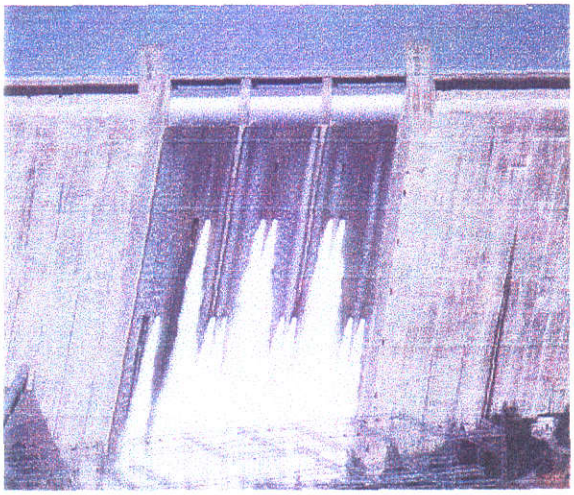
Benefit categories associated with enlarging Shasta Dam include flood control, water supply, power, and environmental. Each of these categories is described below.

Flood Control Operations

There is a recognized need for improved flood protection in various locations along the Sacramento River. Large and small communities, as well as agricultural lands, are under threat from flooding. The flood control issues are very complex. The U.S. Army Corps of Engineers is currently conducting comprehensive basinwide studies of floodplain management issues and options along the Sacramento River. Shasta Dam enlargement options provide opportunities for meeting flood protection needs and floodplain management goals.

Current 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 ft^3/s 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 ft^3/s). 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



Flood control spill at Shasta Dam.

reservation space of 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 require 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 streamflow 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. However, during feasibility studies, an examination of flood plain management opportunities would be assessed. 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 ft^3/s 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 table 12, 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. Additional increased water supply demands are identified for the south coastal and central coastal areas of the State. Water stored in any enlarged facility would facilitate meeting these demands, particu-larly in the Sacramento River Basin. In addition, if managed properly, additional storage in Shasta Lake could augment 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

Table 12.—Estimated future water demands, supplies, and shortages

Resource	*Sacramento River hydrologic basin*		*San Joaquin River hydrologic basin*		*Tulare Lake hydrologic basin*		*Three basins 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

meet all beneficial uses. Table 13 shows the existing active conservation storage space compared to that provided under the various enlargement options.

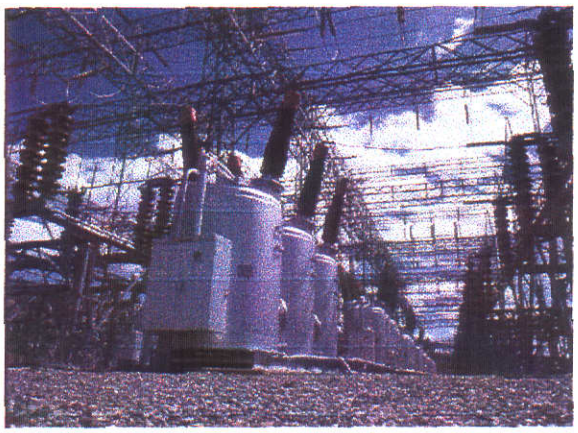
Table 13.—Active conservation storage space

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

The extent of increased yield resulting from enlarging Shasta Dam has been studied several times in the past. The rainfall areas of the State which have large volumes of rainfall 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 by entities outside this appraisal study has identified somewhere in the neighborhood of 1.6 million acre-feet of surplus water available on a long-term annual average for storage in an increased capacity Shasta Lake. Surplus water is that water available for capture over and above meeting current water supply and environmental demands on the system.

While the water available for storage as a long-term annual average 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 than the 1978 estimates.



Switchyard at Shasta Dam.

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

There are potential adverse impacts to power generation at Pacific Gas and Electric's Pit 7 powerhouse on the Pit River arm under certain flow and reservoir elevation conditions. The frequency and extent of these operational impacts would have to be analyzed at the feasibility level.

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.

Conclusions

Based on 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 provide feasible opportunities for efficiently developing additional water supply storage at the existing Shasta Dam site.

- The maximum height Shasta Dam can be raised without encountering significant geologic, relocation, and cost constraints is about 200 feet.

- The minimum height to which the dam can be raised without affecting the existing Union Pacific Railroad and Interstate Highway 5 Pit River Bridge crossing at Bridge Bay is elevation 1084.

- There are no engineering considerations which preclude any enlargement possibilities below 200 feet.

- The replacement of the Union Pacific Railroad and Interstate Highway 5 at Bridge Bay represents a significant structural feature and cost, bearing on any decision to enlarge the dam and reservoir 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 effects this operation would have on the environment and other traditional water supply uses.

- Environmental effects associated with raising the dam are relatively proportional to the height of raise. Any proposed raise will require extensive study and coordination related to environmental and legal issues.

- The cost of the Intermediate and High Options, exceeding $3.8 and $5.8 billion, respectively, pose significant challenges in developing required financing packages.

Recommendations

It is recommended that feasibility studies examining a low raise option enlargement of 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, and

benefits can be optimized in relation to meeting multiple demands. Development of a feasibility study program should be coordinated with the State of California and other entities to ensure 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