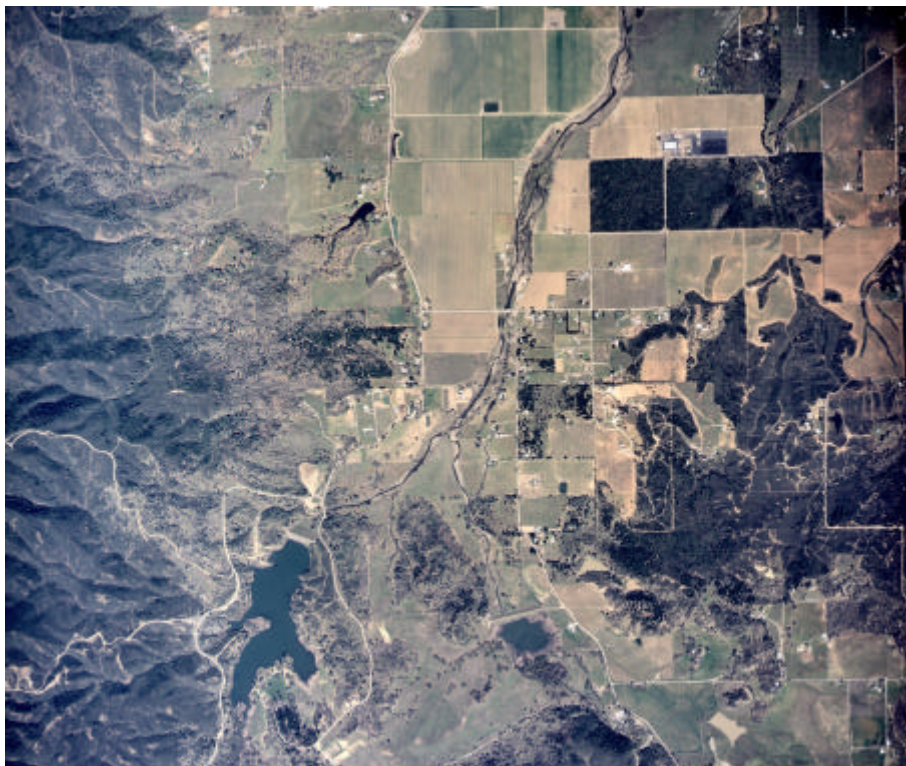




Lake County
Flood Control and Water Conservation District

Adobe Creek Conjunctive Use Project Feasibility Study



April 2002



Prepared By
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FEASIBILITY STUDY

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1. SUMMARY

Overdraft of groundwater resources has long been recognized as a problem in Big Valley, a predominantly agricultural area in Lake County, California.

Impacts include:

- ▶ Periodical shortages of water supply that reduce agricultural production impacting the local economy,
- ▶ Drying up of wells during dry periods and droughts,
- ▶ Increases in energy needed for pumping water,
- ▶ Deterioration in groundwater quality due to intrusion of geothermal water rich in iron and boron,
- ▶ Impacts on fish, wildlife and riparian vegetation due to drying up of creeks due to lowered water table,
- ▶ Ground subsidence which reduces groundwater storage and changes surface drainage patterns.

On May 18, 1999, the Lake County Flood Control and Water Conservation District (District) adopted the "Big Valley Groundwater Management Plan" pursuant to the State of California's Groundwater Management Act (AB 3030 - 1992). The purpose of the plan is to monitor, conserve and manage Big Valley's groundwater resources. One component of the plan is to facilitate conjunctive use of surface and groundwater storage to help replenish the groundwater basin.

The Adobe Creek Conjunctive Use Project provides the District with a unique, opportunity to cost-effectively utilize an existing reservoir to help meet the goals of the Plan. The proposed project involves:

- ▶ Improving control of water storage in Highland Springs Reservoir by retrofitting seven hydraulically operated sluice gates to the existing Principal Spillway. Operating equipment and controls would be housed in a small building to be constructed on the east abutment of the existing dam.
- ▶ Modifying reservoir operations to provide for storage of a small portion of winter inflow that is normally spilled to Clear Lake (i.e. about 6% of average annual spill). The stored water would be released later during spring, summer and fall. Maximum reservoir water levels are determined by the magnitude of floods and will not change.
- ▶ Groundwater recharge by natural percolation of releases from the reservoir into the streambeds of lower Highland and Adobe Creeks. The natural recharge area extends 3.2 miles downstream from



Highland Springs Dam to the boundary of the unconfined aquifer about 1300 feet downstream of the Merritt Road crossing.

- ▶ Relocating the existing water intake in Highland Springs Park to accommodate lower reservoir water levels in fall. Modifying the shoreline area within the existing floodplain to accommodate higher water levels during summer.

Reservoir operation would be changed to incorporate conjunctive-use. There would be four seasonal modes of operation as follows:

Winter This mode of operation would be maintained during the peak winter flood season that normally occurs in December and January. Operation of the reservoir would be the same as it is now. The designated flood control pool would extend from El. 1462.5 to El. 1485. The new crest gates would be kept open so that the reservoir can continue to attenuate peak flood flows.

Spring This mode would normally occur from February through May/June depending on the water year. The new gates would be closed until the water level reaches El. 1470 and then would be regulated to maintain water level between El. 1468 and El. 1470. If the water level exceeds El. 1470 due to a storm, the gates would automatically open to release reservoir surcharge. When the inflow recedes and the reservoir returns to El. 1470 outflow would then be regulated to enhance flow conditions for spawning of the Clear Lake Hitch. The 200 ac-ft of storage between El. 1470 and El. 1468 would be used to regulate flow from Highland Creek into Adobe Creek to enhance upstream fish passage and prevent dewatering of spawning areas. In late spring and early summer, the objective would be to begin the summer/fall groundwater recharge period with the reservoir at El. 1468. This reservoir elevation is judged to be the highest that is suitable for summer recreation use of areas of Highland Springs Park that lie within the flood storage pool.

Summer Groundwater recharge releases would normally made during the latter part of summer and into fall. Releases would normally commence in June or July when the water table in the ground water recharge area drops sufficiently below the stream channel. The level of the reservoir would also be kept within a range of elevation suitable for recreation use. Water levels would decrease from about El. 1468 at the beginning of the period to about El. 1464 by Labor Day in early September.

Fall Recharge releases would continue and the reservoir would reach its annual low of El. 1456 in late fall. The crest gates on the principal spillway would be opened in preparation for the oncoming winter storm season. The new low level regulating gate would be left open to pass through and regulate inflow from smaller early storms to extend the recharge season and maintain maximum storage space available in the reservoir for winter use. When winter runoff and streamflow increases and the groundwater levels rise up to



the bottom of the stream channel, the regulating gate would then be gradually closed to bring the operating level back up to El. 1462.5 during winter.

The timing of this operation regime would be adjusted each year in response to hydrological conditions and groundwater elevations to maximize the benefit of the recharge process.

Engineering studies have determined that it is feasible to retrofit hydraulic gates to the existing Principal Spillway to control the elevation of the water surface of the reservoir. Six remotely operated crest gates and one regulating gate would be added to the existing structure.

Dam safety studies have determined that the updated Probable Maximum Flood would overtop the existing dam by 1.3 feet therefore the hazard classification of the dam is a significant issue and must be established to justify a spillway design flood less than the PMF. This issue relates to the capacity of the emergency spillway and is independent of the proposed conjunctive use project. Studies also show that the antecedent reservoir elevation has insignificant impact on the peak flood stage reached during routing of the PMF so we conclude that the conjunctive use project would not significantly affect freeboard during an extreme flood.

Flood routing studies for the 100-year flood indicate that the proposed conjunctive use of 25% of the controlled flood storage in Highland Springs Reservoir in late winter through summer would be compatible with the flood control purpose of the reservoir and would not increase the estimated 100 year return period peak flood discharge above that estimated in the existing FEMA approved 100 year flood hydrology study.

Reservoir operation studies indicate that modification of reservoir operation would transfer an average of 986 acre-ft of water from the wet season (generally November through April) to the dry season (generally May through October). Assuming that 200 ac-ft of this storage would be used early in the dry season to augment streamflow during the spawning of the Clear Lake Hitch then the estimated average water available for groundwater recharge would be about 786 acre-ft. Further, allowing for conveyance losses in the stream channel due to evaporation the net amount of yield available for groundwater recharge is estimated to be about 750 acre-feet.

Environmental studies¹ have determined that there is potential for presence of special status plant and animal species on the banks of the reservoir that

¹ Presented in the Initial Study prepared pursuant to the California Environmental Quality Act (CEQA)



would be affected by changes in reservoir operation. Mitigation measures are proposed.

The proposed project would enhance downstream fish habitat by providing regulating storage during spring to enhance flow conditions for spawning of the Clear Lake Hitch - a species of special concern. Augmentation of flow during summer in lower Highland and Adobe Creeks will also increase riparian and aquatic habitat.

The estimated capital cost of the project is \$800,000 and the estimated incremental annual operation and maintenance cost is estimated to be \$8,860/year comprised of \$6,560/year operation and maintenance costs and \$2,300/year water purchase costs. The estimated unit cost of conjunctive use yield (including fishery enhancement flows) is in the order of \$70/ac-ft. Comparative cost studies indicate that the cost of water from the project is economically attractive compared with estimated costs of water from other sources.

Implementation of the project is estimated to take 2 years. During the first year, activities would include environmental field surveys, agency consultation, acquisition of permits, producing final design drawings specifications and bid documents and exploring available grants and financing resources. In the second year, bids for supply and installation of equipment would be invited in spring and construction would occur in fall when the reservoir can be drawn down.

The following recommendations are submitted for consideration by the District:

1. ***Proceed with the Conjunctive Use Project*** The proposed project appears to be economically attractive compared to other water supply sources. The District should consider proceeding with permitting, design and implementation of the conjunctive use project.
2. ***Environmental Issues*** In accordance with the California Environmental Quality Act an Initial Study has been prepared and submitted separately for the District's consideration.
3. ***Water Rights*** Since the proposed modification to reservoir operations will result in storage of water for more than 30 days an application for a water rights permit should be prepared.
4. ***Dam Safety*** It is recommended that the District consult with the Division of Safety of Dams regarding the hazard classification of the dam to assist in determining criteria for estimating the spillway design flood. The safety of the dam should then be rechecked. If there is inadequate freeboard then the District could investigate either increasing the capacity of the emergency



spillway or increasing the elevation of the crest of the dam. This dam safety issue is independent of the proposed conjunctive use project.

5. **Highland Springs Recreation Area** Plans for the proposed project should be incorporated into planning of Highland Springs Recreation Area. The proposed project will require modifications to the existing water intake that serves Highland Springs Park. The proposed water levels will also require some changes to parking and picnicking areas presently within the flood pool to accommodate higher water levels during summer. Planting of additional trees above the new summer shoreline could be carried out now to replace trees that may ultimately be inundated or otherwise affected by higher water levels. Any new trails constructed around the reservoir shoreline should be located above El.1470.
6. **Adobe Creek Reservoir** The District should also consider use of Adobe Creek Reservoir for groundwater recharge. This reservoir is smaller and would probably have less yield, however it would still probably be feasible and economically attractive. Since there is funding available through the California Water Bond it appears that the time is ripe to investigate and implement this project.
7. **Funding** The District should be prepared to submit applications for state funding of the project. The proposed project is generally consistent with California's goals of protecting ground water resources and improving water supplies. . The project also lies within the drainage basin that is tributary to the Sacramento-San Joaquin River Delta and the subject of the Cal-Fed process.



2. INTRODUCTION

This report presents the findings of studies commissioned by Lake County Flood Control and Water Conservation District (District) regarding the feasibility of the Adobe Creek Conjunctive Use Project (Project).

The purpose of the study is to investigate the feasibility, costs, benefits and potential environmental impacts of the Project. Findings of the study are to be used as input to planning and decision-making regarding possible permitting and implementation of the project.

2.1 PURPOSE OF PROJECT

The purpose of the Project is to increase groundwater recharge in Big Valley to mitigate overdraft consistent with the Big Valley Groundwater Management Plan adopted by the District on May 18, 1999.

The project involves adding conjunctive use to the operation of Highland Springs Reservoir which is part of the Adobe Creek Flood Control Project. A small portion of inflow to the reservoir during winter that is normally spilled during winter would be retained for groundwater recharge in the Adobe Creek groundwater basin during summer and fall. To facilitate this change in operation, sluice gates would be added to the existing Principal Spillway structure at Highland Creek Dam.

Anticipated benefits of the project include:

- ▶ Higher groundwater levels in portions of the Big Valley Groundwater Basin.
- ▶ Reduction of overdraft that occurs in dry water years.
- ▶ Improvement of reliability of the groundwater supply.
- ▶ Improvement of groundwater quality.
- ▶ Reduction of ground subsidence due to overdraft and associated loss of groundwater storage.
- ▶ Reduction of use of electrical energy to pump groundwater due to higher water levels.
- ▶ Greater control of water levels in Highland Springs Reservoir.
- ▶ Better regulation of spring runoff to enhance spawning habitat in Adobe Creek for the endangered Clear Lake Hitch.
- ▶ Enhancement of aquatic and riparian habitat in the reaches of Highland and Adobe Creeks that are downstream of Highland Springs Reservoir.



2.2 AUTHORIZATION AND SCOPE

The investigations were authorized by the Agreement for Engineering Services for the “*Feasibility and Reservoir Yield Study for the Adobe Creek Conjunctive Use Project*” dated September 5, 2000 between the Lake County Flood Control and Water Conservation District (District) and Christensen Associates Inc. (CAI).

2.3 BACKGROUND

This section summarizes the background to the study. Much of this information is derived from the District’s request for proposals.

2.3.1 Adobe Creek Flood Control Project

In 1962, the Soil Conservation Service (SCS) constructed the Adobe Creek Flood Control Project in Big Valley. The Project resulted in construction of Adobe Creek and Highland Creek Reservoirs to attenuate peak flood flows in Adobe Creek.

Channel modifications to Adobe Creek downstream of the reservoirs to the creek mouth further reduced the flood risk. The project functioned as designed, resulting in significant flood damage reduction. However, the Flood Control Project reduced aquifer storage in two ways:

1. Construction of the Adobe Creek and Highland Creek Dams precluded gravel recharge to lower Adobe Creek. Dam construction is known to cause streambed degradation until a new stable channel configuration is eventually reached.
2. Channelization of Adobe Creek to reduce flooding increased flow velocities, moving more gravel to Clear Lake. The resulting channel degradation reduced storage in the aquifer by lowering the maximum water table level.

Channel degradation was further aggravated by gravel extraction after construction of the dams. In some locations, stream gravels were removed until clay lenses were encountered.

2.3.2 Groundwater Recharge

The combination of intensive, agricultural use of groundwater, increased domestic and municipal groundwater demand, and a reduced groundwater supply due to channel degradation have resulted in water deficits in Big Valley on the average of once every five years.

Between 1966 and 1967, the District commissioned a groundwater recharge study be performed for Big Valley (Basin No. 5-015.00, designated as Kelseyville Valley) to determine the geology and practicality of recharging the



groundwater with an upstream reservoir (originally proposed for Kelsey Creek).

This study found that recharge from an upstream reservoir was possible, provided the releases occurred when groundwater storage was available after the irrigation season started. Improved groundwater quality would also result since the surface water flowing through the basin is of higher quality than the groundwater. The reservoir on Kelsey Creek was not funded due to geologic limitations at the dam site and high costs which could not be born by local water users.

In 1980, the Department of Water Resources (DWR) proposed construction of an instream groundwater recharge structure on Kelsey Creek. The estimated annual recharge from the project was estimated to be 250 acre-feet per year. The Kelsey Creek Detention Structure was constructed in 1987, and has resulted in improved groundwater storage late in the runoff season, and higher groundwater levels throughout the year. Because the structure was constructed within the channel, it must be operated in a manner to allow for the spring spawning run of the Clear Lake Hitch, a species of special concern. This has reduced the structure's effectiveness, however, the improved groundwater supplies are beneficial.

In 1991, the District proposed construction of a structure similar to the Kelsey Creek Detention Structure on Adobe Creek. The California Department of Fish and Game (DFG) objected to the proposal due to the potential loss of spawning habitat for the Clear Lake Hitch. DFG proposed either offstream storage facilities be developed or the existing upstream reservoirs be modified to increase groundwater recharge.

2.3.3 NRCS Conjunctive Use Study

In 1995, the Natural Resources Conservation Service (NRCS) provided a Hydrologic Unit Planning (HUP) Team to evaluate the practicality of modifying Highland Creek Reservoir to allow use of part of the storage for conjunctive use. The HUP team proposed modifying the Principal Spillway with the installation of slide gates, without requiring modification of the dam's structural section. The HUP team also performed a preliminary evaluation of the socio-economic, biological and recreational impacts of the reservoir modification. The team concluded that modification of the Principal Spillway is practical and would have minimal adverse environmental impacts.

2.3.4 Groundwater Management Plan

On May 18, 1999, the District adopted the "Big Valley Groundwater Management Plan" pursuant to the State of California's Groundwater Management Act (1992). The purpose of the plan is to formalize the components of a management plan to monitor, analyze and implement effective management practices to utilize and protect Big Valley's valuable



groundwater resources. One such component of the plan is to facilitate conjunctive use of surface and groundwater storage to replenish the groundwater basin. The plan recommended more detailed studies of modification of the operation of Highland Springs Reservoir including a reservoir yield study and evaluation of modifications of flood control capacity. The present study addresses this component of the plan.

2.4 PRESENTATION OF FINDINGS

Our findings are presented in two documents: This report presents the findings of engineering investigations. The findings of environmental studies are presented separately in an Initial Study prepared pursuant to the requirements of the California Environmental Quality Act CEQA).



3. STUDY PLAN

3.1 SCOPE

The scope of the investigations comprised the following tasks that incorporated into the Agreement for Consulting Services:

- ▶ Task A - Project Management
- ▶ Task 1 – Meetings
- ▶ Task 2 - Hydraulic Routing Capability of Reservoir
- ▶ Task 3 - Conjunctive Use Water
- ▶ Task 4 - Develop Operating Schedule
- ▶ Task 5 - Prepare Water Release Schedule
- ▶ Task 6 - Develop Estimates of Project Benefits
- ▶ Task 7 - Preliminary Design of Spillway Modifications
- ▶ Task 8 - Cost Estimating for Construction and Operation & Maintenance
- ▶ Task 9 - Provide Data for Permits
- ▶ Task 10 - Update Probable Maximum Flood and 100-yr. Flood
- ▶ Task 11 - CEQA Initial Study
- ▶ Task 12 - Prepare Report and Present Findings

3.2 PUBLIC MEETINGS

A public meeting was held on September 27, 2000 at the Lake County Administration Building to discuss the proposed study. The meeting was attended by nine participants, three District Staff and two members of the consulting team. Issues discussed at the meeting are summarized as follows:

- ▶ **Droughts** -Will the study address what happens in drought periods when there is a dire shortage of water? This goes in cycles we have periods of wet years and dry years and are due for another drought.
- ▶ **Condition of Dam** - Is there any problem with the Dam?
- ▶ **Yield** -Do you know how much yield and how many feet of storage will be added ?
- ▶ **Fisheries** Will the Department of Fish and Game be involved.?



- ▶ **Low level Outlet Valve** Will the possibility of using the low level outlet valve to draw the lake down further be evaluated as part of the study?
- ▶ **Silt** Will the study address silting of the reservoir and possible dredging? Previous studies have determined that ultimately the reservoir will be silted up but measurements taken in the reservoir have determined that siltation rates are lower than expected?
- ▶ **Drain Reservoir** Will it be necessary to drain the reservoir to modify the spillway?.
- ▶ **Highland Springs Park** How will the project impact the park?
- ▶ **Cost of Water** Do you know what the new water will cost?
- ▶ **Yolo County** Will Yolo County water rights be addressed?

A second public meeting was held on May 10, 2001 to present the findings of the study and answer questions regarding the proposed project.

3.3 DATA SOURCES

The study was carried out using existing data. No new land surveys, geotechnical investigations, stream measurements or environmental field studies were carried out for this study. References are presented in Chapter 11.



4. NEED FOR THE PROJECT

Water is a scarce resource in California. Meeting growing demand for reliable supplies of water for both public use and environmental protection poses a major challenge. Overdraft of groundwater resources, especially during droughts, has been recognized as a growing problem that needs to be addressed in water supply planning.

This chapter of the report provides an overview of water needs at the State, regional and local level. Most information presented here was extracted from the California Water Plan – Bulletin 160-98 and the Big Valley Groundwater Management Plan 1999.

4.1 CALIFORNIA

The California Water Plan presents an assessment of California's agricultural, environmental, and urban water needs and evaluates water supplies, in order to quantify the gap between future water demands and the corresponding water supplies. The Plan also presents a statewide overview of current water management activities and provides water managers with a framework for making water resources decisions.

California's estimated existing demand for water at a 1995 level of development is about 80 maf² in average years and 65 maf in drought years. California's future water demand in 2020 is forecasted to reach 81 maf in average years and 66 maf in drought years.

California's increasing population is a driving force behind increasing water demands. The State's population is forecasted to increase to 47.5 million people by 2020 (about 15 million people more than the 1995 base). Forty-six percent of the State's population increase is expected to occur in the South Coast Region. Even with extensive water conservation, urban water demand will increase by about 3.2 maf in average years³.

Irrigated crop acreage is expected to decline by 325,000 acres--from the 1995 level of 9.5 million acres to a 2020 level of 9.2 million acres. Reductions in forecasted irrigated acreage are due primarily to urban encroachment and to impaired drainage on lands in the western San Joaquin Valley. Increases in water use efficiency combined with reductions in irrigated acreage are expected to reduce average year agricultural water demand by about 2.3 maf

² maf = million acre-ft

³ The Plan assumes that all urban and agricultural water agencies will implement conservation practices by 2020, regardless of whether they are cost-effective for water supply purposes.



by 2020. Shifts from lower to higher value crops are expected to continue, with an increase in permanent plantings such as orchards and vineyards. This trend would tend to harden agricultural demands associated with permanent plantings, making it less likely that this acreage would be temporarily fallowed during droughts.

The plan estimates statewide groundwater overdraft of about 1.5 maf/yr at a 1995 level of development. Increasing overdraft in the 1990s has reversed the trend of basin recovery seen in the 1980s. Most increases are occurring in the San Joaquin and Tulare Lake regions.

Average and drought year water needs for environmental use are forecasted to increase by about 0.1 maf by 2020. Drought year environmental water needs are considerably lower than average year environmental water needs, reflecting the variability of unimpaired flows in wild and scenic rivers. North Coast wild and scenic rivers constitute the greatest component of environmental water demands. CVPIA implementation, Bay-Delta requirements, new ESA restrictions, and FERC relicensing could significantly modify future environmental demands.

Estimated water shortages at a 1995 level of development are 1.6 maf in average water years, and 5.1 maf in drought years. The magnitudes of shortages shown for drought conditions in the base year reflects the cutbacks in supply experienced by California water users during the 1987-92 drought. The Plan forecasts increased shortages by 2020: 2.4 maf in an average water year and 6.2 maf in drought years. The water management options identified as likely to be implemented could reduce those shortages to 0.2 maf in average water years and 2.7 maf in drought years.

The shortages highlight the need for future water management actions to reduce the gap between forecasted supplies and demands. As Californians experienced during the most recent drought (especially in 1991 and 1992), drought year shortages are large. Urban residents faced cutbacks in supply and mandatory rationing, some small rural communities saw their wells go dry, agricultural lands were fallowed, and environmental water supplies were reduced. By 2020, without additional facilities and programs, these conditions will worsen.

Future water shortages have direct and indirect economic consequences. Direct consequences include costs to residential water users to replace landscaping lost during droughts, costs to businesses that experience water supply cutbacks, or costs to growers who fallow land because supplies are not available. Indirect consequences include decisions by businesses and growers not to locate or to expand their operations in California, and reductions in the value of agricultural lands. Other consequences of shortages are less easily measured in economic terms examples include impacts to recreational activities or environmental resources.



4.2 REGIONAL

The proposed project is located near the western boundary of the Sacramento River Watershed. Adobe Creek flows into Clear Lake which drains to Cache Creek joining the Sacramento River about 12 miles north of Sacramento.

The Sacramento River basin extends 300 miles from the Oregon border south to Collinsville in the Delta. The crest of the Sierra Nevada forms the eastern border of the Sacramento River Region, while the western side is defined by the crest of the Coast Range.

The region is defined by two distinct landforms the foothill and mountain areas of the Sierra Nevada, Cascade, and Coast Ranges, and the valley floor. Mountain elevations range from 5,000 feet along the coast to more than 10,000 feet in the Sierra Nevada.

Precipitation in the region varies substantially depending on location and elevation. In the foothill and higher mountain areas, precipitation ranges from 40 to more than 80 inches annually. The valley receives less rainfall, with average annual rainfall for Redding and Sacramento being 35 inches and 18 inches, respectively. The mountain areas have cold, wet winters with snow contributing runoff for summer water supply. The valley has mild winters and dry, hot summers.

Excluding supplies dedicated to environmental purposes, surface water accounts for about 70 percent of the region's average year water supply. Groundwater provides the remaining supply. During drought years, additional groundwater is pumped to compensate for reduced surface water supplies. The region has 43 major reservoirs, with a combined storage capacity of almost 16 maf. About half of this surface capacity is contained in the Central Valley Project's Shasta Lake and the State Water Project's Lake Oroville.

Water shortages are expected to occur under average and drought conditions, as shown in Table 4-1. The 1995-level average year shortage reflects that groundwater overdraft is not treated as a source of supply. Most of the drought year water shortage is associated with agricultural water use, primarily on the valley floor area north of Sacramento. The data show that water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 85 taf⁴ and 989 taf in average and drought years, respectively.

⁴ taf = thousand acre-feet



Table 4-1
Water Use and Supplies
Sacramento River Hydrologic Region

	1995		2020	
	Average (Taf)	Drought (Taf)	Average (Taf)	Drought (Taf)
Water Use				
Urban	766	830	1,139	1,236
Agricultural	8,065	9,054	7,939	8,822
Environmental	5,833	4,223	5,839	4,225
Total	14,664	14,106	14,917	14,282
Supplies				
Surface Water	11,881	10,022	12,196	11,881
Groundwater	2,672	3,218	2,636	2,672
Recycled and Desalted	0	0	0	0
Total	14,553	13,239	14,832	14,553
Shortage	111	867	85	989

Taf = thousand acre-ft

4.3 LOCAL

The Adobe Conjunctive Use Project is located in Big Valley which is an important agricultural area in Lake County California. Reliability and quality of the water supply are important to the economy of Big Valley. Water shortages during droughts impact agricultural production and cause overdraft of groundwater resources.

A water budget for the Valley is shown on shown on Figure 4-1. The data show that in an average year, the annual amount of runoff greatly exceeds water demand but the mismatch in timing of winter runoff and summer water use dictates the need for storage which is provided by the Big Valley groundwater system.

In drought years, runoff is reduced to less than 10% of the long-term average which creates a deficit in supply and requires carryover storage from wetter years into drier years to meet demand. There is insufficient usable storage in the groundwater system to fully accomplish this which results in overdraft of groundwater resources.

Increased water use is occurring due to geothermal development, commercial and residential development, increases in agricultural acreage, and increases in irrigated agriculture. Recently, this trend has been offset to some degree



by reductions in agricultural water use due to changes in crops from Pears to Grapes⁵ and implementation of drip irrigation.

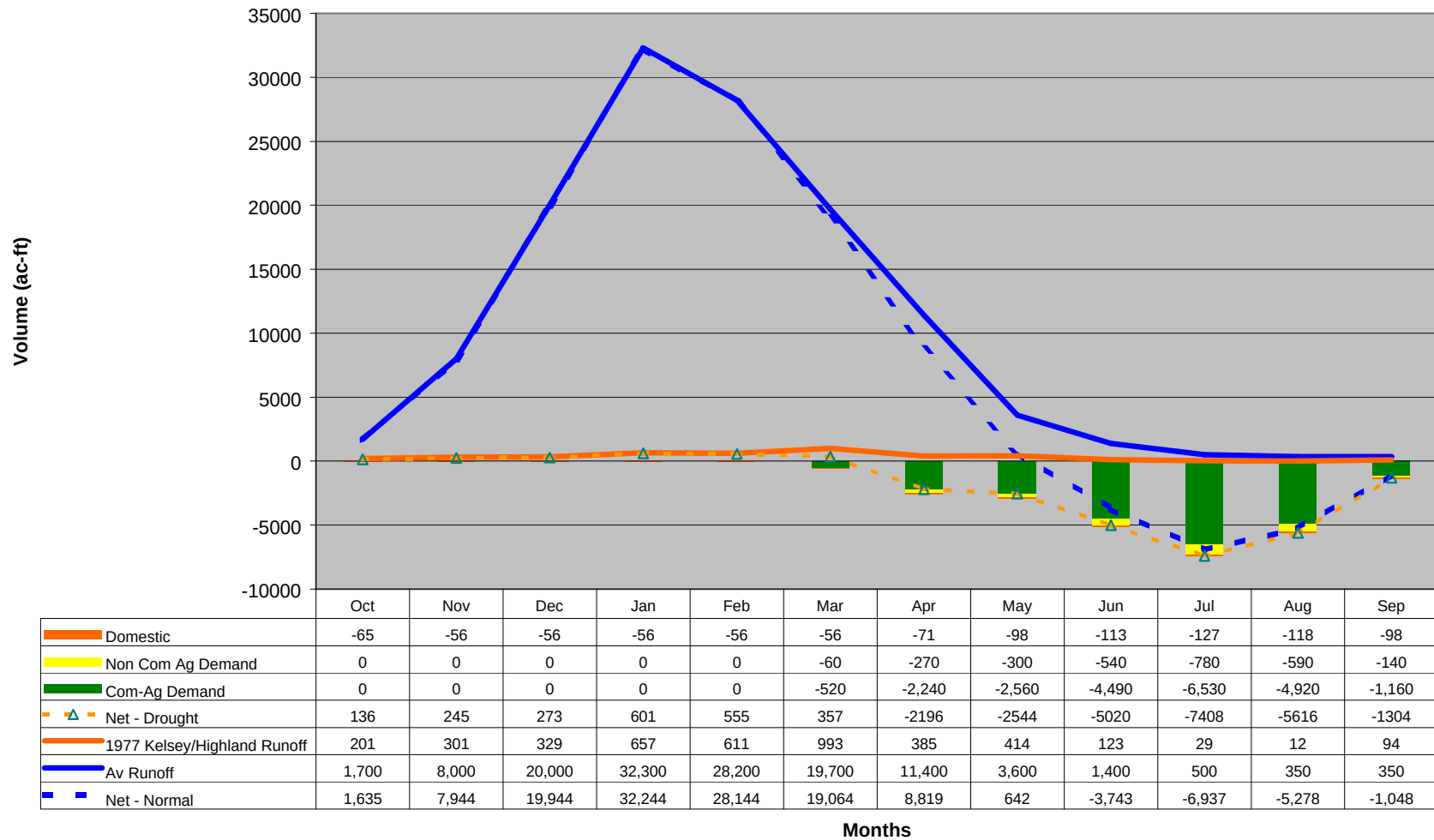
Projections of water supply and demand presented in the Big Valley Groundwater Management Plan indicate that in the year 2020 water supplies in the valley will be insufficient to withstand drought events that occur with a 20-year interval. A similar situation of water demand exceeding the available water supply may occur after two or more successive dryer than normal water years.

Without adequate recharge of groundwater supplies Big Valley Basin will continue to experience problems of groundwater overdraft such as deterioration in groundwater quality, ground subsidence, drying up of wells during droughts, increase in energy needed for pumping, reduced surface water flow in streams due to low water table with the associated environmental impacts, and shortages of supply that limit agricultural production and damage orchard stock.

⁵ Grapes with drip irrigation use about 1.5 acre-ft/acre per year for irrigation and frost control whereas Pears with sprinkler irrigation use about 3 acre-ft/acre per year



Figure 4-1
Big Valley Water Budget – 1985





5. HYDROLOGY

The Project involves recharge of the Big Valley groundwater basin through conjunctive use of surface water from Highland Springs Reservoir. This chapter describes the hydrology of Big Valley and Highland Creek

5.1 BIG VALLEY

5.1.1 Landforms

The area known as Big Valley is located in the west-central portion of Lake County in the northern Coast Ranges of California. Big Valley has a total area of 39.5 square miles, or 25,300 acres. Its maximum width and length are each about 7 miles. The shape of the valley is triangular with southwest and southeast sides being bounded by the Mayacmas Mountains and by Mt. Konocti, respectively, and with the north side opening to Clear Lake.

Big Valley comprises extensive lowland flood plains and terrace-like uplands. Elevations of the lowland portions of the Valley range from 1330 feet, adjacent to Clear Lake, to about 1450 feet at Adobe and Highland Reservoirs. The upland areas are 1450 to about 1600 feet in elevation, with local hilly areas rising to 1800 feet elevation. The surrounding mountains rise to elevations of 2500 to about 4000 feet.

Vegetation consists of orchards, vineyards and some pasture on the lowlands and in some upland areas. Upland areas are mainly grasslands interspersed with oaks changing to brush, chemise and scrub pine in foothill terrain and the Mayacmas Mountains.

The main watercourses in Big Valley are Kelsey Creek on the east side of the valley and Adobe Creek on the west side. Both creeks originate in the interior of the Coast Range and flow northward through the uplands and across the broad lowlands into Clear Lake.

Kelsey Creek is the largest creek in Big Valley and drains an area of about 48 square miles. From its headwaters at about El. 2500 in a saddle between Boggs Mountain and Cobb Mountain, it flows 22 miles northwest to the Shore of Clear Lake.

Adobe Creek is the second largest. It is about 12 miles long and drains a total area of about 30 square miles. The headwaters are at about El. 3250 in the Mayacmas Mountains in steep terrain where the creek descends through steep narrow incised valleys until it reaches the foothills where the valley starts to broaden. Here the slope decreases and the creek flows through rolling terrain and enters Adobe Creek Reservoir at about El. 1440 about 5.5 miles downstream of its source. The lower seven miles of Adobe Creek flow across a broad plain to enter Clear Lake at El. 1330.



Highland Creek is a major tributary of Adobe Creek draining an area of about 14.5 square miles. The creek is about 6.5 miles long originating at about El. 2500 feet in the Mayacmas Mountains above Donovan Valley and terminating at its confluence with Adobe Creek. Most of the watershed is fairly steep rough land with shallow soil cover. Vegetation cover comprises brush, oak and scrub pine. The creek flows generally eastward in an incised valley which broadens at the site of Highland Springs Reservoir located about 0.6 miles upstream of its confluence with Adobe Creek.

5.1.2 Land Use

Land use in Big Valley is predominantly agricultural. Most of the lowland area is cultivated. Pear orchards predominate in the lowlands of northern Big Valley, where groundwater for irrigation is readily obtainable. Walnuts and grapes are grown both in the lowlands and in the drier upland areas. Some of the upland areas are being developed into vineyards with irrigation, but much of the land in these areas is still undeveloped. Considerable land also is used for raising feed crops, and irrigated alfalfa fields are located at various places in the lowlands and on the terrace benches adjacent to Kelsey Creek above Kelseyville.

Most of the undeveloped land in Big Valley is covered with dense California chaparral type brush, though areas of open grassland with scattered brush and trees exist near the head of the Valley.

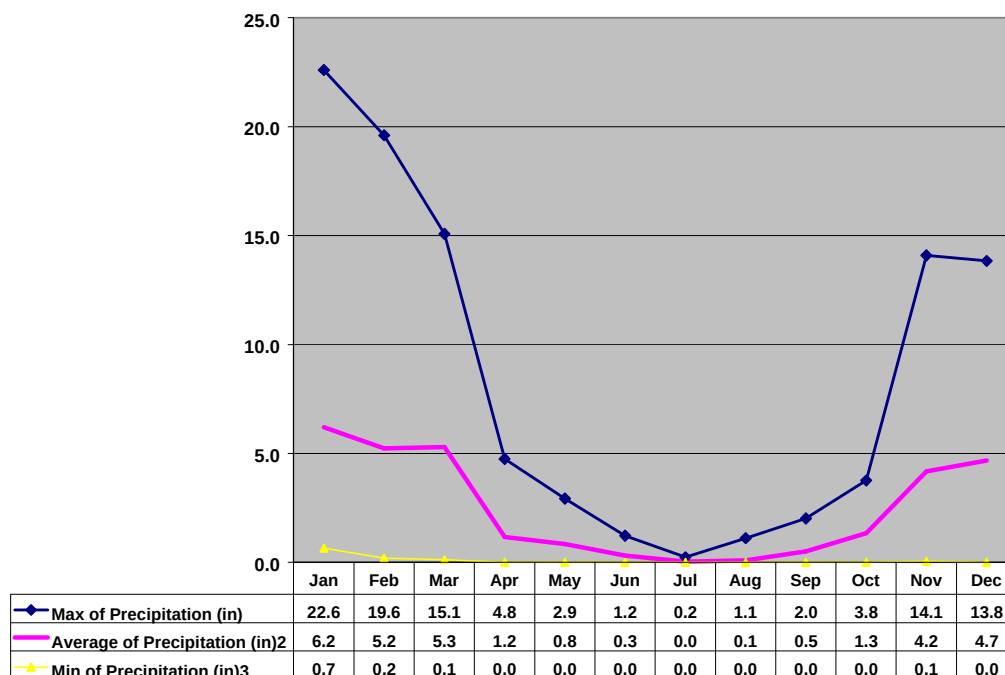
Two small towns, Kelseyville and Finley, are located in the valley. Local industries include fruit packing and processing establishments, wineries, and walnut drying plants.

5.1.3 Precipitation

There are no available precipitation records for the basin however records of monthly precipitation recorded at Lakeport shown on Figure 5-1 illustrate the considerable variability of precipitation in any month and the extreme lows that can occur. During the period of record, (1982-95) which includes the drought of 1987-1992, average annual precipitation at Lakeport was about 30 inches.



Figure 5-1
Monthly Precipitation at Lakeport
Oct 1982 to Sep 1995



Most precipitation occurs during the winter months of December and January and most floods result from major cyclonic winter storms moving inland from the Pacific Ocean. Typically, storms last from 3 to 6 days and are characterized by relatively short duration but high intensity rainfall.

5.1.4 Runoff and Streamflow

Average annual runoff and underflow in the Big Valley basin is approximately 127,500 acre-feet⁶. Most of this water flows into Clear Lake as surface water in Kelsey and Adobe Creeks or groundwater outflow from aquifers in the basin. Annual water demand in the basin is approximately 26,100 ac-ft per year of which 22,420 is needed for agricultural production. Most of this demand is met by groundwater pumping.

5.1.4.1 Highland Creek

Highland Creek, a major tributary of Adobe Creek, is the proposed water source for the proposed conjunctive use project. At present, there are no operational streamflow gages on Highland Creek. Streamflow records are available for Highland Creek from the 1960's to the 1970's as shown on the following table.

⁶ Lake County 1987 Resource Management Plan

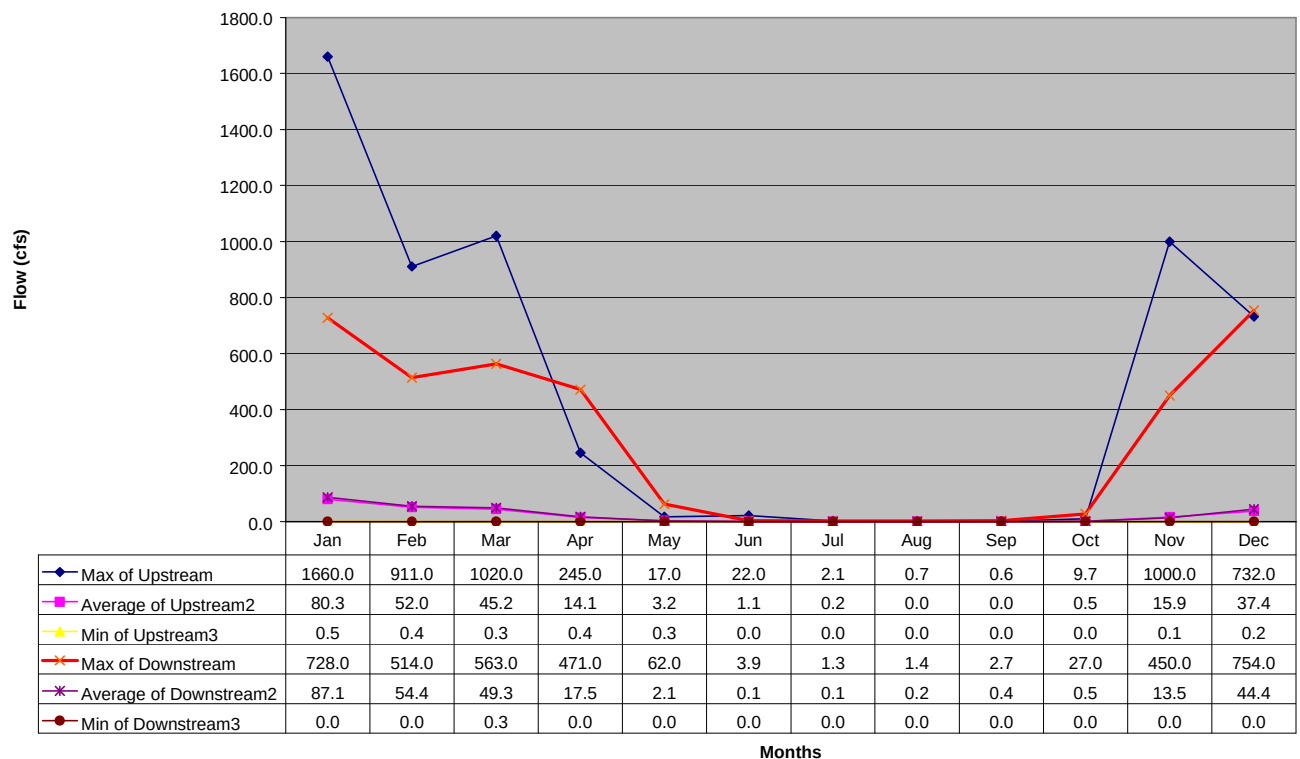


Table 5-1
Streamflow Records for Highland Creek

	Highland Creek Above Highland Springs Reservoir	Highland Creek Below Highland Springs Reservoir
USGS Gage No.	11448900	11449010
Drainage Area (sq mi)	11.9	14.2
Elevation (ft)	1490.07	1416.52
Record	10/01/1962 to 09/30/1978	12/01/1965 to 09/30/1977
Mean Annual Discharge (cfs)	20	22

The monthly distribution of streamflow in Highland Creek is shown in Figure 5-2 . The Figure shows the extreme seasonal variability of streamflow. It also shows the regulating effect of the reservoir. The data also show that Highland Creek can dry up in almost any month of the year.

Figure 5-2
**Highland Creek Upstream and Downstream of
Highland Springs Reservoir**
Daily Average Flow Water Years 1967-1977





5.2 GROUNDWATER

The proposed groundwater recharge area lies in an area called the Adobe-Manning Creek Basin in Big Valley. This section describes the geohydrology of the Big Valley area with particular emphasis on the Adobe-Manning Creek subunit.

The information presented herein has been largely extracted or adapted from the following two documents:

1. *Big Valley Groundwater Plan* - LCFCWCD 1999
2. *Big Valley Ground-water Recharge Investigation* - Soil Mechanics and Foundation Engineers Inc. 1967

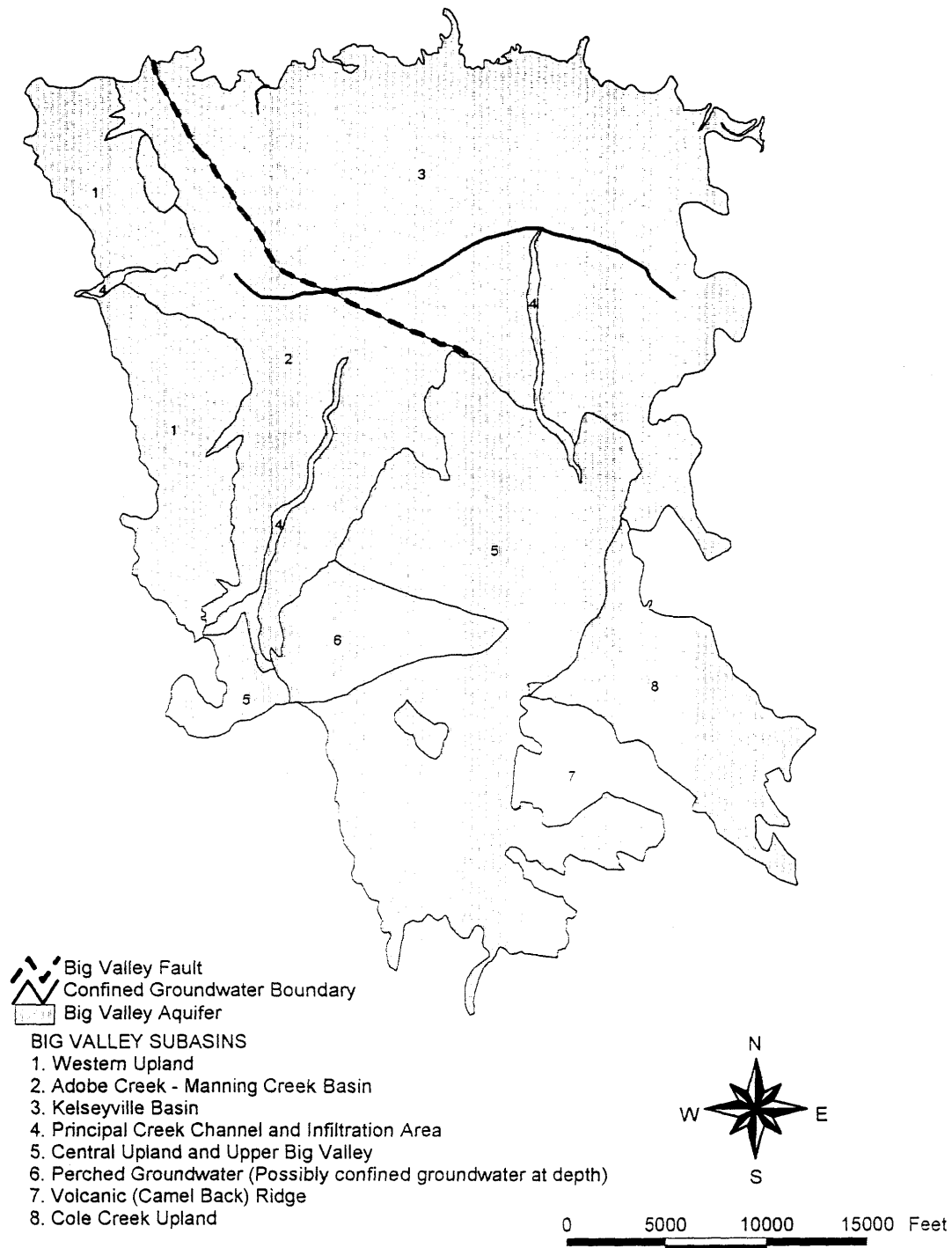
5.2.1 Groundwater Systems

Groundwater occurs in Big Valley in several distinct systems. The elements which define these systems include the surface water and/or groundwater supply for each system, geologic conditions including distribution of materials of varying permeability, presence of boundaries to groundwater flow or storage, and the topography.

In order to facilitate description and discussion of groundwater conditions, a number of geo-hydrologic subunits have been designated within the Valley. The subunits shown on Figure 5-3 have been defined on the basis of their geologic character, as related to groundwater storage, transmission, and recharge, and by behavior of groundwater within them as indicated by well water level readings and by initial water interception data recorded by well drillers.



**Figure 5-3
Big Valley
Groundwater Subunits**



Source: Big Valley Groundwater Management Plan 1999



5.2.2 Groundwater Sources

Most of the groundwater pumped in Big Valley is extracted from the Kelseyville and Adobe Creek-Manning Creek basins. Wells in the Western and Central Upland subunits draw from the “volcanic ash” aquifer and also, to a limited extent, from the upper aquifers in these areas. The four sources of groundwater in the geologic-hydrologic subunits of the Big Valley area are as follows:

5.2.2.1 Basin Sediments

The principal occurrence of groundwater is in the alluvium and lake sediment-filled basins underlying Adobe and Manning Creeks and lower Big Valley (lower Kelsey Creek). Much of the groundwater in these basins is unconfined, but confined areas or zones exist locally where extensive horizons of relatively impermeable clay are present near the surface. Recharge is mainly by direct infiltration of precipitation, percolation from the channels of Adobe Creek and from the reach of Kelsey Creek below Kelseyville. Additional recharge takes place by underflow of groundwater from adjacent, higher level subunits and, to a limited extent, from irrigation.

5.2.2.2 Upland Aquifers

Groundwater occurs in relatively permeable zones in the older, high level alluvial deposits of the Central, Western, and Cole Creek uplands. The groundwater in occurrences of this type is in aquifers of limited areal extent, which are perched on relatively impermeable older lake sediments. Limited recharge occurs by infiltration from the surface and from the channels of ephemeral upland streams.

5.2.2.3 Volcanic Ash

Confined groundwater occurs in a thin bed of “volcanic ash” (lithic tuff) present within the older lake deposits underlying the upland areas (and the upper portion of the Adobe Creek-Manning Creek basin). The ash consists of angular fragments of volcanic rock, of coarse sand to pea gravel size, and is quite permeable. Recharge to this aquifer is believed to occur by infiltration in areas where the ash crops out in stream courses and by leakage into the aquifer from saturated confining strata.

5.2.2.4 Rock Fracture Zones

Varying, though generally limited, amounts of groundwater occur in permeable fracture zones in the volcanic rocks and Franciscan Formation bedrock surrounding and underlying Big Valley.



5.2.3 Adobe Creek - Manning Creek Basin

5.2.3.1 Geology

Adobe Creek-Manning Creek Basin, in common with its downstream continuation, the Kelseyville Basin, is a lake and alluvial sediment filled structural trough. The basin comprises three areas:

- 1) The main trough underlying the channel and flood plain of Adobe Creek,
- 2) A subsidiary trough underlying the channel and flood plain of Manning Creek, oriented normal to the main trough, and
- 3) A “shelf” between the Western Upland and the Big Valley fault, north of Manning Creek.

The main trough is 80 to 120 feet deep and contains three distinctive horizons; a gravel layer 10 to 20 feet thick at the bottom, a 20 to 40 foot thick clay layer in the middle at depths of 60 to 100 feet, and an uppermost horizon of mixed alluvial silt and sand with streaks and channels of gravel. These sediments extend into and merge with the fill in Kelseyville basin.

Some wells in the basin draw water from the “Volcanic ash” aquifer confined in the underlying “Older lake and flood-plain deposits”. This aquifer appears to be hydraulically independent of the aquifers in the overlying basin fill.

5.2.3.2 Recharge

Water is recharged to the Adobe Creek-Manning Creek Basin by percolation from the channels of creeks and by underflow from the Western and Central Upland areas. The most favorable areas for percolation are the channels of Highland and Adobe Creeks from below the dam on each creek to the confluence of the two channels, and the channel of Adobe Creek north to a point 1,300 ft. North of the Merritt Road crossing, a distance of 2.3 miles (12,000 feet) and also a half-mile reach in the channel of Manning Creek where the creek flows from the mountains into Big Valley.

In the 1960's, the subsurface character of the channel of Adobe Creek was investigated by excavation, logging, and partial sampling of nine backhoe test pits. The investigation showed that the channel is quite similar in character to the channel of Kelsey Creek around Kelseyville, with an upper horizon of 10 or more feet of sandy gravel having zones of “open work” gravel, underlain by silt and fine grained sand. The fine-grained bottom layer was not encountered in some pits, and so may be discontinuous. Alternatively, it may exist at greater depth than could be reached with the backhoe. At the north end of the wide channel reach, the creek bed changes from a gravel and sand to a sandy clay or clayey sand “clay pan”. Test pits in this area showed that



the gravel extends under the clayey capping but that the capping increases in thickness downstream.

5.2.3.3 Groundwater Movement

Flow of groundwater in the Adobe Creek-Manning Creek Basin is to the north in the Adobe Creek trough and to the east in the Manning Creek-trough. The water table in each area is nearly parallel to the ground surface. The groundwater flows into and continues flowing within the Kelseyville Basin.

5.2.3.4 Changes in Groundwater Storage

Much of the Adobe Creek-Manning Creek Basin is in the free (unconfined) groundwater zone. Only the “shelf” area, north of the Manning Creek trough, is in the confined, pressure area. Changes in water level within the basin, therefore, indicate changes in quantity of stored water (or, in the case of this basin, water in transitory storage). The variation in elevation of the water table between spring and fall ranges from 5 to 30 feet, with 10 feet being the average for the larger portion of the basin. The difference in volume of water present in the basin between spring high and mid-autumn low water levels is calculated, using an estimated specific yield of 15 percent for material in the zone of fluctuation, to be approximately 6700 acre-feet.

5.2.3.5 Operation of the Groundwater System

The hydraulic groundwater system within the Adobe Creek-Manning Creek basin operates in response to the following conditions:

- ▶ Groundwater levels.
- ▶ Level of unconfined groundwater and of the piezometric surface in Kelseyville Basin, at the interface between the two basins.
- ▶ Availability of water in the creek channel recharge areas.
- ▶ Amount of underflow from adjacent areas.

Groundwater levels are dependent on the extent to which the basin has been recharged by percolation and underflow, or drawn down by well pumping and outflow.

The hydraulic operation of the basin can most easily be described starting from a condition of a lowered water table in late summer and fall. Normally, flow in Highland and upper Adobe Creeks, as released from the reservoirs on these creeks, is quite small so the entire flow of each creek percolates into the channel gravels in the reach around and above the confluence of the two creeks. This water joins with the basin groundwater body and flows northward, down the hydraulic gradient.



When extraction by pumping drops off and losses to evapotranspiration are reduced during fall, the water table rises somewhat, but the recharge-flow system just described continues. However, when Adobe Creek begins to flow more or less continuously, the water table rises to the level of the bottom of the channel, whereupon the basin is essentially filled to capacity. Thereafter, the level of the groundwater in the basin is controlled by underflow from adjacent areas and by very limited percolation in the uppermost reach of the main creek channel.

About midway down the length of the basin, the water table intersects and then rises slightly above the level of the channel bottom. Below this zone of intersection, groundwater seeps into the channel and escapes as surface flow, rather than being recharged from surface flow.

In 1993, District staff performed creek flow measurements that confirmed this relationship still exists. After the first few weeks of flow, the quantity of flow measured near the downstream end of the basin exceeded the quantity measured at Bell Hill Road, near the upstream end, although no significant tributaries discharge into the creek along this reach. The observed excess must have been derived from effluent groundwater discharge into the creek.

5.2.3.6 Well Records

The District maintains records of groundwater levels in Big Valley. Up until 1993, two measurements per year were taken at most wells - one in spring and the other in fall. Since then, many wells now have monthly measurements which provide a more detailed picture of variation in ground water through the seasons. Figure 5-4 and Figure 5-5 show the time series of groundwater levels at two wells near the proposed recharge area. Well No.20 is at the upstream end of the area near Bell Hill Road. Well No. 16 is on the east side of Adobe Creek near Smith Lane .

The data show that annual drawdown increases in the northern i.e. downstream part of the recharge area as total withdrawals increase. The data from Well 16, which is probably the best indicator for conditions in the recharge area, show that ground water levels normally peak in February or March, descend below the level of the stream channel sometimes as early as April and other times as late as June, and generally reach a low at the end of the irrigation season in Fall. Levels then begin to rise generally staying below the stream channel until some time in December through February depending on early winter precipitation and streamflow.



Figure 5-4
Big Valley Ground Water Basin Well 13N-09W-20
Water levels relative to Adobe Creek 1995-2000

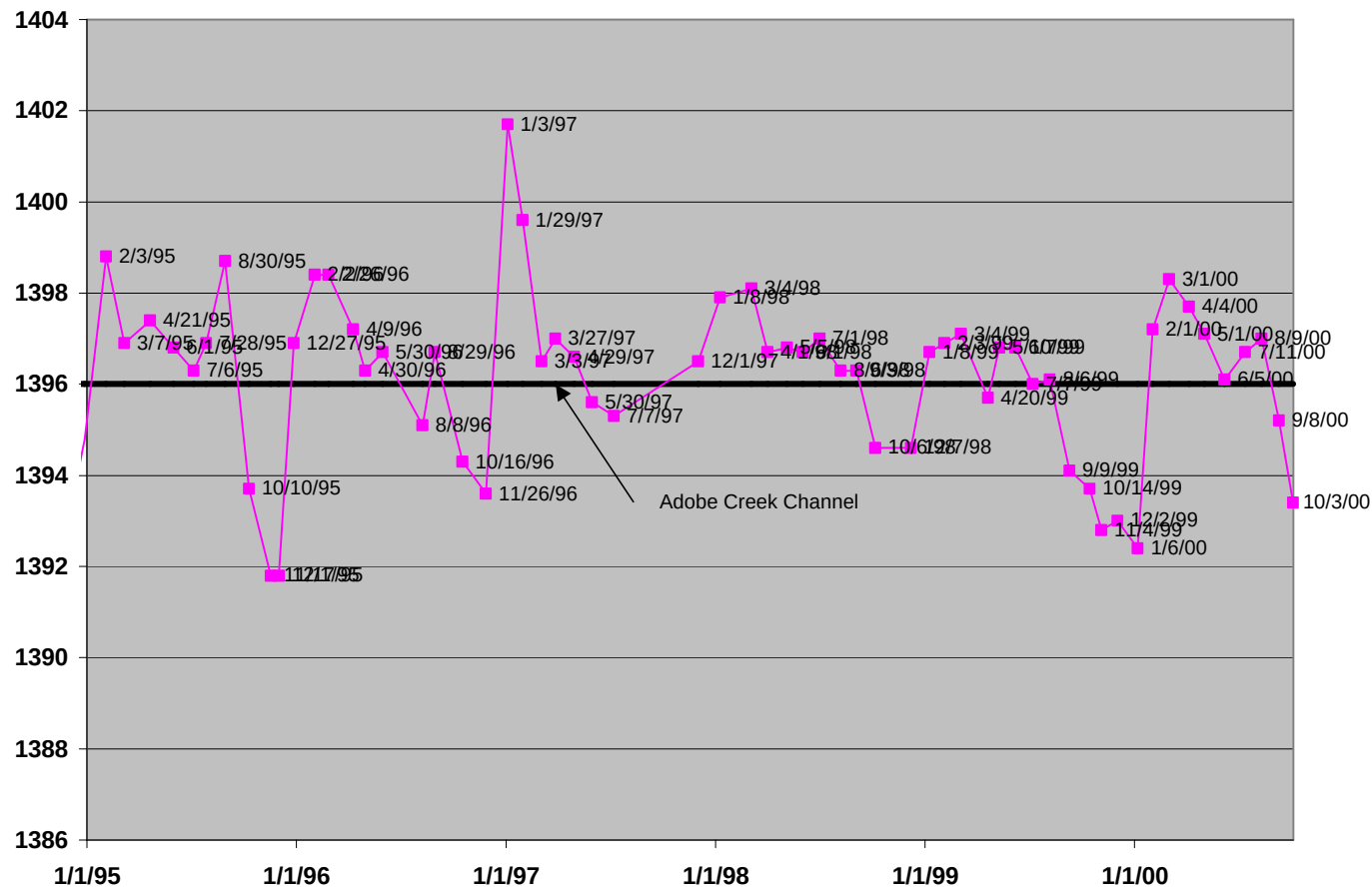
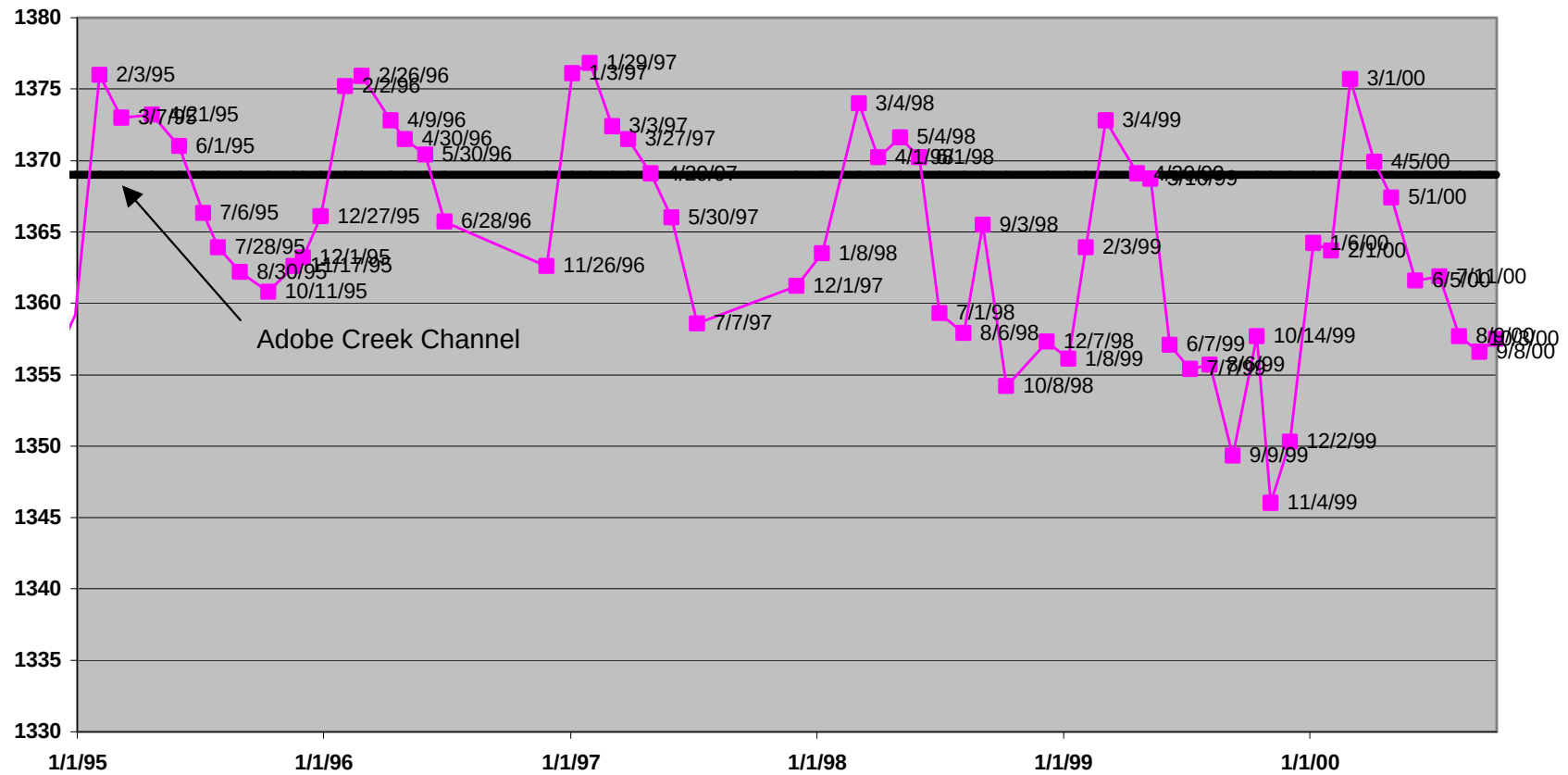




Figure 5-5
Big Valley Ground Water Basin Well 13N-09W-16
Water levels relative to Adobe Creek 1995-2000





6. HIGHLAND SPRINGS RESERVOIR

6.1 LOCATION

Highland Springs Reservoir is located in Lake County, California about seven miles south of the City of Lakeport. See Figure 6-1.

The reservoir is located on Highland Creek in the uplands of a broad valley known as Big Valley. Highland Creek is a major tributary of Adobe Creek which flows across the lowlands of Big Valley to Clear Lake. Road access is via Highland Springs Road which intersects State Highway 29 about 1.5 miles south of its junction with Highway 175 near Lakeport.

6.2 DESCRIPTION OF FACILITIES

The following sections describe existing facilities.

6.2.1 Highland Springs Reservoir

Highland Springs Reservoir is part of the Adobe Creek Flood Control Project. The Reservoir was created in 1962 by construction of Highland Creek Dam on Highland Creek. Its primary purpose is to reduce flooding of the lowlands in Big Valley by regulating peak flows from Highland Creek into Adobe Creek. The Highland Creek watershed upstream of Highland Springs Dam covers an area of about 14.2 square miles.

The nominal storage capacity of Highland Springs Reservoir is 3510 acre-feet at El. 1485 (i.e. the crest of the Auxiliary Spillway). Because the Auxiliary Spillway has an ungated overflow crest there is an additional flood surcharge pool above the flood control pool that is utilized whenever storm runoff exceeds the flood control capacity of the Reservoir. At minimum design freeboard (i.e. water surface El. 1495) the total reservoir capacity is about 5000 acre-ft.

An area-capacity curve is shown on Figure 6-2. The four storage zones in the Reservoir are as follows

1. **Flood Surcharge Pool** - 1490 ac-ft of flood surcharge storage between the crest of the Auxiliary Spillway El. 1485 and the maximum reservoir elevation El. 1495.
2. **Flood Control Pool** 2420 ac-ft of flood control pool between the crest of the Auxiliary Spillway at El. 1485 and the crest of the Principal Spillway at El. 1462.5.
3. **Conservation Pool** 965 ac-ft of conservation storage for fish and wildlife enhancement between El. 1462.5 and El. 1440.
4. **Sediment Storage** - 125 ac-ft of sediment storage below El. 1440.



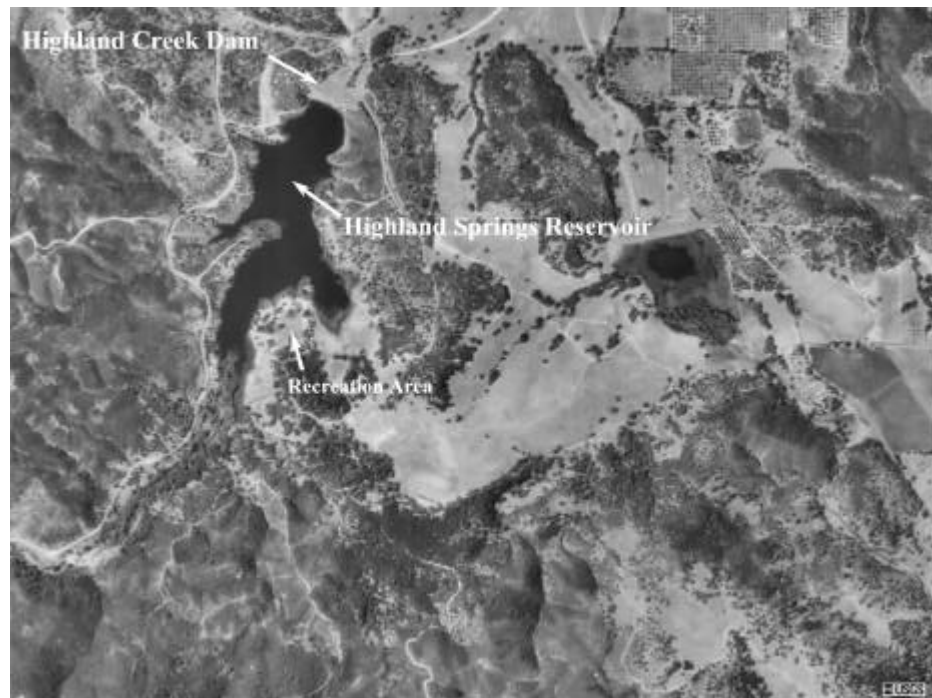
Most of the time the flood control pool is empty and the water level is near the top of the conservation pool i.e. El 1460 to 1463. At these times, the Reservoir appears as a small lake covering an area of about 72 acres surrounded by trees and riparian vegetation. Other than the height of Highland Creek Dam, there is little evidence of the flood control pool which is over twice the area of this small lake.

During summer the Reservoir is used for boating, fishing and swimming. Highland Springs Recreation Area is a county park located on the south side of the Reservoir (See Photograph 6-3.) Near the Reservoir the park has shady picnic areas, toilets, an irrigated grass field, a small boat ramp, parking and swimming areas. In winter, areas of the park within the flood control pool are subject to inundation so picnic tables and trash cans are moved to higher ground.

During storms the Reservoir automatically performs its flood control function. The flood control pool fills when the rate of inflow to the Reservoir exceeds the capacity of the Principal Spillway outlet. The flood control pool is designed to fully regulate the 10 year⁷ return period flood. Smaller floods utilize part of the flood control pool. When the flood control pool is full, the Reservoir surface doubles in area to 146 acres and the water depth increases by about 23 feet. Trees, vegetation and wildlife habitat on the banks of the Reservoir within the 74 acre flood inundation zone surrounding the Reservoir are temporarily flooded for a period lasting from hours to several days.

The Flood Surcharge Pool is only used during large floods that exceed the capacity of the flood control pool. Then the depth of inundation increases to a range of 23 to 33 feet and the water surface area increases up to a total of 180 acres.

⁷ Storm with an average return period of 10 years or expected average annual frequency of exceedance of 10%.



Photograph 6-1
Aerial View of Highland Springs Reservoir



Photograph 6-2
Highland Springs Reservoir taken from the dam looking south Approx.
Water Elevation El. 1461.



Photograph 6-3
Highland Springs Recreation Area

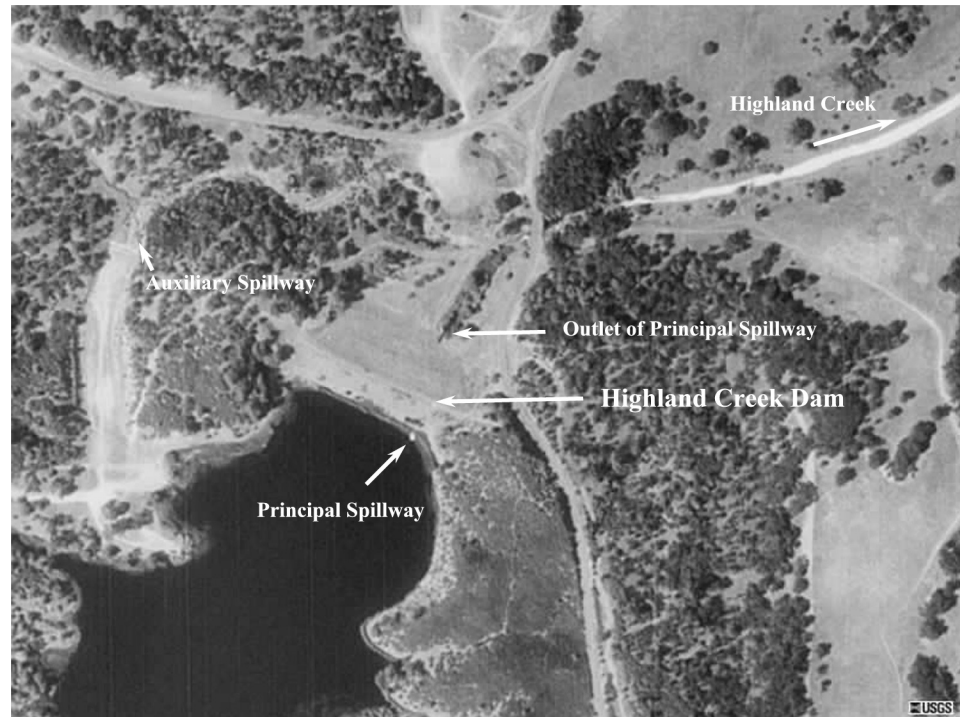
6.2.1.1 Highland Creek Dam

Highland Creek Dam is a 75 feet high embankment dam. It has two outlets: a Principal Spillway conduit under the dam at the east abutment and an Auxiliary Spillway channel through the west abutment.

Table 6-1 summarizes key data and the dam is shown on the following photographs.

Table 6-1
Highland Creek Dam Data

Type	Zoned Earth Embankment
Construction date	1962
Crest Elevation	El. 1497 ft.
Maximum Height	75 ft.
Crest length	625 ft.



Photograph 6-4
Aerial view of Highland Creek Dam



Photograph 6-5
Highland Creek Dam looking west along the crest.



6.2.1.2 Principal Spillway

The Principal Spillway is comprised of four main components: a hooded drop inlet, a vertical riser section, a horizontal conduit section passing under the dam, and an outlet structure that acts as a stilling basin.

The hooded drop inlet is located adjacent to the dam near the right (east) end. Water overflows the sill at El. 1462.5 and drops into the rectangular riser. There is a concrete hood over the structure to control vortex formation and trashracks to prevent blockage by floating debris. There is three feet vertical clearance between the sill and the interior of the hood.

The concrete outlet structure is located at the downstream toe of the dam and discharges into Highland Creek.

According to the original design report the discharge capacity of the Principal Spillway with the reservoir level at the top of the flood control pool (El. 1485) is about 465 cfs.



Photograph 6-6
Highland Springs Reservoir Viewed from Dam Crest showing the
Principal Spillway at the east abutment



Photograph 6-7
Outlet of Principal Spillway



6.2.1.3 Auxiliary Spillway

The Auxiliary Spillway is an open channel located on the west side of the Reservoir about 1500 ft. west of the end of the dam. The flow control section is located in the channel in a rock cut in a topographic saddle. This section is about 75 ft. wide and provided with a concrete cutoff wall with the top located at the top of the flood control pool, El. 1485.

The nominal spillway capacity is 3150 cfs under the spillway design flood hydrograph with a water surface elevation of El. 1490 and 7700 cfs under the minimum freeboard hydrograph with a water surface elevation of El.1495.



Photograph 6-8
Auxiliary Spillway Channel

6.2.1.4 Low Level Outlet

The low level outlet comprises a submerged gated sluiceway located in the Reservoir at El. 1426.25 about 50 ft. from the Principal Spillway intake and a conduit connecting the sluiceway with the Principal Spillway horizontal conduit. The manual sluice gate operator is located on the crest of the dam and the gate stem extends down the sloping upstream face of the dam to the gate.



**Figure 6-1
Project Map**

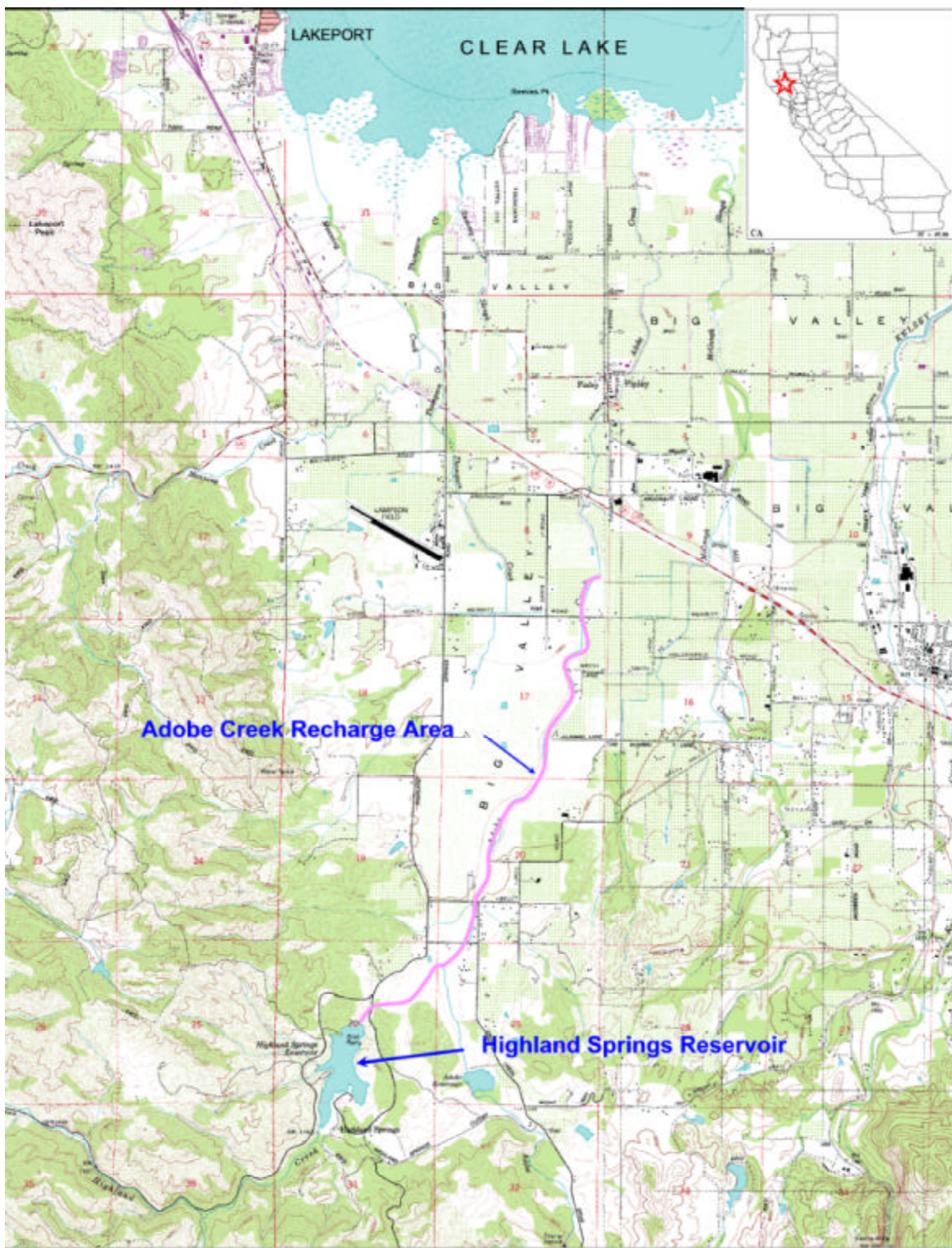
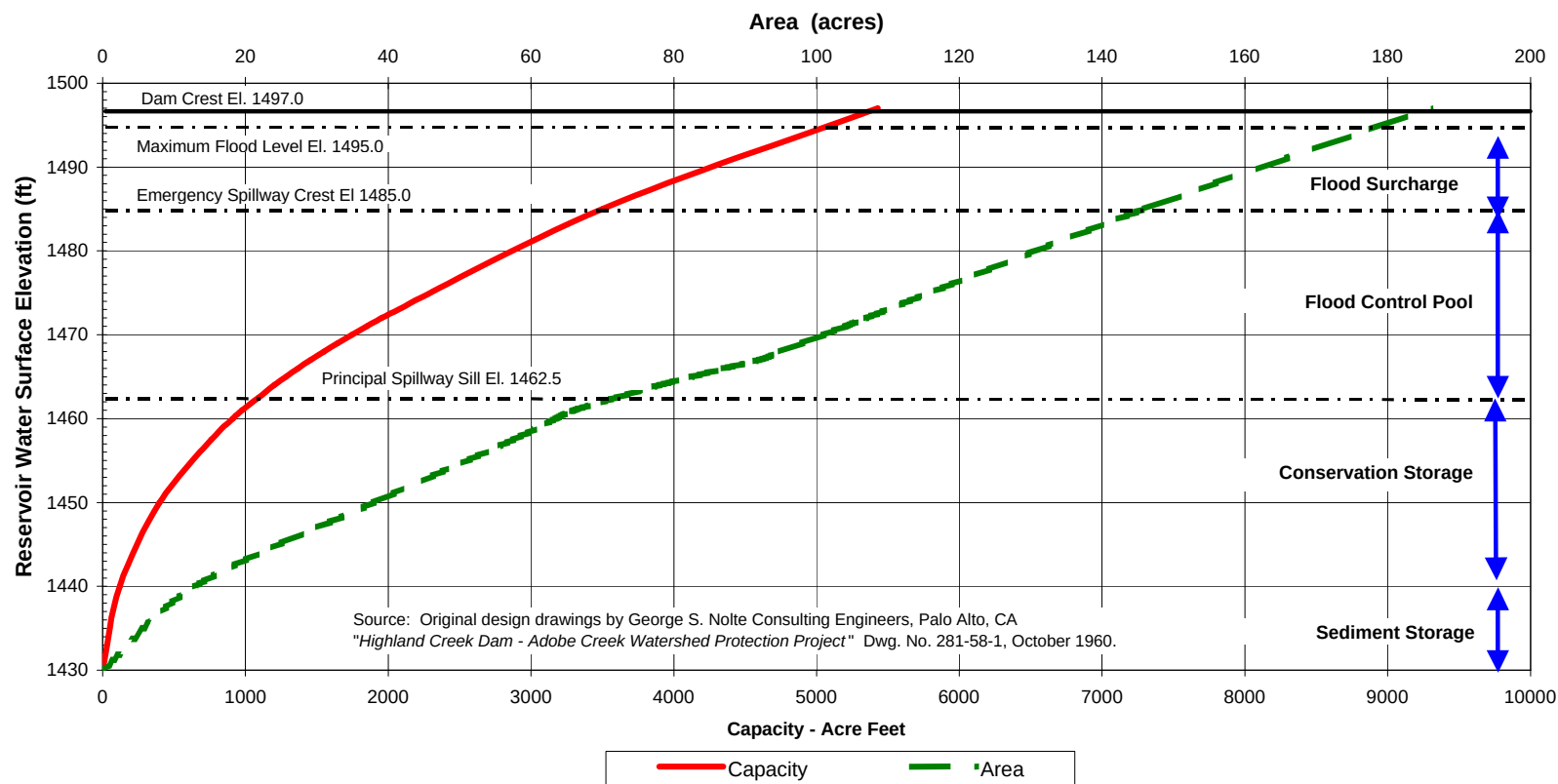




Figure 6-2
Highland Springs Reservoir
Area-Capacity Curve





7. PROPOSED MODIFICATIONS

7.1 HIGHLAND SPRINGS RESERVOIR

7.1.1 Reservoir Storage

The proposed project would modify the seasonal operation of the Reservoir through seasonal reallocation of some of the existing flood control and conservation storage to conjunctive use and fish spawning enhancement. This change would not increase the total size or storage capacity of the existing reservoir or the area of its inundation zone. However, it would modify the allocation of storage capacity on a seasonal basis and modify the operation of the reservoir. Existing and proposed allocations of reservoir storage are shown on Table 7-1.

Table 7-1
Proposed Seasonal Allocation of Storage Capacity

Season	EXISTING		PROPOSED SEASONAL STORAGE ALLOCATION							
	All-Year		Winter		Spring		Summer		Fall	
Operating Goals	Flood Control		Flood Control		Flood Control Conjunctive Use		Flood Control Recreation Conjunctive Use		Flood Control Conjunctive Use	
Storage Allocation										
	Elevation (ft)	Storage (ac-ft)	Elevation (ft)	Storage (ac-ft)	Elevation (ft)	Storage (ac-ft)	Elevation (ft)	Storage (ac-ft)	Elevation (ft)	Storage (ac-ft)
Flood Surge	1495	1490	1495	1490	1495	1490	1495	1490	1495	1490
Flood Control	1485	2420	1485	2420	1485	1760	1485	1960	1485	2420
Fish Spawning Enhancement	0	0	0	0	1470	200	0	0	0	0
Conjunctive Use	0	0	0	0	1468	460	1468	460	1462.5	410
Conservation	1462.5	965	1462.5	965	1462.5	965	1462.5	965	1456	555
Sediment Storage	1440	125	1440	125	1440	125	1440	125	1440	125
Total		5000		5000		5000		5000		5000

It is proposed that there would be no change in storage allocation during winter when most large storms occur. During spring, 460 acre-feet of the flood control pool would be reallocated to water storage for conjunctive use and a further 200 acre-feet would be reallocated to regulating streamflow to enhance spawning conditions for the Clear Lake Hitch. The conjunctive use allocation would stay in effect through the end of the summer season. In fall approximately 410 acre-feet of water conservation storage would be reallocated to conjunctive use to allow the reservoir to be briefly drawn down prior to the start of winter to help recharge the groundwater basin.

The exact timing of the change of seasons would depend on weather and hydrology and therefore would be somewhat flexible from year to year.

7.1.2 Principal Spillway

To accomplish the proposed storage modifications, flow control gates would be added to the Principal Spillway to improve control of reservoir water levels and outflow.



The Principal Spillway and proposed modifications are shown on Figure 7-1 and Figure 7-2. Slide gates would be installed on all four sides of the intake to permit closing of the 3 ft. high water passage between the sill and the bottom of the hood.

Because of the difficult access and limited working space, it is desirable to avoid any construction involving concrete removal or placement of new concrete to provide a mounting surface for the gates. The proposed design incorporates a steel framework specially designed to fit the geometry of the existing structure. It would be attached to the diagonal hood support buttresses, the spillway sill and the bottom of the hood slab and would provide plane surfaces around the perimeter of the opening for attaching the gates to the structure. The framework would be attached to the concrete with drilled-in expansion anchors and would be sealed with grout or sealing strips to prevent leakage.

The total installation would consist of six 3 ft. wide by 3 ft. high slide gates (main gates) and a 12 inch square low flow release gate (release gate). Because of the damp environment and the difficulty of access for maintenance, it is proposed that the supporting metal framework and the gate frames be fabricated from stainless steel. An air vent pipe would be provided to admit air to the spillway and equalize pressure. The vent pipe would run up the sloping upstream face of the dam to the crest.

Hydraulic cylinder gate operators would be installed on top of the anti-vortex hood and gate stems would extend down to the gates through holes drilled through the slab. The operators would be remotely controlled from the dam crest. Hydraulic lines would extend from the operators up the sloping upstream the face of the dam to the control house located at the east end of the dam. Vegetable-based hydraulic fluid will be used instead of petroleum based fluid to address potential concerns about water contamination in the event of leakage of hydraulic fluid into the Reservoir.

The control house would house the hydraulic power unit for all seven gates including connections and valves, and the automated control system. Electric power would be supplied over a new power line about 300 ft long extending from the existing distribution line along East Highland Springs Road.

During fall and winter the large slide gates will remain open. In spring, the slide gates would be closed to allow storage for conjunctive use. When the slide gates are closed, the low-level release gate and slide gates would be automatically operated in sequence to control water levels. The low level release gate would be use continuously to control water levels and the larger slide gates would open periodically during storms when reservoir inflow exceeds the capacity of the smaller low-level release gate.



7.1.3 Highland Springs Recreation Area

The existing water supply intake at Highland Springs Recreation Area is located in a shallow infiltration trench in the shoreline of the existing reservoir. The elevation of the intake would be lowered by relocating it deeper into the Reservoir during the time the reservoir is drawn down for construction in late fall.

During this time, the picnic and boat ramp area in the park adjacent to the reservoir would be raised and re-landscaped to accommodate higher water levels during summer. Additional oak and other suitable shade trees will be planted in the park to replace trees affected by changes in grade or higher water table.

7.1.4 Construction Process

Construction is expected to take from two to three months and would be carried out during late summer and fall. The main construction activities would include the following:

1. Contractor mobilization.
2. Deliver the gates, accessories and construction materials to the project site.
3. Relocate existing water supply intake.
4. Remove debris from around the intake structure.
5. Remove the trash bars to provide access for gate installation.
6. Install special metal framework needed for gate installation.
7. Install gates on the vertical face of the spillway riser.
8. Saw cut hole in side of spillway riser and install low-level release gate.
9. Drill holes in the anti-vortex hood for the gate operator stems.
10. Install gate operator cylinders on the hood connect gate stems.
11. Erect enclosure over gate operating equipment.
12. Erect control building on the dam crest, install hydraulic piping between the operators and the dam crest and install control equipment.
13. Test gate operation.
14. Reinstall trash bars.
15. Site cleanup and demobilization.

In order to install the gates it will be necessary to temporarily draw down the water level of Highland Reservoir. For planning purposes it is expected that the Reservoir would be drawn down to El. 1458.5 in late summer for



installation of the slide gates and would be further drawn down to El. 1455.5 in Fall for installation of the low-level release gate and control systems.



Figure 7-1
Highland Creek Dam – Plan

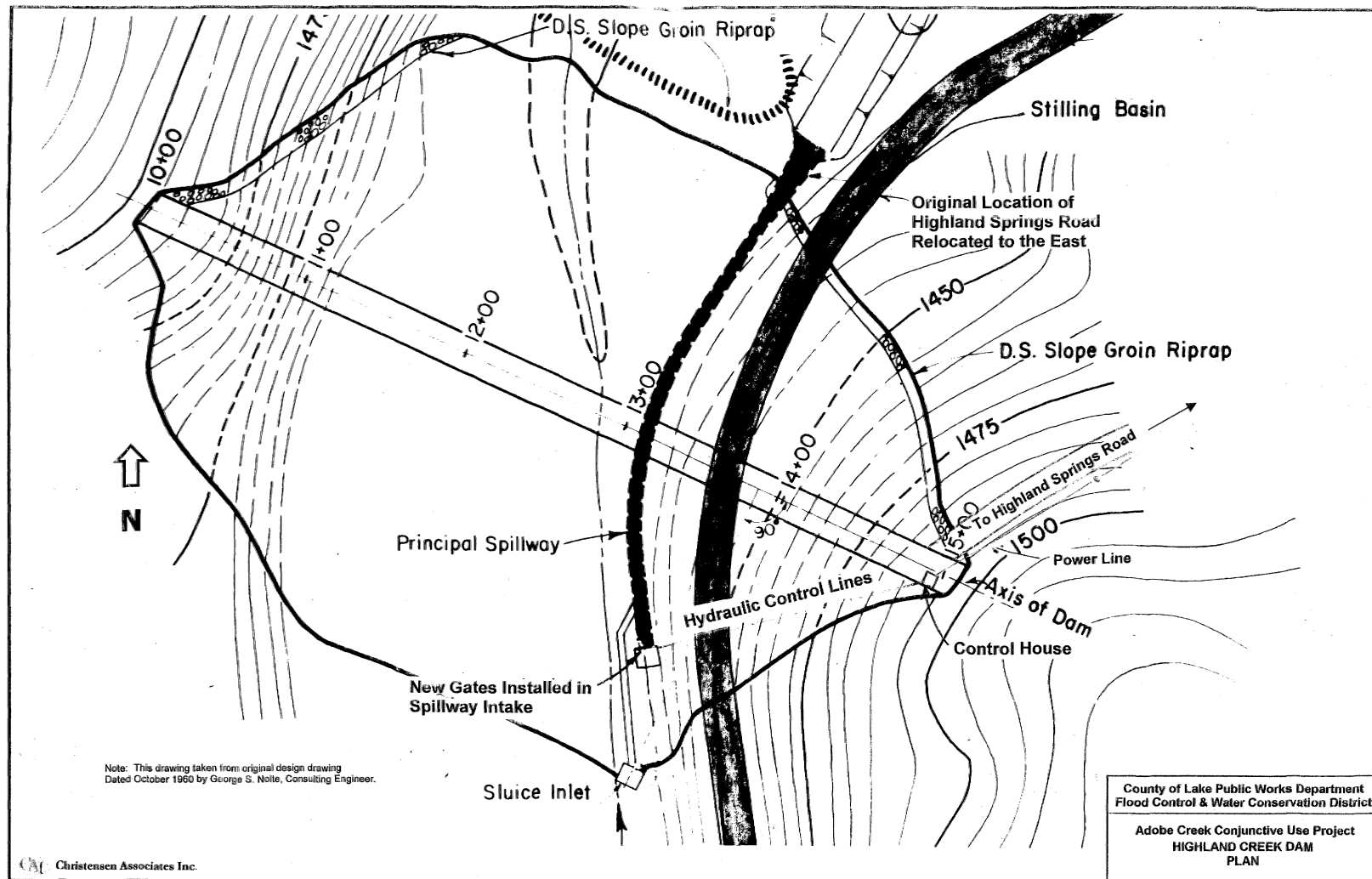
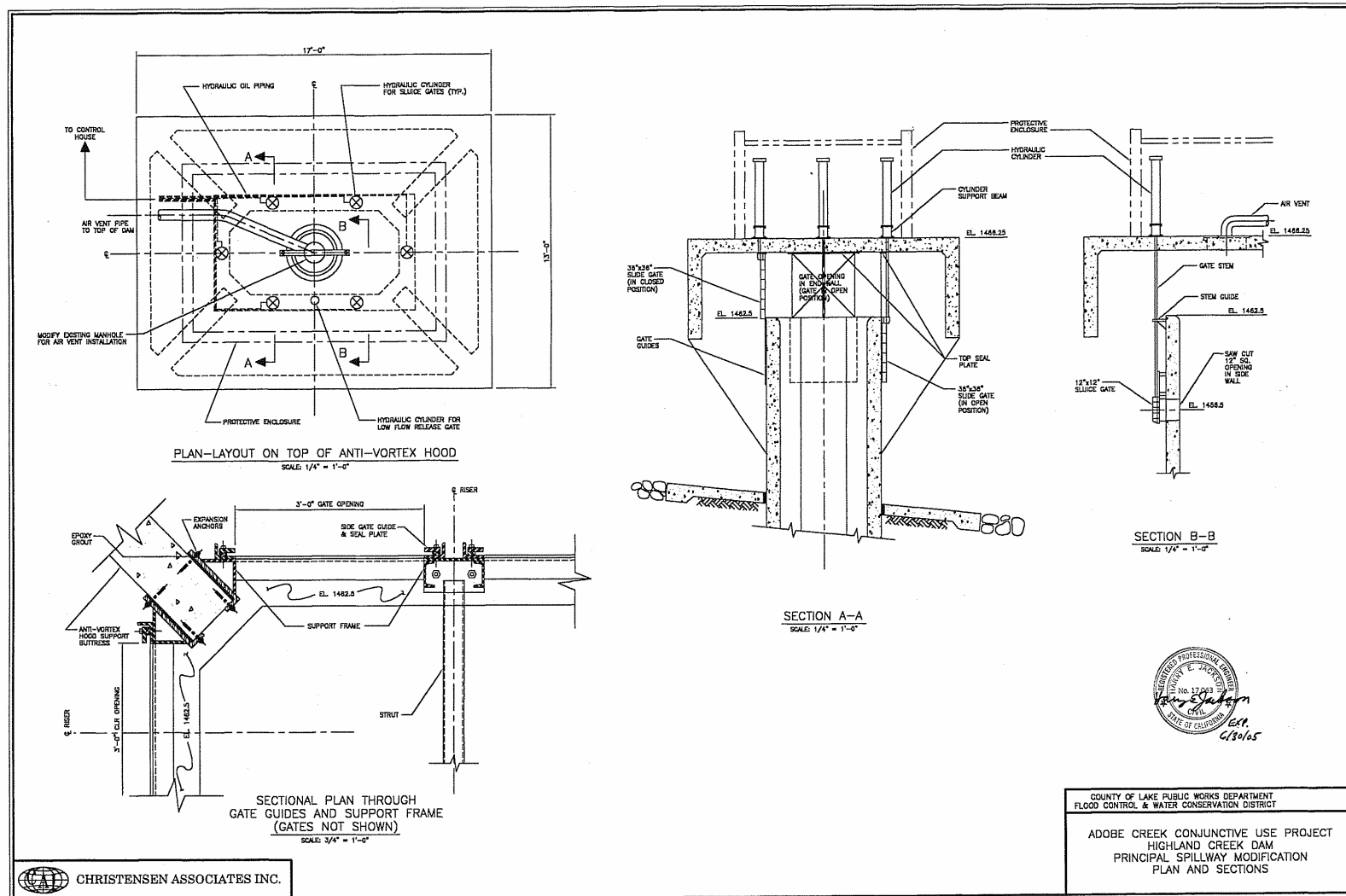




Figure 7-2
Highland Creek Dam - Principal Spillway Modifications





8. RESERVOIR OPERATION AND YIELD

8.1 EXISTING RESERVOIR OPERATION

Presently, the primary purpose of Highland Springs Reservoir is to reduce flood damage in Big Valley by regulating peak outflow from Highland Creek into Adobe Creek. In addition, the reservoir provides recreation opportunities including fishing, boating, swimming, hiking and picnicking. It also provides lake habitat for fish, wildlife and vegetation.

During the winter flood season, generally November through March, the reservoir water level is controlled by the balance between reservoir inflow and overflow through the two spillways. The water level generally fluctuates around El. 1463 to 1464 rising several feet during smaller storms and rising up to and above the crest of the auxiliary spillway at El. 1485 during larger storms. The reservoir was originally designed to contain a 1 in 10 year average frequency storm without overflowing the auxiliary spillway.

Water levels in the Reservoir are not continuously recorded however it has been reported by the District that the water level was about 6 feet above the sill of the Auxiliary Spillway i.e. El 1491 ft. during a large storm that occurred on January 9, 1995. This flood was notable for its sustained rainfall intensity over several days. Other maximum water levels recorded in recent times include a flood that reached El. 1487 on March 9, 1995 and another that reached El. 1488 on January 1, 1997.

During the summer, inflow to the Reservoir drops off to a trickle and evaporation, leakage and minimal outflow gradually lowers the water level below the crest of the Principal Spillway. The Reservoir reaches an annual low in late fall before the winter rains start.

The elevation of the water surface is recorded once a year around the beginning of the new water year in October. Available records of water level are shown on Table 8-1. The data indicate that the Reservoir water level normally drops to between El. 1458.6 to El. 1460 in late fall except for 1986 when it was 1462.5 and 1995 when it was drawn down to El.1455.6. The lowest level for the year may be slightly lower than this level depending on when the winter rains start.



Table 8-1
Highland Creek Reservoir
Fall Water Levels

Date	Water Surface Elevation (ft)
10/10/1985	1459.2
10/02/1986	1462.5
10/02/1987	1459
10/03/1988	1458.6
10/02/1989	1459.2
10/09/1990	1459.9
10/02/1992	1459.5
10/16/1995	1455.6
10/15/1997	1460.0
10/25/1999	1459.8

8.2 PROPOSED MODIFICATIONS

The objective of proposed conjunctive use operations is to utilize some of the flood control pool for groundwater recharge in a way that is compatible with the primary flood control purpose of the reservoir and its other uses.

The proposed project will change the operation of the reservoir within its existing range of maximum and minimum water levels. By enabling greater control of water level, the project will facilitate water storage operations involving higher water levels in spring and lower levels in fall.

Constraints to reservoir operations include:

- ▶ Flood control storage requirements
- ▶ Physical limitations imposed by elevation of existing spillway and outlet facilities
- ▶ Recreation use of the reservoir and Highland Springs Park
- ▶ Impacts of water storage operations to downstream flows on Highland and Adobe Creeks
- ▶ Availability of storage capacity in the groundwater system
- ▶ Impacts on the reservoir shoreline, vegetation and wildlife habitat.
- ▶ Impacts on downstream fish spawning habitat

The following subsections present a discussion of constraints and their affect on the proposed project.



8.2.1 Water Level Considerations

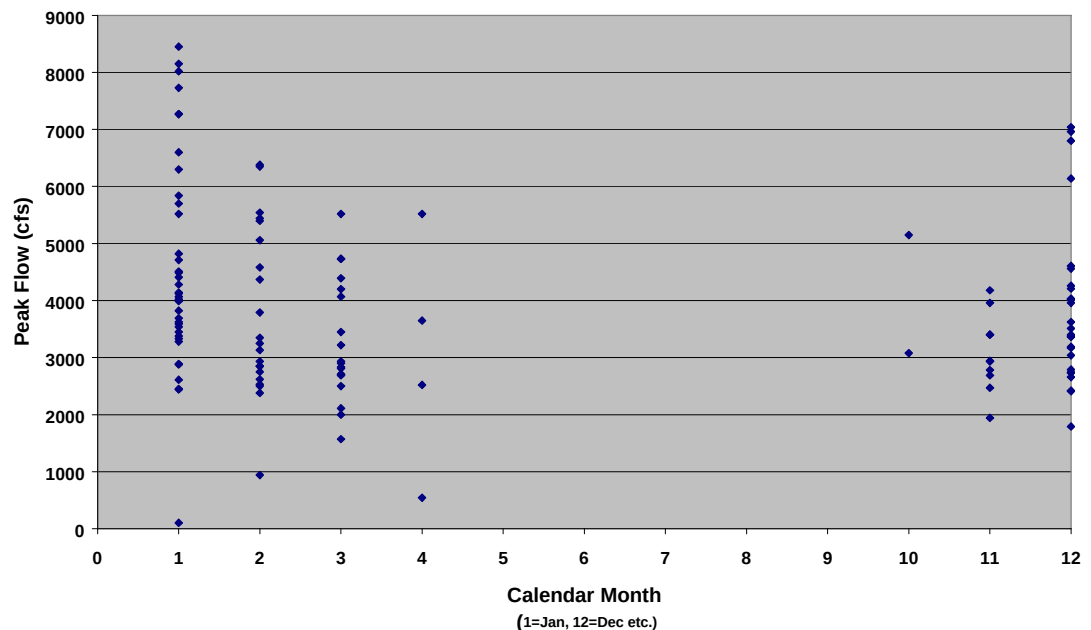
8.2.1.1 Flood Control

During the winter flood season November through March, adequate flood control storage must be maintained to allow the reservoir to perform its primary flood control purpose.

The following two factors have been considered:

1. In the 1999 DWR hydrology study approved by FEMA the starting elevation of the reservoir in routing of the 100-year flood is El. 1470 indicating that reservoir volume beneath this elevation is assumed to not contribute to flood control for the purposes of delineating the 100-year floodplain.
2. Historically the largest flood volumes and peak flows occur during mid winter i.e. in December/January. For example for Kelsey Creek which has streamgage records since 1946 the 10 largest floods in the past 54 years have occurred in December and January. The following graph shows that the largest peak flows have occurred in January followed by December then February

Figure 8-1
Kelsey Creek
Recorded Peak Discharge
1946-1998





Upon considering these factors it was decided that no change in the flood pool would occur in December or January so that the full flood control storage would remain available during the time when most large floods occur. Starting in February the flood control pool would be reduced to store water for conjunctive use.

8.2.1.2 Recreation

Recreation use of the reservoir and reservoir shoreline is another important consideration. Most recreation use of the reservoir shoreline occurs in the Highland Springs Recreation Area. Much of the park area adjacent to the reservoir lies within the flood control pool and is periodically inundated. During winter, facilities in these areas such as picnic tables and garbage cans are relocated to higher ground.

An increase in the frequency of higher water levels during summer for conjunctive use storage will require some modifications to parking and picnic areas to best accommodate the higher summer shoreline and greater range of water level over the summer period.

To accommodate recreation a target range of water level between El. 1468 and El 1463 has been selected for the principal summer recreation period - June through Labor Day in early September.

8.2.1.3 Minimum Water Supply Pool

Two factors were considered in selecting the minimum water supply pool:

1. Physical constraints to installing a new low-level regulating gate.
2. Historic low water levels

Soundings were taken by the District to determine ground level around the Principal Spillway structure. Based on these measurements a minimum sill elevation of El. 1456 was adopted assuming that the new regulating gate would be installed on the south side of the structure. Installing the gate lower than this would be possible but could require difficult underwater excavation around the structure and slope stabilization measures.

8.2.1.4 Reservoir Banks & Vegetation

The existing banks of this flood control reservoir extend some 35 vertical feet from El. 1460 up to El 1495. Most of the time the water level is at or near the crest of the principal spillway (El. 1462.5) other than during storms when the water level rises attenuating peak flows in lower Highland Creek and Adobe Creek..

Vegetation on the banks of the reservoir comprises submergent vegetation that has flourished in the shallows to the detriment of swimming and



boating, a dense fringe of emergent vegetation predominantly hard stem bulrush and cattails that have established between El 1460 and 1463, and typical foothill oak/pine woodlands on most of the higher ground. Tree cover on the banks of the reservoir becomes more dense at the upper end where deposition of sediment by Highland Creek into the upper end of the reservoir has created some marshland densely covered with trees and riparian vegetation.

Raising the water level regime during spring and summer will increase the area of the reservoir surface, increase the length of the summer shoreline and increase the area of the reservoir banks subject to inundation during summer. Increasing the fluctuation of water levels during summer and fall may also change the character of vegetation along the shoreline from that of a stable pond to that of a reservoir favoring riparian species that are better adapted to fluctuating water levels.

Potential environmental impacts of modifying reservoir operation are discussed in a separate environmental document.

8.2.2 Groundwater Recharge

8.2.2.1 Recharge Alternatives

There are several alternative ways of achieving recharge of groundwater in Big Valley. These are:

- ▶ Enhanced natural recharge from stream channels.
- ▶ Injection Wells
- ▶ Spreading Basins
- ▶ In-lieu use of surface water.

These alternatives were investigated in the 1960's with the finding that supplemental natural recharge of the aquifers by increased percolation from stream channels appeared to be the most feasible approach. This process would involve supplementing the flow in the creeks into the summer and fall when basin ground water levels are lowered by pumping for irrigation.

The proposed groundwater recharge area includes the channels of Highland Creek from the Reservoir to the confluence with Adobe Creek and Adobe Creek for a distance of 2.3 miles downstream of the confluence to a point about 1300 feet north of the Merritt Road crossing. Here the aquifer changes from unconfined to confined, due to an extensive horizon of impervious clay.



8.2.2.2 Recharge Process

The process of natural recharge via the stream channel occurs when the groundwater table drops below the water surface in the stream. Water in the stream channel saturates the creek bed which is largely comprised of a layer of up to 10 or more feet of sandy gravel, having zones of “open work” gravel and occasional lenses of silt and clay, that is underlain by silt and fine grained sand. From here, it percolates into the adjacent near-surface alluvium when aquifer storage space is available.

Measurements carried out by the California Department of Water Resources in 1948 – 1950 on Kelsey Creek between Kelseyville and Soda Bay Road (during months of heavy flow) indicated losses of 2400 to 3600 acre-feet per month computed to be an average seepage loss of 1.5 acre-feet per acre per day over the 70 acres of stream channel. A rough check measurement of flow loss in Kelsey Creek above and below the zone of maximum infiltration, made by District staff in November 1996 indicated an infiltration rate of 1.7 ft/day. By comparison, infiltration rates for surface infiltration recharge systems typically range from 1 to 10 ft/day with most systems in the 2 to 5 ft/day range

The proposed groundwater recharge zone between Highland Springs Reservoir and the beginning of the confining clay layer north of Merritt Road is about 70 acres. The channel is about 17,000 feet long and ranges in bank-to-bank width from about 80 feet to about 300 feet with an average of about 180 feet. Assuming a gross infiltration rate of 1.5 ft/day over the entire 70 acres of channel then the maximum daily recharge for a fully wetted channel would be 105 acre-ft per day or about 53 cfs continuous release.

Due to limitations in available storage for conjunctive use, groundwater recharge release rates will be much less than this - probably in the range of 2 to 10 cfs. This amount of flow within the channel of Highland and Adobe Creeks will create a narrow sub-channel following the low point of the streambed. As it flows downstream, flow will be lost to infiltration into the creek bed. This flow will percolate into the shallow flood plain gravels that are hydraulically connected to the streambed to recharge the aquifer drawn down by pumping from wells on surrounding farmlands.

The extent of the storage available during the summer will depend on groundwater elevations. In early summer before the peak irrigation season water released from Highland Springs Reservoir may travel several miles downstream before entering the groundwater table. As irrigation pumping depresses ground water elevations near the creek, the distance of travel down the stream channel will decrease. By late summer, most recharge will occur in Highland Creek and the uppermost reach of Adobe Creek.



Total aquifer storage capacity available in the Adobe Manning Creek Basin in late summer and fall is estimated to be 6700 ac-ft⁸ which is about one order of magnitude more than the proposed annual groundwater recharge release in the range of 600 to 800 ac-ft. This large difference means that availability of storage for groundwater recharge releases should not be an issue as long as releases are made when groundwater levels in the recharge area are drawn down well below the stream channel as indicated by measurements of wells.

Recharge through in-lieu use of surface water may also be feasible on properties that abut Adobe Creek especially in the confined groundwater zone that commences just downstream of the Merritt Road Crossing.

8.2.3 Proposed Operation

Reservoir operation would be modified to incorporate conjunctive use. The goal of conjunctive use is to store a small portion (averaging about 6%) of the reservoir inflow that is normally spilled down Highland and Adobe Creeks to Clear Lake for use in enhancing fish migration in spring, and for groundwater recharge in late summer and fall.

Seasonal modes of reservoir operation are proposed to provide for multiple beneficial use of Highland Springs Reservoir storage for flood control, recreation, fish and wildlife enhancement and groundwater recharge. The following paragraphs describe these multiple uses.

8.2.3.1 Multiple Uses of Highland Springs Reservoir

Flood Control

Flood control operations primarily occur during winter as major Pacific storm fronts cross Northern California. The winter flood season generally lasts from November to March with January being the month with the largest storms. Local thunderstorms can occur at any time of year but are less frequent.

Significant impact on winter flood control operations will be avoided by scheduling conjunctive use operations for the end of the winter flood season. During the winter flood season the new crest gates would remain open so there would be no impact to flood control. Storage of spill for conjunctive use would be scheduled to occur late in the season with the goal of being full by early summer. Conjunctive use would periodically reduce flood control storage by 27%, so 73% of the flood control pool would remain available all year. In addition, the full flood control pool could be recovered in less than one day by evacuating the conservation pool through the Principal Spillway during the onset of a large late-season storm front.

⁸ Big Valley Ground Water Management Plan 1999



Recreation

Recreation use of the reservoir for swimming, boating and fishing mainly occurs during summer between Memorial Day and Labor Day.

Significant impact on recreation use of the reservoir would be avoided by limiting drawdown during the summer recreation season. The water surface elevation would vary about 4 feet from about El. 1468 on Memorial Day to about El. 1464 near Labor Day. Presently the reservoir water surface varies from about El. 1463 on Memorial Day to about El. 1460 on Labor Day. The reservoir would therefore be slightly deeper and larger throughout the recreation season.

Fish and Wildlife Enhancement

The existing reservoir provides aquatic habitat for fish and submerged vegetation and its banks provide habitat for riparian vegetation and associated wildlife.

Significant impact on fish and wildlife habitat provided by the existing reservoir would be avoided by managing reservoir operation to maintain a minimum pool for fish and providing suitable habitat for riparian vegetation on the banks of the reservoir within the flood control pool. In addition, regulation of downstream flow during Hatch spawning season and release of stored water in summer and fall (when the creeks usually dry up) would have the benefit of providing additional enhancement of fish and wildlife habitat in lower Highland and Adobe Creeks.

Riparian vegetation has limited capability to accommodate seasonal fluctuations in water level. The zone of riparian vegetation that has established near the bottom of the flood control pool is subject to periodic short-term inundation by up to 10 to 30 feet of water during storms. However, most of the time the flood control pool is not in use and the water level is fairly stable normally falling about 3 – 4 ft over the summer.

To maintain a viable riparian zone on the banks of the reservoir, conjunctive use operations have been scheduled to keep non-storm reservoir levels (i.e. the level of the reservoir between flood control events) within a band of 7.5 feet (El 1470 to El 1462.5) for most of the year (i.e. December through September). The top two feet of this range would be used briefly during spring to regulate flow to enhance fish spawning habitat in Adobe Creek.

During October and November the reservoir water level would be briefly drawn down a further 6.5 feet from El. 1462.5 to El. 1456 to complete seasonal groundwater recharge. This operation is scheduled for late fall/early winter when it is cooler and there is more precipitation to reduce drying out of the riparian zone.



Groundwater Recharge

Groundwater recharge operations using natural percolation from the Adobe Creek streambed into the Big Valley aquifer system are scheduled to be carried out in summer and fall when the creeks usually dry up.

8.2.3.2 Seasonal Reservoir Operation

Because factors such as weather, streamflow, fish migration and groundwater levels vary from year to year, scheduling of seasonal reservoir operations would be flexible and responsive to hydrological conditions. Conceptually, there will be four operating seasons as follows.

Winter

During the winter flood season the reservoir would be primarily managed for flood control. The existing flood control pool from El. 1462.5 to El. 1485 would be available as long as large floods are anticipated. Near the end of the season in late February or March the new control gates on the Principal Spillway would be raised to commence conservation storage. In the event that another large late-season storm is forecast and the full flood control pool is needed, any conjunctive use storage could be released in a few hours by opening the new gates in preparation for the storm inflow then any conservation storage could be released during the day prior to the storm.

Spring

The frequency of large floods diminishes in late winter and spring. During this period which would normally start in March and end in May, the flood control pool would be reduced by 660 ac-ft (i.e. 27%) by regulating the new gates so that the reservoir water level rises to El. 1470. If the water level exceeds El. 1470 due to a storm, the gates would automatically open to release reservoir surcharge. The 200 ac-ft of storage between El. 1470 and El. 1468 would be used to regulate flow from Highland Creek into Adobe Creek to enhance upstream fish passage and prevent dewatering of spawning areas. The goal would be to begin the summer period with the Reservoir at El. 1468. This water surface elevation is judged to be the highest that is suitable for summer recreation use of areas of Highland Springs Park that lie within the flood control pool.

Summer

During summer i.e. from Memorial Day through Labor Day, the reservoir would primarily be managed for recreation use, augmentation of downstream flows and groundwater recharge. Groundwater recharge releases to Highland and Adobe Creeks would normally commence in June or July when the water table in the ground water recharge area drops sufficiently below the stream channel of Adobe Creek. Intense local thunderstorms can theoretically occur at any time during the year so the flood control role of the reservoir would remain in effect but would be seldom used. Water levels



would normally decrease about 4 feet over the summer from about El 1468 at Memorial Day to about El. 1464 by Labor Day.

Fall

In October and November (i.e. after the main recreation season) the reservoir would be drawn down to El. 1456 to further recharge the groundwater basin. The new crest gates on the Principal Spillway would be opened in preparation for the oncoming winter storm season. When winter runoff and streamflow increases and the groundwater levels rise up to the bottom of the stream channel, the low level regulating gate would then be gradually closed to bring the operating level back up to the crest of the Principal Spillway.

Typical monthly flows and water level operations are shown on Figure 8-2 through Figure 8-5 (located at the back of this section).

Adaptive Management of Reservoir Operation.

The goal of the proposed modifications to reservoir operation is to best meet multiple uses of the reservoir over the seasons of each year. In doing so there are some uncertainties that have to be addressed in real time by adjusting water levels in the reservoir or flow releases down Highland Creek.

The main uncertainties are as follows:

1. *Hydrological uncertainty* Timing and amounts of inflow into the reservoir which vary each year.
2. *Hydrogeology* Seasonal availability of storage in the Big Valley groundwater system to accept recharge.
3. *Fisheries* Timing of releases for the spring run of the Clear Lake Hitch.
4. *Vegetation* The impacts of change of operation on riparian vegetation on the banks of the reservoir and the rate of adaptation to the new regime.

Seasonal factors such as, hydrological conditions, the response of the groundwater system to recharge operations, the condition of riparian vegetation on the banks of the reservoir and along Highland and Adobe Creeks, fish migration and recreation use will be taken into account by County staff in implementing conjunctive use operations. The timing of spring releases for the Clear Lake Hitch will be determined in consultation with the Department of Fish and Game.

In addition, it is proposed that the increase in summer water levels be implemented incrementally over the first three years of operation to help the riparian zone to adapt to the increase in water levels.



8.2.3.3 Yield

The proposed project will result in the seasonal reallocation of a total of 1070 ac-ft of the storage capacity of the reservoir to conjunctive use for fish spawning enhancement and groundwater recharge.

The estimated average additional yield for groundwater recharge after releases for fish spawning enhancement and evaporation losses is 750 ac-ft per year. The net benefit of this additional recharge to the groundwater basin will be greater in dry years when there is a large deficit in natural recharge and less in wet years when there is more natural recharge from precipitation.

8.3 IMPACT ON DAM SAFETY AND FLOOD ROUTING

The primary function of Highland Springs Reservoir is flood control. This section of the report presents updated estimates of flood flow in Highland Creek. It also presents our assessment of the potential impact of conjunctive use operations on dam safety and flood control operations.

8.3.1 Dam Safety

In California, non-federal dams which are 25 feet or more in height, or have an impounding capacity of 50 acre-feet or more, fall under the jurisdiction of the Department of Water Resources' Division of Safety of Dams (DSOD). DSOD reviews plans and specifications for the construction of new dams or for the enlargement, alteration, repair, or removal of existing dams. Operating dams are periodically inspected to assure that they are adequately maintained. Any significant modification to the structure or operation of Highland Creek Dam and Reservoir for conjunctive use is subject to approval of DSOD.

DSOD requires that all dams be capable of safely passing a selected design flood so, in this section we examine the potential impact of conjunctive use on the capability of the dam and spillway to safely pass a large flood. In 1998, new procedures for estimating the probable maximum precipitation in California were issued by the National Weather Service. These procedures were used in updating estimates of the probable maximum precipitation.

Highland Creek Dam was originally designed in the early 1960's in accordance with Soil Conservation Service design criteria for embankment dams. It is reported that the dam was classified as a "Moderate High Hazard Structure" and designed to safely pass an emergency spillway hydrograph and freeboard hydrograph without encroaching on a minimum freeboard of 2 feet specified for the dam. The freeboard hydrograph was derived from a 6-hour storm with an area rainfall of 10.4 inches with a peak inflow of 15,728 cfs.



The magnitude of precipitation used in estimating the design flood is determined by the hazard classification of the dam. The classification is selected using a rating system that considers

1. Reservoir capacity,
2. Dam height
3. Estimated number of people that would be placed in peril and need to be evacuated in anticipation of dam failure, and
4. Potential downstream property damage.

Each factor is categorized as low, moderate, high or extreme. The method produces a composite numerical rating termed the Total Class Weight (TCW). With this system, small remote dams generally have a TCW of 2, while large urban dams might have a TCW of 36

The capacity of an existing reservoir and height of the dam are easily determined. Estimating evacuation and potential downstream damage are more difficult and include assessing the population at risk, possible loss of life, physical property damage, socio-economic consequences and environmental impact. Determination of the hazard classification is made by DSOD staff as part of their role in setting acceptable design criteria for a dam. Through application to the many dams under its jurisdiction, DSOD has developed a coherent and uniform approach to conducting the damage investigations so that consistent total class weights are found.

Typically, probable maximum precipitation storms are required only for dams that impound 1000 acre-feet or more, are at least 50 feet high, would require an estimated evacuation of at least 1000 people, and have a damage potential of \$25,000,000 or greater. Other dams require a design storm falling between the 1000-year event and the probable maximum event.

In the case of Highland Springs Dam the size of the impoundment is more than 1000 ac-ft and the dam is more than 50 feet in height. An assessment of estimated evacuation and damage potential is required to determine the TCW and to determine the spillway design criteria. If DSOD determines evacuation and damage potential to be moderate or low then it is likely that a design flood less than the Probable Maximum event will be acceptable.

Prior to determination by DSOD of the hazard classification we have taken a sensitivity approach whereby we have estimated the updated Probable Maximum Flood and routed it through the reservoir to determine

- ▶ Whether the updated PMF will overtop the existing dam which would establish if hazard classification is a significant issue.



- ▶ Whether use of part of the flood control pool for conjunctive use is likely to impact safe passage of a large spillway design flood.

Two types of probable maximum floods are derived in this report: one is the probable maximum flood caused by a general-type probable maximum precipitation and the other is caused by the probable maximum thunderstorm precipitation. This work is fully described in Appendix A of this report.

The probable maximum flood flow component for the basin was computed using the PMP estimate for each month and the unit hydrograph of the basin. Loss rates were subtracted from the total storm to produce rainfall excess. The PMF peak inflows for the 12 PMP months and the thunderstorm PMP are shown in Table 8-2.

The twelve months (January through December) of PMFs and the thunderstorm PMF were routed through Highland Creek Reservoir to determine the maximum water surface levels during the PMFs. The routing was performed using spillway rating data for the existing configuration of the principal and emergency spillways and including any dam overtopping discharge.

Two routings were performed:

1. Simulation of existing reservoir assuming an antecedent reservoir water level of El. 1462.5. The results are shown on Table 8-2.
2. Simulation of the modified condition assuming an antecedent reservoir elevation of 1470 with the proposed new gates open when the reservoir rises above El. 1470. The results of this routing are shown on Table 8-3.

The routings show that in both cases the dam is overtopped by 1.3 feet and that the higher starting reservoir water surface has an insignificant effect on the maximum water surface level reached during the PMF. This is mainly due to the small capacity of the reservoir relative to the large volume of the flood.

Our conclusions are as follows:

- ▶ The updated PMF would overtop the existing dam by 1.3 feet therefore the hazard classification of the dam is significant and must be evaluated to justify a spillway design flood less than the PMF. This outcome is independent of the proposed conjunctive use project and relates to the selection of the design flood.
- ▶ The antecedent reservoir elevation has insignificant impact on the peak flood stage reached during routing of the PMF so we



conclude that the conjunctive use project would not significantly affect minimum freeboard during the design flood.



Table 8-2
Summary of PMF Flood Routing
Highland Creek Dam
Antecedent Reservoir Level at Elev 1,462.5 ft

Study Item (Storm/Flood)	Duration of Storm (hrs)	Depth of Storm (in)	Inflow		Reservoir			Overtop (ft)	Freeboard (ft)
			Peak (cfs)	5-day Volume (ac-ft)	Peak Outflow (cfs)	Peak Storage (ac-ft)	W. S. Elevation (ft)	Dam Crest Elev. = 1,497.0 ft	
General Storm PMP:									
October-March	72	34.94	17,330	21,740	17,100	5,620	1,498.3	1.3	
April	72	23.67	11,950	13,460	9,800	5,260	1,496.3	0.7	
May	72	15.65	8,120	8,120	5,760	4,600	1,492.5	4.5	
June	72	11.79	6,830	5,900	3,500	4,280	1,490.3	6.7	
July	72	10.32	5,890	5,000	2,410	3,980	1,488.4	8.6	
August	72	10.96	5,650	5,030	2,360	3,960	1,488.2	8.8	
September	72	23.67	11,950	13,460	9,800	5,260	1,496.3	0.7	
Thunderstorm PMP	6	6.19	14,720	-----	2,600	4,040	1,488.8	8.2	

Note: 1. The antecedent reservoir level for routing all the PMP was assumed to start Elev 1462.5 ft.



Table 8-3
Summary of PMF Flood Routing
Highland Creek Dam
Antecedent Reservoir Level at Elev 1,470 ft

Study Item (Storm/Flood)	Duration of Storm (hrs)	Depth of Storm (in)	Inflow		Reservoir			Overtop (ft)	Freeboard (ft)
			Peak (cfs)	5-day Volume (ac-ft)	Peak Outflow (cfs)	Peak Storage (ac-ft)	W. S. Elevation (ft)	Dam Crest Elev. = 1,497.0 ft	
General Storm PMP:									
October-March	72	34.94	17,330	21,740	17,100	5,620	1,498.3	1.3	
April	72	23.67	11,950	13,460	9,900	5,280	1,496.4	0.6	
May	72	15.65	8,120	8,120	6,480	4,700	1,493.3	3.7	
June	72	11.79	6,830	5,900	4,780	4,460	1,491.6	5.4	
July	72	10.32	5,890	5,000	3,370	4,260	1,490.2	6.8	
August	72	10.96	5,650	5,030	3,260	4,250	1,490.0	7.0	
September	72	23.67	11,950	13,460	9,900	5,280	1,496.4	0.6	
Thunderstorm PMP	6	6.19	14,720	-----	3,760	4,320	1,490.6	6.4	

Note: 1. The antecedent reservoir level for routing all the PMP was assumed to start Elev 1,470.0 ft.



8.3.2 Flood Control Operations

This section of the report deals with the potential impact of conjunctive use project on flood control operations and in particular the peak discharge released from the reservoir during a 100-year return period flood. The 100-year flood is selected, as it normally is the basis for flood plain delineation for land use planning and for flood insurance studies.

As noted earlier, the Flood Mapping Study Hydrologic Calculations prepared by the Department of Water Resources in 1999 and approved by FEMA addresses proposed conjunctive use of the reservoir because it is based on an antecedent reservoir elevation of El.1470 rather than El. 1462.5. So, utilization of the storage below this elevation for conjunctive use should not affect the estimated peak discharge during a 100-year return period flood. The DWR study estimated a peak discharge of 1939 cfs at a water surface elevation of El. 1487.4, i.e. 2.4 feet above the crest of the emergency spillway.

To quantitatively determine the potential impact of conjunctive use operations on flood control, CAI developed estimates of the 100 year precipitation for each month of the year and routed the storm through the reservoir assuming existing conditions i.e. antecedent reservoir elevation of El. 1462.5 and modified conditions i.e. El. 1470. This work is fully described in Appendix B of this report.

Results are summarized on Table 8-4. The table shows that the estimated maximum 100-year precipitation occurs in December with an estimated precipitation amount of 6.64 inches in 24 hours and peak reservoir inflow of 4240 cfs. Routing this storm through the reservoir assuming existing conditions i.e. antecedent water level of 1462.5 results in a peak discharge of 680 cfs with the reservoir rising to 0.3 feet above the crest of the emergency spillway. With the conjunctive use project there is no proposed change in reservoir operation i.e. the new gates would be open in December and January so there would be no change to this operation. The study also shows that the bottom of the flood pool could be raised to El. 1470 in December and January without exceeding the DWR 100 year peak flood discharge but in most years (other than during extreme droughts) there is ample flow in February and March to fill the reservoir for conjunctive use so that the storage may as well be allocated to flood control.

The proposed storage period for conjunctive use is late winter and spring i.e. February through to July. Precipitation data show that the most severe 100-year storm during this period is likely to occur in February. The estimated amount of precipitation is 6.14 inches and the estimated peak inflow is 3860 cfs. Assuming an antecedent reservoir elevation of El. 1470 due to conjunctive use, the peak discharge is 1240 cfs with a maximum surface elevation of El. 1486.2 i.e. about 1.2 ft above the crest of the emergency spillway.



The study shows that the modified reservoir will still perform its flood control function reducing peak flows and that the estimated 100-year peak discharges from the reservoir will not exceed the 100-year flood peak adopted for flood plain management i.e. 1939 cfs.

Table 8-4
Summary of Routing the Monthly 100-yr, 24-hr Storm
Under Existing Condition and Proposed Flood Pool Elevation
Highland Creek Dam

Month	Depth of Storm (in)	Peak Inflow (cfs)	Existing Conditions		Conjunctive Use	
			Antecedent W.S. Elev 1,462.5	Reservoir W.S. Elev (ft)	Antecedent W.S. Elev 1,470.0	Reservoir W.S. Elev (ft)
October	2.90	1,430	390	1,467.8	400	1,474.7
November	5.49	3,370	450	1,479.7	540	1,485.1
December	6.64	4,240	680	1,485.3	1,670	1,486.9
January	6.49	4,130	480	1,485.0	1,550	1,486.7
February	6.14	3,860	460	1,483.1	1,240	1,486.2
March	5.00	3,000	440	1,477.3	460	1,482.8
April	2.82	1,380	392	1,467.5	380	1,474.4
May	1.26	320	130	1,463.6	80	1,471.0
June	0.74	120	70	1,463.1	70	1,470.8
July	0.20	70	70	1,463.1	70	1,470.8
August	0.46	70	70	1,463.1	70	1,470.8
September	0.94	170	80	1,463.2	70	1,470.8

- Note:
1. All routings assumed that the spillway gates would be fully opened at the start of the storm.
 2. Monthly 100-yr, 24-hr storms were interpolated from rainfall-depth-duration frequency estimates made for the precipitation gage at Lakeport (NWS No. 4701) using methods by JD Goodridge, developed in the Department of Water Resources, California.

8.4 ESTIMATED YIELD

This section describes assumptions, methodology and the results of analyses performed to estimate the additional water yield available through conjunctive use.

The estimated average annual net flow available for groundwater recharge is therefore 750 acre-feet.

In a drought, the proposed project would increase carryover storage into the first year of the drought increasing groundwater levels and available water



supply. But, during an ensuing extreme drought year (such as water year 1977) there would be little or no spill available for regulation by conjunctive use and therefore little or no carryover storage into the following year. In addition, groundwater level would be drawn down below the stream channel all year so that any small outflows from the reservoir during winter would recharge groundwater.

8.4.1 Simulation of Reservoir Operation

To demonstrate conjunctive use of the reservoir, a mathematical simulation of the reservoir was carried out during a range of water years. The 10 year period 1967 through 1976 was used to characterize a typical range of hydrological conditions. This period was chosen as there is historic streamflow data available for this period.

8.4.1.1 Inflow Data

Stream flow measurements recorded at USGS Gage 11448900 *Highland Creek above Highland Springs Reservoir* in the period water year 1967 through 1976 were used as the source for inflow data. This gage which was discontinued in 1978, was located in Highland Creek just upstream of the reservoir and had a drainage basin of 11.9 square miles.

There was also a gage just downstream of the reservoir *USGS Gage 11449010 Highland Creek Below Highland Creek Dam* which had a drainage basin of 14.2 square miles and was discontinued in 1977.

Adjustments were made for basin area by comparing contemporaneous measurements taken above and below Highland Springs Dam and estimated evaporation from the reservoir. An overall adjustment of +9.2% to the flow measured upstream of the reservoir was made to estimate total inflow to the reservoir accounting for ungaged inflow downstream of the gage.

Yield will change each year according to hydrologic conditions. To explore a range of possible conditions four index hydrological periods were selected as follows:

**Table 8-5
Index Periods**

Water Conditions	Years	Computed Inflow (cfs)	Percent Average
Average	1967-76	24.8	100%
Wet	1974	49.4	199%
Dry	1972	7.1	29%
Drought	1976	2.3	9%



8.4.1.2 Losses

It was assumed that 15 acre-feet of water would be used annually for consumptive use at the caretaker's residences and irrigation of landscaping of Highland Springs Park.

Adjustments for evaporation from Highland Springs Reservoir are based on CIMIS estimates for Reference Evapotranspiration⁹ ETo at Lakeport, California shown on Table 8-6.

Table 8-6
Assumed Evaporation Losses

MONTH	REFERENCE EVAPOTRANSPIRATION ETo(in)
October	2.9
November	1.2
December	0.9
January	1.1
February	1.3
March	2.6
April	3.5
May	5.1
June	6.0
July	7.3
August	6.1
September	4.7
Total	42.7

Conveyance losses due to evaporation from recharge releases flowing from Highland Creek Dam to the recharge area are expected to be relatively small. Estimated evapotranspiration through the summer period June through October is estimated to be 27 inches. The surface area of the entire stream channel within the recharge area is about 70 acres however the small recharge releases would probably only occupy an estimated 5% of the total area of the channel or about 3.5 acres. In addition increased evapotranspiration losses from riparian vegetation along the banks of the stream channel would contribute to water losses. An allowance for 5 to 10 acres of such vegetation is included. Incremental evaporation loss from the water channel and the riparian area are therefore estimated to be in the range of 20 to 30 ac-ft per year and an allowance of 30 ac-ft/year is included.

8.4.1.3 Groundwater Recharge

The goal of conjunctive use reservoir operation is to recharge the groundwater basin during summer and fall when there is storage capacity

⁹ Estimated evaporation from well watered grass.



available with surface water carried over in Highland Reservoir from winter and spring storms.

Proposed operating rules used in the model are described in Section 8.2.3.2. Under conjunctive use the reservoir would be operated to meet monthly storage targets that are summarized on the following table. The storage targets are at the beginning of each month.

Table 8-7
Beginning of Month Reservoir Storage Targets

Month	Target Water Level (ft)	Target Storage (ac ft)
Jan	1462.5	1089
Feb	1462.5	1089
Mar	1466.0	1373
Apr	1470.0	1746
May	1470.0	1746
Jun	1468.0	1553
Jul	1467.0	1461
Aug	1465.5	1330
Sep	1464.0	1206
Oct	1462.5	1089
Nov	1456.0	665
Dec	1456.0	665

It is anticipated that release of water to assist the spawning of the Clear Lake Hitch would be accomplished in concert with the movement of the hitch up Adobe Creek. In terms of storage targets this is simulated by reducing the reservoir water level from El. 1470 to El. 1468 during Spring to augment streamflow in Adobe Creek during periods of low flow between storms. The actual timing of the releases would vary each year with hydrologic conditions and the timing of movement of the Hitch. It was also assumed that a minimum downstream release of 0.5 cfs would be maintained all year.

8.4.1.4 Simulation Results

Annual water conservation and ground water recharge operations were simulated in each of the selected water years.

The results of the water yield analysis are summarized in Table 8-8 . The data indicate that modification of reservoir operation would transfer an average of 986 acre-ft of water from the wet season (generally November through April) to the dry season (generally May through October). Assuming that 200 ac-ft of this storage would be used early in the dry season to augment streamflow during the spawning of the Clear Lake Hitch then the estimated average water available for groundwater recharge would be about 786 acre-ft. Further, allowing for conveyance losses in the stream channel



due to evaporation the net amount of yield available for groundwater recharge is estimated to be about 750 acre-feet.

Table 8-8
Summary of Conjunctive Use Yield

Month	Historic Outflow (ac-ft)	Regulated Outflow (ac-ft)	Difference (ac-ft)
May	139	390	251
June	9	131	122
July	5	100	95
August	13	84	72
September	23	86	63
October	33	416	383
Annual Average	222	1208	986

Hydrographs showing inflow, outflow and reservoir water elevations are shown on Figure 8-2 through Figure 8-5.



Figure 8-2
Reservoir Operation
Average WY 1967-76

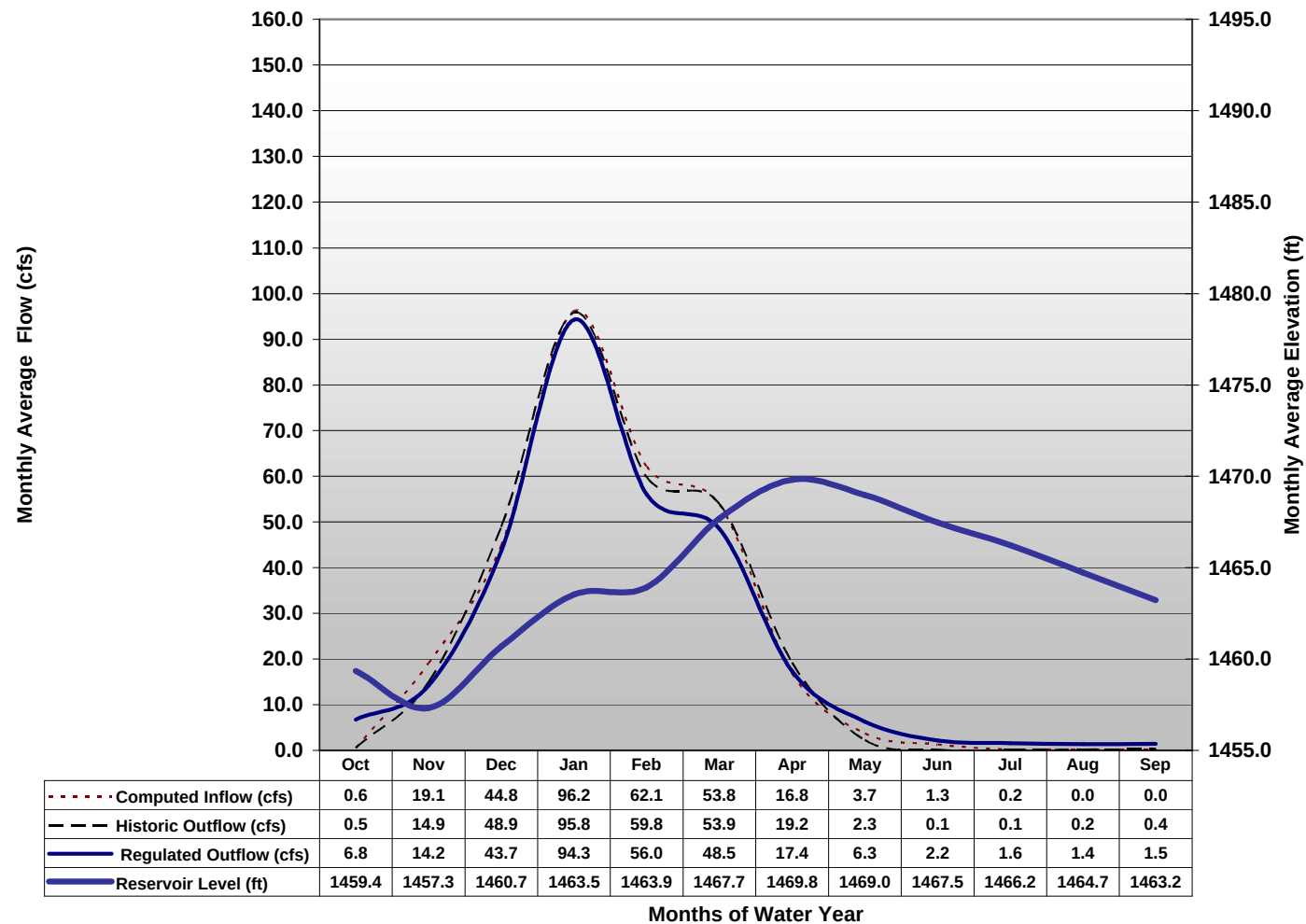




Figure 8-3
Reservoir Operation
Wet Year – WY 1974

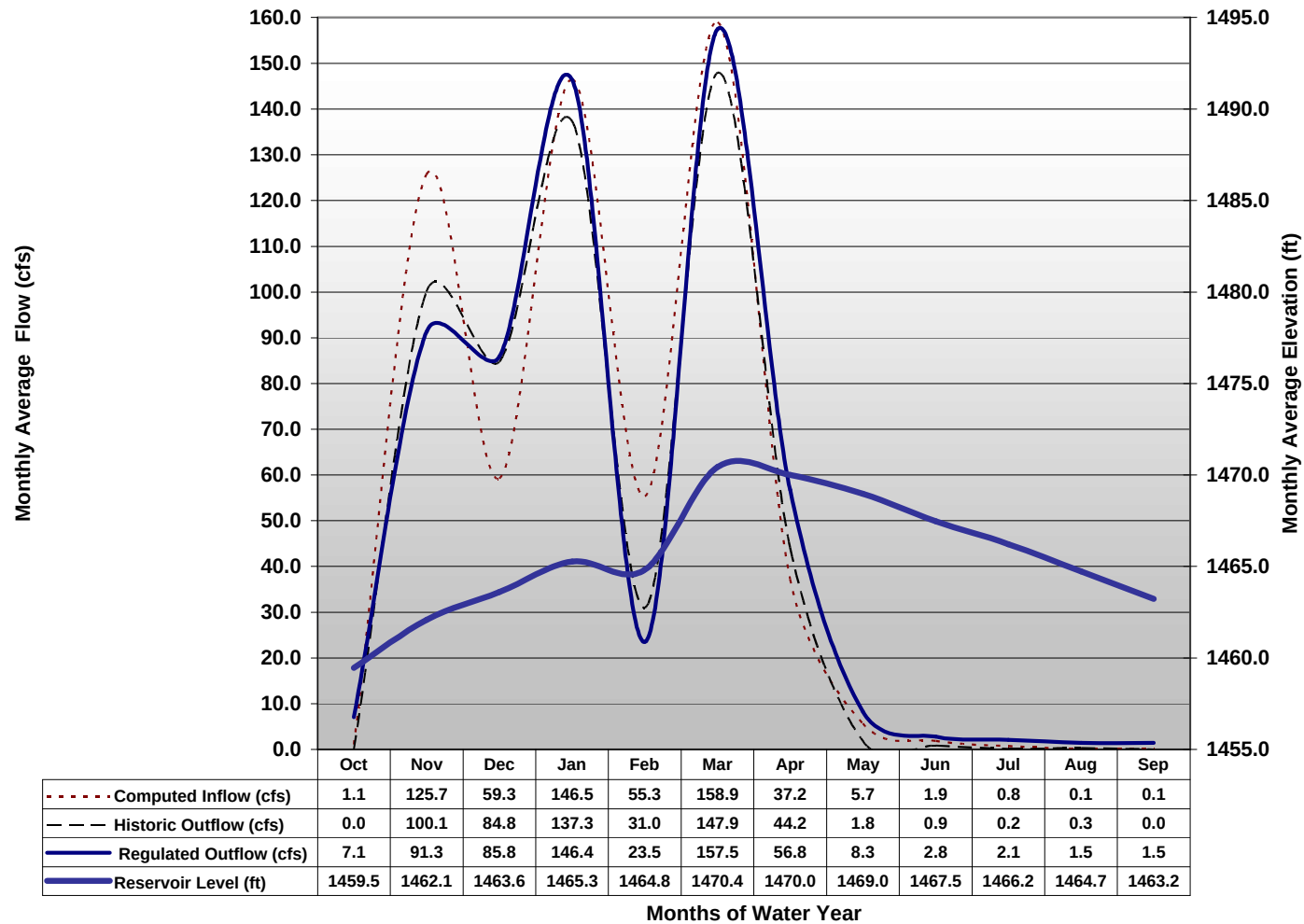




Figure 8-4
Reservoir Operation
Dry Year WY 1972

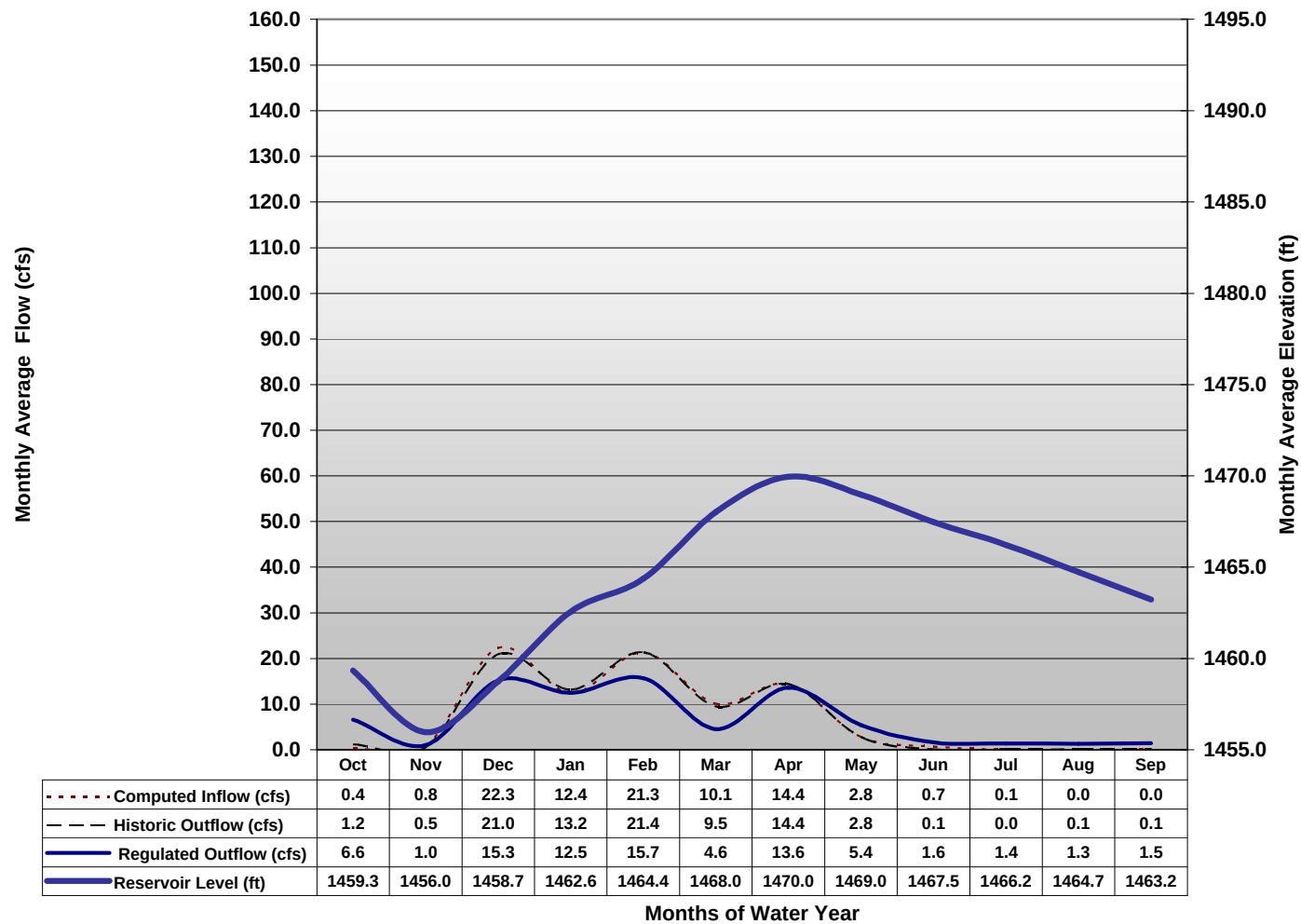
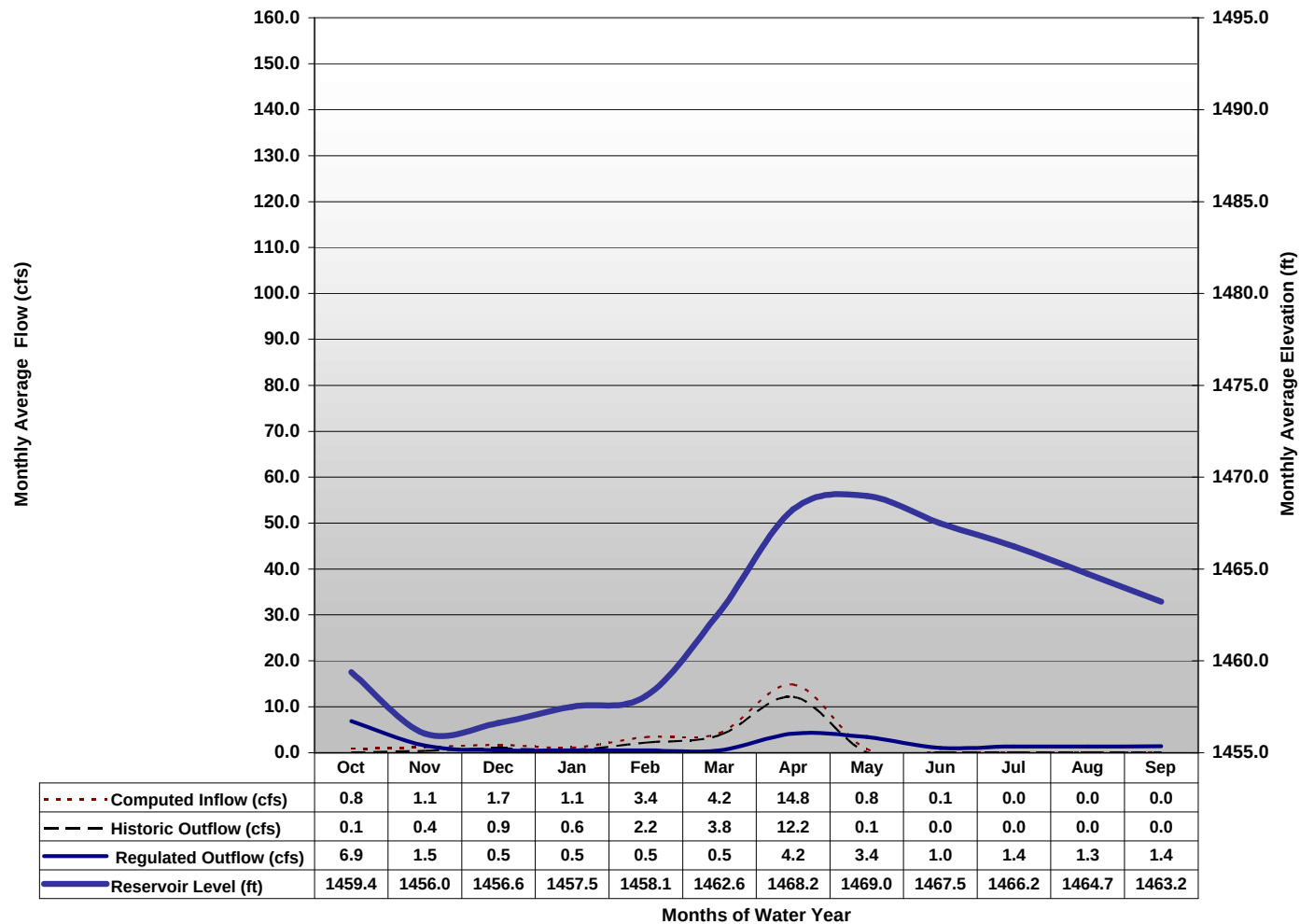




**Figure 8-5
Reservoir Operation
Drought Year WY 1976**





9. BENEFITS AND COSTS

This chapter presents information on benefits and costs of the project and the estimated unit cost of additional yield for groundwater recharge.

9.1 BENEFITS

The District's Adobe Creek Conjunctive Use Project presents the opportunity to utilize an existing water resource asset to help meet the District's water conservation goals and specific goals in its Big Valley Groundwater Management Plan. The Plan prepared pursuant to A.B. 3030 and adopted in 1999, presents a plan for protecting and enhancing groundwater resources of Big Valley.

The proposed project would have the following benefits

- ▶ Increase groundwater levels in the area of Big Valley recharged by percolation from Adobe Creek.
- ▶ Improve the water supply by replenishing 750 ac-ft/year of groundwater extracted by water users and increasing carryover storage from one water year to the next.
- ▶ Help mitigate overdraft that occurs during droughts
- ▶ Help reduce intrusion of poor quality geothermal groundwater rich in Iron and Boron into the aquifer system.
- ▶ Help to reduce ground subsidence due to overdraft and associated loss of groundwater storage.
- ▶ Provide a small reduction in use of electrical energy to pump groundwater.
- ▶ Improve regulation of flow in Adobe Creek during spring to enhance spawning habitat for fish - particularly the Clear Lake Hitch.
- ▶ Enhance summer flow and riparian habitat in the upper reaches of Highland and Adobe Creeks downstream of Highland Springs Reservoir.

9.1.1 Higher Groundwater levels

Groundwater is the principal source of irrigation and municipal water in Big Valley. During summer, groundwater levels are normally drawn down between 4 to 30 feet by groundwater extraction.

In drought periods, there is insufficient precipitation during winter to recharge groundwater levels so in the following summer they are depressed even further. The lowered groundwater level increases groundwater pumping costs, increases the cost of wells and sometimes requires deepening of existing wells, increases potential interference between wells, reduces



groundwater quality by increasing intrusion of geothermal groundwater and increases ground subsidence.

Ground subsidence was observed during the 1976-1977 and 1987-1992 drought periods when groundwater levels were drawn down significantly. In several locations along Finley East Road, ground subsidence of 12 to 16 inches was measured. While these amounts are significantly less than observed in Scott's Valley, there is a potential for disruption of surface drainage patterns and decrease in long-term groundwater storage.

9.1.2 Groundwater Quality

Groundwater quality in some areas of Big Valley is affected by intrusion of geothermal water containing dissolved salts. Elevated levels of iron and boron have been noted at greater depths and adjacent to inferred faults that underlie the aquifer. Boron and iron levels also tend to be higher in the fall when groundwater levels are lower. The "hot" well along Merritt Road during the 1976-77 drought also shows the infusion of geothermal water during periods of low groundwater levels

Maintenance of higher groundwater levels would be beneficial to maintaining higher groundwater quality for consumptive use and irrigation.

9.1.3 Energy Use

Higher groundwater levels would also help reduce the energy needed to pump groundwater although the savings would be small. Assuming that there were savings of 10 feet of draft for 750 acre-feet of water the annual savings would be about 10,000 kwh/yr worth on the order of \$500 to \$1000 per year depending on energy prices.

9.1.4 Enhancement of Fish Habitat

The Clear Lake Hitch (*Lavinia exilicauda*) is a fish species in decline mainly due to alteration of its spawning streams and introduction of competing species (such as Threadfin Shad) into Clear Lake.

The following abridged excerpt from "Swimming Upstream without a Hitch" by Richard Macedo provides an excellent description of the Hitch and its reproductive cycle.

Clear Lake Hitch (Lavinia exilicauda) are in the minnow family. Adults reach lengths of up to 14 inches and exceed one pound in weight. Beginning each spring, the entire hitch population stirs and their methodical search for food is interrupted by a compelling urge to seek out inlet streams. This stirring usually begins by mid-February and may last through July.

Hitch must race against time to complete spawning. Unlike most salmon spawning streams, all tributaries leading into Clear Lake go dry during summer months. In drought years, some spawning streams may dry as early as April. To



successfully spawn, hitch must ascend swiftly flowing streams, overcome barriers, avoid predators and find suitable habitat.

Hitch spawning is an uncomplicated act. A ripe female will seek out a shallow area, usually near a stream bank, where winter stream flows have deposited silt—free gravel. Overhanging vegetation such as willows or blackberries are a bonus, as they provide cover from potential predators.

After selecting an appropriate site, a female is joined by one to five eager males which coax her into releasing her eggs. Males fertilize eggs as they are released. Clear Lake hitch are not nest builders. Once fertilized, eggs swell to about four times their initial size and sink to the stream bottom where they disperse along the streambed. Absent of any adhesive quality, many eggs settle into openings in the gravel bed, while others are carried by currents to downstream areas— including Clear Lake, where survival rates are very low.

Eggs hatch in five to 10 days. Larval hitch need another five to 10 days to become proficient swimmers. Once this is accomplished, juvenile hitch will slowly migrate downstream and into Clear Lake

For eons, hitch managed to win the race against drying streams. However, human activities have altered their spawning habitat and jeopardized the outcome of this primeval race. Clear Lake hitch are not strong swimmers or jumpers. This species had no reason to develop exceptional swimming and jumping abilities because native spawning streams were gradually sloped and void of large waterfalls and rapids. During the spawning run, their only concern was the drying of streams during the summer months.

Today, bridges, stream crossings and other in—stream structures threaten hitch spawning. Many old bridges and stream crossings in Lake County were not designed with Clear Lake hitch in mind. By changing the direction of stream flows or creating waterfalls of one or more feet, bridges can delay migration or completely block upstream access for spawning hitch.

Dams, such as those on Adobe and Highland Creeks, completely block upstream access. Newer dams such as the Kelsey Creek dam have retractable gates which can be opened during the spawning season. However, newer dams are not without problems. Altered flow patterns and slight increases in the slope of the streambed have been enough to reduce the number of spawning hitch above the Kelsey Creek dam.

The Department of Fish and Game, in cooperation with Lake County and Caltrans, have worked to correct some of these problems. Caltrans engineers now consider hitch migration in their road and bridge designs. County personnel have assisted Fish and Game in improving conditions at county facilities. This cooperative effort has improved conditions for Clear Lake hitch.



One final impact to Clear Lake hitch habitat results from agricultural irrigation in the valley and domestic water diversion in upper watershed areas. Prior to discharging into Clear Lake, most Clear Lake tributaries meander through rich agricultural lands which produce pears, wine grapes, walnuts and kiwis. To support these water dependent crops, farmers pump water from aquifers which directly affects surface flows in tributary streams. Water use by residential users is also increasing.

The diversions have caused streams to dry prematurely and have restricted the time hitch have to successfully spawn. Although numbers are well below historic levels, hitch continue to survive in the Clear Lake basin despite these significant alterations.

The proposed project will help to mitigate the latter problem. A portion of the flood control storage has been allocated to help address this problem by augmenting flow in the stream during late spring when the lowering of the water table due to groundwater pumping prematurely dries up Adobe Creek. In particular, this can occur during a cold dry spell in spring when frost protection is required and considerable early pumping occurs.

Estimated average annual water use for frost protection is 1.5 acre-feet/acre for pears and about 0.7 ac-ft/acre for grapes. This use normally occurs during 10 to 20 cold nights in April and May.

9.1.5 Enhance Riparian Habitat

Summer and fall releases from the reservoir will benefit riparian vegetation along the banks of Highland and Adobe Creeks. It will also provide a water source for wildlife and new habitat for species that need a more reliable water supply.

9.2 COSTS

This section presents feasibility study estimates of construction and annual operating and maintenance costs that form the basis for estimating the unit supply cost of water for comparison with other water sources

9.2.1 Construction

The construction cost estimate covers direct and indirect costs of installation of new slide gates, gate operators and controls on the Principal Spillway.

The effective base date for the cost estimate is October 31, 2000 and all estimated costs are applicable to that date. For escalating future or deferred costs, a reasonable approximation for construction inflation is presently 4% cumulative per year.

The estimate of construction cost has been prepared based on the preliminary drawings included with this report. Unit prices shown in the estimate include allowances for performing activities normally required to



execute the work shown on in the drawings. This includes preparatory work such as site preparation and debris removal, supply of miscellaneous ancillary materials and cleanup of the project site when work is complete.

Mobilization shown in the estimate is an allowance for costs incurred by a contractor in transporting equipment and setting up at the site. This has been estimated as 5% of the cost of work on site exclusive of the supply of gates.

Quantities used in the estimate have been calculated using dimensions shown on the conceptual drawings or scaled from those drawings. Where no details are shown on the drawings, quantities have been estimated based on prior experience. Unit prices used in the estimate have been derived from historical costs for similar work. The estimate includes contractor's direct costs of labor, materials and equipment and contractor's indirect cost and profit, to construct and commission the facilities.

The estimated costs of the gates, operator cylinders and control equipment are based on preliminary informal vendor quotations. Market conditions at the time of bidding may result in actual prices that differ from these estimates. Gate installation estimates include the cost of transportation from the manufacturer's plant and the provision of suitable storage of components at the project site in addition to the cost of labor and equipment to install the gates.

Cost allowances are provided to cover other non-construction tasks such as design engineering, environmental services, construction management, environmental mitigation costs, administration, legal and financing costs. These cost allowances are essentially placeholders until the scope and the cost of these tasks is better defined.

A contingency allowance is provided to cover the cost of performing work that is not foreseeable at the present time. This contingency does not include any provision for cost inflation due to delay of the work.

The resulting feasibility level estimate of adding control gates to the Principal Spillway at Highland Springs Dam is \$800,000



**Table 9-1
Feasibility Level
Project Cost Estimate**

Description	Unit	Quantity	Unit Price (\$)	Amount (\$)
Construction				
Mobilization / demobilization	LS	1	\$9,000	\$9,000
Site preparation including debris removal and removal and replacement of trash bars	LS	1	2,400	2,400
Saw cut 12 in. square hole in side of spillway riser	LS	1	1,000	1,000
Furnish and install stainless steel supporting framework and other miscellaneous metalwork	LBS	4500	6	27,000
Furnish and install 3 ft. x 3 ft. metal slide gates including gate frame, stems and hydraulic cylinders	EA	6	10,300	61,800
Furnish and install 12 in. square metal sluice gate including gate frame stem and hydraulic cylinder	EA	1	5,200	5,200
Construct 8' x 10' control house	SF	96	100.00	9,600
Construct protective enclosure on spillway hood	SF	117	50	5,900
Excavate trench and furnish and install precast concrete cable trench for hydraulic piping	LF	175	44	7,700
Furnish and install hydraulic piping	LF	2450	3	7,400
Furnish and install vent piping	LS	1	5000	5,000
Furnish and install hydraulic power unit including automated control system	LS	1	30,000	30,000
Construct electric power supply line	LF	300	50	15,000
Install downstream measuring weir	LS	1	1000	1,000
Total Construction Cost				\$188,000
Other Costs				
Planning, engineering and design	Allowance			154,000
Administration and Construction Management	Allowance			50,000
License fees	Allowance			6,000
Land purchase / easements	Allowance			260,000
Environmental Mitigation / enhancement	Allowance			30,000
Subtotal				\$500,000
Contingencies	Allowance			\$100,000
Total Project Cost				\$788,000
Rounded				\$800,000



9.2.2 Operation and Maintenance Costs

It is assumed that routine operation and maintenance activities would be performed by the District staff with support from local mechanical equipment service contractors. It is proposed that the control system for the gates have remote monitoring and alarm capability to minimize the costs of regular operation. The operation and maintenance costs would also be incremental to existing costs of regularly monitoring Highland Springs Reservoir.

1. Weekly
 - Brief inspection to check security and verify system status.
2. Annual inspection prior to filling season:
 - Exercise gates
 - Inspect piping and connections for leaks – repair if necessary
 - Check hydraulic fluid for contamination and accumulation of water
 - Remove trash from trashracks and general cleanup
 - Clean hydraulic cylinders
 - Check control system
3. Filling season
 - Monitor runoff forecasts
 - Adjust gates as required
4. Release season
 - Monitor groundwater wells
 - Adjust Gates as Required
5. Ten-year maintenance
 - Check gate seals and replace as necessary
 - Recondition hydraulic cylinders as necessary
 - Repaint as necessary

Estimated annual operation and maintenance costs are shown on Table 9-2. The costs are based on the estimated number of labor hours required to perform the above tasks with allowances for vehicle use and small tools and miscellaneous supplies.

The cost of the 10-year maintenance program is estimated to be \$6,000 in yr. 2000 dollars. The annualized cost was determined using an assumed average inflation rate of 4% and an interest rate of 6%.



Table 9-2
Operation and Maintenance Cost Estimate

Item	Hours	Rate	Amount
Additional monitoring for security (1 hour per week)	52	\$35	\$1,820
Annual inspection and maintenance (2 men x 1 days)	16	\$35	\$560
On call maintenance	8	\$35	\$280
Planning and monitoring operation during fill and release seasons (10 months @ 4 hours/mo.)	40	\$35	\$1400
Subtotal	116	\$35.00	\$4060
Supervision	20	\$65.00	\$1300
Vehicle allowance			\$300
Small tools & miscellaneous supplies			\$300
Annualized cost of 10 year overhaul			\$600
Total			\$6,560

Note: these are estimated additional costs over and above existing O&M costs

9.2.3 Other Costs

The proposed project will store water during winter that would otherwise flow into Clear Lake. Yolo County Flood Conservation and Water Conservation District (YCFCWCD) owns and operates Cache Creek Dam at the outlet of Clear Lake and has prior vested water rights to the waters of Clear Lake.

The District purchases water from YCFCWCD under an agreement dated May 12, 1992 which provides stipulated amounts of use and a three tier price structure for municipal, agricultural and recreation use. In addition, the District has negotiated a rate for groundwater recharge in conjunction with its Kelsey Creek Detention Structure.

For this study it is assumed that the groundwater recharge rate (currently \$5.95 per acre-ft would apply. It is also assumed that this payment would only be due in 50% of the water years because the agreement provides that no payment is due when Clear Lake fills to El. 7.56 on the Rumsey gage and this happens every other year on average. It is further assumed that there would be no charge for the 200 ac-ft stored in winter and released in spring to enhance fish habitat.

The average cost of payments to Yolo County is therefore assumed to be \$2300/year. The agreement provides for inflation of unit prices.

9.2.4 Unit Cost of Water

The estimated unit cost of water is the sum of annualized costs for construction, operation and maintenance and purchase of water. The estimate is shown on Table 9-3.

Table 9-3
Estimated Unit Cost of Water

Item	Capital Cost	Annual Cost	Unit Cost of	Unit Cost of
------	--------------	-------------	--------------	--------------



			Recharge Yield	Total Yield
	\$	\$/year	\$/ac-ft	\$/ac-ft
Development	\$800,000	\$58,120	\$77.49	\$61.17
Operation & Maintenance		\$6,560	\$8.74	\$6.90
Water Purchase		\$2,300	\$3.06	\$2.42
Total (year 2000)		\$66,420	\$89.29	\$ 70.4970.49
Rounded		\$67,000	\$89	\$70

Annualized cost based on 6% interest

In the estimate the unit cost of water is computed two ways: in the first the yield is the recharge yield 750 ac-ft which is the net yield allocated to recharge, in the second, the total yield is 950 ac-ft which includes the additional 200 ac-ft of storage allocated for enhancing spawning habitat for the Clear Lake Hitch. Since the spring fish releases are part of the beneficial conjunctive yield i.e. 950 ac-ft yield is used in this study with an estimated initial unit cost of \$70/ac-ft. If the fish release is excluded the estimated unit cost increases to \$89/ac-ft.

These unit costs are representative of current unit water prices as of the date of the estimate (excluding price escalation prior to construction and project financing expenses). The estimated unit cost of water appears to be economically attractive compared to typical costs of new water supply in California. The California Water Plan Update - Bulletin 160-98 presents a comprehensive evaluation of water supply options for the State. The Bulletin 160 series assesses California's agricultural, environmental, and urban water needs and evaluates water supplies, in order to quantify the gap between future water demands and the corresponding water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making water resources decisions.

Chapter 8 of the bulletin discusses options for the interior region of California. Three options located in Lake County are presented. The estimated unit cost of additional water supply varies from \$30 ac-ft for the Big Valley (Adobe Creek) Conjunctive Use Project up to \$390/ac-ft for the Thurston Lake Pumped Storage Project.

Updated estimates of the unit cost of surface water supply from a small new reservoir on Dry Creek Project near Middletown in Lake County indicate a cost of yield in the range of \$150 to \$250 per acre-foot. The project involved construction of a 129-foot high embankment dam that would have impounded a 6,600 ac-ft reservoir.



These data indicate that the unit cost of additional water from the Adobe Creek Conjunctive Use Project appears to be economically attractive compared with typical costs from other new supply sources in the region.



10. FINDINGS & RECOMMENDATIONS

10.1 FINDINGS

Overdraft of groundwater resources in dry years is recognized as a problem in Big Valley, a predominantly agricultural area in Lake County. Problems include:

- ▶ Drying up of wells during droughts,
- ▶ Environmental impacts due to drying up of creeks due to low water table.
- ▶ Shortages of water supply during droughts that reduce agricultural production impacting the local economy.
- ▶ Ground subsidence,
- ▶ Increase in energy needed for pumping,
- ▶ Deterioration in groundwater quality due to intrusion of geothermal water,

On May 18, 1999, the District adopted the “Big Valley Groundwater Management Plan” pursuant to the State of California’s Groundwater Management Act (AB 3030 - 1992). The purpose of the plan is to monitor, conserve and manage Big Valley’s groundwater resources. One component of the plan is to facilitate conjunctive use of surface and groundwater storage to replenish the groundwater basin.

The Adobe Creek Conjunctive Use Project provides the District with a unique, opportunity to cost-effectively utilize an existing reservoir to help meet the goals of the Plan. The proposed project involves:

- ▶ Improving control of water levels in Highland Reservoir by retrofitting seven hydraulically operated sluice gates to the existing Principal Spillway. Operating equipment and controls would be housed in a small building to be constructed on the east abutment of the dam.
- ▶ Modifying reservoir operations to provide for storage of a small portion of winter inflow (i.e. about 6% on average) that is normally spilled to Clear Lake. Maximum reservoir water levels are determined by magnitude of floods and will not change. The stored water would be released during spring, summer and fall. Conjunctive use will increase the normal range of water levels over summer and fall from about 4 to 7 feet to about 14 feet.
- ▶ Groundwater recharge by natural percolation of releases from the reservoir into the streambeds of lower Highland and Adobe Creeks. The recharge area extends 3.2 miles downstream from Highland



Springs Dam to the boundary of the unconfined aquifer about 1300 feet downstream of the Merritt Road crossing.

- ▶ Relocating the existing water intake in Highland Springs Park to accommodate lower reservoir water levels in fall. Modifying the shoreline area within the existing floodplain to accommodate higher water levels during summer.

Engineering studies have determined that it is feasible to retrofit hydraulic gates to the existing Principal Spillway to control the elevation of the water surface of the reservoir. Six remotely operated crest gates and one regulating gate would be added to the existing structure.

Dam safety studies have determined that the updated Probable Maximum Flood would overtop the existing dam by 1.3 feet therefore the hazard classification of the dam is significant and must be evaluated to justify a spillway design flood less than the PMF. This issue relates to the capacity of the emergency spillway and is independent of the proposed conjunctive use project. Studies also show that the antecedent reservoir elevation has insignificant impact on the peak flood stage reached during routing of the PMF so we conclude that the conjunctive use project would not significantly affect freeboard during an extreme flood.

Flood routing studies for the 100-year flood indicate that the proposed conjunctive use of 25% of the controlled flood storage in Highland Springs Reservoir in late winter through summer would be compatible with the flood control purpose of the reservoir and would not increase the estimated 100 year return period peak flood discharge above that estimated in the existing FEMA approved 100 year flood hydrology study.

Reservoir operation studies indicate that modification of reservoir operation would transfer an average of 986 acre-ft of water from the wet season (generally November through April) to the dry season (generally May through October). Assuming that 200 ac-ft of this storage would be used early in the dry season to augment streamflow during the spawning of the Clear Lake Hitch then the estimated average water available for groundwater recharge would be about 786 acre-ft. Further, allowing for conveyance losses in the stream channel due to evaporation the net amount of yield available for groundwater recharge is estimated to be about 750 acre-feet.

Environmental studies have determined that there is potential for presence of special status plant and animal species on the banks of the reservoir that would be affected by changes in reservoir operation. Mitigation measures are proposed.

The proposed project would enhance downstream fish habitat by providing regulating storage during spring to enhance flow conditions for spawning of the Clear Lake Hitch - a species of special concern. Augmentation of flow



during summer in lower Highland and Adobe Creeks will also increase riparian and aquatic habitat.

The estimated capital cost of the project is \$800,000 and the estimated incremental annual operation and maintenance cost is estimated to be \$8,860/year comprised of \$6,560/year operation and maintenance costs and \$2,300/year water purchase costs. The estimated unit cost of conjunctive use yield (including fishery enhancement flows) is in the order of \$70/ac-ft. Comparative cost studies indicate that the cost of water from the project is economically attractive compared with estimated costs of water from other sources.

Implementation of the project is estimated to take 2 years. During the first year, activities would include environmental field surveys, agency consultation, acquisition of permits, producing final design drawings specifications and bid documents and exploring available grants and financing resources. In the second year, bids for supply and installation of equipment would be invited in spring and construction would occur in fall when the reservoir can be drawn down.

10.2 RECOMMENDATIONS

The following recommendations are submitted for consideration by the District:

1. ***Proceed with the Conjunctive Use Project*** The proposed project appears to be economically attractive compared to other water supply sources. The District should consider proceeding with permitting, design and implementation of the conjunctive use project.
2. ***Environmental Issues*** In accordance with the California Environmental Quality Act an Initial Study has been prepared and submitted separately for the District's consideration.
3. ***Water Rights*** Since the proposed modification to reservoir operations will result in storage of water for more than 30 days an application for a water rights permit should be prepared.
4. ***Dam Safety*** It is recommended that the District consult with the Division of Safety of Dams regarding the hazard classification of the dam to assist in determining criteria for estimating the spillway design flood. The safety of the dam should then be rechecked. If there is inadequate freeboard then the District could investigate either increasing the capacity of the emergency spillway or increasing the elevation of the crest of the dam. This dam safety issue is independent of the proposed conjunctive use project.



5. **Highland Springs Recreation Area** Plans for the proposed project should be incorporated into planning of Highland Springs Recreation Area. The proposed project will require modifications to the existing water intake that serves Highland Springs Park. The proposed water levels will also require some changes to parking and picnicking areas presently within the flood pool to accommodate higher water levels during summer. Planting of additional trees above the new summer shoreline could be carried out now to replace trees that may ultimately be inundated or otherwise affected by higher water levels. Any new trails constructed around the reservoir shoreline should be located above El.1470.
6. **Adobe Creek Reservoir** The District should also consider use of Adobe Creek Reservoir for groundwater recharge. This reservoir is smaller and would probably have less yield, however it would still probably be feasible and economically attractive. Since there is funding available through the California Water Bond it appears that the time is ripe to investigate and implement this project.
7. **Funding** The District should be prepared to submit applications for state funding of the project. The proposed project is generally consistent with California's goals of protecting ground water resources and improving water supplies. . The project also lies within the drainage basin that is tributary to the Sacramento-San Joaquin River Delta and the subject of the Cal-Fed process

In March 2000, California voters approved Proposition 13 (2000 Water Bond), which authorizes the State of California to sell \$1.97 billion in general obligation bonds to support safe drinking, water quality, flood protection and water reliability projects throughout the State.



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Appendix A

Updated Probable Maximum Flood

**PROBABLE MAXIMUM FLOODS
AT
HIGHLAND CREEK DAM**

Highland Creek, California

State of California Dam No. CA00828

Prepared for

**Lake County Flood Control and Water Conservation District
255 North Forbes Street
Lakeport, CA 95453**

Prepared by

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December 5, 2000

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PROBABLE MAXIMUM FLOODS

AT

HIGHLAND CREEK DAM

Highland Creek, California

1 INTRODUCTION

1.1 Purpose and Scope

This report summarizes the review, evaluation and the development of the probable maximum floods (PMF) for Highland Creek Dam in the Highland Creek basin of the Lake County Flood Control and Water Conservation District of Lake County, California. It presents basic hydrologic data concerning the dam and reservoir and describes the derivation and development of the probable maximum floods flowing into the reservoir. The report assembles the various hydrologic data, information, and bases of assumptions used in the determination of the probable maximum floods (PMF) at Highland Creek Dam.

Two types of probable maximum floods are derived in this report: one is the probable maximum flood caused by a general-type probable maximum precipitation and the other is caused by the probable maximum thunderstorm precipitation. Since the dam and its watershed are located below the snowline of the area, snowmelt was not included in the study.

1.2 Authorization

The hydrologic analysis and subsequent preparation of this report was initiated in response to a request from Mr. Harry Jackson, Chief Engineer, Christensen and Associates, to review the and reevaluate the probable maximum floods at Highland Creek Dam using updated parameters and criteria currently in use and acceptable to the California Division of Safety of Dams (DSOD). The request was authorized under Subcontract Agreement by and between

Christensen Associates, Inc. and Catalino B. Cecilio, Consulting Engineer, executed on September 11, 2000.

1.3 Previous Studies and Reports

Previous estimates of the probable maximum precipitation were tabulated in a report prepared by Mr. Edward J. Schmit dated January 6, 1995 (1). The 24-hr storm was estimated for the months of October, November, December, January-February, March and April. The storms were apparently estimated using the superseded Hydrometeorological Report No. 36, "Interim Report, Probable Maximum Precipitation in California." The report indicated that the PMP hydrographs were routed through the existing structure, but no summary of the routing was tabulated in the report.

1.4 Methods of Current Investigations

The probable maximum precipitation (PMP) is derived in accordance with the criteria of the U.S. National Weather Service Hydrometeorological Report (HMR) No. 58 (2) and No. 59 (3). The theoretical storms are converted to flows using the unit hydrograph and uniform loss technique with the aid of the computer program HEC-1 (4).

1.5 Description of Project

Highland Springs Reservoir is formed by the Highland Creek Dam which is an embankment dam constructed in 1962. Table 1 shows the physical characteristics of the dam.

The dam is within Highland Springs, California 7½-minute U.S.G.S. topographic quadrangle map, scale 1:24,000.

Table 1
Pertinent Data
Highland Creek Dam

General

Name of Dam	Highland Creek Dam
Stream	Highland Creek
Drainage Area	14.15 sq mi

Dam

Type	Earthfill
Elevation of Crest	1,497.0 ft
Maximum Height	75 ft
Length of Crest	625 ft

Reservoir

Normal Maximum W.S. Elevation	1,462.5 ft (crest of principal spillway)
Maximum Storage	3,500 ac ft (crest of emergency spillway)
Maximum Area	146 ac (at crest of emergency spillway)

Spillway

Principal Spillway:

Crest Elevation	1,462.5 ft
Dimension of Vertical Conduit Section	4' x 8' rectangular drop inlet
Type	Drop Inlet Structure
Gates	None (Retrofit with 6-3'x3' slide gates is proposed)

Emergency Spillway:

Crest Elevation	1,485.0 ft
Total Crest Length	75 ft
Type	Trapezoidal open channel
Gates	None

Note: All elevations are in the National Geodetic Vertical Datum (NGVD).

2 PROBABLE MAXIMUM FLOOD

2.1 General

The term probable maximum flood (PMF), as used in the official documents of the Corps of Engineers, identifies estimates of hypothetical flood characteristics (peak discharge, volume, and hydrograph shape) that are considered to be the most severe “reasonably possible” at a particular location, based on relatively comprehensive hydrometeorological analyses of critical runoff-producing precipitation (and snowmelt, if pertinent) and hydrologic factors favorable for maximum flood runoff. This type of flood is generally used as a spillway design flood for reservoirs impounding large quantities of water and constructed above a populated community and where failure from overtopping cannot be tolerated. The probable maximum flood is also defined by the Bureau of Reclamation, the Corps of Engineers and the Federal Energy Regulatory Commission as the flood that is derived from appropriate hydrometeorological reports prepared by the National Weather Service.

The PMF determination for the basin was prepared by estimating the areal distribution of the probable maximum precipitation (PMP) over the 14.15 sq-mi drainage basin of Highland Creek Dam. Excess runoff from the critically arranged precipitation was modeled by the unit hydrograph to produce inflow into the basin. The basin flow is determined using the U.S. Army Corps of Engineers computer program HEC-1 (4).

2.2 Probable Maximum Precipitation (PMP)

The probable maximum precipitation (PMP) is the theoretically greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year. (This definition is a 1982 revision of that used previously (American Meteorological Society 1959); and results from mutual agreement among the National Weather Service, the U.S. Army Corps of Engineers, and the Bureau of Reclamation.) No recurrence interval is assigned to the PMP.

For the area under study, PMP estimates are of two types: one is the general-type storm; and the other is the convective type or local thunderstorm.

2.2.1 General-Type PMP

Basin-mean probable maximum precipitation for the 14.15-sq-mi drainage was developed in accordance with the criteria presented in the National Weather Service Hydrometeorological Report No. 58 (2). The frontal-type general storm is calculated for the months from January through December. The estimate of a PMP extends to a 72-hr duration.

Table 2 presents the calculated PMP for each PMP months in the study area.

Table 2
Depth-Duration Table
Probable Maximum Precipitation Estimates
Highland Creek Dam

Month	Duration (hr)									
	1	6	12	18	24	30	36	48	60	72
Oct-Mar	2.69	9.34	15.38	18.62	21.75	24.75	26.83	30.20	32.85	34.94
April	1.94	6.64	10.89	13.01	14.64	16.20	17.71	20.62	22.32	23.67
May	1.43	4.87	7.88	9.37	10.45	11.46	12.45	14.10	15.11	15.65
June	1.22	4.01	6.42	7.45	8.35	9.22	10.05	10.92	11.45	11.79
July	1.06	3.51	5.62	6.61	7.31	7.98	8.52	9.54	10.01	10.32
August	1.00	3.41	5.52	6.51	7.31	8.05	8.68	9.73	10.46	10.96
September	1.94	6.64	10.89	13.01	14.64	16.20	17.71	20.62	22.32	23.67

2.2.1.1 Time Distribution

To produce a reasonably critical flood hydrograph from the probable maximum precipitation, it is necessary to specify the time sequence of the precipitation. However, time distribution was not studied in HMR 58. Instead the report made a recommendation of arranging the 72-hr PMP similar to the recommended precipitation pattern from the previous "Interim Report, Probable Maximum Precipitation in California," Hydrometeorological Report No. 36, October 1961 with Revisions of October 1969(5). Based on experience on the most reasonable pattern, this study adopted the time distribution similar to the sequence shown in Figure 7.3(c) of HMR 36. The maximum one hour precipitation occurs in the 40th hour and the maximum 6-hour precipitation from the 37th to the 42nd hour.

2.2.1.2 Antecedent Storm

Based on historical storms in the basin, it is possible to have antecedent storms occurring before the major flood producing winter storms. This meteorological sequence is therefore applicable to studies involving PMP estimate in the area. However, as a general rule, the critical PMP in a small basin results primarily from extremely intense small-area storms, whereas in large basins the PMP usually results from a series of less intense large-area storms. Therefore, because of this characteristic, no antecedent flood was routed through Highland Creek Dam.

2.2.1.3 Antecedent Snowpack and Snowmelt

Because of the elevation of the drainage basin of Highland Creek Dam, antecedent snowpack or coincident snowmelt was not assumed for all the PMP events.

2.2.2 Local PMP

Intense localized thunderstorms during the summer season have produced the greatest observed short-duration rainfalls over small areas in the study area. HMR 49 (6) indicates that the greatest frequency of occurrence of local storms in the area occur in spring or fall.

The thunderstorm PMP estimate for the Highland Creek Dam watershed is also calculated from HMR 58 and is shown in Table 3.

Table 3
Depth-Duration Table
Thunderstorm PMP Estimate
Highland Creek Dam

Duration (hrs)	1/2	1	2	3	4	5	6
Depth (in)	3.66	4.93	5.67	5.89	6.02	6.11	6.19

2.3 Runoff Model (Unit Hydrograph)

To transform the rainfall excess to runoff, the unit hydrograph approach was used. The unit hydrograph, which was introduced by Sherman in 1932 (7) has been shown to be a practical tool for converting rainfall excess to direct runoff. It is defined as the hydrograph of storm

runoff at a given point that will result from an isolated event of rainfall excess occurring within a unit of time and spread in an average pattern over the contributing area. Rainfall excess is that portion of the rainfall that enters the stream channel as storm runoff. A “unit of time” is an interval that is brief enough so that fluctuations of the intensity of rainfall during the interval will not materially affect the shape of the resulting hydrograph (7).

The unit hydrograph for the watershed above Highland Creek Dam was taken directly from the HEC-1 runoff model developed by the California Department of Water Resources in 1999 (8).

2.4 Loss Rates

Similarly, the loss rates for the basin were adopted from the California Department of Water Resources study (8). An initial and uniform loss of 0.10 inch was assumed for all the general-type probable maximum precipitation events.

The initial loss of 0.15 inch and uniform loss of 0.13 inch were assumed for the basin during the thunderstorm event. This is based on an assumption that the infiltration rate during the occurrence of a thunderstorm is much greater than during the occurrence of the general-type PMP. It is also based on the concept that thunderstorms generally occur during the season when the ground is almost dry.

2.5 Base Flow

The base flow used for all the current study was adopted from the California Department of Water Resources study (8). The study assumed a starting flow of 5 cfs per square mile at the start of the storm.

2.6 Probable Maximum Flood Flow

Theoretically, there is one probable maximum flood (PMF) estimate for each probable maximum precipitation (PMP) estimate. Since there are 12 PMP months, there are also 12 PMF months for the general-type of PMP. In addition, there is also the PMF that is produced by the thunderstorm PMP over the drainage area. The occurrence of the thunderstorm PMF in the area could be during the months of spring and fall.

The probable maximum flood flow component for the basin was computed using the PMP estimate for each month and the unit hydrograph of the basin. Loss rates were subtracted from the total storm to produce rainfall excess.

The PMF peak inflows for the 12 PMP months and the thunderstorm PMP are shown in Table 4.

2.7 Flood Routing under Existing Condition

The twelve months (January through December) of PMFs and the thunderstorm PMF were routed through Highland Creek Reservoir to determine the maximum lake surface levels and duration of dam overtopping occurring during the PMFs. The routing was performed using spillway rating data for the existing configuration of the principal and emergency spillways and including dam overtopping discharge.

The antecedent reservoir level was assumed to be at normal maximum elevation at Elev 1,462.5 ft with the gates opened at the beginning of all the floods.

The results of the routing are summarized in Table 4. The results of the routing shows that the October-March PMF produced the highest peak inflow and outflow. The October-March PMF is the controlling PMF for the dam because it produces an overtopping of 1.3 ft above the dam.

Figure 1 shows a plot of the routing of the controlling October-March PMF. The routing of the thunderstorm PMF did not produce an overtopping but it is shown in Figure 2 as a separate plot because the event is considered different from the general-type PMP.

2.8 Flood Routing under Proposed Condition

It is proposed to install slide gates on the principal spillway and modify the operating procedures for Highland Springs Reservoir to provide conservation storage for ground water recharge. A second set of flood routing was therefore performed to determine the effects of the modified operation upon the PMF flood routing. The antecedent reservoir level was assumed to be at the bottom of the proposed flood pool Elev 1,470.0 ft with the gates opened at the beginning of all the floods.

The results of the routing are summarized in Table 5. The results of this routing show that the higher starting reservoir water surface has minor effect on the maximum water surface level reached during the PMF.

Table 4
Summary of Flood Routing
Highland Creek Dam
Antecedent Reservoir Level at Elev 1,462.5 ft

Study Item (Storm/Flood)	Duration of Storm (hrs)	Depth of Storm (in)	Inflow		Reservoir			Overtop (ft)	Freeboard (f.)
			Peak (cfs)	5-day Volume (ac-ft)	Peak Outflow (cfs)	Peak Storage (ac-ft)	W. S. Elevation (ft)		
General Storm PMP:									
October-March	72	34.94	17,330	21,740	17,100	5,620	1,498.3	1.3	
April	72	23.67	11,950	13,460	9,800	5,260	1,496.3		0.7
May	72	15.65	8,120	8,120	5,760	4,600	1,492.5		4.5
June	72	11.79	6,830	5,900	3,500	4,280	1,490.3		6.7
July	72	10.32	5,890	5,000	2,410	3,980	1,488.4		8.5
August	72	10.96	5,650	5,030	2,360	3,960	1,488.2		8.3
September	72	23.67	11,950	13,460	9,800	5,260	1,496.3		0.7
Thunderstorm PMP	6	6.19	14,720	-----	2,600	4,040	1,488.8		8.2

Note: 1. The antecedent reservoir level for routing all the PMP was assumed to start Elev 1462.5 ft.

Table 5
Summary of Flood Routing
Highland Creek Dam
Antecedent Reservoir Level at Elev 1,470 ft

Study Item (Storm/Flood)	Duration of Storm (hrs)	Depth of Storm (in)	Inflow		Reservoir			Overtop (ft)	Freeboard (ft)
			Peak (cfs)	5-day Volume (ac-ft)	Peak Outflow (cfs)	Peak Storage (ac-ft)	W. S. Elevation (ft)		
			General Storm PMP:						
October-March	72	34.94	17,330	21,740	17,100	5,620	1,498.3	1.3	
April	72	23.67	11,950	13,460	9,900	5,280	1,496.4		0.6
May	72	15.65	8,120	8,120	6,480	4,700	1,493.3		3.7
June	72	11.79	6,830	5,900	4,780	4,460	1,491.6		5.4
July	72	10.32	5,890	5,000	3,370	4,260	1,490.2		6.8
August	72	10.96	5,650	5,030	3,260	4,250	1,490.0		7.0
September	72	23.67	11,950	13,460	9,900	5,280	1,496.4		0.6
Thunderstorm PMP	6	6.19	14,720	-----	3,760	4,320	1,490.6		6.4

Note: 1. The antecedent reservoir level for routing all the PMP was assumed to start Elev 1,470.0 ft.

3 CONCLUSIONS

3.1 General

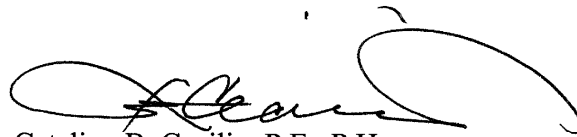
The methods employed in deriving the hypothetical floods for Highland Creek Dam conform to the current practice in hypothetical flood determination. The use of the recently released Hydrometeorological Reports Nos. 58 and 59 from the National Weather Service and the use of the most acceptable computer model HEC-1 makes the current PMF studies more up-to-date.

3.2 Conclusions

Tables 4 and 5 show that the routing of all the probable maximum floods have an amount of overtop equal to 1.3 ft at the Highland Creek Dam during the critical months from October through March.

CERTIFICATION

I hereby certify that this report was prepared by me and that I am a duly certified Professional Hydrologist, under the rules and regulations of the American Institute of Hydrology. I am also a Professional Engineer in the State of California.



Catalino B. Cecilio, P.E., P.H.
Consulting Engineer
Professional Hydrologist
Certificate No. 487
Certified by the American Institute of Hydrology



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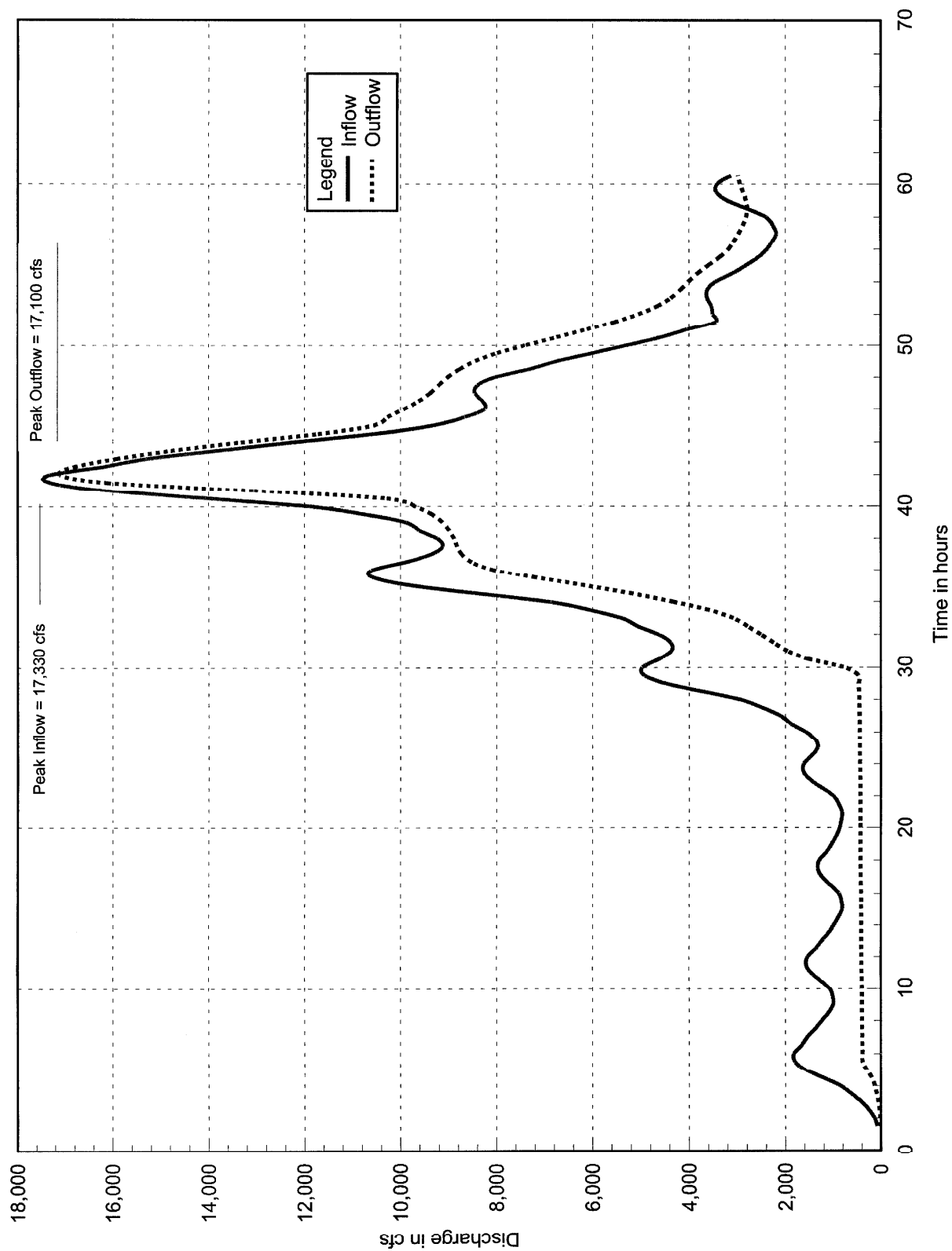


FIGURE 1: ROUTING OF THE OCTOBER-MARCH PMF

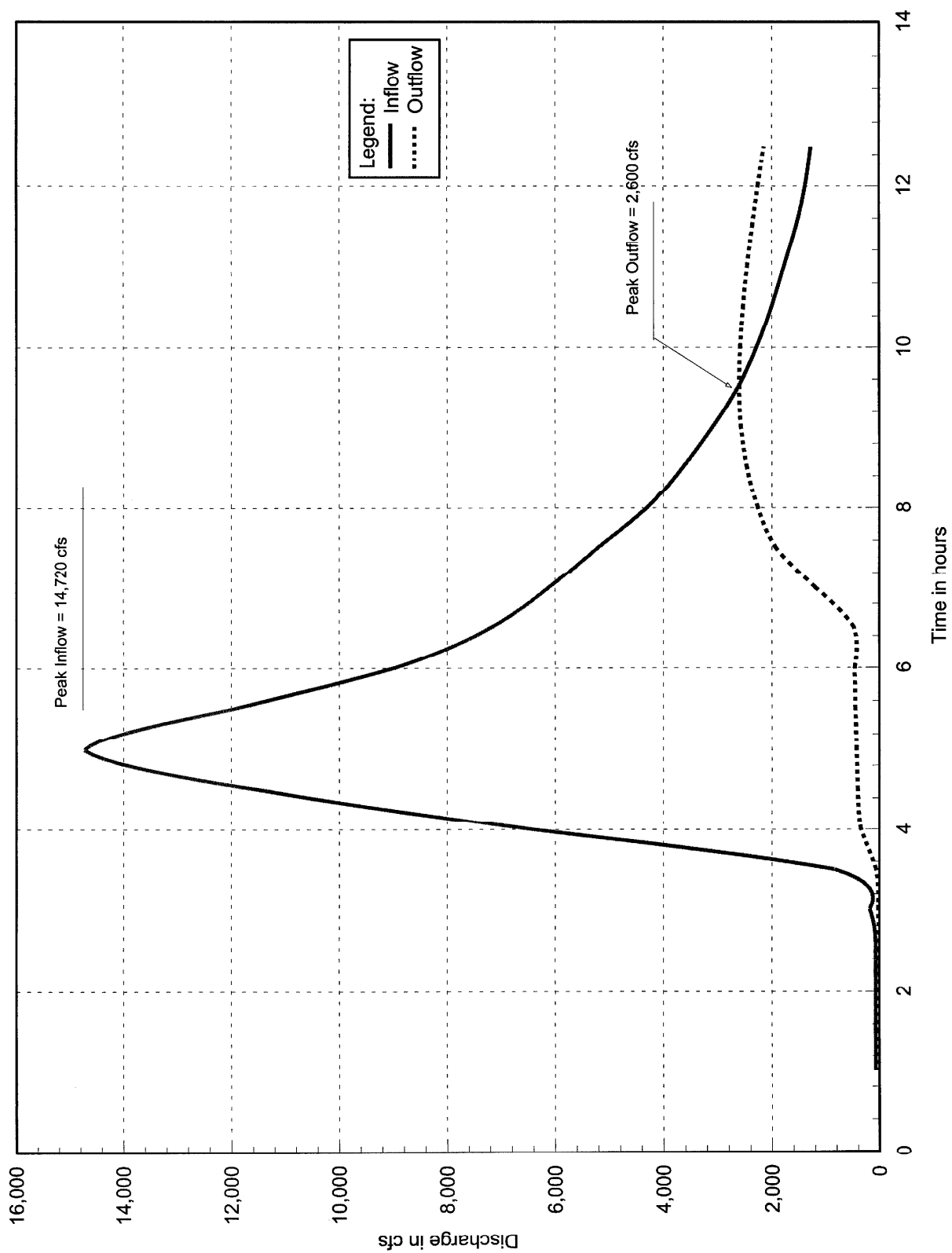


FIGURE 2: ROUTING OF THE THUNDERSTORM PMF



Appendix B

100 Year Flood Routing Studies

SUMMARY REPORT
ROUTING OF THE FLOOD FROM THE 100-YR, 24-HR STORM
AT
HIGHLAND CREEK DAM

Highland Creek, California

State of California Dam No. CA00828

Prepared for

Lake County Flood Control and Water Conservation District
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Lakeport, CA 95453

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Summary Report
Routing of the Flood from the 100-yr, 24-hr Storm
at
Highland Creek Dam
Highland Creek, California

1 INTRODUCTION

1.1 Purpose and Scope

This report summarizes the review, evaluation and the development of the flood from a 100-yr, 24-hr storm for Highland Creek Dam in the Highland Creek basin of the Lake County Flood Control and Water Conservation District of Lake County, California. It presents basic hydrologic data concerning the dam and reservoir and describes the derivation and development of the flood flowing into the reservoir. The report assembles the various hydrologic data, information, and bases of assumptions used in the determination of the flood from the 100-yr, 24-hr storm at Highland Creek Dam.

Since the dam and its watershed are located below the snowline of the area, snowmelt was not included in the study.

1.2 Authorization

The hydrologic analysis and subsequent preparation of this report was initiated in response to a request from Mr. Harry Jackson, Chief Engineer, Christensen and Associates, to review the and reevaluate the flood from the 100-yr storm at Highland Creek Dam using updated parameters and criteria currently in use and acceptable to the California Division of Safety of Dams (DSOD). The request was authorized under Subcontract Agreement by and between Christensen Associates, Inc. and Catalino B. Cecilio, Consulting Engineer, executed on September 11, 2000.

1.3 Previous Studies and Reports

Previous estimate of the flood from the 100-yr, 24-hr storm was included in a report prepared by the California Department of Water Resources (DWR), Division of Planning and Local Assistance, Central District, dated June 6, 1999 (1) for use in flood insurance studies. The 100-yr storm was derived by DWR in accordance with the criteria from the National Weather Service, NOAA Atlas No. 2, Volume XI – California, “Precipitation-Frequency Atlas of the Western United States,” 1973 (2).

The report included the input and output files from the Corps of Engineers computer program “Flood Hydrograph Package, HEC-1”. These files were used as reference to the current study.

1.4 Methods of Current Investigations

The 100-yr, 24-hr storm used for this current investigation adopted the estimate prepared by the Department of Water Resources in their 1999 study (1) since the values were estimated from the National Weather Service NOAA Atlas No. 2.

The theoretical storm is converted to flows using the unit hydrograph and uniform loss technique with the aid of the computer program HEC-1 (3).

1.5 Description of Project

Highland Springs Reservoir is formed by the Highland Creek Dam which is an embankment dam constructed in 1962. Table 1 shows the physical characteristics of the dam.

The dam is within Highland Springs, California 7½-minute U.S.G.S. topographic quadrangle map, scale 1:24,000.

Table 1
Pertinent Data
Highland Creek Dam

General

Name of Dam	Highland Creek Dam
Stream	Highland Creek
Drainage Area	14.15 sq mi

Dam

Type	Earthfill
Elevation of Crest	1,497.0 ft
Maximum Height	75 ft
Length of Crest	625 ft

Reservoir

Normal Maximum W.S. Elevation	1,462.5 ft (crest of principal spillway)
Maximum Storage	3,500 ac ft (crest of emergency spillway)
Maximum Area	146 ac (at crest of emergency spillway)

Spillway

Principal Spillway:

Crest Elevation	1,462.5 ft
Dimension of Vertical Conduit Section	4' x 8' rectangular drop inlet
Type	Drop Inlet Structure
Gates	None <i>(Retrofit with 6-3'x3' slide gates is proposed)</i>

Emergency Spillway:

Crest Elevation	1,485.0 ft
Total Crest Length	75 ft
Type	Trapezoidal open channel
Gates	None

Note: All elevations are in the National Geodetic Vertical Datum (NGVD).

2 FLOOD FROM THE 100-YR, 24-HR STORM

2.1 100-YR, 24-HR STORM

As mentioned earlier, the 100-yr, 24-hr storm was derived from the National Weather Service NOAA Atlas No. 2, Volume XI – California, “Precipitation-Frequency Atlas of the Western United States,” 1973. The mean depth of the 100-yr, 24-hr storm over the basin was estimated by DWR to be 6.64 inches.

2.2 Time Distribution

To produce a reasonably critical flood hydrograph from the 100-yr, 24-hr storm, it is necessary to specify the time sequence of the precipitation. The DWR study adopted the Type 1A distribution recommended by the Natural Resources Conservation Service (formerly, Soil Conservation Service) as the most appropriate time distribution for the 100-yr, 24-hr storm. The current study also adopted the same time distribution.

2.3 Antecedent Storm

No antecedent storm was assumed prior to the occurrence of the 100-yr, 24-hr storm. However, it was assumed that the reservoir was at their normal maximum reservoir levels.

2.4 Runoff Model (Unit Hydrograph)

The runoff model used in this study is the same as the one used in the DWR study. No change was made. As a matter of fact the input data from the HEC-1 model was used in this study.

The U. S. Army Corps of Engineers computer program, “Flood Hydrograph Package, HEC-1” was used to apply the runoff model of the basin.

2.5 Loss Rates

The loss rates for this study adopted those that were used by DWR for the 100-yr storm. The study assumed an initial loss of 0.1 inch and a uniform loss rate of 0.1 inch/hour for the basin during the occurrence of the storm.

2.6 Routed Flood Flow

The flood flow component for the basin was computed using the areally distributed storm estimates and the unit hydrograph of the basin. Loss rates were subtracted from the total storm to produce rainfall excess. The computer program HEC-1 was used in routing the flood.

Table 2 shows a summary of the flood routing through the reservoir. Two antecedent reservoir levels were evaluated for this routing study.

Table 2
Summary of Routing the Monthly 100-yr, 24-hr Storm
Under Existing Condition and Proposed Flood Pool Elevation
Highland Creek Dam

Month of Storm	Depth of Storm (in)	Peak Inflow (cfs)	Starting W.S. Elev 1,462.5		Starting W.S. Elev 1,470.0	
			Peak Outflow (cfs)	Reservoir W.S. Elev (ft)	Peak Outflow (cfs)	Reservoir W.S. Elev (ft)
October	2.90	1,430	390	1,467.8	400	1,474.7
November	5.49	3,370	450	1,479.7	540	1,485.1
December	6.64	4,240	680	1,485.3	1,670	1,486.9
January	6.49	4,130	480	1,485.0	1,550	1,486.7
February	6.14	3,860	460	1,483.1	1,240	1,486.2
March	5.00	3,000	440	1,477.3	460	1,482.8
April	2.82	1,380	392	1,467.5	380	1,474.4
May	1.26	320	130	1,463.6	80	1,471.0
June	0.74	120	70	1,463.1	70	1,470.8
July	0.20	70	70	1,463.1	70	1,470.8
August	0.46	70	70	1,463.1	70	1,470.8
September	0.94	170	80	1,463.2	70	1,470.8

Note: 1. All routings assumed that the spillway gates would be fully opened at the start of the storm.
2. Monthly 100-yr, 24-hr storms were interpolated from rainfall-depth-duration frequency estimates made for the precipitation gage at Lakeport (NWS No. 4701) using methods by JDGoodridge, developed in the Department of Water Resources, California.

CERTIFICATION

I hereby certify that this report was prepared by me and that I am a duly certified Professional Hydrologist, under the rules and regulations of the American Institute of Hydrology. I am also a Professional Engineer in the State of California.



Catalino B. Cecilio, P.E., P.H.
Consulting Engineer
Professional Hydrologist
Certificate No. 487
Certified by the American Institute of Hydrology



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1. Department of Water Resources, "Estimate of the 500-Year, 100-Year, 50-Year, and 10-Year Event Discharges for the following streams in Lake County: Adobe Creek, Highland Creek and Schindler Creek," 1999
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