the avoidance of the replacement 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 extending 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 encroaching 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 floodflows. 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 December23, the amount of empty flood control space which must be maintained depends upon established rainflood parameters.

Spring operations usually begin in March or April, and 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 relatively small, compared to other times of the year. Thus, the increased releases and decreased inflow lower 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 summer operations, and all water needs, except navigation, decrease. During the fall, a major objective of the operations is to reach a stable release which can be sustained through December. The intent is to provide 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 starts 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 the Sacramento River
- Depth requirements to provide for "navigation" and associated depths in the Sacramento River
- Guidelines to coordinate releases from Spring Creek Debris Dam with releases from Spring Creek Powerplant and coordination of operations during flood periods
- Flow depth guidelines in the Sacramento River to minimize seepage damage to adjacent agricultural lands
- Operational guidelines for the Anderson-Cottonwood Irrigation District
- Operational 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 River water to the Sacramento River Basin that has historically occurred. The waters that were transferred from the Trinity River 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 have 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 in-basin uses in the Sacramento River 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 storage behind 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 U.S. Fish and Wildlife Service have issued biological opinions to protect winter-run chinook salmon and other species. The opinions affect long-term operations of Shasta Dam and Reservoir. Operational criteria established as a result of these opinions include:

- 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 TCD 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 Dam

Any future operations of an enlarged Shasta Dam must continue to meet some form of the existing standards identified above. If an enlarged Shasta Dam 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 to meet enhanced ecosystem demands.

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 have 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 1944-97. The second period of analysis shows the historic monthly average storage elevation for the period of record from 1980-97. 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 floodflows for release at other times of the year. This would result in increased average annual monthly storage in the reservoir. Increased floodflows 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

Table 5.—Monthly average storage in Shasta Reservoir

Month	Average monthly storage elevation 1944-97	Average monthly storage elevation 1980-97	Change in average storage elevation	Change in average storage in acre-feet
Oct	991	984	-7	-142,375
November	992	986	-6	-123,048
December	995	990	-5	-104,524
January	998	998	0	0
February	1008	1010	2	45,588
March	1021	1024	3	73,035
April	1036	1034	-2	-51,819
May	1040	1036	-4	-105,175
June	1036	1030	-6	-153,937
July	1023	1015	-8	-191,775
August	1007	993	-11	-241,153
September	995	984	-11	-226,222

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 18 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 12 outlets modified), and 88,000 ft^3/s at reservoir elevation 1075.5 for the low dam raise option (with 4 outlets modified).

Construction of the TCD at Shasta Dam to provide selective-level withdrawal capability to the existing penstock intakes was completed in 1997. The TCD 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. Consequently, no modifications to the TCD have been included in this study. As formulated in this appraisal study, when reservoir levels are within the current range of operating head, the TCD would function, and the powerplant would be used to generate power. When reservoir levels exceed this range, the TCD would not be operated, and all power would be generated through the new powerplant. More detailed studies of power generation opportunities and TCD 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 issues, 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 and presented, and the documents could also become an issue at a hearing before the SWRCB. Such issues as the proposed use of any new yield for the Central Valley Project and State Water

Project, 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 State-filed application is filed, it is anticipated that it would take a minimum of 2 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.

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

Transportation Route Relocations and Replacements

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

Union Pacific Railroad Relocation.—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

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.

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 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.

A realignment of the railroad is required for any raise in the water surface elevation above about elevation 1084. Any replacement must be constructed to Union Pacific main line standards:

- Design speed of 70 miles per hour for freight operations
- Maximum of 20-degree curves
- 500 feet of reversing tangent between curves
- Centralized traffic control
- 1 percent or less grades

The railroad replacement 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 between five and nine bridges.

The maximum design grade is 1 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 1 mile north of the Pit River crossing, the railroad enters its first tunnel. About a mile farther, the rail enters its second tunnel; and 2 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 River 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 6.—Summary of Union Pacific Railroad replacement for High Option

Feature	Data
Total project length	35.8 miles
Excavation (yd^3)	24,000,000
Embankment (yd^3)	29,000,000
Tunnels:	
Number	4
Total length (feet)	10,650
Major bridges:	
Length of Bridge Bay crossing	[1] 5,900 [2] 900 S.T.
Lengths of other bridges	1,400 S.T. 910 S.T. 1,300 S.T. 500 D.T.
Number of passing tracks (each 9,000 feet long)	7

[1] Combined highway/railroad crossing
[2] S.T. = single track; D.T. = double track

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

Table 7.—Union Pacific Railroad realignment tunnel requirements

Tunnel	Length
Packers Gulch Tunnel	3,850 feet Maximum cover = 420 feet
O'Brien Tunnel	1,000 feet Maximum cover = 200 feet
Salt Creek Tunnel	2,700 feet Maximum cover = 180 feet
Gregory Creek Tunnel	3,100 feet Maximum cover = 440 feet

from about 19,000 to 15,000 feet. The number of major bridge crossings would also be reduced.

Interstate Highway 5 Replacement.—A summary of the Interstate 5 replacement for the High Option is found in table 8. The replacement 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, Turntable Road undercrossing and overcrossing, Sidehill Viaduct, Power Line Road, Tunnel Gulch, Johns Cove Viaduct, Island Viaduct, O'Brien undercrossings, Gilman Road overcrossing, Upper Salt Creek undercrossing, Antler Summit overcrossing, the Sacramento River bridge, Antler undercrossing, Lakehead undercrossing, Dog Creek, Vollmers Road undercrossing, Gables overcrossing, the Slate Creek Bridge, and, potentially, the LaMoine Road overcrossing.

Table 8.—Summary of Interstate 5 replacement 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 (feet)	5,900
Length of other bridges (feet)	1,812
Number of highway interchanges	4

Pit River Bridge at Bridge Bay.—The relocation of the Pit River Bridge, at Bridge Bay, will pose perhaps 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

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 replacing the bridge.