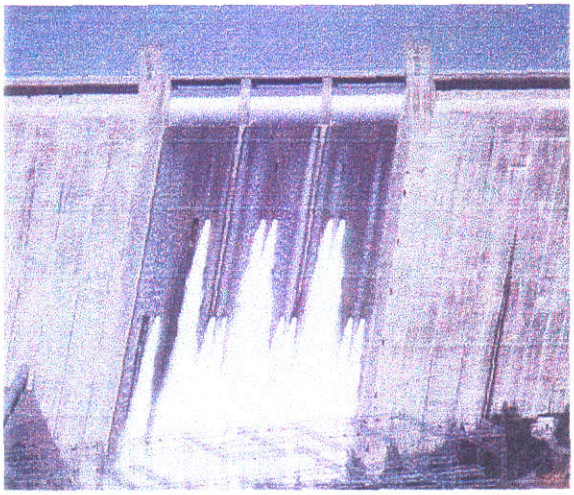
Benefit categories associated with enlarging Shasta Dam include flood control, water supply, power, and environmental. Each of these categories is described below.

## 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.

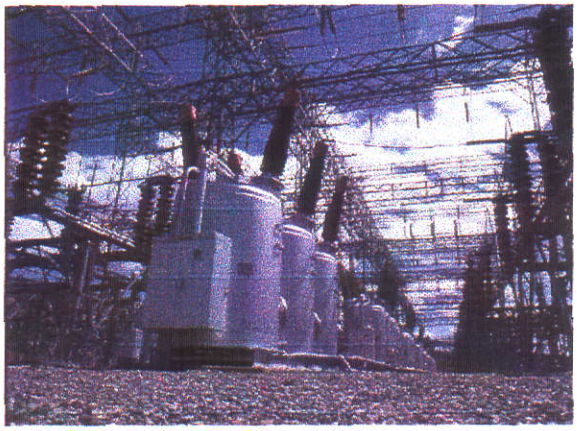
Table 13.—Active conservation storage space

| 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 and Recommendations

## 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 |