement studies confirmed variably porphyritic to fine-grained meta-andesite flows with occasional medium- to course-grained pyroclastic layers with subordinate brecciated lenses. Weathering effects were found to decrease with depth in all seven drill holes, and the weathering boundaries encountered were generally consistent with the results of a geophysical survey performed in 1982. Eighty-four percent of the rock core recovered was very intensely fractured. Rock strength tests ranged from average to hard rock (unconfined compressive strengths from 5,000 to 16,000 lb/in^2), and permeability was considered low (K from zero to 350 feet per year).

Rock on the right abutment is of similar origin and exhibits similar weathering conditions. Most of the rock recovered in drill holes is moderately to slightly fractured, hard (unconfined compressive strengths from 8,000 to 16,000 lb/in^2), and has a low permeability (K less than 100 feet per year).

Original construction documentation states that the existing dam foundation was explored meticulously and zones of weakness were effectively treated. In general, the quality of the foundation improves with depth and despite the surface fracturing, the individual pieces or blocks are sound and fit together tightly.

Removal of Existing Structures

Enlargement of Shasta Dam will require the removal of existing structures on the dam crest, including the parapet walls and crest cantilever, sidewalks, curbing, crane rails, and spillway bridge. The existing elevator towers are assumed to be retained for the low dam raise option only. The spillway drum gates and frames, cantilever support walls, control equipment, and bridge piers must be removed for all dam raise options to accommodate the new spillway gates. The high and intermediate dam raise options will require the complete removal of the spillway training walls, and minor excavation of the stilling basin floor at the downstream toe contact. The existing concrete surfaces will be prepared for new concrete placement by the application of high-pressure water jets (over 6,000 lb/in^2), consistent with normal practice for preparing construction joints, rather than the bush-hammering or sand-blasting assumed in previous studies. This method of surface preparation was used successfully for the modifications to

Theodore Roosevelt Dam in Arizona, which was designed by Reclamation with construction being completed in 1996.

The existing 125-ton gantry crane will likely be replaced with new equipment, due to its age (over 50 years old). Other mechanical equipment to be removed includes various river outlet gates and valves, steel piping, and operating equipment.

Concrete Dam Main Section and Abutments

High Option - Crest Elevation 1280.- As described previously, a mass concrete overlay on the existing dam crest and downstream face is required. The upstream face within the curved nonoverflow sections will extend vertically to the new dam crest at elevation 1280, and the downstream face will have a 0.7:1 slope. The mass concrete will be placed in alternating high-low blocks, with 10-foot lift heights and keyed contraction joints, similar to the recent dam raise modifications to Theodore Roosevelt Dam in Arizona.

Due to the thickness of the concrete overlay, a longitudinal contraction joint may be required, which would also be keyed and grouted. The dam crest will be completed with a crest cantilever for the roadway surface, sidewalks, and parapet walls. The existing elevator shafts will be extended to the new dam crest, and new elevator towers will be provided.

The overflow (or spillway) section will require a thicker section to accommodate the gated spillway crest (similar to the profile for the existing spillway).

The left and right abutments will be excavated to the top of moderately weathered rock, to provide foundations for roller-compacted concrete (RCC) wing dams. Assumed excavation depths average 70 feet on the left abutment and 60 feet on the right abutment. This excavation will be performed following the construction of the upstream cellular cofferdams and will include the removal of embankment materials and concrete core walls.

Extensive dental concrete treatment may be required for expected shear zones within the excavated foundation surface, and shaping concrete will be required to provide a suitable surface for roller compacted concrete placement. The roller compacted concrete will be rolled and compacted in 1- to 2-foot lifts between slip-formed concrete facing elements at the upstream and downstream faces, similar to Upper Stillwater Dam in Utah, designed by Reclamation and with construction completion in 1988 . This will provide a similar appearance to the mass concrete dam section.

For crest elevation 1280, the left abutment wing dam will extend approximately 1,500 feet and the right abutment wing dam will extend approximately 570 feet. The existing grout and drainage curtains for Shasta Dam will be made deeper for the higher reservoir pressures, and will be extended on both abutments. Extensive instrumentation will be required for the dam raise construction, including new thermistors and jointmeters throughout the mass concrete blocks. The existing instruments will be extended or replaced. Specific instrumentation monitoring requirements will be developed in future studies.

The new dam crest will include a crest roadway and spillway bridge, passenger and freight elevators, and a total of three gantry cranes sized to handle mechanical equipment, one located at the upstream face for the river outlets in the spillway section (60-ton capacity), one for the penstocks for the existing powerplant (125-ton capacity), and one for the new powerplant (175-ton capacity). A modern lighting system will be provided for the dam crest, and lighting and ventilation will be provided for the new galleries. The proposed configuration of the dam modifications will permit retention of the Upper Vista House and parking lots. Figure 3 shows a plan, profile, and section drawing of the proposed High Option.

<u>Intermediate Option - Crest Elevation 1180</u>.- The appraisal-level designs for the intermediate dam raise option are very similar to those for the high dam raise option. The left wing dam will extend approximately 1,380 feet and the right wing dam will extend approximately 420 feet. The overflow (or spillway) section will be made thicker to accommodate the gated spillway crest. The mass concrete overlay for the intermediate dam raise option will be significantly thinner than for the high dam raise option, and may not require a longitudinal contraction joint or an extension of the stilling basin.

<u>Low Option - Crest Elevation 1084</u>.- The dam raise in this option will be limited to the existing dam crest only, with mass concrete placed in blocks on the existing concrete gravity section, including the new spillway crest section, and with precast concrete panels used to retain compacted earthfill placed on the embankment sections (assuming reinforced-earth methods as used for Lake Sherburne Dam in Montana). No additional material is needed on the face of the existing dam.

Construction is assumed to require the removal of selected features from the existing dam crest, including the gantry crane and rails, the spillway bridge, the sidewalks and parapet walls, and miscellaneous concrete on both abutments. The spillway drum gates and control equipment, and the concrete cantilever support walls, would also be removed to accommodate the higher reservoir levels. It is assumed that personnel access can be provided to the existing elevator towers in order to retain them.

Spillway and Outlet Works (All Options)

The spillway structure layouts for all three dam raise options are basically the same. The existing spillway crest length of 330 feet is retained, but is divided into six 55-foot-long gated sections, rather than the three 110-foot-long openings provided for the existing drum gates. This significantly reduces the spillway bridge spans, and allows a 2:1 gate width to height ratio for design of the new radial gates. Location of the radial gates on the crest requires the spillway bridge to be shifted upstream, which affects the horizontal alignment of the crest roadway. The spillway bridge girders should also remain above the water surface for the design flood.

The existing stilling basin has a 12:1 sloping apron approximately 304 feet long, and walls up to 94 feet high and 392 feet long. The high dam raise option will result in a concrete overlay thickness which serves to reduce the existing stilling basin length, and

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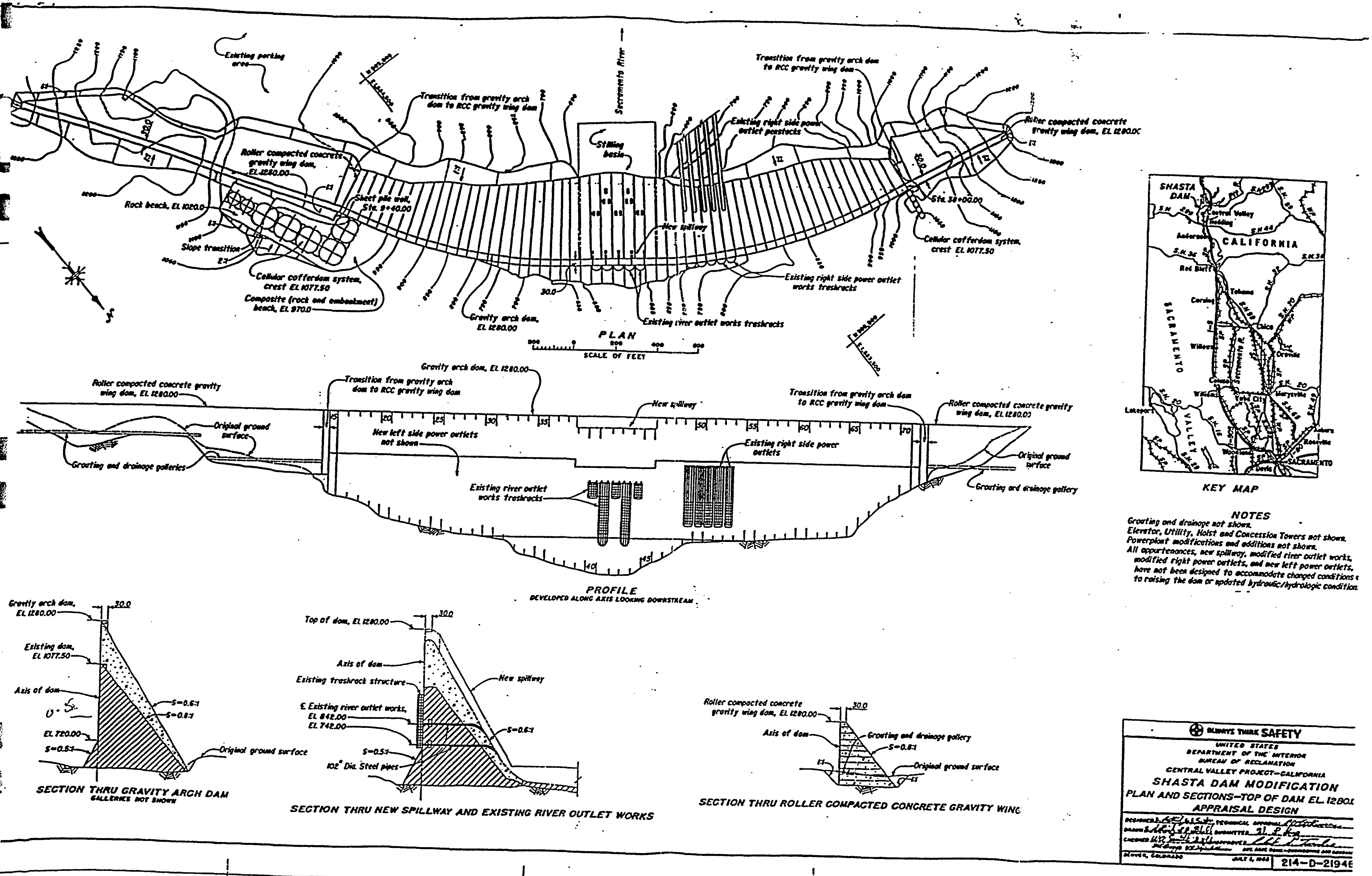

Figure 3

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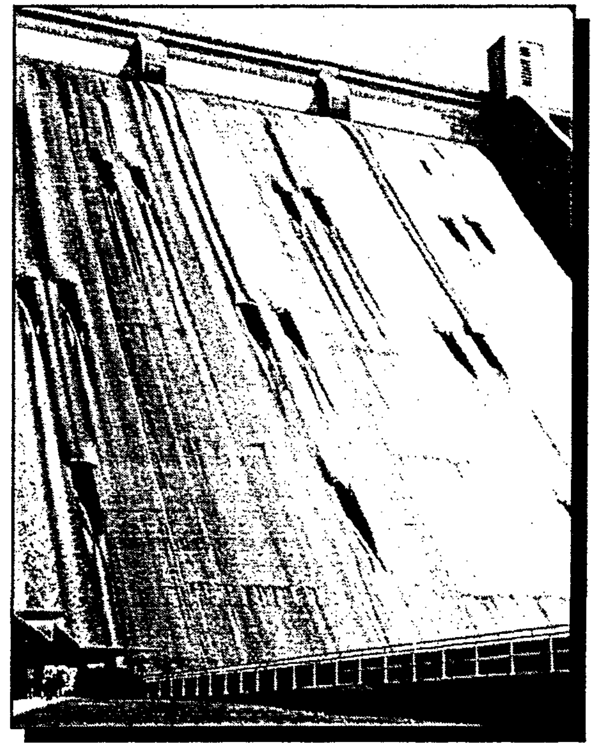
will require at least a corresponding increase in basin length by extending the downstream end of the basin. The existing stilling basin floor and walls were extended 50 feet for the appraisal-level design estimate (high dam raise option only), but further analysis will be required for future studies.

There are three tiers of river outlets in the spillway overflow section - the upper tier has six outlets at elevation 942.0; the middle tier has eight outlets at elevation 842.0; and the lower tier has four outlets at elevation 742.0, for a total of eighteen outlets. All existing river outlets are to be retained for all dam raise options, modified as necessary, to help meet reservoir evacuation requirements.

Spillway Drum Gates.- The existing spillway drum gates will be removed for all dam raise options. Previous studies have shown the drum gates and cantilever support walls to be susceptible to failure during the maximum credible earthquake, and gate stresses may be near maximum allowable values for the current storage level at elevation 1067 (with flashboard gates in place).

The current appraisal-level designs assume the installation of six 55- by 27.5-foot steel radial gates, with a total crest length of 330 feet. Radial gates were selected for their economy and operating reliability. Each radial gate would be operated using a gate hoist (with wire ropes) located on an operating deck above the gate. Reservoir storage would be permitted to the tops of the radial gates, which establishes the top of joint-use storage.



Spillway Bridge.- The spillway bridge must be located upstream of the radial gates and operating decks to permit their operation, which results in an horizontal offset from the dam crest roadway centerline.

Outlet Works Modifications.- The current studies assume river outlet modifications will include the installation of two 102-inch-diameter ring-follower gates in tandem at the present locations of the 96-inch outlet gates (at elevations 942 and 842) and the 102-inch tube valves (at elevation 742). Ring-follower gates should be more economical than other gate options, and will allow the maximum release capacity for the system, but they are not regulating gates. The upstream gates will serve as guard gates for emergency closure. The downstream gates are only to be operated fully open or fully closed, as is the case for the existing outlet gates. If additional flow regulation is determined to be required, as is now available with the four tube valves, two or more river outlets could be fitted with 96-inch jet-flow gates for a range of gate openings (proposed in previous studies for all river outlets). Larger (126-inch-diameter) linings would be required downstream of the jet-flow gates, however.

The high dam raise option (crest elevation 1280) would require the replacement of all fourteen outlet gates and all four tube valves, due to the higher reservoir pressures. The intermediate dam raise option (crest elevation 1180) would allow the retention of the upper tier of outlet gates, as they were originally designed for the same (higher) head as the middle tier of outlet gates, and could accommodate the 100-foot higher reservoir head. The low dam raise option assumes the replacement of the four existing tube valves, to provide greater operating reliability and improved discharge capacity.

The proposed ring-follower gate size matches the diameter of the existing steel liners (to be retained), and essentially provides a pressure pipe system with downstream control. Concrete excavation will be required in both the floor and the roof of the existing gate chambers to permit removal of the existing embedded gates and valves, and installation of the larger ring-follower gates. The new gates would be delivered in sections through the existing elevator shafts and access galleries, for assembly in their final locations. The gate chambers would be completed with concrete backfill, and new gate control systems would be installed.

The installation of tandem gates to meet emergency closure requirements would permit the utilization of a more economical, upstream coaster-type bulkhead gate with lifting frame for gate maintenance purposes. Bulkhead gate guides for each river outlet would extend to just below the spillway crest, for installation of the single bulkhead gate using a new 60-ton gantry crane on the spillway bridge. The upstream bulkhead gate would also be used during construction for installation of the new ring-follower gates below the reservoir level.

The existing 102-inch-diameter steel pipes for the river outlet works, as originally designed and shown on the available drawings, are considered to be fully functional for handling the increased external and internal pressures resulting from all dam raise options. The existing pipes would have to be physically and ultrasonically examined to determine whether any pipe wall loss has occurred over the years.

The downstream portion of the steel pipe for each river outlet would have to be removed where it begins to bend downward to the 93-inch-diameter end (a length of about 41 feet). Straight sections of new 102-inch piping (with about a 3/4-inch wall thickness) would be added to the existing piping to extend the river outlets to the new downstream face of the dam. The ends of the new outlet pipe extensions would be made similar to the existing ones, with a 41°19' downward angle and a transition to the 93-inch-diameter by 5/8-inch-wall steel pipe.

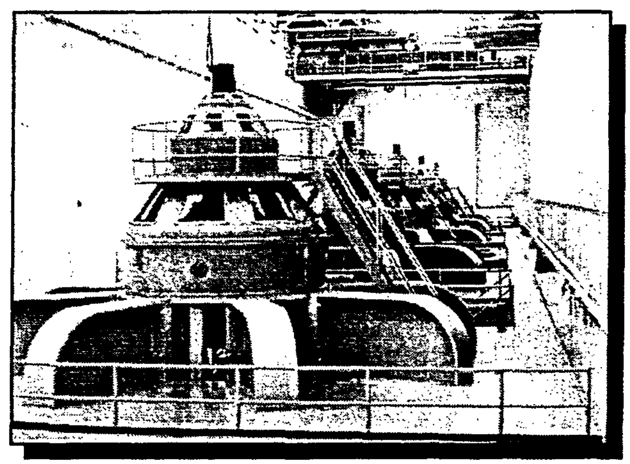
New 36-inch-diameter steel piping would be connected to the existing air vent pipes, located downstream of the ring-follower gates, to provide air to the new gates. The existing air inlet pipes would be extended downstream through the concrete overlay to the new dam face, outside the spillway training walls at approximately elevation 988. New air valves and filling lines would be provided for each gate tandem to fill the space between the two gates.

Hydropower Features

Hydropower facilities associated with Intermediate and High enlargement options fall under two categories, those dealing with modifications to the existing powerplant and those dealing with new hydropower development. Modifications of the existing powerplant or development of new facilities requires consideration of the powerplants themselves, the penstocks that deliver water to power generating equipment, a whole host of various pieces of electrical equipment, switchyards, and transmission lines. Each of these elements is discussed in more detail below. The Low Option requires only minor modifications to the appurtenant control facilities.

Existing powerplant. - No modifications are currently planned for the existing powerplant structure for any of the dam raise options, so power generation will be restricted to current reservoir operating levels between elevations 840 and 1065 (with a minimum operating head of 275 feet). The powerplant units are currently rated at 578 MW, but an uprating (generator rewind) program is expected to increase this capacity to 676 MW, with a total plant flow of 19,500 ft^3/s. Upstream isolation valves will be provided for each unit for the high dam raise option. These valves are required to protect the existing spiral cases and will be closed when the reservoir level exceeds an elevation of approximately 1186 feet.

Previous studies included the installation of new turbine/generator units within the existing powerplant, but indicated a potential requirement for major modifications to the existing structure to accommodate the new units and overhead cranes, which were never quantified. Very elaborate and expensive modifications may also be required for the recently constructed TCD to accommodate a higher design discharge. Currently, there are also efforts to initiate studies to evaluate the potential for upgrading the existing turbines. The current studies assume the potential costs to modify the powerplant and TCD would outweigh the benefits, especially with consideration of the uprated capacity of the



plant related to the rewind program and the potential for replacing the turbines. This assumption should be confirmed for future studies.

New powerplant. - A new powerplant structure will be constructed to the left of the spillway stilling basin, for both the high and intermediate dam raise options. The arrangement of the existing powerplant and the new powerplant is assumed to be approximately symmetrical about the spillway centerline. The current appraisal-level designs include five unit bays, a service bay, and a control bay similar to those found in the existing powerplant. The unit bays for the new powerplant will be 20 feet deeper than for the existing powerplant due to the higher reservoir head, and about 60 feet long in the longitudinal direction.

The new powerplant will contain five 260 MW turbine/generator units with a design head of 575 feet for the high dam raise option, for a combined plant capacity of 1,300 MW, and will operate between reservoir elevations 980 and 1280 (with a minimum operating head of 402 feet). For the intermediate dam raise option, the new powerplant will contain five 215 MW units with a design head of 482 feet, for a combined plant capacity of 1,075 MW, and will operate between reservoir elevations 890 and 1180 (with a minimum operating head of 313 feet). Total design flow through the new powerplant for both options will be 30,000 ft^3/s, or 6,000 ft^3/s per unit. Two 500-ton overhead traveling cranes will be provided in the new powerplant for both dam raise options.

A service yard will be located at the left end of the new powerplant, with an access road extending alongside the tailrace area downstream to the existing Sacramento River bridge. Approximately 1,500,000 yd^3 of rock excavation will be required for the powerplant, service yard, tailrace, and access road. The existing steep rock wall along the left bank of the river downstream of the spillway may be partially retained to serve as a cofferdam during initial excavation for the plant structure. The new powerplant excavation will require the relocation of the existing switchyard.

Modifications to existing penstock intakes. - The centerline of the penstock intakes will remain at elevation 815 and the existing trashrack structures will remain in place. The gate hoist structures above the existing trashrack structures will be removed to elevation 1068.75 and the existing coaster gate operators will be removed. To seal the interior of the dam against the higher reservoir elevations, the stairway between the gate hoist structures and the gallery at elevation 1065 will be plugged with concrete. The reinforced concrete gate hoist structures will then be extended to the new dam crest elevations.

New hoist-operated, 16- by 25-foot wheel-mounted gates (designed for the higher reservoir head) will replace the existing coaster gates for the high and intermediate dam raise options. The existing gate frames around the penstock intakes will be replaced with new gate frames, and the gate guides will be extended to the new dam crest elevations. One set of stoplogs designed for the higher reservoir elevations will be provided. Estimates include quantities for extending the existing stoplog guides to the new dam crest elevations, but do not include items for replacing the existing stoplog guides. It is assumed that the stoplogs will be used to unwater the gated intake area for installing the new gate frames.

New penstock intake selective-level withdrawal. - Five new 20-foot-diameter power penstocks through the dam will supply water to a new powerplant on the left abutment for the high and intermediate dam raise options. The total design discharge capacity of the new powerplant will be 30,000 ft^3/s.

For the high dam raise, the centerline of the penstock intakes will be located at elevation 970, and the new powerplant will operate for reservoir water surface levels between elevations 995 and 1280, assuming a 25-foot minimum intake submergence requirement.

For the intermediate dam raise, the centerline of the penstock intakes will be located at elevation 880, and the new powerplant will operate for reservoir water surface levels between elevations 905 and 1180, again assuming a 25-foot minimum intake submergence requirement. Hoist-operated, 20- by 31-foot wheel-mounted gates and associated gate frames and guides will be installed at each intake. Each intake will have stoplog guides, but only one set of stoplogs will be provided for use on all five new intakes.

The layout of the new penstock intake structures assumes that the reservoir water surface during construction will be at elevation 1010. Above elevation 1010, the intake structures will be reinforced concrete. Below El. 1010, only that part of the intake structure associated with the wheel-mounted gate guides and frames, and stoplog guides and support, will be reinforced concrete; the rest of the intake will consist of steel cladding attached to structural steel frames. Because the penstock intakes will be underwater during construction, it will be necessary to construct the concrete portions of the new intakes to El. 1010 and install the stoplogs, before excavating through the dam for the new penstocks.

Each penstock intake structure will have two openings, with hoist-operated gates and trashracks in front of each opening, to allow selection of the reservoir withdrawal level. For the high dam raise, the five upper gates will act as vertically adjustable intakes (or weirs) between elevations 1125 and 1225. Assuming 35 feet minimum submergence, the upper gates may be operated for reservoir water surface elevations between 1160 and 1280. The five lower gates will control the flow through intakes between elevations 890 and 990. Assuming 25 feet minimum submergence for the penstock intakes, the lower gates may be operated for reservoir water surface elevations between 995 and 1280. To keep entrance velocities around 2 ft/s, the lower gate should be open a minimum of 65 feet.

For the intermediate dam raise, the five upper gates will act as vertically adjustable intakes (or weirs) between elevations 1040 and 1140. Assuming 35 feet minimum submergence, the upper gates may be operated for reservoir water surface elevations between 1075 and 1180. The five lower gates will control the flow through intakes between elevations 830 and 930. Assuming 25 feet minimum submergence for the penstock intakes, the lower gates may be operated for reservoir water surface elevations between 905 and 1180. Again, to keep entrance velocities around 2 ft/s, the minimum lower gate opening should be 65 feet.

<u>Existing penstocks</u>. - Embedded portions of the five existing 15-foot-diameter steel penstocks must be replaced with new, thicker pipes (with about a 1-1/4-inch wall

thickness) for both the high and intermediate dam raise options, to accommodate the potential increase in external hydrostatic pressures when the penstocks are unwatered. This will require concrete excavation within the dam to provide an oversized (approximately 17-foot-diameter) opening for installation and concrete encasement of the new penstocks. Construction will be performed with the upstream wheel-mounted gates and stoplogs in place. The intake centerline will remain at elevation 815, and the design discharge will remain at 19,500 ft^3/s.

Exposed portions of the five existing penstocks between the dam and the powerplant are believed to meet design standards for the increase in internal pressure, based on their design thickness and strength. By limiting operation of the existing powerplant units to reservoir levels at or below elevation 1065, the penstocks will be subjected to higher static heads only, without potential waterhammer loads. The ring girder supports for the exposed penstocks will have to be strengthened for maximum potential earthquake loads, however, and additional concrete saddle supports must be provided.

The existing spiral cases within the powerplant are not adequate for the increase in static internal pressure under the high dam raise option (for reservoir levels above approximately elevation 1186, or 600 feet of reservoir head). A 15-foot-diameter butterfly isolation valve will be provided for each penstock to isolate the powerplant from higher reservoir heads, as a precaution. Filling lines and air valves are provided for the isolation valves. The current design studies assume the isolation valves are located in five new valve vaults immediately upstream of the powerplant; however, the valves could be located at the downstream toe of the dam, where the new embedded penstocks will join the existing exposed penstocks, to reduce the design head for the valves and simplify installation. Mobile crane access should be provided at the valve vaults, since no special valve handling gantry is planned.

<u>New penstocks</u>. - Five new 20-foot-diameter steel penstocks (with about a 1-3/4-inch wall thickness) will be provided through the dam on the left abutment, for both the high and intermediate dam raise options, to serve the new powerplant. The centerline of the new penstock intakes will be at elevation 970 for the high dam raise and at elevation 880 for the intermediate dam raise, requiring concrete excavation of an oversized opening (approximately 22-foot-diameter) for each penstock, under reservoir head. This will require construction of the intake structure and installation of the wheel-mounted gates and stoplogs. The exposed portions of the new penstocks between the dam and the new

powerplant will be designed for maximum earthquake loads. The assumed design discharge for the new penstocks is 30,000 ft^3/s.

Modifications to existing temperature control device. - The five 15-foot-diameter power penstocks that serve the existing powerplant have an intake centerline at elevation 815. The temperature control device (TCD) provides selective-level withdrawal capability to the existing penstock intakes. It was completed in 1997. The temperature control device is a steel structure consisting of a shutter structure and low-level intake structure. High level withdrawal, at or above the existing intake elevation, is controlled by the 250-foot-wide by 300-foot-high shutter structure that encloses all five existing power penstock intakes. Three openings with hoist-operated gates and trashracks on the front of each shutter unit allow selection of the reservoir withdrawal level. The 125-foot-wide by 170-foot-high low-level intake structure, located to the left of the shutter structure, acts as a conduit extension to access the deeper, colder water near the center of the dam. The TCD is designed for a discharge capacity of 19,500 ft^3/s, and has a reservoir operating range between elevations 840 and 1065.

No modifications to the operation of the existing powerplant have been adopted for the current studies. As such, only modifications to raise the TCD operating equipment above the new maximum reservoir water surface elevations have been included in the cost estimates. These modifications include removing the existing hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel from their current locations at elevation 1071.9, and installing new hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel at the new dam crest elevations. The existing rigid frames will remain in place to support the shutters and low level intakes. Sloping trashracks will be added to the top of the shutters at elevation 1067.5 to prevent debris from entering the TCD. The existing temperature monitoring equipment will be extended if possible, or completely raised, to the new hoist platform elevation. New rigid frames will be anchored to the raised dam near the crest elevation to support the new hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel.

Electrical Equipment.-

Main generating units. - Five new generators, each rated 260 MW, 0.95 pf (power factor) at 13,800 volts for the high dam raise option, and 215 MW, 0.95 pf at 13,800 volts for the intermediate dam raise option, will be required for the new powerplant. These generators are of the vertical-shaft synchronous type, and will be provided with a static excitation system.

Bus and power circuit breakers. - One 15-kV isolated-phase bus, rated 12,500 amps for the high dam raise option and 11,000 amps for the intermediate dam raise option, will run from each generator through its associated unit power circuit breaker out to the unit transformer.

Generator step-up transformer. - Three single-phase outdoor transformers will be provided for each unit to transform the generator's 13.8 kV output voltage to 230 kV for use in the new switchyard. One spare transformer will also be provided to minimize down-time for a single transformer failure.

Station service. - The station service power supply will be obtained by tapping off two of the generators' 13.8 kV-bus, and by providing step-down transformers to transform the voltage down to 480 volts. The plant station service needs will be provided by the 480-volt distribution equipment located inside the plant's double-ended unit substation.

Duplex control switchboards. - Duplex control switchboards will provide all control, protective, and monitoring (indication) features required for the main generators. Manual, automatic, and supervisory type functions will be provided to allow full flexibility in plant operations.

600-Volt motor control centers. - 600-volt motor control centers will be provided in the plant for operating all of the auxiliary systems, such as hydraulic pumps, water cooling pumps, electrically driven valves, air compressors, and sump pumps.

Switchyards- Prior to commencing construction for the new powerplant, the existing switchyard will be replaced with a new 230 kV switchyard at a downstream location (to be determined), to permit continued power generation to some degree throughout construction using the existing powerplant and available units. A new 525 kV switchyard will be constructed concurrent with construction for the new powerplant, to serve the new plant. Overall site dimensions for the new switchyards were developed for the 1978 studies, as follows: 1,250- by 400-feet for the 230 kV switchyard, 700- by 500-feet for the 525 kV switchyard for dam crest elevation 1270, and 350- by 500-feet for the 525 kV switchyard for dam crest elevation 1180.

Construction of a new 525 kV (and other) transmission lines will be required to accommodate the new power output from both powerplants, but is not included in the current appraisal-level studies.

Cofferdam Features

Construction of the new gravity wing dams on both abutments will require the construction of upstream cellular cofferdams. The left abutment cofferdam will consist of four large cloverleaf cells founded on an excavated bench at elevation 970, and three to four smaller circular cells founded on an excavated bench at elevation 1020. The right abutment cofferdam will consist of four small circular cells and connecting arcs above elevation 1050. The cells will consist of interlocking steel sheet piling backfilled with a free-draining sand and gravel material, extending to the existing dam crest at elevation 1077.5. Cell diameters are assumed to be equal to the cell heights to ensure stability. Concrete will be placed to provide water barriers at the contacts with the existing dam and abutments. The steel sheet piling and free-draining backfill will be removed from both locations following construction; however, the backfill and anchor concrete will remain. Details related to the construcability of these cofferdams is discussed later.

Downstream cofferdams will be required within the tailrace area for unwatering the stilling basin, and for construction of the new powerplant, to retain tailwater levels during reservoir releases. The stilling basin cofferdam may be subject to overtopping for passage of flood flows from the river outlets. Details for these cofferdams will be developed for future feasibility-level designs.

Reservoir Dikes

Four reservoir dikes are required to contain new reservoir levels up to elevation 1280, at the Centimudi, Bridge Bay, Jones Valley, and Clickapudi Creek sites. Reservoir dikes at the Jones Valley and Clickapudi Creek sites only will be required to contain reservoir levels up to elevation 1180. No reservoir dikes are assumed to be required for the low dam raise option, although the available topography suggests some minor protection may be required. Better site topography should be developed for future feasibility-level designs.

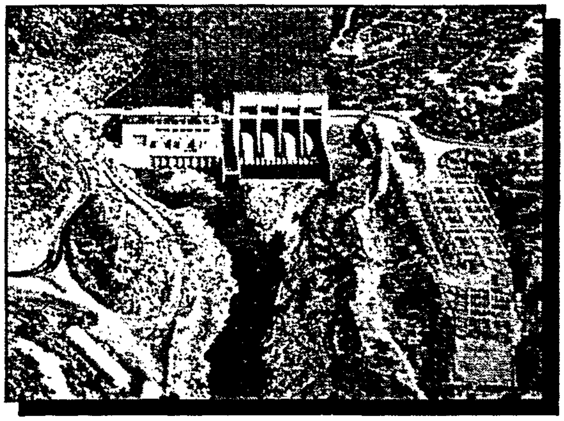
The appraisal-level design for each reservoir dike is based on a zoned earthfill structure with a ten foot freeboard allowance. The entire foundation for each dike will be stripped to a suitable depth, with special attention to the contact surface for the central impervious core. A core trench will be excavated to reduce the potential seepage through the foundation. The depth of the core trench will be dependent upon site conditions for the removal of highly fractured rock, especially in the area of faults or shear zones that will require foundation treatment. The appraisal designs include a line of pressure grout holes to depths of 40 feet, and quantities for slush grouting and dental concrete treatment.

The central impervious core (zone 1) will have a top elevation 2 feet above the maximum reservoir level. It will have a top width of 15 feet and sideslopes of 0.75 to 1. The placement and compaction requirements will be determined based on the materials to be used. A chimney drain with a 10-foot horizontal width will be provided on the downstream slope of the central core, and will be connected to a 10-foot-thick blanket drain placed on the dike foundation between the core and the downstream toe. The chimney drain will act as a filter to prevent fines migration from the core. A 12-inch perforated toe drain pipe will be provided near the downstream toe to collect the seepage through the dike embankment and foundation. Because of the assumed highly-fractured condition of the bedrock foundation, the depth of the toe drain should be significant (assumed 20 feet).

An outer (zone 2) shell of semipervious to pervious materials will be provided both upstream and downstream of the central core, with the more pervious materials being placed in the downstream portion. The outer slopes will be 2.5:1 on the upstream face and 2:1 on the downstream face. Compaction requirements will be determined based on the materials to be used. Riprap placed on a bedding layer will be provided to protect the upstream shell against wave action. Each reservoir dike will be completed with suitable instrumentation for future monitoring.

Keswick Dam and Powerplant Modifications

Modifications to Keswick Dam and powerplant would be required to increase the storage capacity of Keswick Reservoir if increased releases are made from the new Shasta powerplant for peaking power. The



extent of modifications required at Keswick will be dependent upon more refined studies of power and water operations and a determination of downstream storage requirements needed to maintain flow release capability and restrictions. Enlargement of the reservoir would be achieved by either increasing the height of the existing dam by up to 25 feet, or by construction of a new concrete structure about two miles downstream. Preliminary designs and estimates for an enlarged Keswick Dam were prepared in 1982, and provide the basis for indexed costs used for this study. Preliminary designs and estimates for a new Keswick powerplant were prepared by Bookman-Edmonston Engineering in 1996. Appraisal-level designs for an enlarged and/or new dam and powerplant should be prepared after the need for an enlarged afterbay reservoir has been determined. It should be noted that raising the existing Keswick Dam would increase tailwater levels at both Shasta Dam and Spring Creek Debris Dam, reducing power generation capacity and requiring additional structural modifications at both powerplants to prevent flooding.

Constructability

Constructability issues associated with implementation of any proposed enlargement were reviewed during this appraisal study. Issues that were assessed include material sources, reservoir operations, equipment/material transportation, sequencing/scheduling, cofferdam construction, penstock construction, and access. No issues were identified that were unsolvable.

Materials.- Several material borrow sources have been identified in previous studies. Several potential rock and earthfill sources within an area up to about 6.2 miles east and 15.6 miles south of Shasta Dam have been examined in previous studies. The most promising aggregate sources were located south of Shasta Dam. Earth materials are available in an area several miles to the southeast of Project City. Road distances to proven sources of concrete aggregate range from about 13.7 miles to 16.2 miles. Borrow areas within the reservoir have also been identified. This source will be dependent on reservoir fluctuations. Since the alternative borrow sites were identified some time ago, a new evaluation of these potential sites will be required. It is not anticipated that borrow material areas will be a major issue, however.

Reservoir Operations.- During construction water releases for temperature control, water quality, and water supply will still be required. Release capabilities through the dam will need to be maintained during construction to meet these demands. Close coordination between dam operators and construction managers should address this issue.

Power generation during the construction period will have to assessed in detail. A construction sequence permitting continued operation of four of the five existing powerplant units during modifications to the existing penstocks and temperature control device, for power generation and downstream releases would be developed. The powerplant release capacity should be sufficient for passage of normal reservoir inflows during construction. Sufficient river outlet capacity must also be maintained throughout construction to provide for passage of potential diversion floods, up to the downstream channel capacity of 79,000 ft^3/s. The current studies assume no more than two river outlets would be unavailable for releases at any time, using the new bulkhead gate and the existing coaster gate to provide upstream closure for gate replacement. Replacement of the four tube valves at elevation 742 should be completed first, to provide increased release capacity from the lower tier of river outlets. Flood releases from river outlets located above the concrete overlay block construction should of course be avoided, but may be required during construction.

Equipment/Material Transport.- Construction materials and equipment may be delivered on site by either truck or rail transportation modes. Lake Boulevard will be severely affected during construction work on the left abutment. In addition, Shasta Dam Boulevard will need widening.

The existing rail alignments are not conducive to efficient handling of materials. Reworking of the existing railroad lines would be required if extensive use of the railroad is anticipated. Without reworking of the alignments double handling of materials may be required. Preliminarily, it appears that the use of truck traffic will be the most efficient transportation mode. Some materials such as the power transformers may not be deliverable by truck however and may require double handling.

Cofferdam.- Perhaps the most difficult constructability issues associated with any enlargement project involve the construction of the cofferdams. For both the Intermediate and High Options, two cofferdams on the left abutment and one on the right abutment are proposed. All cofferdams would be built to a crest elevation of 1077.5. On the left abutment, one cofferdam would be constructed on a bench established at elevation 970. The second cofferdam on the left abutment would be established on a bench at elevation 1020. On the right abutment, the cofferdam is built on a bench at about elevation 1050.

Construction of these cofferdams is done most efficiently and cost effectively in the dry. Table 1 shows the range of monthly Shasta reservoir elevations for the period of record from 1944 to 1997. Depending on the type of cofferdam, a drawdown period of five to six months may be required to complete all of the cofferdam construction. For construction of the lower bench cofferdam on the left abutment to be done completely in the dry, a reservoir drawdown to elevation 965 is required. While Table 1 shows this to be feasible in drier years, additional drawdown of the reservoir would likely be required in normal and wet years. The feasibility of making additional drawdowns in the reservoir during construction will be very difficult given the various temperature and water quality criteria in the lower river and Delta. If reservoir drawdown is absolutely required, the water costs could be significant. Such a drawdown could result in a loss of water

Table 1 Mean Monthly Shasta Reservoir Elevations, 1944-1997

Month	Minimum	Maximum	Average
January	700	1053	998
February	787	1045	1008
March	846	1053	1021
April	884	1063	1036
May	895	1067	1040
June	890	1066	1036
July	866	1060	1023
August	843	1049	1007
Sept.	839	1037	995
October	849	1032	991
Nov.	846	1036	992
December	852	1033	995
Mean Annual	841	1050	1012

supply with impacts on water deliveries, recreation, power, and potentially to fish and wildlife. Finding replacement water could be costly and may only partially offset the adverse affects of a drawdown for construction.

Based upon average mean monthly elevations the construction period for the higher benched cofferdam on the left abutment could easily occur between the months of August through March. Similarly, the cofferdam on the right abutment could be done throughout the year. Under an average year, construction on the left abutment low bench cofferdam could be accomplished September through January if an additional 30 feet of drawdown were to occur. This low level cofferdam may be constructed early if reservoir levels are expected to be low before the prime contract is awarded.

Alternatively, the low bench cofferdam could be done working in about 30 feet of water at additional costs. Construction of the lower portions of the cellular cofferdams underwater is possible, and has been performed previously on smaller cofferdams in water depths up to about 60 feet. Foundation excavation would be much slower, however, and tremie methods would be required for concrete placement. Construction costs and durations would increase significantly.

Use of roller compacted concrete construction methods on the dam abutments may also shorten the drawdown period. A full assessment of the construction of this low bench cofferdam needs to be accomplished at more detailed level studies.

Access.- There are several residences on the ridge above the right side of the dam. Relocation of the powerplant road/bridge for access to the right side may be necessary to provide them access.

New Penstocks.- Development of a new powerplant on the left side of the dam will require developing a new hole through the dam to accommodate the new penstock pipes that take water from the reservoir to the powerplant turbine generators. The centerline of the new penstocks is anticipated to be at elevation 970. Drawdown conditions in the reservoir again will preclude the normal water surface from being below this elevation for any appreciable time. Consequently, construction will require underwater work on the upstream face of the dam. This work would entail placing some type of temporary underwater structure that would seal off the area where the new penstock hole would be drilled through the upstream face of the dam.

Sequencing/Scheduling.- Preliminary indications are that required construction activities to raise Shasta Dam may take 8 to 10 years for the maximum proposed raise to crest elevation 1280. Figure 4 shows a schematic of the potential construction period.

Financial considerations may make the division of project work into separate contracts desirable. Dam features which may be considered for construction under separate contracts (apart from the prime contract) include the reservoir dikes, the 230 kV switchyard, the 525 kV switchyard, the new powerplant, and the upstream cellular cofferdams.

The 230 kV switchyard should be completed before construction for the new powerplant begins, while the 525 kV switchyard will not be needed until several years later, when the new powerplant is completed and operational. A separate contract for the new powerplant could extend to a penstock connection point identified in the prime contract.

The majority of the reservoir dikes are located several miles from Shasta Dam and would be easily separated, even if some construction materials are developed from required excavation under the prime or other contracts. Construction of the reservoir dikes can be completed later in the process as the reservoir is likely to fill slowly. Although the remaining heavy construction work for the dam raise, spillway, river outlets, power outlets, and penstock intakes would not be easily divided, the larger mechanical items could be included under separate supply contracts to reduce the cost of the prime contract.

Appendix B is a complete technical evaluation of engineering considerations related to enlarging the dam. Table 2 summarizes the features of the various options.

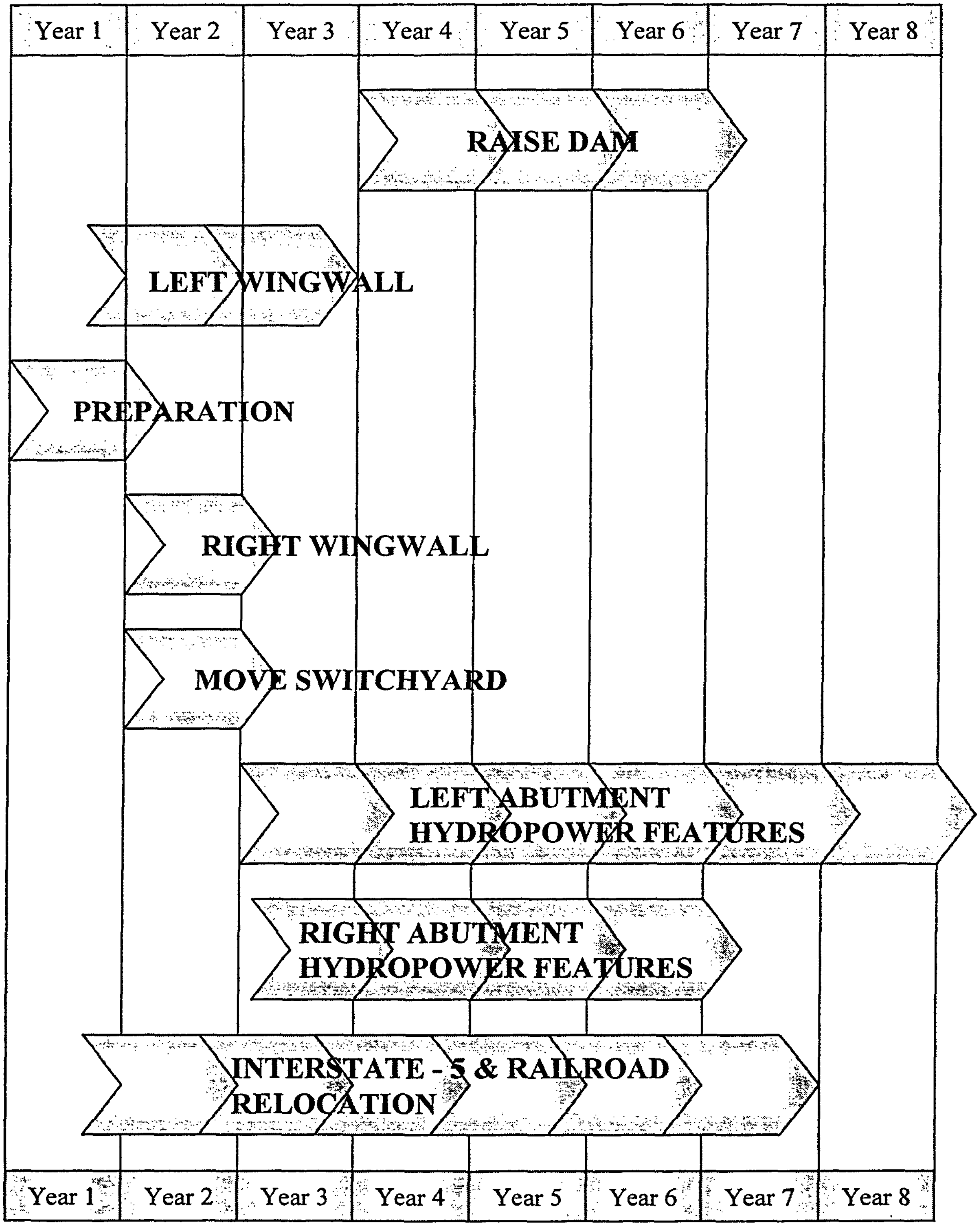
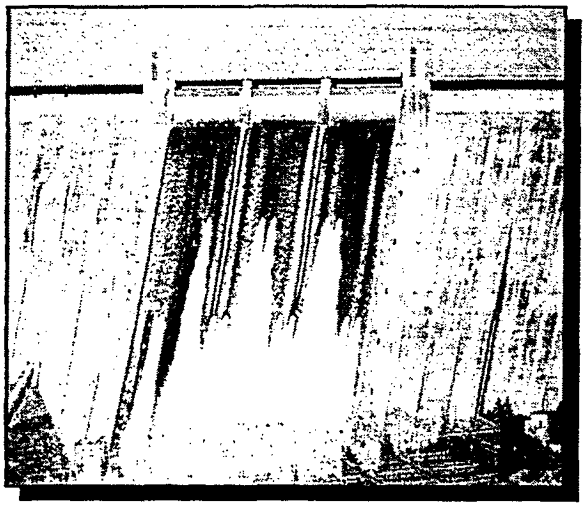


Figure 4 Eight-Year Construction Schedule

Table 2 Summary Table - Enlargement Option Features

FEATURE	EXISTING DAM	HIGH OPTION	INTERMEDIATE OPTION	LOW OPTION
Dam Crest Elevation (ft)	1,077.50	1,280	1,180	1,084
Dam Crest Length (ft)	3,460	4,930	4,590	3,660
Height Raise (ft)	None	202.5	102.5	6.5
Joint Use and Top of Gates Elevation (ft)	1,067	1,273.50	1,173.50	1,077.50
Total Reservoir Capacity (MAF)	4.5	14	8.5	4.9
Increase in Capacity (MAF)	None	9.5	4	0.4
Spillway Crest Elevation (ft)	1,037	1,246	1,146	1050
Spillway Gates	three 28' by 110' drum type	six 27.5- by 55-foot radial	six 27.5- by 55-foot radial	six 27.5- by 55-foot radial
Outlet Works	18 outlets in 3 tiers at elev. 950 (six 96" tubes), 850 (eight 96" tubes), and 750 (four 102" tubes)	Replace all 14 existing outlet tubes to handle increased head	Replace outlets in two lower tiers of existing dam (upper tier can accommodate increased head from raise)	Replace 4 tube valves on lower tier outlets for greater reliability and discharge capacity
Relocations				
Interstate 5-Union Pacific Railroad Bridge- Bridge Bay	Not applicable	Yes	Yes	No
Recreation Facilities	Not applicable	Yes	Yes	Minor
Resort Facilities	Not applicable	Yes	Yes	No
Communities	Not applicable	Yes	Yes	No
Hydropower Features				
Temperature Control Device	250' by 300' shutter structure and 125' by 170' with operating range between elev. 840 and 1065.low level intake structure	Raise operating controls	Raise operating controls	Raise operating controls
Existing Penstocks and Penstock Intakes	Five 15' diameter steel penstocks at elev. 815	New 16' by 25' gates, Replace existing pipes with thicker walled steel pipes, strengthen exposed pipe supports	New 16' by 25' gates, Replace existing pipes with thicker walled steel pipes, strengthen exposed pipe supports	Strengthen exposed pipe supports
New Penstocks and Penstock Intakes	Not applicable	Five new 20' diameter penstocks and intakes at elev. 970 on left abutment	Five new 20' diameter penstocks and intakes at elev. 880 on left abutment	None
Existing Powerplant	Currently rated at 578 MW with ongoing uprating program to increase generation to 676 MW. Operation level between elev. 840 and 1065.	No modifications for existing powerplant to upgrade power generation.Upstream isolation valves required to protect existing spiral cases for reservoir elevations above 1186 feet.	No modifications for existing powerplant to upgrade generation. New upstream isolation valves not required.	No modifications for existing powerplant to upgrade generation. New upstream isolation valves not required.
New Powerplant	Not applicable	Five 260 MW turbine/generator units (combined capacity of 1,300 MW) for operation between elevations 980 and 1,280 feet.	Five 215 MW units (combined plant capacity of 1,075 MW) operating between elevations 890 and 1180.	None
Switchyard	Existing switchyard located at left abutment.	Replace the existing switchyard with a new 230kV switchyard (required space 1,250' by 400') at a downstream location. Develop a new 525 kV switchyard (required space 700' by 500')along left abutment.	Replace the existing switchyard with a new 230kV switchyard (required space 1,250 by 400') at a downstream location. Develop a new 525 kV switchyard (required space 350' by 500') along left abutment.	None
Reservoir Dikes				
Centimundi	No	Yes	No	No
Bridge Bay	No	Yes	No	No
Jone's Valley	No	Yes	Yes	No
Clickapudi Creek	No	Yes	Yes	No
Other				
Keswick Dam and Powerplant	Not applicable	Enlargement required up to 25 feet to accommodate increased releases from new powerplant.	Enlargement required up to 25 feet to accommodate increased releases from new powerplant.	None
Scheduling/Sequencing	Not applicable	8 to 10 year construction period	8 to 10 year construction period	4 year construction period
Total Investment Cost	Not applicable	$5,810,927,000	$3,889,729,000	$122,281,000



Hydrology

Flood frequency hydrographs were developed in 1985 for the winter season, and are summarized in Table 3 below. An updated frequency flood study is recommended for future feasibility-level studies.

Table 3 - Frequency Floods for Shasta Dam

Frequency	Volume (15 day vol. Ac-ft)	Peak Inflow (cfs)
25-year	1,773,400	187,000
50-year	2,016,900	219,000
100-year	2,235,600	251,000

Mean monthly streamflow data for Shasta Dam from 1922 to 1996 were obtained from Water Supply reports, and were averaged to represent normal inflow conditions. These values range from less than 4,000 ft^3/s from July through October, to nearly 14,000 ft^3/s in February and March, as indicated in Table 4 below.

Table 4 - Mean Monthly Streamflow Data, Shasta Reservoir

Month	Streamflow (cfs)	Month	Streamflow (cfs)
January	11,201	July	3,815
Feb.	13,981	August	3,430
March	13,609	Sept.	3,482
April	11,603	October	3,963
May	8,189	Nov.	5,637
June	5,339	Dec.	8,525

Determination of a probable maximum flood is an estimation of the worse flood that is likely to occur within a basin. This flood is used as a design tool to establish spillway capacities and the size of other physical features incorporated into the dam. The current probable maximum flood (PMF) for Shasta Dam has a peak inflow of 623,000 ft^3/s and a 15-day volume of 4,266,000 acre-feet. This PMF was developed in 1984 using appropriate data available at the time. A review of these data has indicated that a complete reassessment of the PMF would likely lead to a decision to reduce the size of the PMF. A rough approximation of the new PMF peak inflow indicates that it would be about 91 percent of the current value. The new 15-day volume of a revised PMF is estimated to be about 80 percent of the existing PMF volume. Formal determination of the new PMF will be performed for future feasibility-level studies. A smaller design PMF would enable a more efficient design of the spillway to allow more storage at a given height raise. This is particularly significant in the Low Option, where the amount of storage developed is limited by the avoidance of the relocation of Interstate-5 and the Union Pacific Railroad.

Existing Operations

General.- The storage and release of water at Shasta Reservoir at any particular time is established on the basis of one or a combination of the various purposes for which the water is used. The reservoir operation normally goes through four main phases each year based upon the season.

Winter operations can be considered as starting after the first significant storm each fall and usually extends into early March, although sometimes longer. During this period, tributary inflow into the Sacramento River below Shasta is normally large enough to meet all water demands along the river. Under these circumstances, the Shasta operations are geared to meet fish and power requirements, and to store as much water as possible without encroachment into the empty space which must be maintained for flood control. Empty space for flood control purposes must be maintained beginning on October 1 of each year. In most years the water level in the reservoir rises rapidly after each major storm and the water is retained if possible. However, if the bottom of the required flood control space has been reached, water can only be stored to temporarily reduce downstream flood flows. After the peak flows have diminished the excess water must be released. The maximum space required for flood control purposes is 1,300,000 acre-feet and this amount of space must be available by December 1 of each year. After December 23, the amount of empty flood control space which must be maintains is dependent upon established rainflood parameters.

Spring operations usually begin in March or April, the runoff both into and below Shasta decreases and water demands increase. Reservoir releases are made to the extent needed. These releases are usually less than the reservoir inflow and the storage level in Shasta rises gradually, until it reaches its maximum level, usually sometime between mid-May and mid-June. Every effort is made to fill the reservoir during this period. However, if the spring runoff is only average or below normal, there usually is insufficient water to fill the reservoir.

Summer operations consist of increased releases to meet the relatively large demands of the Sacramento Valley and the Delta exports, while runoff both above and below Shasta is quite small, thus lowering the reservoir level. These releases for the Delta and Sacramento Valley demands are often more than sufficient to provide the minimum flows needed for navigation and for generation of dependable power. In addition summer flows are made to meet temperature requirements in the lower Sacramento River.

Fall operations are much the same as the summer operations, and all water needs, except navigation, decrease. During the fall, a large part of the operations is to reach a stable fall release which can be sustained through December. The intent is to proved a stable river environment for the fall run chinook salmon. During the fall runoff is still small and releases cause the reservoir to continue to decrease, although more slowly than in the summer. This slow drawdown in the fall continues until the first significant storm of the winter season, and then the cycle stars again.

In addition to regulating runoff on an annual basis, Shasta Reservoir is used to capture water in wet years and to carry it over into subsequent dry years. Thus, a period of several years may occur during which the reservoir does not fill, and the water level may be drawn successively lower each year (as in 1976-77) until another wet year comes along. Variations in the runoff pattern and the changing water demands make each year different from the last, and make the next year unpredictable in detail. Operations are adjusted each day throughout the year to meet the functional requirements under the various conditions and thus obtain maximum authorized benefits for the project.

Specific Operational Considerations.- Policies and guidelines which affect the operations at Shasta Reservoir include the Central Valley Project Operations Criteria, Trinity River flows and diversions, Central Valley Project-State Water Coordinated Operations Agreement, Bay-Delta Water Quality Criteria, and biological opinions on endangered species.

Central Valley Operations Criteria.- The Central Valley Project Operations Criteria address several considerations which must be factored into the overall operations of Shasta Reservoir. These are summarized below:

- Minimum flow releases into and from Keswick reservoir.
- Ramping restrictions on Keswick Dam releases to minimize flow fluctuations.
- Anadromous fishery temperature requirements on the Sacramento River.
- Flood control objectives for Shasta Lake.
- Recreation use guidelines for Shasta Lake and Sacramento River.
- Depth requirements to provide for "navigation" and associated depths in the Sacramento River.
- Guidelines to coordinate releases from the Spring Creek Debris Dam with releases from the Spring Creek powerplant and coordination of operations during flood periods.
- Flow depth guidelines in the Sacramento River to minimize seepage damages to adjacent agricultural lands.
- Operation guidelines for the Anderson-Cottonwood Irrigation District.
- Operation guidelines for the Red Bluff Diversion Dam diversion to the Tehama-Colusa Canal.
- Optimization of power generation in conjunction with meeting other project demands.
- Flood control objectives for the lower Sacramento River.

Trinity River Flows and Diversions.- Instream flow requirements in the Trinity River basin are mandated by various policy decisions over the last two decades. These decisions have led to increased instream flow requirements for the Trinity River. This has reduced the amount of interbasin transfer of Trinity water to the Sacramento River basin that has historically occurred. The waters that were transferred from the Trinity basin historically were valuable in meeting temperature and other water quality objectives on the Sacramento River. Historically, operations of the Trinity Project were coordinated with those of Shasta Lake to more efficiently make beneficial use of the composite water supply. Increased instream flow requirements for the Trinity River has led to more reliance on Shasta Lake supplies to meet project objectives.

Coordinated Operations Agreement.- . The Central Valley Project and State Water Project reservoir releases are coordinated in accordance with the Coordinated Operations Agreement. This agreement defines the rights and responsibilities of the State Water Project and the Central Valley Project in meeting inbasin uses in the Sacramento Basin, including compliance with Delta water quality standards. Shasta Lake is the primary component in meeting the obligations under this agreement.

Bay-Delta water Quality Criteria.- The Sacramento-San Joaquin Delta is affected by releases from storage on the major rivers, including Shasta Dam. Changes in flow patterns can drastically alter salinity patterns and aquatic habitat conditions. The State of California has adopted water quality standards in the Delta to provide ecosystem protections. Shasta Lake is a primary source of water for meeting these standards.

Biological Opinions on Special Status Species.- The National Marine Fisheries Service and the Fish and Wildlife Service have issued biological opinions to protect winter run chinook salmon and other species which affect long-term operations of Shasta Dam and reservoir. Operational criteria established as a result of these opinions includes:

- Minimum carryover storage in Shasta Reservoir.
- Minimum flows from Keswick Dam into the Sacramento river.
- Flow reduction ramping criteria for releases from Keswick Dam.
- Maximum daily water temperatures for the Sacramento River at a compliance point.
- Restrictions on the operations of Red Bluff Diversion Dam.
- Operation of the Temperature Control Device at Shasta Dam.
- Use of flows from Trinity River to control temperatures in the Sacramento River.
- Operation of Spring Creek Debris Dam and Shasta Dam to minimize acute and chronic exposure of winter run chinook salmon to toxic metal concentrations.

Operations Under an Enlarged Shasta

Any future operations of an enlarged Shasta Dam will continue to have to meet the existing standards identified above or some form of them. If an enlarged Shasta is part of a larger CALFED plan, new standards may be adopted in the future. It is likely that additional water supplies will be needed in the future to meet enhanced ecosystem demands.

Table 5 - Monthly Average Storage in Shasta Reservoir

Month	Avg. Monthly Storage Elev. 1944-1997	Avg. Monthly Storage Elev. 1980-1997	Change in Avg. Storage Elev.	Change in Average Storage in Acre-Feet
Oct	991	984	-7	-142375
Nov.	992	986	-6	-123048
Dec.	995	990	-5	-104524
Jan.	998	998	0	0
Feb.	1008	1010	2	45588
Mar.	1021	1024	3	73035
Apr.	1036	1034	-2	-51819
May	1040	1036	-4	-105175
June	1036	1030	-6	-153937
July	1023	1015	-8	-191775
Aug.	1007	993	-11	-241153
Sept.	995	984	-11	-226222

Increased demands on Shasta to meet project demands, changing operational criteria, and natural variations in the hydrologic cycle of the watershed since the early 1980s has affected average storage within the reservoir. Table 5 shows the monthly average storage for Shasta Reservoir analyzed over two time periods. The first period of analysis shows the historic average monthly storage elevation in the reservoir for the period of record from 1944 to 1997. The second period of analysis shows the historic monthly average storage elevation for the period of record from 1980 to 1997. Comparing these two periods of analysis, the monthly average annual storage in Shasta Reservoir has decreased up to 11 feet in late summer (August and September).

This look at historical monthly average storage in Shasta Lake demonstrates the susceptibility of water supplies to the natural hydrologic variations as well as the increasing demands for multiple purposes. The operational objective in raising Shasta Dam is to improve the capability to capture flood flows for release at other times of the year. This would result in increased average annual monthly storage in the reservoir. Increased flood flows captured in the primary winter months of January, February, and March would improve the reliability of meeting future increased environmental, urban, and agricultural demands.

Under the enlargements evaluated in this study, the spillway design discharge capacity is 250,000 ft^3/s, the same as for the existing spillway, and is consistent with the design release capacity of Keswick Dam downstream. A reservoir water surface height of approximately 34 feet above the spillway crest is required to produce the design discharge. This discharge establishes the maximum water surface elevation for each dam option. Reservoir operating restrictions will be required for flood control, similar to the current requirements. No flood routings were performed for the appraisal-level studies.

Discharge capacities for the modified river outlets were computed based on the existing bellmouth entrance conditions and other hydraulic factors. The resulting maximum discharge capacities for the modified river outlets (High Option) exceed the maximum capacities of the existing outlets at reservoir elevation 1067 by 19 and 15 percent for the upper and middle tier outlets, respectively (due to the smaller size of the existing 96-inch outlet gates), and by 12 percent for the lower tier outlets (due to the reduced discharge efficiency of the 102-inch tube valves). The maximum combined discharge capacity of all eighteen river outlets is 133,600 ft^3/s at reservoir elevation 1271.5 for the high dam raise option (with all outlets modified), 113,600 ft^3/s at reservoir elevation 1171.5 for the intermediate dam raise option (with twelve outlets modified), and 88,000 ft^3/s at reservoir elevation 1075.5 for the low dam raise option (with four outlets modified).

Construction of the temperature control device at Shasta Dam to provide selective-level withdrawal capability to the existing penstock intakes was completed in 1997. The temperature control device is a steel structure consisting of a shutter structure and low-level intake structure. High level withdrawal, at or above the existing intake elevation, is controlled by the 250-foot-wide by 300-foot-high shutter structure that encloses all five existing power penstock intakes. Three openings with hoist-operated gates and trashracks on the front of each shutter unit allow selection of the reservoir withdrawal level. The 125-foot-wide by 170-foot-high low-level intake structure, located to the left of the shutter structure, acts as a conduit extension to access the deeper, colder water near the center of the dam. The temperature control device is designed for a discharge capacity of 19,500 ft^3/s, and has a reservoir operating range between elevations 840 and 1065.

No modifications to the operation of the existing powerplant have been adopted for the current studies. Consequently, no modifications to the temperature control device have been included in this study. As formulated in this appraisal study, when reservoir levels are within the current range of operating head, the temperature control device would function and the powerplant would be used to generate power. When reservoir levels exceed this range the temperature control device would not be operated and all power would be generated through the new powerplant. More detailed studies of power generation opportunities and temperature control device operations would need to be carried out in more advanced feasibility studies to determine the most optimum project for power generation as integrated with other project water demands.

Water Rights

Any future operations of an enlarged dam and reservoir would be contingent upon acquisition of any additional water and diversion. On February 9, 1961 the State Water Right Board adopted Decision 990 issuing permits pursuant to applications held by Reclamation for the appropriation of water at Shasta Dam. These permits include the storage of up to 4,493,000 acre-feet each year (the estimated gross capacity of the reservoir at the time the permits were issued). The State Water Rights Board considered it to be proper to issue permits for a quantity equal to the gross capacity of the reservoir to provide for the possibility that at some future time it may be necessary to completely drain the reservoir and refill it.

The enlargement of Shasta Dam may require filing an additional application for the appropriation of water (or a petition for the assignment of an existing state filed application) with the California State Water Resources Control Board (SWRCB), formerly the State Water Rights Board. Whether to file an application or a petition for the assignment of an existing state filed application would be discussed with the staff of the SWRCB. The application or petition could be filed by Reclamation when definite plans for the enlargement of Shasta Dam are completed. The application or petition would be published in various newspapers and sent to known interested parties. The interested parties are given a period of time to file protests against the application or petition. It is possible that protests would be filed based on injury to prior rights, environmental, and other issues. The resolution of any protests could be complex. If the protests are not resolved the SWRCB would conduct a formal hearing.

Reclamation would need to present a hydrology study at a hearing held before the SWRCB that demonstrates unappropriated water is available for appropriation.

Environmental documents prepared for the enlargement of Shasta would need to be completed, presented and could also become an issue at a hearing before the SWRCB. Such issues as the proposed use of any new yield for the CVP and SWP, coordinated operations, and water quality in the Delta may become issues at water rights hearings.

An investigation of any impacts to water rights held by relocated landholders would also have to be made. Such an investigation could begin as soon as it is determined what land area and which landholders would be impacted by the enlargement of Shasta Dam. Water right settlement agreements would need to be developed with the impacted landholders. Any landholders that did not agree to a settlement would most likely appear as a protestant at a hearing before the SWRCB.

After the application or petition for the assignment of a stated filed application is filed, it is anticipated that it would take a minimum of two years (depending in part on the extent of the protests) for the SWRCB to process an application for the appropriation of water for the enlargement of Shasta Dam.

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There are three main categories of relocations that are of particular concern when considering enlarging Shasta Dam and Lake. These are transportation route relocations, recreational facility relocations, and community relocations. The required relocations are described below.

Transportation Route Relocations

The two primary transportation route relocations required under enlargement proposals are the Union Pacific Railroad relocation and the Interstate Highway-5 relocation. There are also several county and local roads which will be affected by some optional height raises but the Interstate-5 and railroad relocations far override the other relocation in terms of cost and engineering requirements.

<u>Union Pacific Railroad Relocation</u>.- Union Pacific Railroad is the largest railroad in North America, operating in the western two-thirds of the United States. The system serves 23 states, linking every major West Coast and Gulf Coast port. Union Pacific is the primary rail connection between the United States and Mexico. It also interchanges traffic with the Canadian rail system.

In 1996 Union Pacific acquired Southern Pacific enabling Union Pacific to establish an "I-5 Corridor" that offers the most efficient possible north-south transportation service to freight customers in all three Pacific Coast states. The north-south I-5 corridor route ties to the main east-west routes at Portland, in central California and at Los Angeles. The traffic load on the section of this corridor extending from Roseville, California to the Pacific Northwest carries 22 trains daily. The traffic is mixed freight and Intermodal. Traffic loads are expected to increase in the future.

The Union Pacific rail system in California. The "I-5 Corridor" rail route from Klamath Falls, Oregon through Redding, California is a major rail link connecting the Pacific Northwest with Mexico. This route travels along the Sacramento arm of Shasta Lake and crosses the lake at Bridge Bay over the Pit River Bridge.

A realignment of the railroad is required for any raise in the water surface elevation above about elevation 1084. Any relocation must be constructed to Union Pacific main line standards with a design speed of 70 miles per hour for freight operations, maximum of 20 degree curves, 500 feet of reversing tangent between curves, must have centralized traffic control, and 1 percent or less grades. The railroad relocation required for the High Option is summarized in Table 6. As formulated at this appraisal stage, the railroad realignment begins in Redding directly north of the Sacramento River at Caldwell Park. The realignment is about 35.8 miles long and ends near LaMoine. The proposed route includes four tunnels and somewhere between 5 and 9 bridges.

Table 6 - Summary of Union Pacific Rail Relocation for High Option

FEATURE	DATA
Total Project Length	35.8 miles
Excavation (yd³)	24,000,000
Embankment (yd³)	29,000,000
Tunnels: Number Total Length (ft)	 4 10,650
Major Bridges: Length of Bridge Bay Crossing Lengths of Other Bridges	 5,900 [a] 900 S.T. [b] 1,400 S.T. 910 S.T. 1,300 S.T. 500 D.T.
Number of Passing Tracks (each 9,000 feet long)	7

[a] Combined highway/railroad crossing
[b] S.T. = Single Track; D.T. = Double Track

The maximum design grade is one percent and the minimum radius of curvature is 1,400 feet. The realignment trends northerly from its beginning until it reaches Summit City where it turns to the northeast and enters the Klamath Mountains. Between Summit City and the Pit River numerous cuts and fills are required. A bridge will span the lake across the Pit River. This bridge is described separately below. About one mile north of the Pit River crossing the railroad enters its first tunnel. About a mile further, the rail enters its second tunnel, and two miles later enters a third. A bridge spans the Salt Creek arm and then the rail enters its fourth and last tunnel, daylighting near Lakeshore. The rail continues along the east shore of the Sacramento arm of the lake. A large bridge is required at Middle Salt Creek and a number of smaller drainages must be spanned before the realignment ends near LaMoine. The new tunnels required are summarized in Table 7.

Table 7 - Union Pacific Railroad Realignment Tunnel Requirements

TUNNEL	LENGTH
Packers Gulch Tunnel	3,850 feet Max. Cover=420 ft.
O'Brien Tunnel	1,000 feet Max. Cover=200 ft.
Salt Creek Tunnel	2,700 feet Max. Cover=180 ft.
Gregory Creek Tunnel	3,100 feet Max. Cover=440 ft.

Other minor bridge crossings may also be needed. At this appraisal stage, the exact location and number of these minor bridges is uncertain.

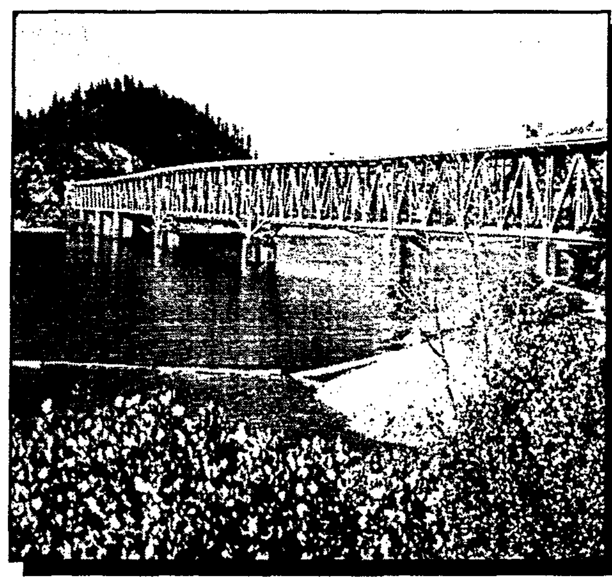
The railroad distance between Redding and Bridge Bay would be lengthened by about 3.3 miles. The reach north of Bridge Bay would be about as long as it is now but there would be four fewer tunnels and the combined tunnel length would be reduced from about 19,000 to 15,000 feet. The number of major bridge crossings would also be reduced.

Interstate Highway-5 Relocation.- A summary of the Interstate-5 relocation for the High Option is found in Table 8. The relocation of Interstate-5 begins near Bridge Bay. From Bridge Bay northward the number of bridges, undercrossings, and overcrossings affected by a relocation are extensive. The bridges, overcrossings, and undercrossings include the Pit River Bridge, the Turntable Road undercrossing and over crossing, the Sidehill Viaduct, Power Line Road, Tunnel Gulch, Johns Cove Viaduct, Island Viaduct, O'Brien undercrossings, the Gilman Road over crossing, the Upper Salt Creek undercrossing, the Antler Summit overcrossing, the Sacramento River bridge, the Antler undercrossing, the Lakehead undercrossing, Dog Creek, the Vollmers Road undercrossing, the Gables overcrossing, the Slate Creek Bridge, and potentially the LaMoine Road overcrossing.

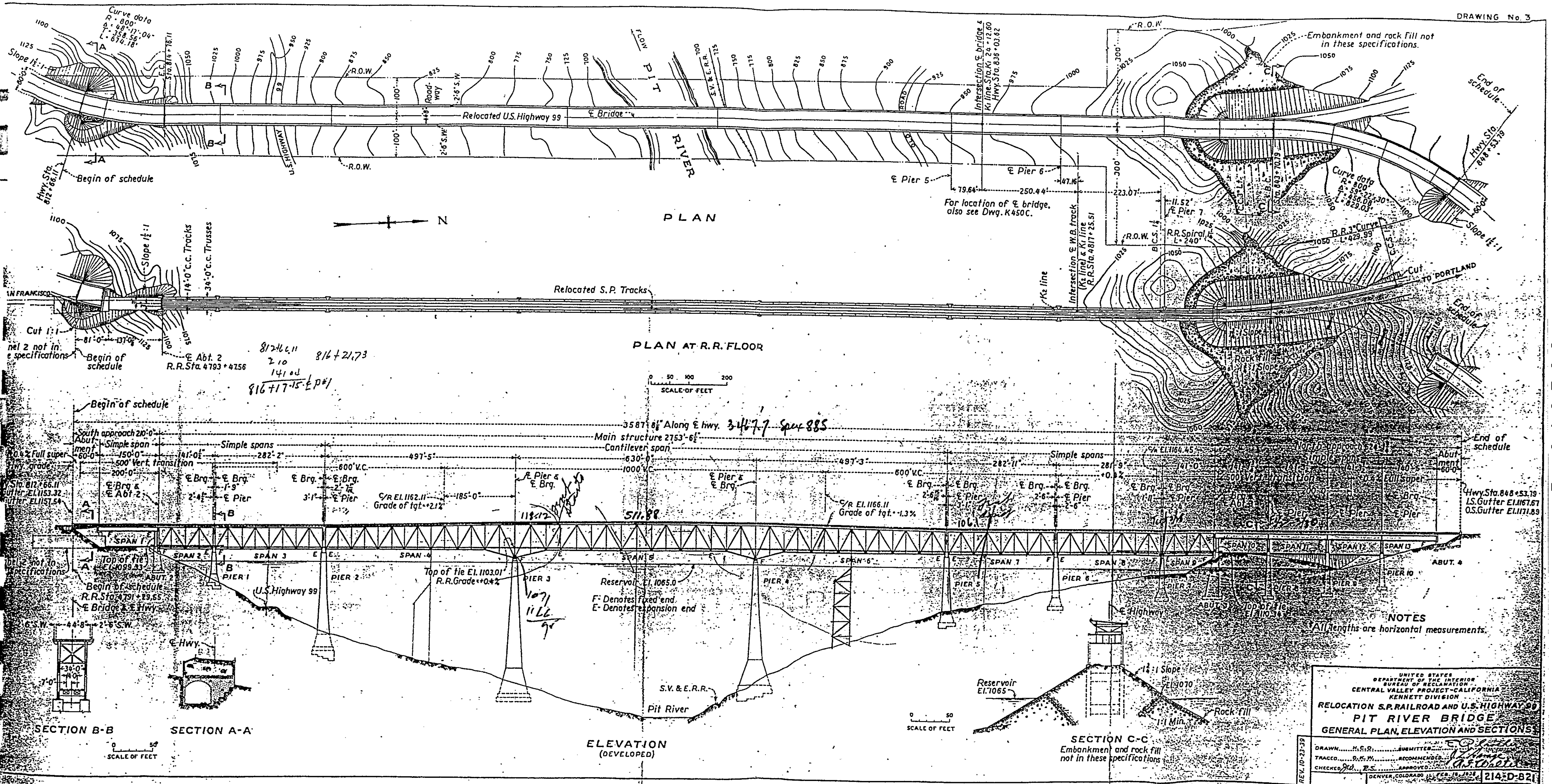
Table 8 - Summary of Interstate-5 Relocation for High Option

FEATURE	DATA
Total Project Length (miles)	18.5
Excavation (yd^3)	23,000,000
Embankment (yd^3)	19,130,000
Major Bridges: Length of Bridge Bay Crossing (ft.) Length of Other Bridges (ft.)	 5,900 1,812
Number of Highway Interchanges	4

Pit River Bridge at Bridge Bay.- The relocation of the Pit River Bridge at Bridge Bay will perhaps pose the single greatest engineering challenge to any enlargement project. Figure 5 shows the general plan, elevation, and sections of the existing bridge as designed in 1938. As shown in this figure, the bottom truss superstructure dips at Piers 3 and 4 located in the deepest part of the old Pit River channel. The elevation of the top of piers 3 and 4 is at 1067 feet, the height of the joint-use water surface elevation in the existing reservoir. The ledge supporting the support bearings of the truss section at Abutment 2 located at the southern end of the bridge is at elevation 1088.03 (top of rail tie elevation shown at 1099.33). These elevations govern the extent to which Shasta Dam can be raised without relocating the bridge. A crest elevation of 1084 (four feet below the hinge at Abutment 2) was selected as the



The Pit River Bridge at Bridge Bay carries vehicular traffic of Interstate-5 on its upper deck and railroad traffic on its lower deck. Piers 3 and 4, seen here in the center-left of the photo, where the truss superstructure dips down, govern the extent Shasta Dam can be raised without relocating the bridge.



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maximum height the dam could be raised without requiring relocation of the bridge. In the Low Option the maximum water surface elevation of 1075.5 would still minimally inundate the truss structure at Piers 3 and 4. In the Low Option, to account for this, the truss and support bearing components at Piers 3 and 4 would be specially treated to withstand infrequent inundation for short periods of time. This flood proofing would provide protection against corrosion whenever the water surface elevation went above 1067. In addition, in the Low Option, the structure at Piers 3 and 4 would be protected against the potential for floating debris. Protection against floating debris would be provided by installation of steel trash deflectors. Also, even under a flood condition where flood surcharge storage space is utilized, in the Low Option there would still be a minimum of 14 feet of clearance under the truss section, except in the immediate vicinity of the lower truss sections at Piers 3 and 4, to allow passage of recreational house boat traffic. These minimal measures were deemed adequate for the Low Option given the frequency and duration at which they would be inundated.

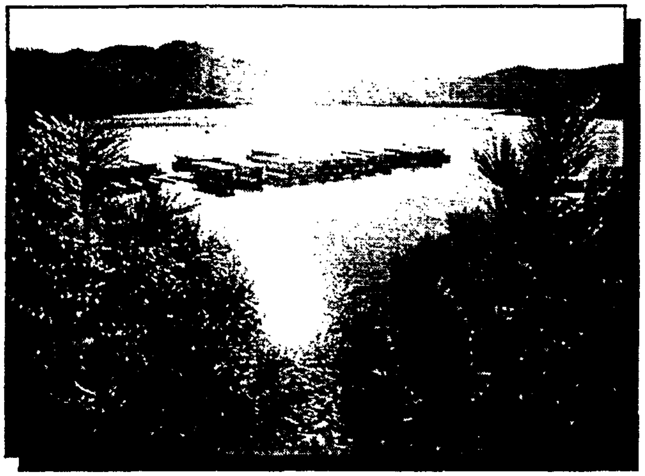
For any enlargement options above elevation 1084, relocation of the bridge is necessary. In past studies of this bridge relocation, two sites have been considered. Two designs, a suspension and a through- truss design, have been considered for an alignment located west of the existing bridge structure. In addition, a suspension design has been examined for an eastern alignment in past investigations. In this appraisal evaluation, a suspension bridge that carries both the highway and railroad traffic on the eastern alignment has been considered. This proposed eastern crossing site is located 200 feet east of the existing bridge.

The new bridge is proposed to be designed to higher standards, including 6 traffic lanes, inside and outside shoulders for each direction, a center median, and sidewalks, for a total deck width of 110 feet. The width of the existing bridge deck is less than 52 feet. A railroad bridge deck beneath the highway deck would be provided (as for the existing bridge) with a 35-foot width. The bridge piers would be constructed in the dry with the reservoir at or below elevation 1010. The high dam raise option would require a suspension bridge with a main span of 2,700 feet, and end spans of 900 feet, at deck elevation 1360.

There have been very few suspension bridges built that carry both rail and vehicular traffic. In earlier studies carried out in the 1980s the only known suspension bridge that also carried rail traffic was built in Lisbon, Portugal. Now however, a suspension or cable-stayed bridge having the required dimensions is considered within the current engineering state-of-the-art. The Akashi Kaikyo suspension bridge with a 95-foot-wide highway deck above a light rail line is now under construction in Japan, with a main span of 6,527 feet and a total length of 12,825 feet. Completion is expected later this year. The Golden Gate Bridge in California has a main span of 4,200 feet and a deck width of 90 feet.

Recreational Facility Relocations

There has been extensive development of rural recreational facilities around Shasta Lake. Most facilities are near the existing shoreline. Table 9 shows a list of most of



the recreational features found around the lake. This list was developed from the best available information. Figures 6 through 8 show the location of these facilities. Recreation facilities include campsites, picnic sites, swimming beaches, and boat ramps. Relocations of recreation facilities also included relocation of appurtenant facilities including roads, power utilities, telephone, bridges, administrative buildings, resorts, special use permit recreation residences, and other recreational support facilities.

Most recreation facilities lie above elevation 1085. Consequently, the Low Option raise to elevation 1084 (joint use water surface elevation 1075.5) reduces substantially any need for relocation of recreational facilities. Some modifications to existing facilities may still be required at some sites but complete relocation will not be required for the most part. For all options above 1085, recreational facilities will need to be relocated. Raising the lake to any of the proposed elevations is not likely to affect Shasta Caverns other than possibly limiting expansion plans under the highest elevations of opening caverns below elevation 1271.5. Shasta Caverns is a highly visited tourist attraction in the area. A privately operated company conducts tours of the caverns.

The entrance to Samwell Cave however, is at elevation 1270. Filling of the reservoir will likely adversely affect this cavern since most of the cave is below the entrance. Other caves below 1271.5 will potentially be flooded.

Community Relocations

Two small communities at Lakehead and Lakeshore are affected at the Intermediate and High Option enlargements. Detailed topographic surveys need to be completed but preliminary information indicates that these communities would only be minimally affected, if at all, under the Low Option where the joint use water level is at 1075.5. Several other smaller communities or developments would also be affected by the higher raise options. These include the communities or developments at Delta, Vollmer, and Antler among others. These communities would also have to be relocated.

Table 9 - Summary List of Recreational Features Around Shasta Lake

Sacramento River Arm
Dry Creek Trail
Fisherman's Point Picnic Area
Centimundi Boat Ramp
Digger Bay Marina
Shasta Marina
Goosneck Cove Campground
Old Man Campground
Lakeshore Resort
Beehive Point
Sugarloaf Resort and Marina (Boat ramp)
Sugarloaf Cottages
Taesdi Resort
Shasta Lake Trails Resort
Gregory Beach
Gregory Creek Campground
Antlers Campground
Antlers Trailer Resort
Antlers Resort
Salt Creek
Lower Salt Creek Resort
Nelson Point Campground
Upper Salt Creek Resort
Salt Creek Picnic Area
Salt Creek Point Campground
Oak Grove Campground

McCloud River Arm
Bailey Cove Campground
Wintoon Campground
Shasta Caverns
Holiday Harbor Resort
Lakeview Marina Resort
Greens Creek Campground
Hirz Bay Day Campgrounds
Dekkas Rock Picnic Area and Campground
Moore Creek Campground
Ellery Creek Campground
Samwell Cave Nature Trail
Pine Point Campground
McCloud Bridge Campground
Pit River Arm
Packers Bay Boat Ramp
Bridge Bay Resort
Ski Island Boat Camp and Marina
Silverthorn Marina
Mariners Point Campground
Rocky Ridge Campground
Jones Valley Campground
Upper Jones Valley
Lower Jones Valley
Jones Valley Resort
Jones Valley Boat Ramp
Rend Island Campground
Arbuckle Flat Boat Camp

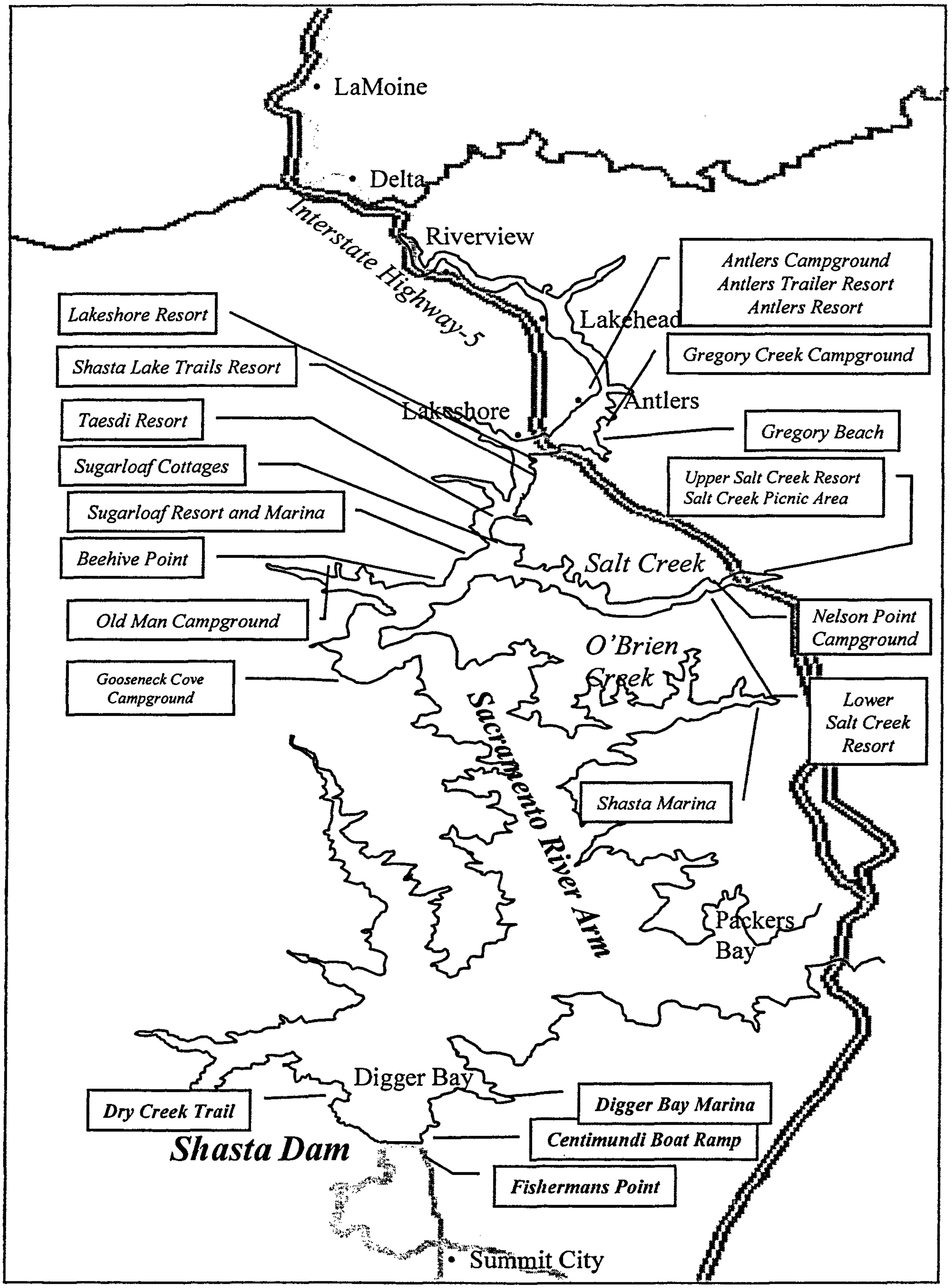


Figure 6 Recreation Facilities Sacramento River Arm

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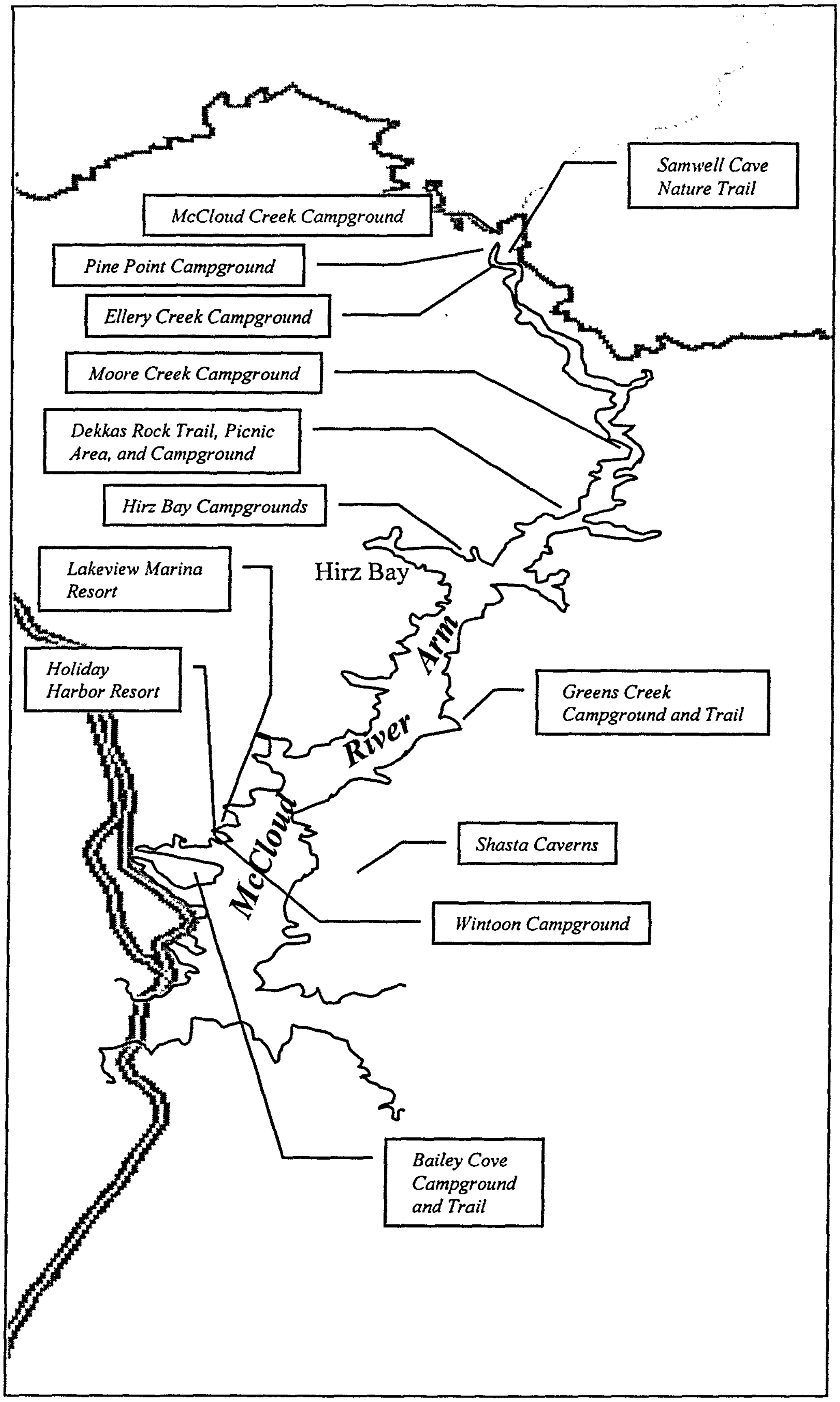


Figure 7 Recreation Facilities McCloud River Arm

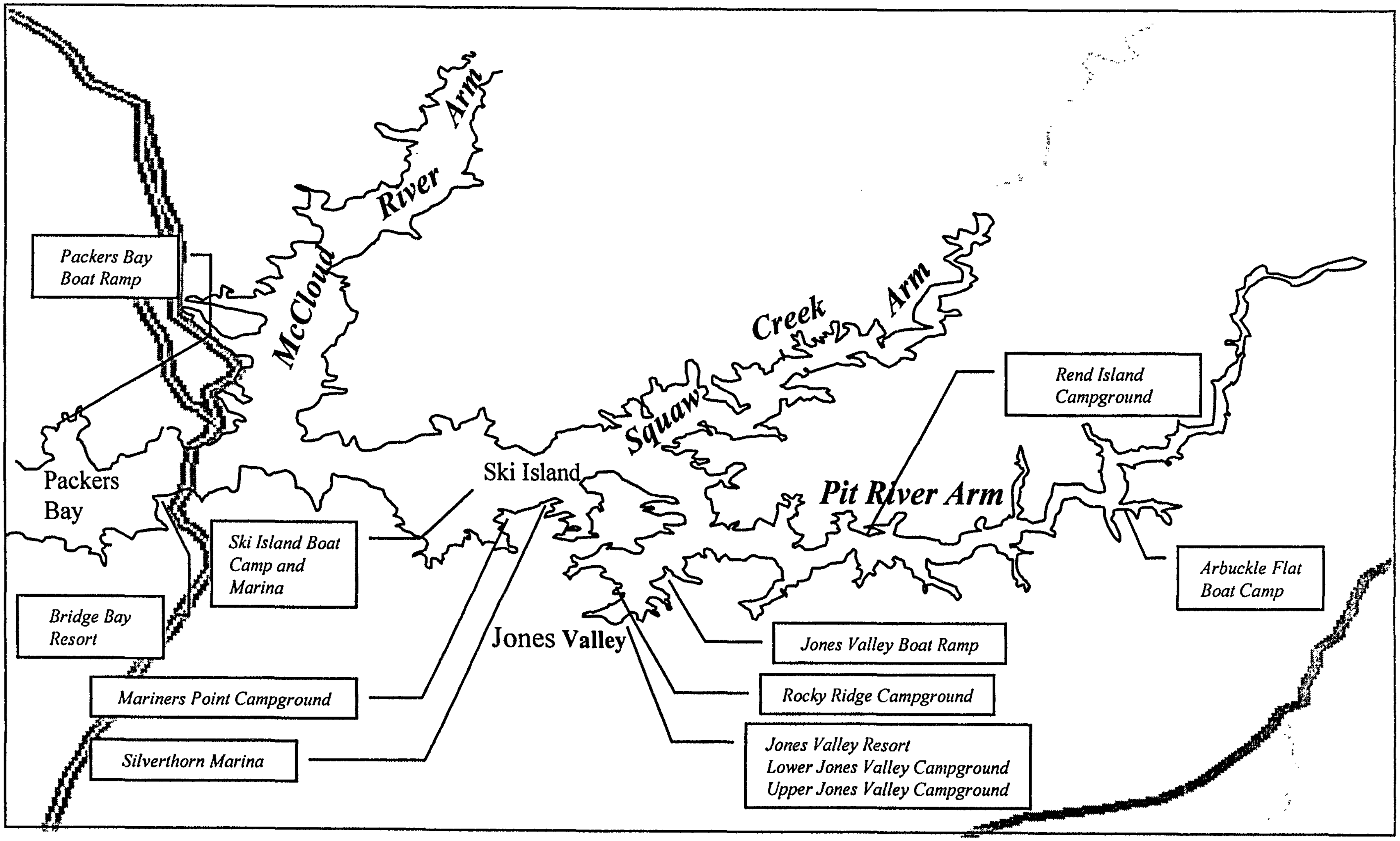
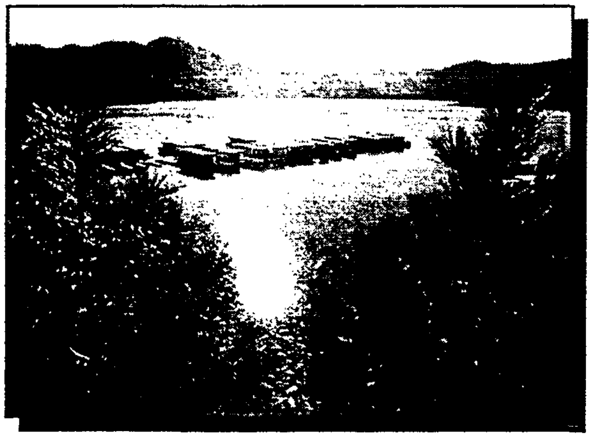


Figure 8 Recreation Facilities Pit River Arm



Shasta Dam, due to its reservoir size, and strategic location at the north end of the Central Valley, is an important component of California's complex water system. The size and location of the dam and reservoir allows significant operational flexibility to meet the water requirements for environmental and instream flow demands as well as the traditional water supply demands. This water is also being touted as a mitigation source for proposed actions on the American River and areas further downstream. With increased stress on the water resources of the State, reliance on Shasta for meeting ecosystem demands is likely to become even more important in the future.

Geographically, fish and wildlife issues directly associated with any proposed enlargement extend from the Sacramento-San Joaquin Delta to the headwaters of the Sacramento River and its tributaries above Shasta Lake. Indirectly, the issues extend further because increased water storage at Shasta would facilitate operational changes in the Delta and San Joaquin Valley that would benefit fish and wildlife. While there would be certain adverse environmental affects associated with raising the dam, the increased storage also affords opportunities to better manage an already highly manipulated water resource.
The role any proposed enlargement of Shasta Dam and Lake may play in maintaining ecosystem values is described below along with potential adverse affects of raising the dam.

The Role of Shasta Dam in Maintaining Ecosystem Values

Ecosystem demands on the water resource developed at Shasta Dam include: (1) meeting Bay-Delta water quality standards, (2) meeting requirements for the endangered winter-run chinook salmon and Delta smelt, (3) meeting water temperature standards in the Sacramento River, (4) providing flows for dilution of acid mine drainage originating in the Spring Creek watershed, and (5) meeting instream flow requirements of the Central Valley Project Improvement Act.

The ecosystem standards which have been developed for the Bay-Delta and the Sacramento River have been deemed necessary for restoration of many aquatic and terrestrial species and their associated habitat. In California's highly managed water system, Shasta Dam is a critical feature in reliably providing cold water for fishery restoration goals in the Sacramento River as well as providing volumes of water necessary to maintain water quality standards in the Sacramento-San Joaquin Delta.

In December 1994 the Bay-Delta Plan Accord established an interim agreement that provided for the Central Valley Project and the State Water Project to meet the water quality goals of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. The purpose of this accord is to contribute to the protection of beneficial uses in the estuary, including objectives for municipal and industrial, agricultural, and fish and wildlife. Fish and wildlife water quality objectives are established for dissolved oxygen, salinity, Delta outflow, river flows, export limits, and Delta Cross Channel gate operation. The Sacramento River flow objectives are to provide attraction and transport flows and suitable habitat for the various life stages of aquatic organisms, including delta smelt and chinook salmon. Under the Coordinated Operations Agreement, the operations of California's State Water Project and the Federal Central Valley Project are to be coordinated for sharing the obligation to meet the standards established for the Delta. Shasta Lake is the primary facility by which the Federal Central Valley Project meets these water resource demands.

In 1990 and 1991 the State Water Resources Control Board issued Water Rights Orders 90-5 and 91-01. These orders established a daily average water temperature objective of 56 degrees Fahrenheit in the Sacramento River at the Red Bluff Diversion Dam. The Central Valley Project attempts to maintain these temperatures within the winter-run salmon spawning grounds below Keswick Dam from April through September. In 1993, the National Marine Fisheries Service also issued a biological opinion that called for minimum instream flows in the Sacramento River of 3,250 cfs below Keswick Dam from October 1 through March 31. Again, the water resources developed at Shasta Lake are critical in meeting these requirements. Interbasin water transfers from the Trinity Basin are also vital in meeting temperature requirements, but as pressure increases to reduce the amount of inter-basin transfers from the Trinity River Basin to the Sacramento River Basin the demand on Shasta facilities for temperature control will continue to increase.

Another ecosystem value the water resource of Shasta Dam protects relates to dilution of acid mine drainage originating in the Spring Creek watershed. Spring Creek flows into Keswick Reservoir downstream of Shasta Dam. Acid mine drainage from abandoned mines in the upper Spring Creek watershed leach heavy metals into the watercourses. These heavy metals under lower flow conditions flow into Spring Creek Reservoir for a regulated release into Keswick Reservoir. During flood conditions Spring Creek Reservoir occasionally fills and spills into Keswick Reservoir. Unless dilution water can be supplied from Shasta Lake or Spring Creek powerplant a high concentration of heavy metals can move downstream into the lower Sacramento River. This acid mine drainage is very toxic to fisheries and water is required to dilute acid mine drainage runoff and prevent fish kills. Typically water diverted from the Trinity Basin into the Sacramento River

Basin, combined with Shasta releases, is used to dilute these toxins. Water diverted from the Trinity Basin has historically been an important component in providing dilution flows. Again however, reducing the amount of inter-basin transfers from the Trinity Basin to the Sacramento River Basin will lead to an increased reliance on Shasta Dam water supplies to meet dilution flow requirements.

Adverse Affects

Potential adverse affects associated with raising the dam vary depending upon the geographic area. For purposes of evaluating potential adverse environmental impacts the basin can be divided into three areas. These are: (1) Upstream of Keswick Dam; (2) Sacramento River below Keswick Dam; and the (3) Sacramento-San Joaquin Delta and Bay. The environmental issues associated with each of these geographic areas are discussed below.

Upstream of Keswick Dam

Shasta Lake and its tributary streams support cold- and warm-water fisheries. The gamefish species are rainbow trout, brown trout, smallmouth bass, largemouth bass, black crappie, bluegill, green sunfish, channel catfish, white catfish, brown bullhead, landlocked white sturgeon, and land locked silver salmon. Nongame species include hard head, golden shiner, threadfin shad, and Sacramento squawfish.

The proposed dam raise project could have both beneficial and adverse affects on the fishery resources, primarily dependent upon project operations. Enlarging the reservoir would, in general, improve the reservoir fishery. Nutrient leaching in newly inundated areas would improve reservoir production during the first years following the enlargement. However, the inundation under a large raise (elevation 1280) would inundate about 42 miles of stream habitat including 6 miles of the McCloud River, 16 miles of the Sacramento River, and a portion of Squaw Creek. Inundation of these areas would adversely affect trout production. Since the stream gradients on the upper tributaries are relatively constant inundation affects are expected to generally be proportional to the raise in dam elevation.

The potential for inundating old mines, thereby increasing acid mine drainage wastes in the reservoir and the Sacramento River is of particular concern. A preliminary review of mining claims and holdings in the vicinity of Shasta Dam indicate that even under the largest dam raise alternatives flooding of actual mine sites would not occur. At about elevation 1100, a raise in the maximum water surface elevation of about 30 feet, partial or complete inundation of the old Bully Hill Refinery site would occur on a seasonal basis. However, since this is only a refinery site, and not an actual mining area, the materials of concern would be old spoils heaps and surficial site contaminants, not the more extensive deposits of a mine itself. A feasibility level study would investigate the toxicity of these deposits. Sporadic flooding and exposure of the refinery site could possibly be mitigated by either burial or removal of the tailings and surficial materials.

The predominant vegetation in this area are northern yellow pine forests, Sierra montane forests, and blue oak-digger pine forests.

The lower elevation areas are dominated by shrub and scrub oak. The project area supports nearly 200 species of birds, 55 species of mammals, reptiles, invertebrates, and amphibians. Typical species include owl, raven, gray squirrel, black bear, deer, hummingbird, swallow, elk, ducks, and geese. Lower elevation areas in the McCloud River Sacramento River, Pit River, and Squaw Creek drainages are winter ranges for deer. Elk winter range is located in the McCloud and Pit River peninsulas.

The inundated area under the Elevation 1280 alternative is about 60,500 acres. This is an increase of about 30,500 acres over the existing reservoir. The increase in inundated area for the Elevation 1180 alternative is about 15,500 acres and for the Elevation 1084 is about 2,000 acres. The adverse affects to wildlife habitat are relatively proportional to the increase in area inundated.

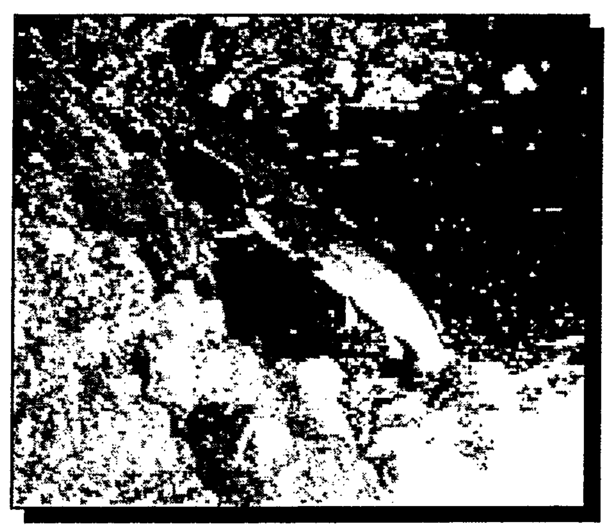
Eleven fish and wildlife species have been designated as rare, threatened, endangered, or sensitive in the Shasta Lake/Keswick Reservoir area. Among these are the bull trout (state endangered), the Shasta salamander (state rare), and *Arnica venosa* (federal sensitive plant). The project would inundate habitat used by the bull trout. Also, enlarging the lake would result in the loss of about 5 percent of the habitat used by the Shasta salamanders. Further surveys are required to determine if the *Arnica venosa* plant species is actually present. Habitat for the resident bald eagle population should increase.

Sacramento River Downstream from Keswick Dam

Along this reach the Sacramento River collects flow from nine major creeks and the Feather and American Rivers. Water quality is generally good along the upper half of the reach except when toxic mine releases occur near Keswick. The upper half of the reach is good trout and salmon habitat. Along the lower half of the reach, agricultural drain water reduces water quality by increasing water temperature and turbidity. Warm water fish populations increase below Red Bluff.

The Sacramento River supports a wide variety of resident and anadromous fish. Affects to these resources are described below.

Chinook Salmon.- Commercially, the most important anadromous fish is the chinook salmon. The Sacramento River and its tributaries support spring, fall, late fall, and winter races. There are adult and juvenile chinook in the river during every month of



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the year. The fall chinook run is the largest. Most fall run spawning occurs in the mainstem Sacramento River between Hamilton City and Keswick Dam. Late fall and winter run chinook spawn primarily in the mainstem above Red Bluff. Genetically pure spring run spawn in a few tributaries, but spring-fall hybrids spawn in the mainstem.

The project could beneficially or adversely affect chinook salmon, depending on operations. Flow changes are of primary concern. How any operations are carried out will determine the positive or negative affects of any enlargement. Flow changes affect chinook spawning habitat by altering water depths and velocities. Flow changes can also affect rearing habitat availability and juvenile outmigration success. Mainstem flow reductions could reduce the dilution of tributary stream inflows, increasing the concentration and duration of turbidity sources. A deeper reservoir may also affect dissolved oxygen concentrations in releases from the deeper reservoir. These pollution and turbidity changes could adversely affect egg and juvenile chinook survival rates.

The other major concern associated with operations are temperature conditions within the Sacramento River. Any of the proposed raises should augment the size of the cold water pool and should not affect the ability to meet water temperature standards through use of the existing temperature control device. An increase in reservoir storage may increase cold water resources.

Wildlife habitat Along the River.- There are four main wildlife habitat areas adjacent to this reach of the Sacramento River: the Sacramento River riparian zone, the Butte Basin, the Colusa Basin, and the Yolo Basin. Wildlife habitat in these areas includes agricultural lands, riparian zones, permanent marshes, seasonal marshes, and uplands. Any proposed enlargement project could adversely affect wildlife populations, dependent upon the amount of flooded land areas. Managed wetland habitats should not be harmed. Of concern is the threat of conversion of riparian zones to agricultural zones, due to reduced flooding. Separate, ongoing efforts are addressing these problems and any future analysis of these potential affects would have to be coordinated with those efforts. Also of concern is the affect of reduced flood releases during the winter time and higher flows in other times of the year on riparian habitat. Reduced flooding could also reduce the amount of habitat that supports diverse populations of wildlife through a reduction in water supplies to the riparian zone.

Special species of concern that inhabit the riparian zone in this reach include bald eagle, peregrine falcon, yellow-billed cockoo, and giant garter snake. In addition, the California red-legged frog, western spadefoot toad, sharp-tailed snake, and Pacific pond turtle inhabit this reach.

The Delta

The Sacramento-San Joaquin Delta is the point of convergence of the Sacramento, San Joaquin, Mokelumne, and Consumnes Rivers. Functionally, it is part of the San Francisco Bay Delta ecosystem, consisting of sloughs and islands that are subject to tidal influences.

The most significant fish species in the Delta are anadromous species including chinook salmon, steelhead trout, white sturgeon, non-native striped bass, and American shad. These species use the Delta as a passage to upstream spawning areas and as juvenile rearing areas. Another significant species is the Delta smelt.

Important factors that affect the Delta fishery and ecosystem in general are adequate circulation and dispersion of nutrients, and upstream fish losses at diversions. Water circulation and nutrient dispersion are influenced by watershed runoff, upstream water storage, and Delta area diversions that reduce freshwater outflows. Delta outflows affect the various zones within the area which form the areas of highest biological activity in the estuary. Adequate outflows are also required to prevent saltwater intrusion into the Delta and to flush pollutants from the area. Saltwater intrusion can adversely affect food availability for Delta fish and wildlife.

Also of concern is the potential for fish losses at diversions and the Delta area export facilities operated by the California State Water Project and the Federal Central Valley Project. The potential for increased exports in dry years under any enlarged Shasta proposal could result in increased losses of fish eggs, fry, and fish food organisms at the pumping facilities.

Mitigation Strategies

Potential mitigation strategies for adverse affects associated with any enlarged dam proposal may include, but are not limited to, any of the following actions:

Upstream from Keswick Dam.-

- Leave natural vegetation or install artificial fish cover in the reservoir drawdown zone.
- Improve stream habitat in the project area and other critical habitat locations away from the project.
- Land acquisition and management efforts to focus on improving deer, elk, and other wildlife habitat.

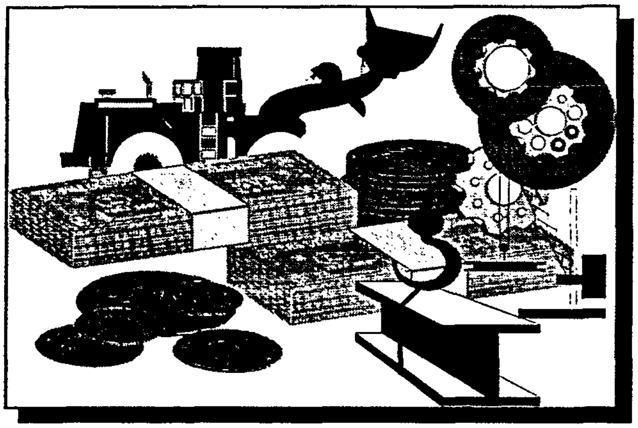
Sacramento River Downstream From Keswick.-

- Improve fish passage and habitat on the Sacramento River and tributaries.
- Water releases to enhance fish production and riparian habitat.
- Salmon habitat monitoring program to ensure maintenance of quality fish habitat.
- Maintenance of releases to dilute Spring Creek acid mine wastes.
- Control predation on salmonids.
- Manage meander belt zones to protect and enhance wildlife habitat.

Delta.-

- Modify flow management and provide additional fish protection facilities.

Many ongoing programs are addressing resource issues associated with some of the potential strategies identified above. Any future development of a mitigation program would have to be carefully coordinated with these ongoing programs.



Detailed construction cost estimates based on current unit prices, were prepared for the appraisal-level design features included in this study. These project features include the concrete dam overlay and RCC wing dams, spillway, river outlets, TCD modifications, selective-level intake, penstocks, new powerplant, switchyards, cellular cofferdams, and reservoir dikes. Appraisal-level estimates include an allowance of 10 or 15 percent for unlisted items depending on the feature, and an allowance of 25 percent for contract contingencies. The higher allowance for unlisted items of 15 percent was used for the concrete dam to cover a potential uncertainty in the concrete quantities, and a higher than usual mobilization cost (10 percent) was assumed for the extensive concrete batching and delivery systems required.

Additional project features have been indexed to current price levels to provide an estimate of total project costs for each dam raise option. These features include the relocations for the Interstate 5 Highway and the Union Pacific Railroad, potential modifications to Keswick Dam and powerplant, resort relocations, land rights, reservoir clearing, recreation facilities, and Sacramento River seepage mitigation. In addition, a preliminary cost for a new Pit River Bridge (or Bridge Bay Crossing) was developed for this study.

Cost Summaries

Estimated costs for the three dam enlargement options included in this appraisal-level study are summarized in Table 10. The detailed cost estimate worksheets for each option are provided in Appendix B.

Table 11 shows the cost per acre-foot of storage. The cost per acre-foot of storage is shown both in terms of first costs and total investment costs. This cost per acre-foot of storage does not represent the cost per acre-foot of reservoir yield. These costs provide a basis of comparison to other storage options being considered in the CALFED process.

The total estimated field, first and investment costs for each dam raise option are plotted on Figure 9. While these data points have been plotted as a smooth curve for these appraisal-level estimates, discrete jumps should be expected at various points where significant cost increases would occur. These primarily include the points between elevations 1084 and 1180 for which

Table 10 - Cost Summaries for Dam Raise Options

Description	Crest El. 1084	Crest El. 1180	Crest El. 1280
Cofferdams	$ 0	$ 29,000,000	$ 29,000,000
Structure Removal	7,200,000	11,000,000	11,000,000
Concrete Dams	15,500,000	550,000,000	1,100,000,000
Spillway	22,000,000*	17,500,000	24,000,000
River Outlets	15,500,000	58,000,000	80,000,000
Existing Powerplant	10,500,000**	57,000,000	80,000,000
New Powerplant	0	473,000,000	510,000,000
Switchyards	0	60,300,000	114,300,000
Reservoir Dikes	0	28,900,000	98,000,000
SUBTOTAL A	**$ 70,700,000**	**$ 1,284,700,000**	**$ 2,046,300,000**
Keswick Dam & PP	0	0	253,000,000
Pit River Bridge	1,000,000	340,000,000	340,000,000
I-5 Relocation	0	181,190,000	235,050,000
UPRR Relocation	0	353,000,000	455,000,000
Reservoir Clearing	3,000,000	24,000,000	46,000,000
Resort/Land Rights	5,000,000	59,000,000	77,000,000
Rec. Relocation	0	210,000,000	210,000,000
Rec. Facilities	0	48,000,000	57,000,000
Seepage Mitigation	3,000,000	43,000,000	86,000,000
SUBTOTAL B	**12,000,000**	**$ 1,258,190,000**	**$ 1,759,050,000**
TOTAL FIELD COSTS	**$ 82,700,000**	**$ 2,542,890,000**	**$ 3,805,350,000**
Mitigation Costs***	12,405,000	127,145,000	190,268,000
Engineering & Design Costs	8,270,000	178,002,000	266,375,000
Construction Management	4,135,000	76,287,000	114,161,000
TOTAL FIRST COST	**$107,510,000**	**$2,924,324,000**	**$4,376,154,000**
Interest During Construction	14,771,000	965,405,000	1,434,773,000
TOTAL INVESTMENT COST	**$122,281,000**	**$3,889,729,000**	**$5,810,927,000**
AVERAGE ANN. COST****	**$9,001,000**	**$286,312,000**	**$427,725,000**

* Includes mass concrete in spillway crest (included in dam for other options).
** Includes field cost of modifications to temperature control device.
*** Mitigation costs estimated at 15% for Elev. 1084 option, and 5% for Elev. 1180 and 1280 options. Engineering and design costs estimated at 10% for the Elev. 1084, and 7% for Elev. 1180 and 1280. Construction management costs est. at 5% for Elev. 1084 option, and 3% for the Elev. 1180 and 1280 options.
****Average annual costs based upon 7.125% interest over 50 year period.

Table 11 Average Costs Per Acre-Foot of Storage

Description	Crest El. 1084	Crest El. 1180	Crest El. 1280
Total Field Cost	82,700,000	2,542,890,000	3,805,350,000
Total First Cost	$107,510,000	$2,924,324,000	$4,376,154,000
Total Investment Cost	$122,281,000	$3,889,729,000	$5,810,927,000
Added Storage (a-f)	290,000	3,920,000	9,340,000
Cost Per Acre-Foot Based on First Cost	371	746	469
Cost Per Acre-Foot Based on Total Investment Cost	422	992	622

the new powerplant and switchyard would be constructed; the I-5 and Union Pacific relocations would be required (including replacement of the Pit River Bridge); the recreation facilities relocations would be required; the left abutment cofferdam would be constructed to remove the existing left wing dam; and the dam crest raise would require an overlay on the downstream face for stability. Significant points between elevations 1180 and 1280 include the elevations for which modification or replacement of the existing Keswick Dam and powerplant would be required, and for construction of the Centimudi and Bridge Bay Dikes.

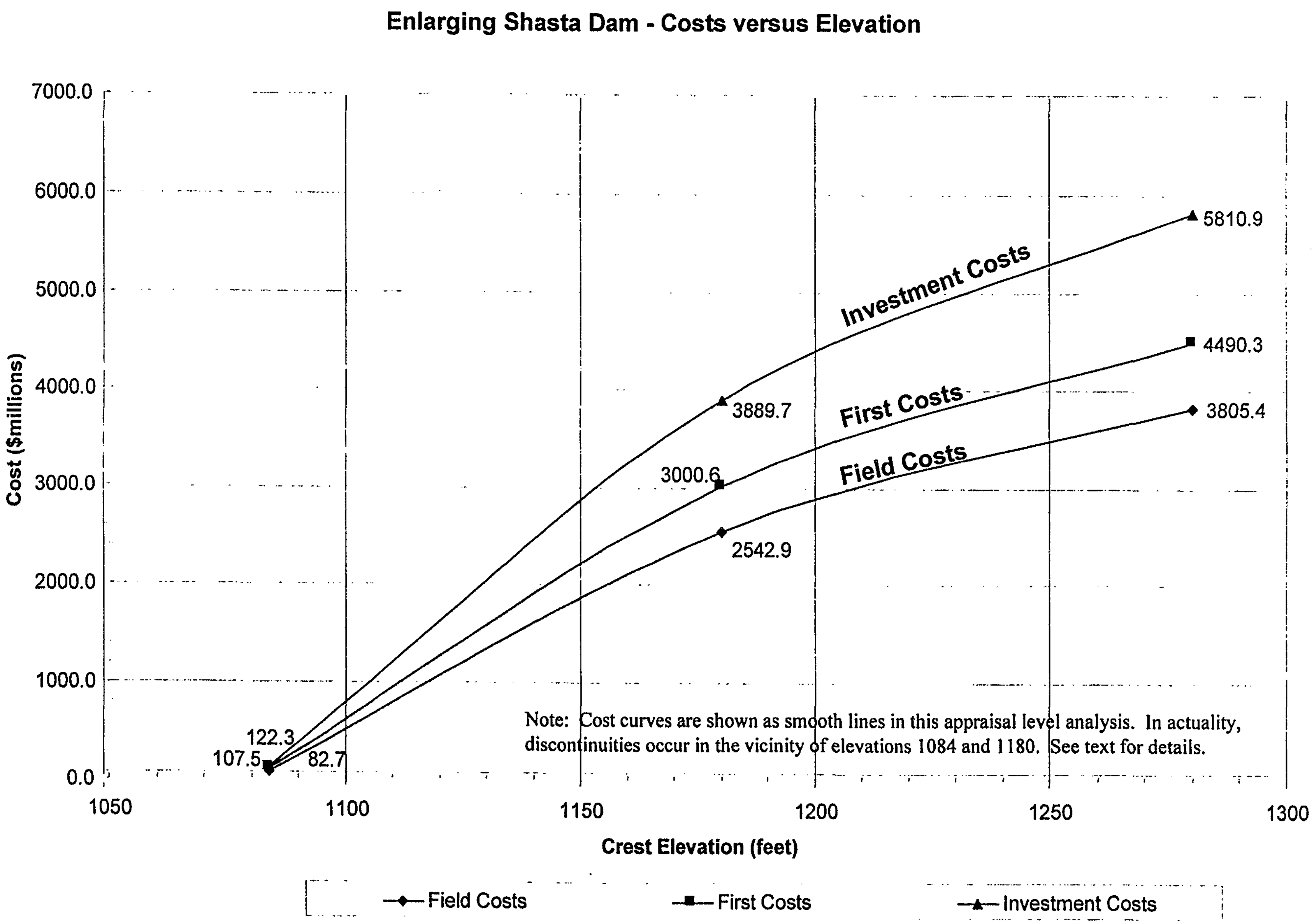
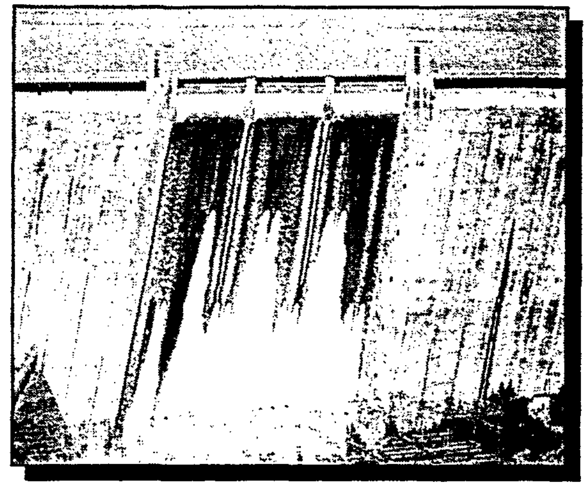


Figure 9 Cost Versus Elevation Curve

Benefit categories associated with enlarging Shasta dam include environmental, flood control, water supply, and power. Each of these categories is described below.

Flood Control Operations

Present regulation of Shasta Dam for flood control requires that releases be restricted to quantities that will not cause downstream flows or stages to exceed, insofar as possible, 1) a flow of 79,000 cubic feet per second at the tailwater of Keswick Dam, and 2) a stage of 39.2 feet at the Sacramento River at Bend Bridge gaging station near Red Bluff (corresponds roughly to a flow of 100,000 cubic feet per second). Storage space of up to 1.3 million acre-feet below elevation 1067 is also kept available for flood control purposes in the reservoir in accordance with the Flood Control Diagram, as directed by the U.S. Army Corps of Engineers. Under the Flood Control Diagram, flood control storage space increases from zero on October 1 to a maximum of 1,300,000 acre-feet on December 1 and is required until December 23. A variable flood control reservation space up to a maximum of 1,300,000 acre-feet (elevation 1018.55) from December 23 to June 15 is required. During this time period, this space varies according to parameters based on the accumulation of seasonal inflow. This variable space allows for the storage of water for conservation purposes unless it is required for flood control purposes based upon basin wetness parameters and the level of seasonal inflow.



Provision of this space, therefore allows a more efficient operation of the project. The flood control operation each day consists of determining the required flood storage space reservation and scheduling releases in accordance with flood operating criteria. This procedure requires a forecast of reservoir inflow.

Flood control operations of Shasta Lake requires forecasting of flood runoff both above and below the dam. Rapidly changing inflows are continually monitored and the forecasts of the various inflows are adjusted as required. The time of stream flow travel from Shasta Dam to Bend Bridge is about 9 to 10 hours under higher flow conditions.

No flood routing studies of hydrologic updates were done at this appraisal level to quantitatively determine levels of additional flood protection provided by various size enlargements. For purposes of this appraisal study it was assumed that operations similar to existing conditions would be carried out under any enlargement project. The current maximum flood control space of 1,300,000 acre-feet, as originally formulated, represented a 100-year flood and is the maximum flood controllable to project objective outflows of 79,000 cubic feet per second at Keswick.

When assessing flood control benefits, it must be remembered that the function of any additional storage space developed at Shasta is to capture floodwater. Maintaining 1,300,000 acre-feet of dedicated flood control space in any proposed enlargement would allow the storage of significant amounts of additional floodwater before flood space in encroached. Since any enlargement is essentially capturing floodwaters, the additional storage space provided under the intermediate and high options can capture multiple large flood events above the existing storage levels before ever encroaching on the new flood control space. It is felt that this additional storage would provide substantial amounts of additional flood protection to downstream interests.

Water Supply

Water demands in the State are expected to continue to increase. In its January 1998 public review draft of "The California Water Plan Update Bulletin 160-98 Volume 2," the California Department of Water Resources has attempted to quantify future demands. Table 12 summarizes the year 2020 demand and projected shortage information provided in Bulletin 160-98 for the Sacramento, San Joaquin, and Tulare hydrologic basins. As is shown in this table, significant shortages of water supplies are predicted for the future, particularly in drought years, but also in average hydrologic years. For the Central Valley, shortages of up to 4,456,000 acre-feet are predicted in drought years and . 1,746,000 acre-feet in normal years. Water stored in any enlarged facility would facilitate meeting these demands, particularly in the Sacramento River Basin. In addition, if managed properly, additional storage at Shasta could facilitate augmentation of environmental flows in south of the Delta streams while meeting existing water contract demands.

Enlargement of the dam and reservoir significantly increases the size of the active conservation storage space. Active conservation storage space holds water supplies that are not subject to release for flood control purposes. The water stored in this zone of the reservoir is available to meet all beneficial uses. Table 13 shows the existing active conservation storage space compared to that provided under the various enlargement options.

Several studies have been done in the past to identify the extent of increased yield resulting from enlarging Shasta Dam. The surplus rainfall areas of the state are the north coast and the Sacramento River watershed. The north coast streams are reserved as wild and scenic rivers, and storage on the Sacramento's major tributaries is already well developed. Thus, the main Sacramento River offers the best opportunity for a major new water supply project. Very preliminary modeling done by entities outside of this appraisal study has identified somewhere in the neighborhood of a long term average annual 1.6 million acre-feet of surplus water available for storage in an

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Table 12 Estimated Future Water Demands, Supplies, and Shortages

Resource	*Sacramento River Hydrologic Basin*		*San Joaquin River Hydrologic Basin*		*Tulare Lake Hydrologic Basin*		*Three Basin Combined*	
	Year 2020 Volume (acre-feet)		**Year 2020 Volume (acre-feet)**		**Year 2020 Volume (acre-feet)**		**Year 2020 Volume (acre-feet)**	
	Average Year	**Drought Year**	**Average Year**	**Drought Year**	**Average Year**	**Drought Year**	**Average Year**	**Drought Year**
Applied Water:								
Urban	1,139,000	1,236,000	954,000	970,000	1,099,000	1,099,000	3,192,000	3,305,000
Agricultural	7,939,000	8,822,000	6,450,000	6,719,000	10,123,000	9,532,000	24,512,000	25,073,000
Environmental	5,951,000	4,344,000	3,087,000	2,205,000	1,771,000	846,000	10,809,000	7,395,000
Total Applied Water	15,029,000	14,402,000	10,491,000	9,895,000	12,992,000	11,476,000	38,512,000	35,773,000
Supplies:								
Surface Water	12,188,000	10,011,000	7,364,000	5,502,000	7,871,000	3,611,000	27,423,000	19,124,000
Groundwater	2,636,000	3,281,000	2,323,000	2,912,000	4,386,000	5,999,000	9,345,000	12,192,000
Recycled/ Desalted	0	0	0	0	0	0	0	0
Total Supplies	14,824,000	13,292,000	9,687,000	8,414,000	12,257,000	9,610,000	36,768,000	31,316,000
Shortages	206,000	1,109,000	805,000	1,481,000	735,000	1,866,000	1,746,000	4,456,000

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Table 13 Active Conservation Storage Space

Option	Conservation Space	Increase in Conservation Space
Existing	2,664,960	-
Low	2,952,870	290,000
Intermediate	6,582,870	3,920,000
High	12,002,870	9,340,000

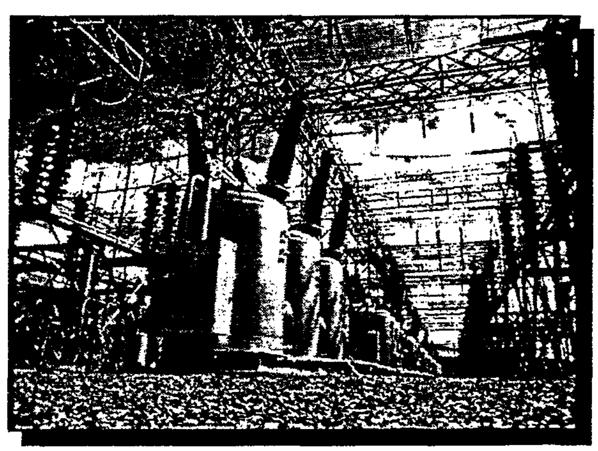
increased capacity Shasta Dam. Surplus water is that water available for capture over and above meeting current water supply and environmental demands on the system. While the long term average annual water available for storage is estimated at 1.6 million acre-feet, analysis of the hydrologic nature of the basin shows that this water actually occurs infrequently during heavy flood periods. In essence, tremendous volumes of water are available infrequently. With the current reservoir, during these flood periods this water must be dumped from Shasta Dam in a relatively short time period to fall within the operational capabilities of the existing dam. This results in high peak flows down the Sacramento River over a relatively short period of time. The advantage of increasing the storage at Shasta is the ability to capture these floodwaters for use in later years as carryover.

Water yield studies have been conducted in the past to determine the actual yield potential of enlarging the reservoir. These yield studies however were conducted in 1978 and many operational parameters and criteria have changed since that time. Table 14 shows the results of these previous yield studies as a point of reference. Operational demands under current day criteria are higher than in 1978 when these previous studies were done. Many new detailed operational studies are required to determine expected yields from enlarging the dam and reservoir given current operational criteria and updated hydrology. It is likely that the yields would be much lower.

Table 14 1978 Yield Studies

Added Height to Dam (feet)	Added Water Supply (acre-feet)
33	250,000
133	1,000,000
203	1,400,000

Power
For this appraisal study, only power benefits for the new powerplant on the left abutment were developed. The estimated average annual benefits for the Intermediate Option are $8 million and for the High Option, $10



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million. These estimates are based upon preliminary operational assumptions and need to be refined in more detailed studies.

Environmental
Potential environmental benefits have been described in the chapter concerning environmental considerations. The primary potential for environmental benefits relates to flow and temperature management for ecosystem values in the Sacramento River and in the Delta. The extent of these opportunities has not been fully developed at this level of investigation. Efforts to quantify these benefits will require extensive modeling of the system to optimize operations for environmental benefits.

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Conclusions

Based upon the appraisal investigations completed to date the following conclusions can be reached regarding the feasibility of enlarging Shasta Dam:

- The geographic and hydrologic characteristics of the upper Sacramento River Basin provides feasible opportunities for efficiently developing additional water supply storage at the existing Shasta Dam site.
- The maximum height Shasta Dam can feasibly be raised is about 200 feet. Geologic, relocation, and cost constraints prevent further enlargements beyond this point.
- The minimum height the dam can be raised without affecting the existing Union Pacific Railroad and Interstate Highway - 5 Pit River Bridge crossing at Bridge Bay is to elevation 1084.
- There are no engineering considerations which preclude any enlargement possibilities below 200 feet.
- The relocation of the Union Pacific railroad and Interstate Highway 5 at Bridge Bay represents about 20 percent of the total cost of enlarging the dam and reservoir for options above elevation 1084.
- Enlargement of Shasta Dam and reservoir offers the potential for significant benefits to flood control, urban and agricultural water supply reliability, power, and environmental uses.
- Additional studies and modeling are needed to better define how any enlargement project would be operated and what affects this operation would have on the environment and other traditional water supply uses.

Recommendations

It is recommended that feasibility studies examining the opportunities for enlarging Shasta Dam and reservoir proceed. Through more advanced studies engineering considerations and cost savings measures can be refined, operational opportunities can be further defined in the context of statewide water issues and programs, benefits can be optimized in relation to meeting multiple demands, and a determination of the optimum height of enlargement can be completed. Development of a feasibility study program should be developed in coordination with the State of California and other entities to ensure development of an acceptable plan for implementation.

APPENDIX A

STORAGE - AREA - ELEVATION RELATIONSHIPS OF SHASTA RESERVOIR

STORAGE - ELEVATION RELATIONSHIPS - SHASTA RESERVOIR					
ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)
544	0	621	2699	667	20499
576	0	622	2374	668	21153
577	1	623	3058	669	21823
578	2	624	3249	670	22507
579	6	625	3449	671	23208
580	10	626	3658	672	23924
581	16	627	3874	673	24657
582	23	628	4100	674	25406
583	31	629	4334	675	26171
584	41	630	4578	676	26953
585	53	631	4830	677	27752
586	66	632	5091	678	28567
587	81	633	5362	679	29400
588	98	634	5642	680	30251
589	117	635	5931	681	31115
590	137	636	6230	682	32004
591	161	637	6535	683	32907
592	186	638	6855	684	33828
593	214	639	7182	685	34766
594	245	640	7514	686	35723
595	279	641	7864	687	36698
596	315	642	8219	688	37692
597	355	643	8584	689	38704
598	398	644	8958	690	39735
599	445	645	9341	691	40784
600	495	646	9734	692	41853
601	549	647	10137	693	42940
602	607	648	10549	694	44047
603	669	649	10971	695	45173
604	735	650	11404	696	46319
605	806	651	11846	697	47485
606	862	652	12299	698	48670
607	962	653	12762	699	49876
608	1047	654	13236	700	51102
609	1138	655	13721	701	52348
610	1234	656	14217	702	53615
611	1335	657	14724	703	54902
612	1443	658	15243	704	56211
613	1556	659	15775	705	57541
614	1675	660	16318	706	58893
615	1801	661	16875	707	60266
616	1933	662	17444	708	61662
617	2072	663	18027	709	63080
618	2218	664	18624	710	64522
619	2371	665	19234	711	65087
620	2531	666	19859	712	67475

STORAGE - ELEVATION RELATIONSHIPS - SHASTA RESERVOIR					
ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)
713	68988	759	173207	805	364674
714	70526	760	176345	806	365973
715	72089	761	179528	807	375327
716	73679	762	182752	808	380739
717	75294	763	186020	809	386205
718	76937	764	189332	810	391736
719	78607	765	192683	811	397323
720	80306	766	196089	812	402969
721	82033	767	199535	813	403677
722	83790	768	203026	814	414445
723	85578	769	206563	815	420274
724	87397	770	210146	816	426166
725	89247	771	213775	817	432121
726	91129	772	217450	818	438139
727	93043	773	221171	819	444220
728	94991	774	224939	820	450366
729	96972	775	228752	821	456605
730	99967	776	232612	822	462906
731	101036	777	236519	823	469267
732	103120	778	240471	824	475690
733	105238	779	244469	825	482176
734	107392	780	248514	826	488723
735	109582	781	252603	827	495333
736	111807	782	256739	828	502007
737	114068	783	260919	829	508743
738	116366	784	265144	830	515543
739	118699	785	269414	831	522407
740	121069	786	273738	832	529336
741	123475	787	278090	833	536330
742	125918	788	282496	834	543388
743	128397	789	286947	835	550512
744	130913	790	291443	836	557702
745	133466	791	295986	837	564958
746	138055	792	300574	838	572280
747	138682	793	305209	839	579670
748	141346	794	309891	840	587157
749	144048	795	314621	841	594655
750	146785	796	319395	842	602251
751	149566	797	324225	843	609915
752	152383	798	329100	844	617648
753	155238	799	334026	845	625450
754	158132	800	339002	846	633323
755	161066	801	344030	847	641264
756	164048	802	349111	848	649276
757	167055	803	354244	849	657358
758	170111	804	359432	850	665511

STORAGE - ELEVATION RELATIONSHIPS - SHASTA RESERVOIR					
ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)
851	673736	897	1132134	943	1764137
852	682032	898	1143965	944	1779960
853	690401	899	1155883	945	1795883
854	698841	900	1167888	946	1811905
855	707355	901	1179892	947	1828027
856	715941	902	1191981	948	1844246
857	724602	903	1204158	949	1860571
858	733336	904	1216422	950	1876996
859	742144	905	1228773	951	1893516
860	751027	906	1241213	952	1910141
861	759943	907	1253739	953	1926867
862	768935	908	1266356	954	1943696
863	778000	909	1279060	955	1960627
864	787142	910	1291854	956	1977659
865	796358	911	1304737	957	1994796
866	805651	912	1317711	958	2012037
867	815020	913	1330774	959	2029381
868	824465	914	1343929	960	2046829
869	833988	915	1357174	961	2064285
870	843589	916	1370511	962	2081845
871	853266	917	1383940	963	2099510
872	863023	918	1397461	964	2117278
873	872857	919	1411074	965	2135150
874	882770	920	1424780	966	2153127
875	892763	921	1438506	967	2171210
876	902836	922	1452324	968	2189399
877	912988	923	1466235	969	2207692
878	923221	924	1480240	970	2226093
879	933535	925	1494336	971	2244600
880	943929	926	1508528	972	2263214
881	954341	927	1522813	973	2281936
882	964832	928	1537193	974	2300765
883	975405	929	1551667	975	2319700
884	986060	930	1566238	976	2338747
885	996795	931	1580903	977	2357900
886	1007613	932	1595665	978	2377163
887	1018514	933	1610523	979	2396536
888	1029497	934	1625478	980	2416019
889	1040564	935	1640529	981	2435579
890	1051713	936	1655678	982	2455251
891	1062947	937	1670925	983	2475031
892	1074866	938	1686270	984	2494924
893	1085668	939	1701713	985	2514928
894	1097156	940	1717255	986	2535041
895	1108729	941	1732785	987	2555268
896	1120388	942	1748411	988	2575607

STORAGE - ELEVATION RELATIONSHIPS - SHASTA RESERVOIR					
ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)	ELEVATION (FEET)	STORAGE (ACRE-FEET)
989	2596059	1035	3661442	1200	9850000
990	2616622	1036	3687415	1210	10400000
991	2637299	1037	3713517	1220	10900000
992	2658089	1038	3739744	1230	11500000
993	2678994	1039	3766100	1240	12000000
994	2700013	1040	3792590	1250	12600000
995	2721146	1041	3819060	1260	13200000
996	2742395	1042	3845663	1270	13800000
997	2763757	1043	3872390		
998	2785237	1044	3899248		
999	2806832	1045	3926323		
1000	2828544	1046	3953347		
1001	2850335	1047	3980594		
1002	2872244	1048	4007969		
1003	2894270	1049	4035473		
1004	2916410	1050	4063108		
1005	2938672	1051	4090874		
1006	2961049	1052	4118773		
1007	2983548	1053	4146802		
1008	3006162	1054	4174961		
1009	3028895	1055	4203354		
1010	3051750	1056	4231683		
1011	3074723	1057	4260238		
1012	3097817	1058	4288934		
1013	3121030	1059	4317759		
1014	3144365	1060	4346717		
1015	3167820	1061	4375658		
1016	3191401	1062	4404728		
1017	3215097	1063	4433933		
1018	3238920	1064	4463270		
1019	3262862	1065	4492742		
1020	3286929	1066	4522347		
1021	3311027	1067	4552090		
1022	3335251	1070	4650000		
1023	3359595	1080	5000000		
1024	3384062	1090	5250000		
1025	3408655	1100	5600000		
1026	3433371	1110	6000000		
1027	3458210	1120	6350000		
1028	3483173	1130	6750000		
1029	3508264	1140	7100000		
1030	3533478	1150	7500000		
1031	3558818	1160	7950000		
1032	3584283	1170	8400000		
1033	3609875	1180	8850000		
1034	3635596	1190	9350000		

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AREA - ELEVATION RELATIONSHIPS - SHASTA RESERVOIR					
ELEVATION (FEET)	AREA (ACRES)	ELEVATION (FEET)	AREA (ACRES)	ELEVATION (FEET)	AREA (ACRES)
820	6178	1088	32453	1134	38568
830	6835	1089	32576	1135	38711
840	7509	1090	32699	1136	38854
850	8192	1091	32822	1137	38997
860	8893	1092	32946	1138	39142
870	9640	1093	33071	1139	39286
880	10417	1094	33196	1140	39431
890	11197	1095	33321	1141	39576
900	11986	1096	33447	1142	39721
910	12839	1097	33574	1143	39867
920	13726	1098	33701	1144	40014
930	14620	1099	33828	1145	40160
940	15535	1100	33956	1146	40307
950	16475	1101	34084	1147	40454
960	17439	1102	34213	1148	40602
970	18449	1103	34342	1149	40750
980	19517	1104	34472	1150	40899
990	20621	1105	34602	1151	41047
1000	21756	1106	34733	1152	41196
1010	22916	1107	34864	1153	41346
1020	24095	1108	34996	1154	41496
1030	25282	1109	35128	1155	41646
1040	26478	1110	35260	1156	41796
1050	27701	1111	35393	1157	41947
1060	28955	1112	35526	1158	42098
1067	30000	1113	35660	1159	42249
1068	30111	1114	35794	1160	42401
1069	30223	1115	35929	1161	42553
1070	30336	1116	36064	1162	42705
1071	30449	1117	36200	1163	42858
1072	30563	1118	36336	1164	43011
1073	30677	1119	36472	1165	43165
1074	30792	1120	36609	1166	43318
1075	30907	1121	36746	1167	43472
1076	31023	1122	36884	1168	43626
1077	31139	1123	37022	1169	43781
1078	31256	1124	37160	1170	43936
1079	31373	1125	37299	1171	44091
1080	31491	1126	37439	1172	44246
1081	31610	1127	37578	1173	44402
1082	31729	1128	37719	1174	44558
1083	31848	1129	37859	1175	44714
1084	31968	1130	38000	1176	44871
1085	32089	1131	38141	1177	45028
1086	32210	1132	38283	1178	45185
1087	32331	1133	38425	1179	45342

AREA - ELEVATION RELATIONSHIPS - SHASTA RESERVOIR					
ELEVATION (FEET)	AREA (ACRES)	ELEVATION (FEET)	AREA (ACRES)	ELEVATION (FEET)	AREA (ACRES)
1180	45500	1226	53007	1280	62223
1181	45658	1227	53174		
1182	45816	1228	53342		
1183	45975	1229	53510		
1184	46133	1230	53679		
1185	46292	1231	53847		
1186	46452	1232	54015		
1187	46611	1233	54184		
1188	46771	1234	54353		
1189	46931	1235	54522		
1190	47091	1236	54691		
1191	47252	1237	54860		
1192	47413	1238	55029		
1193	47574	1239	55199		
1194	47735	1240	55368		
1195	47897	1241	55538		
1196	48058	1242	55708		
1197	48220	1243	55878		
1198	48382	1244	56048		
1199	48545	1245	56218		
1200	48708	1246	56388		
1201	48870	1247	56558		
1202	49033	1248	56729		
1203	49197	1249	56899		
1204	49360	1250	57070		
1205	49524	1251	57241		
1206	49688	1252	57412		
1207	49852	1253	57583		
1208	50016	1254	57754		
1209	50181	1255	57925		
1210	50346	1256	58096		
1211	50511	1257	58267		
1212	50676	1258	58439		
1213	50841	1259	58610		
1214	51007	1260	58781		
1215	51172	1261	58953		
1216	51338	1262	59125		
1217	51504	1263	59296		
1218	51671	1264	59468		
1219	51837	1265	59640		
1220	52004	1266	59812		
1221	52170	1267	59984		
1222	52337	1268	60156		
1223	52504	1269	60328		
1224	52672	1270	60500		
1225	52839	1271.5	60758		

APPENDIX B

Technical Memorandum No. SHA-8130-TM-98-1
Shasta Dam and Reservoir Enlargement
Initital Assessment Study
Central Valley Project, California

Technical Service Center,
Denver, Colorado

U.S. Department of the Interior
U.S. Bureau of Reclamation

APPENDIX B TO BE INCLUDED IN FINAL DOCUMENT

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