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# TECHNICAL MEMORANDUM

**TO:** Doug Johnson – Canyon Fuel Company **HCI-1787**

**FROM:** Roger Howell

**DATE:** September 23, 2002

**SUBJECT:** DRAFT – Evaluation of Water Balance for Electric Lake Reservoir

## EXECUTIVE SUMMARY

Low water levels in Electric Lake, PacifiCorp' s water-supply reservoir in upper Huntington Creek, more likely reflect reservoir management practices in recent years than, as suggested by PacifiCorp, a recent diversion of water into the Skyline Mine. PacifiCorp's own records show that as water levels have fallen over the last 4 years, more water has been discharged through the gates of the reservoir, relative to the measured precipitation in the drainage basin, than in any 4-year period in the reservoir' s history. The data indicate that in the current year (2002), there has been both a record rate of lake-level decline and a record high discharge volume relative to basin precipitation.

Measurements taken by PacificCorp in June 2002 show an imbalance between inflow to and outflow from Electric Lake, indicating a volume of "missing water" totaling about 12 cubic feet per second (cfs). The results of an independent analysis of the data conducted by Hydrologic Consultants, Inc. of Colorado (HCI) together with additional meteorological data strongly suggest that a water imbalance is not new to Electric Lake and most likely is attributable to water that has been leaking from the reservoir since it was constructed in 1974. A water balance calculation for the entire Upper Huntington Creek drainage basin shows that water has been flowing unmeasured out of the basin at a mean rate of about 11 cfs for the last 28 years. The water balance in any given year varies from the mean in response to more or less ground-water recharge and discharge and variations in the rate of evapotranspiration. A preliminary review of water-discharge records from nearby Scofield and Joes Valley Reservoirs indicates that these reservoirs (and their drainage basins) lose similar amounts of water to unmeasured outflow.

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## INTRODUCTION

This Technical Memorandum presents preliminary findings by Hydrologic Consultants, Inc. of Colorado (HCI) from our evaluation of discharge and water level data for the Electric Lake reservoir and meteorological data from stations within and near the Upper Huntington Creek drainage basin. The review was conducted by HCI at the request of Canyon Fuel Company (CFC) in response to inquiries by PacifiCorp regarding a possible relationship between current ground-water inflows to the Skyline Mine (Skyline) and a perceived loss of water from the Electric Lake reservoir.

During a meeting among CFC, HCI, and PacifiCorp at PacifiCorp' s offices near Huntington, Utah on 10 July 2002, PacifiCorp presented data on lake stage, discharge, and precipitation and some general observations and interpretations of the data. As part of the meeting, PacifiCorp provided CFC with the following data:

- Monthly stages for Electric Lake from November 1973 to May 2002 and a calculated storage-volume relationship,

- Monthly average discharge of Huntington Creek below Electric Lake Dam dam site, from January 1969 to May 2002,

- Precipitation from PacifiCorp' s gage below the dam site for the period October 1970 to July 2002, and

- Pan evaporation records from the weather station below the dam site from January 1969 to July 2002, and calculated lake evaporation from November 1973 to May 2002..

PacifiCorp did not provide any measurements of inflow to the reservoir prior to 20 June 2002 since no such historical records were kept.

For our evaluation, HCI used the above data provided by PacifiCorp together with the following additional data and information:

- Precipitation records from two other nearby weather stations from the National Water and Center, USDA,

- An estimate of evapotranspiration from the Global Hydrologic Archive and Analysis System (GHAAS) and consumptive use factors from the literature,

- Flow records from springs tributary to the lake, kept by Skyline, and
- Reports pertaining to dam construction and repair, from the Division of Dam Safety for the State of Utah.

## WATER BALANCE CALCULATED BY PACIFICORP

At the meeting on 10 July 2002, PacifiCorp asserted that the level of Electric Lake is unusually low in comparison to levels during other periods of drought even though discharge rates have remained essentially the same. Graphs were presented in support of their assertion which show the stage of the lake through time plotted with the absolute discharge rate and with a calculation of the Palmer Drought Index.

In addition, PacifiCorp reported that the measured inflow to and outflow from Electric Lake during the period 20 June to 30 June 2002 do not balance, indicating a difference of about 12 cubic feet per second (cfs). PacifiCorp calculates the imbalance, or so-called " missing water", by the following equation:

$$X = I_m - (\Delta S + D + Evap) \qquad (1)$$

where:

$X$ = missing water ($L^3$).
$I_m$ = measured inflow ($L^3$),
$\Delta S$ = change in lake storage ($L^3$),
$D$ = measured lake discharge ($L^3$), and
$Evap$ = evaporation from lake surface ($L^3$).

PacifiCorp has asserted that the circumstance of missing water is a recent and unique one and suggests that it may be related to recent mine inflows at Skyline Mine. However, results of a re-evaluation of the water-balance by HCI suggest that water has been " missing" throughout the history of the reservoir.

## EVALUATION OF PACIFICORP 'S ANALYSIS

HCI believes that the observations made by PacifiCorp are based on more or less accurate measurements (HCI, 2002a). However, a more comprehensive review and evaluation of the data, as described below, indicates that what PacifiCorp interprets to be anomalous conditions in late 2001 and early 2002 is more likely the normal historical pattern for Electric Lake and its drainage basin during periods of drought.

The long-term hydrologic and meteorological data do not support PacifiCorp' s assertion that lake levels are unusually low relative to discharge rates in similar periods of drought. HCI compared the rate at which water has been discharged from the lake in each of the last 28 years to the total yearly precipitation. Figure 1 is a plot of lake storage vs. computed total precipitation minus total discharge for each year. During this 28-year period, water levels in the lake have in fact risen when total precipitation exceeded lake discharge by about 30,000 acre-ft/year or more, and water levels have fallen during those times when the difference has been less than about 30,000 acre-ft/year.

Figure 1 demonstrates that low lake levels in 2001 and 2002 correspond to periods of high discharge relative to precipitation. Since 1999, on a yearly basis, precipitation has consistently exceeded discharge by less than 30,000 acre-ft, the only period that the values have remained below this benchmark for four successive years. Very low precipitation in 2002 follows a similarly dry year in 2001. This two-year period comprises the only instance in the history of the lake when precipitation minus discharge remained below 25,000 acre-ft in successive years. For all of 2002, precipitation is projected to exceed discharge by only 23,300 acre-ft. This will be the smallest excess since the lake began filling in 1974. Consequently, it should be expected that lake storage is at a record low level and is decreasing more rapidly than at any time since the lake was filled.

## RE-EVALUATION OF WATER BALANCE BY HCI

For a number of reasons, Equation 1 does not accurately describe a water balance for Electric Lake. First, there are virtually no data for the inflow component (before 20 June 2002). PacifiCorp attempted to use a " calculated inflow" (based on discharge, storage change, and evaporation) to compare other trends. Such a " calculated inflow" cannot be used in a water balance calculation because it is, by definition, a circular argument.

An additional difficulty in applying Equation 1 to a water balance for the reservoir is that the term for inflow, $I_m$, is too restricted. Not all inflow to the lake can be directly measured at the flume in Huntington Creek. It is apparent from HCI' s reconnaissance of the east shore of the lake that water seeps into the reservoir from ground-water storage. It is likely that additional inflow occurs from subsurface flow beneath the Huntington Creek channel and from bank storage as the lake level falls. These peripheral inflows are not readily visible and very difficult to quantify. By the same token, not all outflow can be measured by the discharge weir and evaporation pan.

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Consequently, HCI suggests using a more generalized water balance equation, one that balances water not just in the reservoir, but in the entire drainage basin above the dam:

$$Ppt + U_{in} = \Delta S_{gw} + \Delta S_l + D + Evap + Et + U_{out} \qquad (2)$$

where

$Ppt$ = measured total precipitation across the drainage basin ($L^3$),
$U_{in}$ = unmeasured water entering the basin ($L^3$),
$\Delta S_{gw}$ = change in ground-water storage ($L^3$),
$\Delta S_l$ = change in lake storage ($L^3$),
$D$ = measured discharge from basin ($L^3$),
$Evap$ = evaporation from lake surface ($L^3$),
$Et$ = evapotranspiration from total drainage basin ($L^3$), and
$U_{out}$ = unmeasured water leaving the basin ($L^3$).

Equation 2 simply states that all water entering the drainage basin is balanced by all water leaving the basin plus changes in storage. Equation 2 can be simplified with the assumption that over a sufficiently long period of time, ground-water recharge will balance ground-water discharge within the basin, so that the term for $\Delta S_{gw}$ becomes insignificant. Consequently, over a long period of time, it does not matter in the accounting whether the water flows to the lake via seasonal runoff, stream baseflow, ground-water seepage, or bank storage. Over this time, all water that enters the drainage basin by precipitation that is not subsequently removed by evapotranspiration will flow into the lake. Once in the lake, water will either evaporate or be discharged. Any imbalance constitutes unmeasured seepage out of the basin ($U_{out}$) and/or into the basin ($U_{in}$). To evaluate the so-called " missing water", $\Delta S_{gw}$ can be deleted and Equation 2 can be rearranged as:

$$(U_{out} - U_{in}) = Ppt - (Et + \Delta S_l + D + Evap) \qquad (3)$$

where the combined value $(U_{out} - U_{in})$ is the net unmeasured flow through the basin, or in other words, the missing water. A positive value for $(U_{out} - U_{in})$ would indicate net flow out of the basin, whereas a negative value would indicate a net gain from inter-basin ground-water flow. Values for the parameters are discussed below.

## Precipitation

The precipitation recorded at the Electric Lake weather station, located at the base of the dam, is not sufficiently representative of precipitation in the basin above the station to be used in water balance calculations. The Electric Lake station lies at an elevation of 8,400 ft (NGVD), an elevation significantly lower than all other areas of the drainage basin. Figure 2 shows the average precipitation measured at the Electric Lake weather station vs. the average precipitation measured over similar periods (1978 to 2001) at two nearby stations. The two nearby stations, Mammoth-Cottonwood and Red Pine Ridge, lie at elevations of 8,800 and 9,200 ft, respectively. Figure 2 indicates that the average precipitation increases almost linearly with elevation and is about 33 percent higher at the 9,200 ft station than at the Electric Lake station. These data demonstrate a strong orographic influence on precipitation rates and suggest that more water has been entering the drainage basin over the years than would be calculated based on the Electric Lake weather station data.

Because the average elevation of the drainage basin is 9,200 ft (i.e., 49 percent of the area of the drainage basin lies above 9,200 ft), the precipitation data from the 9,200-ft station at Red Pine Ridge have been used in all of HCI' s calculations. Red pine Ridge data are available from August 1978 through September 2001. In order to look at the entire history of Electric Lake Reservoir, precipitation data for 1970 to 1978 and from 2001 to 2002 were synthesized by linear regression on the full Electric Lake data set.

The measured and synthesized Red Pine Ridge data show that since August 1974 (the start of the 1975 water year, the first full year of lake filling) precipitation has averaged about 30.3 inches per year, and over the 19,730 acre basin has totalled more than 1.41 million acre-ft (Table 2).

## Evapotranspiration

The U.S. Hydrologic (GHAAS) Database (Vorosmarty and Schloss, 2000) estimates a mean annual evapotranspiration (*Et*) of 15.4 inches per year for the area centered approximately on upper Winter Quarters Creek. The estimate is derived from eleven Potential Evapotranspiration factors as described in Vorosmarty and others (1998). The factors are obtained from weather station data and remote sensing measurements. The database estimate is not necessarily accurate for the purposes of this study because of the large area (20 miles by 30 miles) over which the Et factors were averaged.

Consequently, the GHAAS value for *Et* was checked by calculating a potential *Et* using consumptive use factors measured in field studies. The calculated value of Et is obtained from:

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$$Et = \frac{[(C_F + I_F + S_F) \cdot A_F] + [(C_G + I_G + S_G) \cdot A_G]}{(A_F + A_G)} \qquad (4)$$

where:

- $E_t$ = potential evapotranspiration per year (L/t),
- $C_F$ = consumptive use of water by forest land (L/t),
- $C_G$ = consumptive use of water by grass and sage land (L/t),
- $I_F$ = water intercepted by forest canopy (L/t),
- $I_G$ = water intercepted by grass/sage canopy (L/t),
- $S_F$ = winter sublimation from snow beneath forest (L/t),
- $S_G$ = winter sublimation from snow beneath grass/sage (L/t),
- $A_F$ = area of forested land ($L^2$), and
- $A_G$ = area of grass and sage land ($L^2$).

Consumptive use factors for the various plant groups were obtained from literature and are shown in Table 1. All consumptive use factors were estimated from summer soil-moisture depletion studies, and combine consumption with canopy interception. Johnston and others (1969) studied water consumption by various forest plant groups at 14 sites in the Wasatch Range. Croft and Monninger (1953) studied a single aspen plot in northern Utah, whereas Tew (1967 studied 6 aspen plots in central Utah at various elevations and aspects. Brown and Thompson studied water consumption by different plant groups on Black Mesa, Colorado, where foliage, elevations (9,000 to 10,000 ft) and precipitation rates (21 inches per year) are similar to the Huntington Creek area.

Croft and Monninger (1953) compiled the results of several snow sublimation (evaporation) studies in Utah and Colorado. The study conducted under conditions most similar to the Huntington Creek area found that about 2.2 inches sublimed from the snow surface during the period of snow cover. Finally, Croft and Monninger (1953) suggest adding approximately 1 inch to the total Et for all forests to account for transpiration by trees during the winter months.

HCI estimates that in the upper Huntington Creek drainage, forests cover approximately 65 percent of the drainage basin and sage/grassland covers approximately 35 percent. (Coverages were estimated by coloration on 7½minute USGS topographic maps, although this is not a particularly accurate form of differentiation.) HCI also estimates that aspen comprises about half of the forest cover, and spruce/fir comprises the remaining half. Using these coverage estimates with the average consumptive use values from the Utah and Colorado studies, and adding the sublimation estimate, Equation 4 yields an average potential evapotranspiration rate of 15.2 inches per year for the entire drainage basin.

A final check of Et was made by comparing the consumptive use results to actual basin water balance studies. Leaf (1975) reported the findings of 5 water balance studies in subalpine watersheds in Colorado and Wyoming. Precipitation in the study areas varied from 20 to 55 inches per year. Drainage basin forests consisted of aspen, fir, spruce, and lodgepole pine. The average Et of the 5 basins calculated by yearly water balance was 16.9 in/yr. However, the density of forest coverage was not reported for any of the study basins. In a separate study Leaf and Alexander (1975) reported the results of forest thinning projects in two experimental watersheds in Colorado. Et in the basins before thinning (essentially 100 percent forest cover) averaged 16.8 in/yr. After 40 percent of the forests were cut and replaced by low shrubs and aspen sprouts the Et averaged 14.6 in/yr. These water-balance comparisons show that the consumptive use value calculated above for the Huntington basin, 15.2 in/yr, is within a reasonable range for Et in western subalpine watersheds with partial forest cover.

Using the consumptive use value calculated above, the total average *Et* in the 19,730-acre basin (after subtracting the 430 acres of lake surface) was calculated to be 24,400 acre-ft/year. Since 1974, then, evapotranspiration has totalled nearly 0.7 million acre-ft. This comprises a large abstraction relative to yearly precipitation, and all of the following calculations were found to be sensitive to changes in the estimate of the *Et* rate. HCI recommends that any expansion of the current investigation include a more rigorous estimation of *Et*, especially a more precise estimate of plant-group coverage in Huntington Creek basin.

## Discharge

HCI field checked the methods used by PacifiCorp to measure discharge below the Electric Lake dam (HCI, 2002a). The flow rate measured by HCI on 17 July 2002 was about 12.4 cfs vs. about 13.1 cfs reported by PacifiCorp on 16 July 2002. The difference between the two values probably reflects the relatively low precision in the measuring method, but not necessarily a low degree of accuracy in either measurement. The distinction is very important when applying Equation 3 to a long-term water balance. If the measuring method is inaccurate (systematic in error), then in the long term errors would be cumulative, and a very large error in total discharge could be computed. Conversely, if the measuring method is merely imprecise, then random errors would tend to cancel in the long term.

The method used by PacifiCorp to measure discharge is regularly calibrated to a standard Natural-Section/Velocity-Area measurement using industry-verified flow-meter technology and is assumed to be reasonably accurate. PacifiCorp measures flow at only one location, however, so discharge could be under-estimated if underflow in the valley gravels is significant. To check that possibility, HCI measured flow rates at several points downstream of the PacifiCorp station (HCI, 2002a). No systematic changes in streamflow were found within ½mile below the dam, and HCI concludes that the discharge measurements provided by PacifiCorp are acceptable for the purposes of this study.

The records provided by PacifiCorp show that from August 1974 through July 2002, the discharge from Electric Lake reservoir totalled more than 483,000 acre-ft.

**Lake Storage and Evaporation**

HCI used PacifiCorp' s calculated values of storage without review. The total change in storage during the period August 1974 to July 2002 turned out to be slightly negative, because the lake had been partially filled by August 1974, and had dropped to near-record low levels in July 2002.

Lake evaporation values were also used as provided by PacifiCorp. HCI believes that there could be some error in PacifiCorp' s calculation of the values, based on the location of the pan below the dam (i.e., sheltered from wind and sun, and surrounded by grasses), and on the use of an untested pan/lake conversion factor. Nevertheless, the totals are sufficiently small (21,000 acre-ft) that even a large percentage change in the evaporation estimate would not significantly alter the outcome of the water balance.

**Unmeasured Water**

The unmeasured water in Equation 3 would consist of inter-basin flow into and out of the Electric Lake drainage basin, including leakage into and out of the reservoir. Except as described below, inter-basin flow, if it occurs and if it affects the water balance, would require a connection between the shallow and deep ground-water systems.

However, Mayo and Morris (2000) found that ground water in the Skyline Mine area is essentially separated into a shallow and a deep system in which the shallow system, including surface recharge and discharge is, for all practical purposes, independent of the deep system. Monitoring of water levels in deep and shallow wells support this disconnection of the two systems (HCI, 2002b). Figure 3 demonstrates the concept of disconnected shallow and deep ground-water systems where the shallow ground water is in communication with surface water and flows under the influence of local topography. Deep ground water neither affects discharge nor is affected by recharge. Figure 3 is consistent with the findings of Toth (1963) and Freeze and Witherspoon (1967) who describe ground-water flow in areas of pronounced local relief as being dominated by local, topographically defined cells. Regional flow systems (i.e., cells of deep flow across the well defined drainage basin divides) are generally subordinate.

Even though it is unlikely that deep inter-basin flow occurs at a rate that would significantly affect the surface water balance in the Electric Lake drainage basin, HCI believes that a small amount of shallow ground water might cross the local drainage divides. Numerous springs in a reach of Huntington Creek between James Canyon on the south and Little Swens Canyon on the north probably result from ground-water flow in shallow sandstones which crop out on the east side of the canyon in the Mud Creek drainage. Flow monitoring records from the springs in Huntington Canyon show that flow rates generally vary with precipitation rates on a near-annual basis. The flow variability is indicative of springs that are recharged from a shallow, nearby source. Nevertheless, as illustrated in Figure 3, some recharge to the sandstones might originate in the drainage to the east. A series of piezometers across the ridge could prove and quantify or disprove such inter-basin flow. However, for the purpose of this report, HCI assumes that no significant quantity of water enters the drainage basin from the east via the springs in upper Huntington Creek. As will be seen in the results of calculations below, this simplifying assumption is very conservative.

## CONCLUSIONS

Table 2 summarizes the results of the basin water balance calculated by HCI using the relationships in Equation 3. Over a period of 28 years, beginning with the 1975 water year, estimated inflows to the basin (precipitation) have exceeded estimated abstractions by over 225,000 acre-ft. The excess, about 15 percent of the total precipitation over the period, constitutes unmeasured flow of water from the basin, or essentially, missing water. The average loss rate, shown in Table 2, is about 11 cfs.

As described above, the basic assumption of Equation 3 -- that ground-water recharge balances ground-water discharge -is valid only over relatively long periods of time. Therefore, Equation 3 cannot be used to calculate an accurate basin water balance over short time periods (i.e., those of approximately three years or less). In addition, evapotranspiration is computed as an average, whereas in reality it will be somewhat higher in wet years and lower in dry years. During relatively wet years, Equation 3 will tend to exaggerate water " losses" as a consequence of both more water entering the shallow ground-water system (temporarily exiting the water balance) and actual Et rates slightly higher than the computed average. Conversely, during relatively dry years, the calculation will yield low or even negative water " losses", reflecting actual Et rates lower than the computed average and ground water re-emerging to the surface system at a rate that is high relative to the rainfall in that year. The resulting trend of higher apparent losses with higher precipitation can be seen in Figure 4, which plots the net water imbalance vs. precipitation, calculated on a yearly basis.

Figure 5 shows the net results of the water balance for each year from 1971 to present. Even though a water imbalance for any single year cannot accurately be estimated using the relationships in Equation 3, this plot clearly shows that water losses from the drainage basin are not a new phenomenon. Rather, some form of water imbalance has been occurring at least since the reservoir was first filled.

A preliminary look at water-discharge records of other reservoirs in the area shows that similar long-term water imbalances probably exist at the Scofield and Joes Valley reservoirs (HCI, 2002d). Based on rainfall records from the Electric Lake station (the average elevation of the Scofield drainage is approximately 8,400 ft) and assuming the same *Et* rate as for the Electric Lake drainage basin, Equation 3 suggests an average net loss of water from Scofield drainage basin since 1974 of about 32 cfs. (This " loss" must be decreased by the volume of water diverted through the Fairview ditch and the Narrows Tunnel.) A water balance for the Joes Valley drainage basin incorporates precipitation records from several stations within the basin and a computed potential Et rate using the factors described above. The Joes Valley water balance suggests that the drainage basin may be losing as much as 35 cfs.

## FATE OF WATER

HCI has not investigated the fate of water that is flowing unmeasured from the Electric Lake drainage basin. However, the most likely explanation of the long-term water imbalance is a systematic loss of water from Electric Lake reservoir itself. The average basin water imbalance in the 4 water years prior to the filling of Electric Lake was less than 4 cfs, compared to 11 cfs for the 28 years after filling the reservoir (Figure 5 and Table 2). As described above, 4 years may not be a sufficiently long period of time over which to obtain an accurate average water balance using Equation 3. However, other evidence is also suggestive of a leaky reservoir. According to Wahler Associates (1986), there was considerable leakage from the dam and sandstone abutments during the first five years of the reservoir that was at least partially mitigated by grouting. It is likely that the fractured sandstones underlying the lower end of the reservoir still provide a pathway for water to leak from the reservoir. Any theory addressing the fate of the water after it leaves the reservoir must account for leakage over decades and not just for the three years since ground water has been encountered in the Skyline Mine.

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Attachments: Figure 1 - Discharge from Electric Lake and Precipitation Data from Nearby Station
Figure 2 - Orographic Influence on Precipitation
Figure 3 - Possible Inter-Basin Ground-Water Flow in Upper Huntington Canyon
Figure 4 - Water Losses from Electric Lake vs. Precipitation
Figure 5 - Water Losses from Electric Lake 1971-2002
Table 2 - Water Balance of Electric Lake Drainage Basin 1970-2002

Table 1
Evapotranspiration at Huntington Drainage Calculated using Consumptive Use Factors

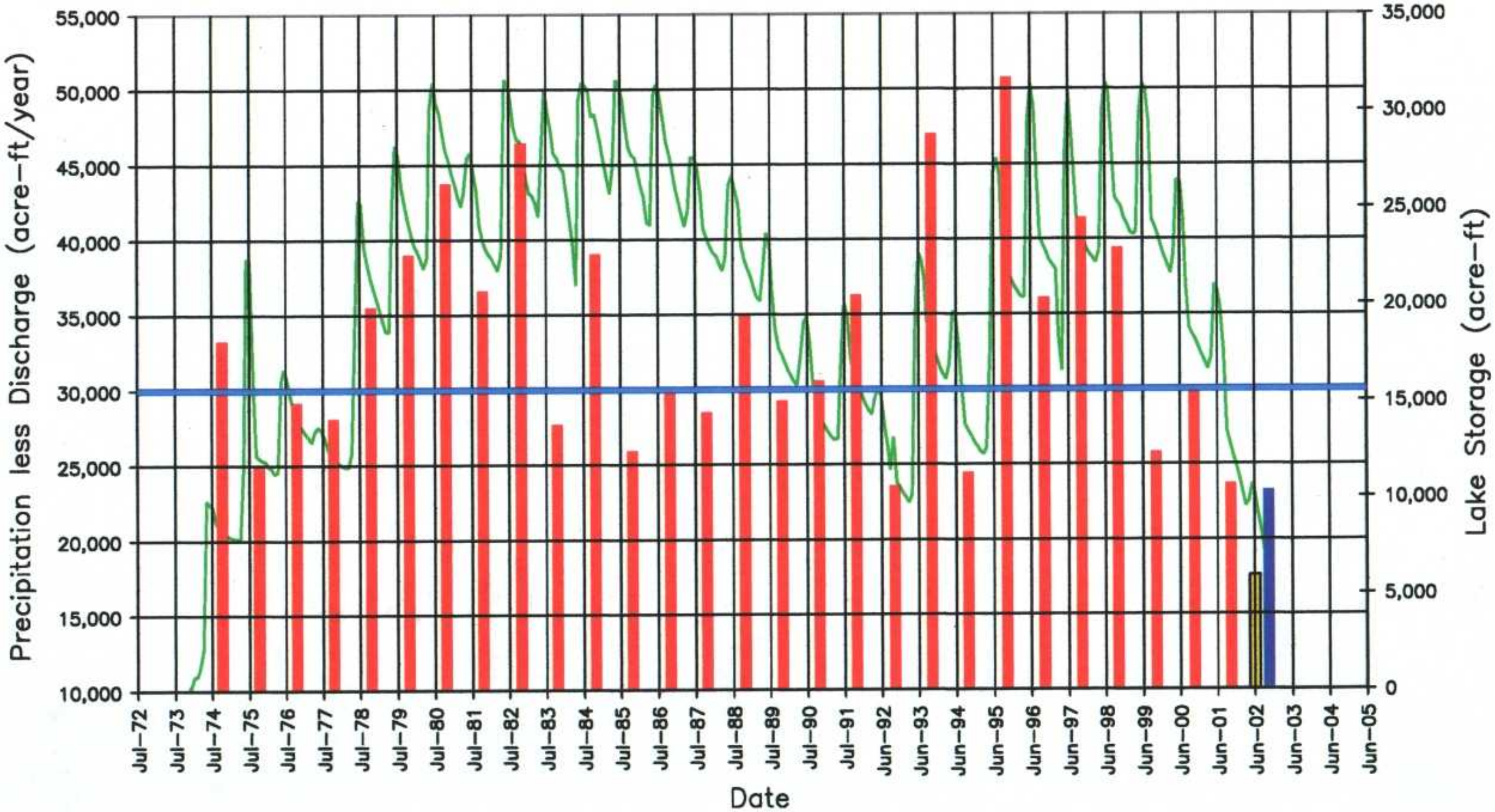
| Consumptive Use plus Canopy Interception, Growing Season only (inches) | | | | | | Plant coverage Huntington Drainage Basin | Snow Sublimation (in) | Winter |
|---|---|---|---|---|---|---|---|---|
| | Croft and Monninger, 1953 | Johnston, et al, 1969 | Brown & Thompson, 1965 | Tew, 1967 | Average Use | | | |
| Aspen | 17.7 (1 site) | 14.9 (average of 8 sites) | 19.2 (1 site) | 15.11 (6 sites) | 15.4 | 32.5% | 2.2 | 1.( |
| Spruce | | | 14.9 (1 site) | | 14.9 | 16.25% | | |
| Fir | | 12.8 (2 sites) | | | 12.8 | 16.25% | | |
| Mountain Sage/grassland | | 7.0 (1 site) | 8.9 (1 site) | | 8.0 | 35% | 2.2 | 0.( |
| | | | | Summer Et: | **12.3** | **Yearly Et:** | **15.2 inches t** | |

**Table 2**
**Water Balance of Electric Lake Drainage Basin 1970-2002**

| Parameter | Area (acre) | Pre-Lake: Oct-70 to Jul-74 (acre-ft) | Post-Lake: Aug-74 to Jul-02 (acre-ft) |
|---|---|---|---|
| Precipitation | 19,700 | 181,400 | 1,415,000 |
| Evapotranspiration | 19,300 | 91,600 | 685,000 |
| Change in Storage | - | 9,500[1] | -300[1] |
| Lake Evaporation | Variable | 175[1] | 21,300 |
| Discharge | - | 69,400 | 483,300 |
| Imbalance[2] (acre-ft) | - | **10,700** | **225,700** |
| Days | | 1,339 | 10,227 |
| "MissingWater" (cfs) | | **4.0** | **11.2** |

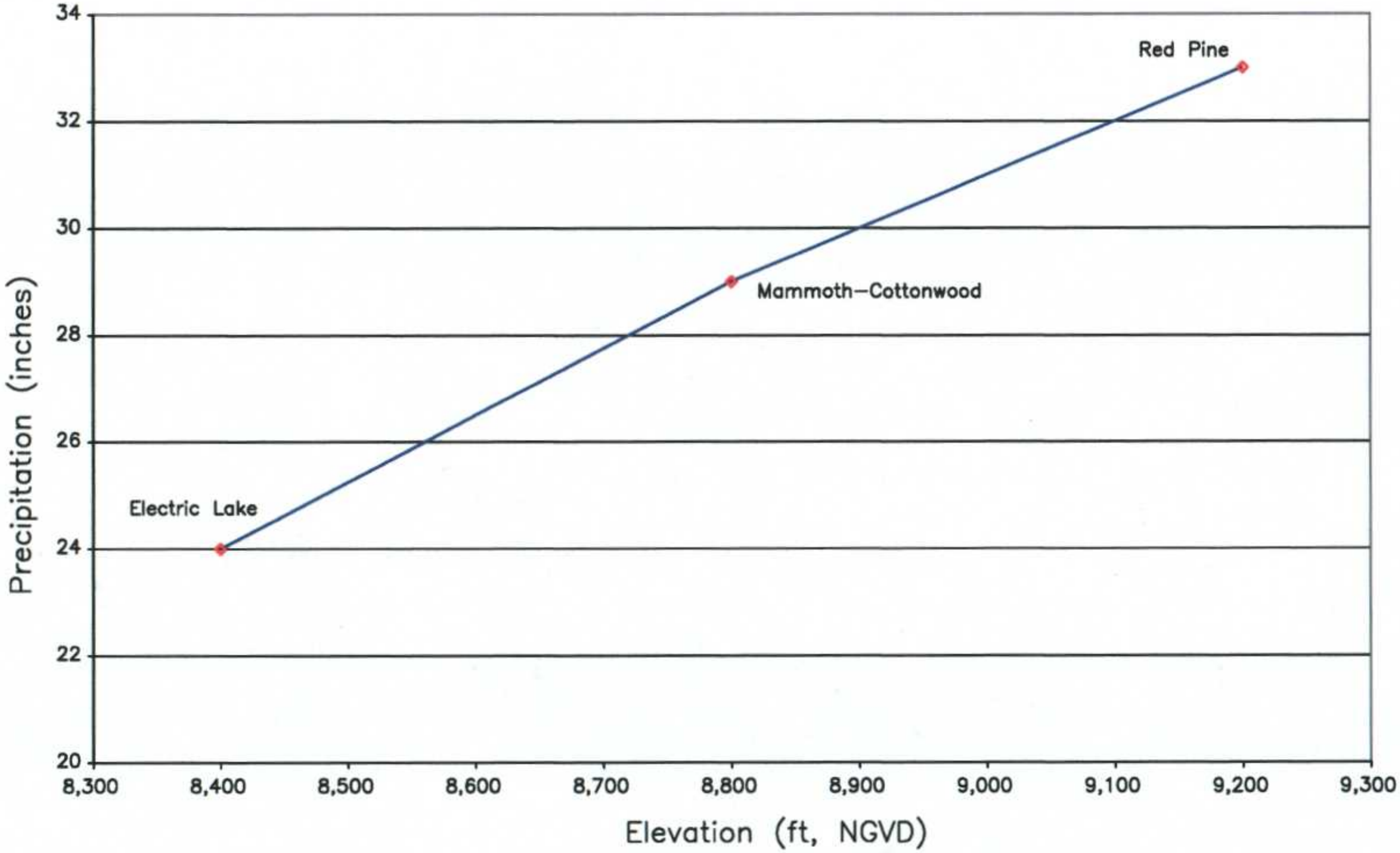
1) Lake began filling part way through the 1974 water year.

2) Defined by $(U_{out} - U_{in})$ in Equation 3 in text.




1. Precipitation/discharge values are computed from November through October.
2. Precipitation was calculated by multiplying total feet of rainfall at the Red Pine Ridge weather station by 19,730 acres

| HCI HYDROLOGIC CONSULTANTS, INC. | JOB NO. HCI-1787 | DATE: 8/19/02 | **Discharge from Electric Lake and Precipitation from Nearby Station** | FIGURE 1 |
|---|---|---|---|---|
| | BY: RLH | DWG FILE: GRAPH1 | | |
| | DRAWN: SAC | PLOT FILE: GRAPH1 | | |
| | CHECKED: | PLOT DATE: 8/23/02 | | |

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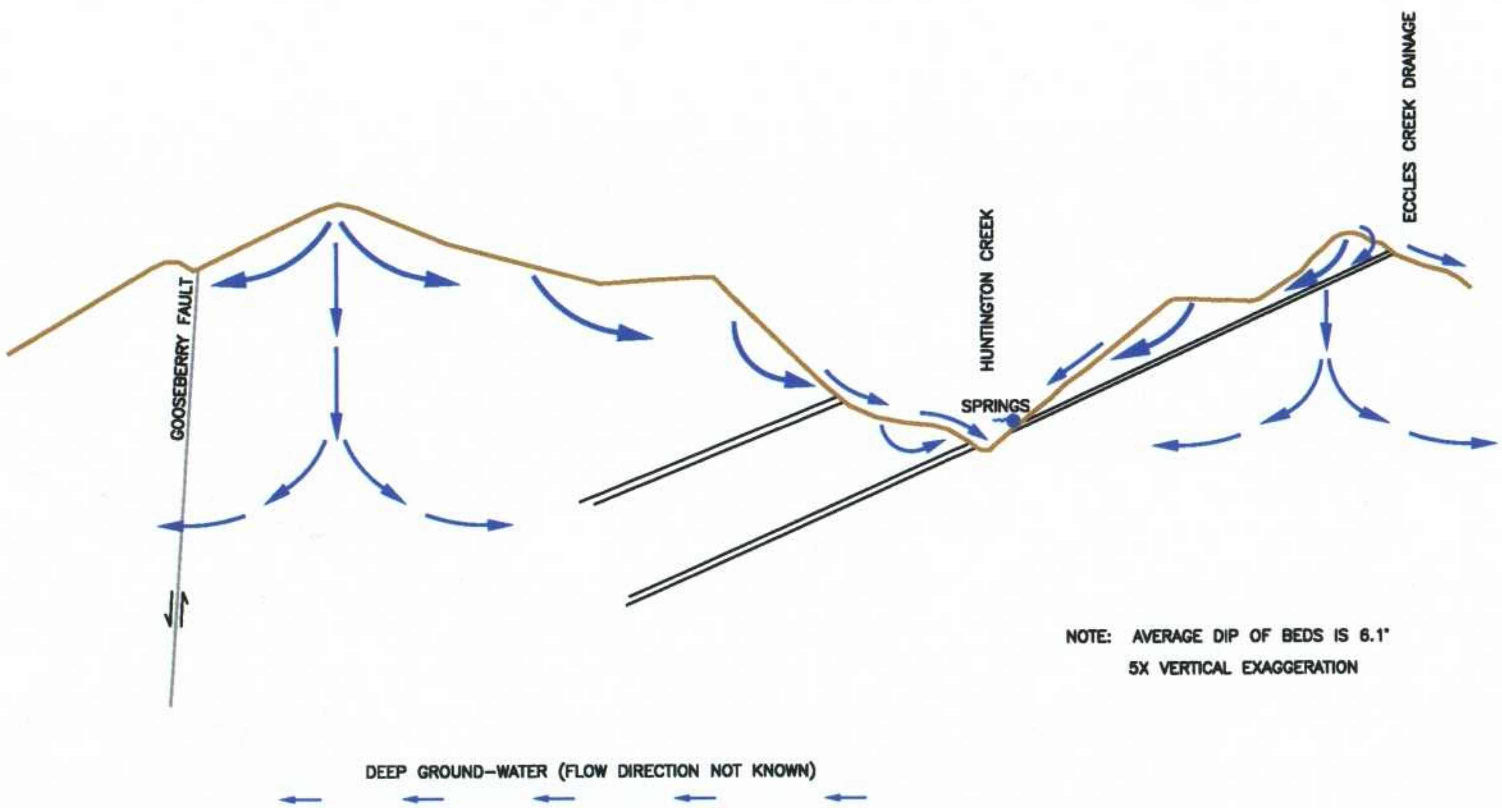
| JOB NO. | HCI–1787 | DATE: | 8/19/02 |
| BY: | RLH | DWG FILE: | GRAPH2 |
| DRAWN: | SAC | PLOT FILE: | GRAPH2 |
| CHECKED: | | PLOT DATE: | 8/19/02 |

**Orographic Influence on Precipitation**

FIGURE 2




| | | | |
|---|---|---|---|
| JOB NO. | HCI-1787 | DATE: | 7/29/02 |
| BY: | RLH | DWG FILE: | IB-GW-FLOW |
| DRAWN: | SAC | PLOT FILE: | IB-GW-FLOW |
| CHECKED: | | PLOT DATE: | 8/22/02 |

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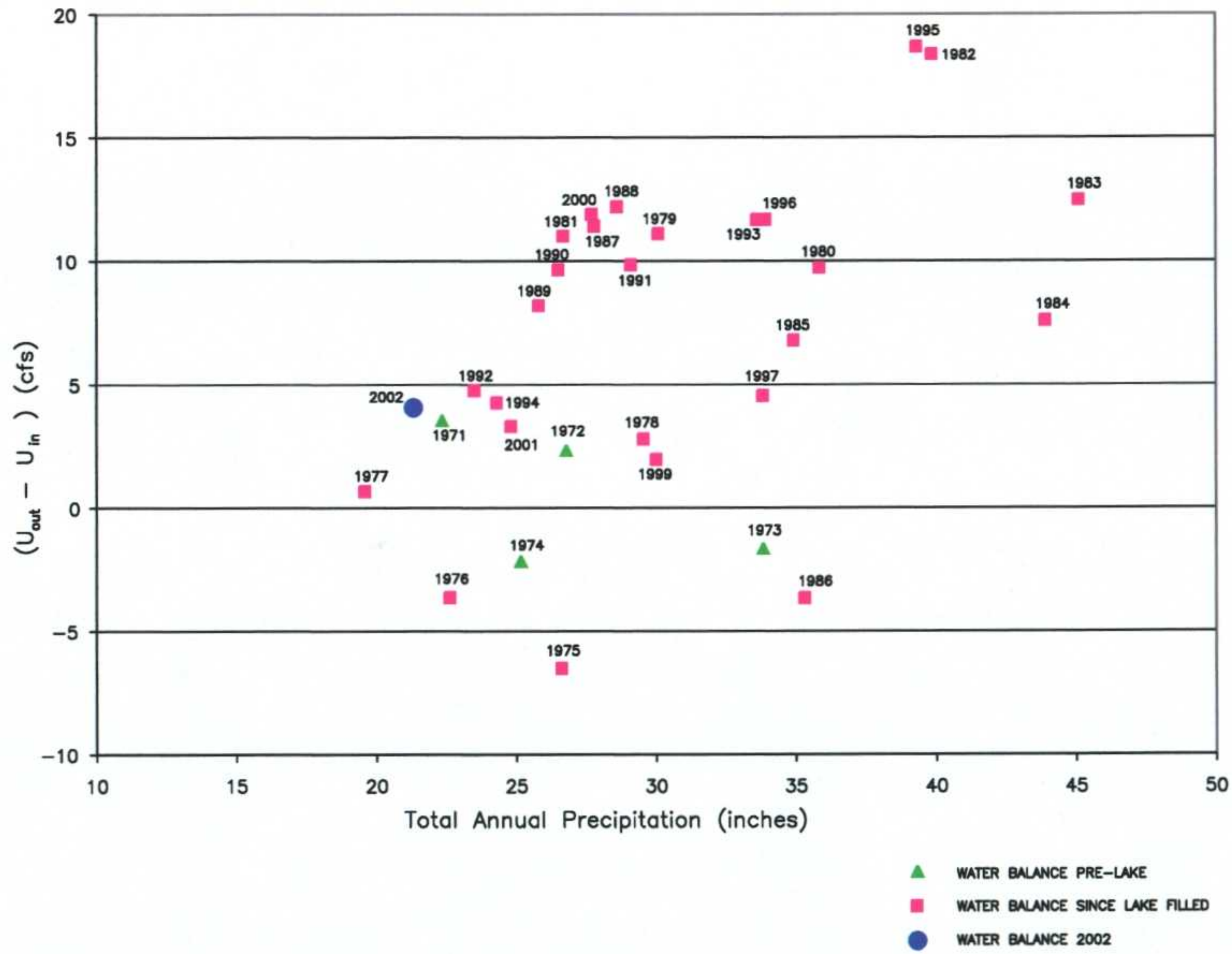
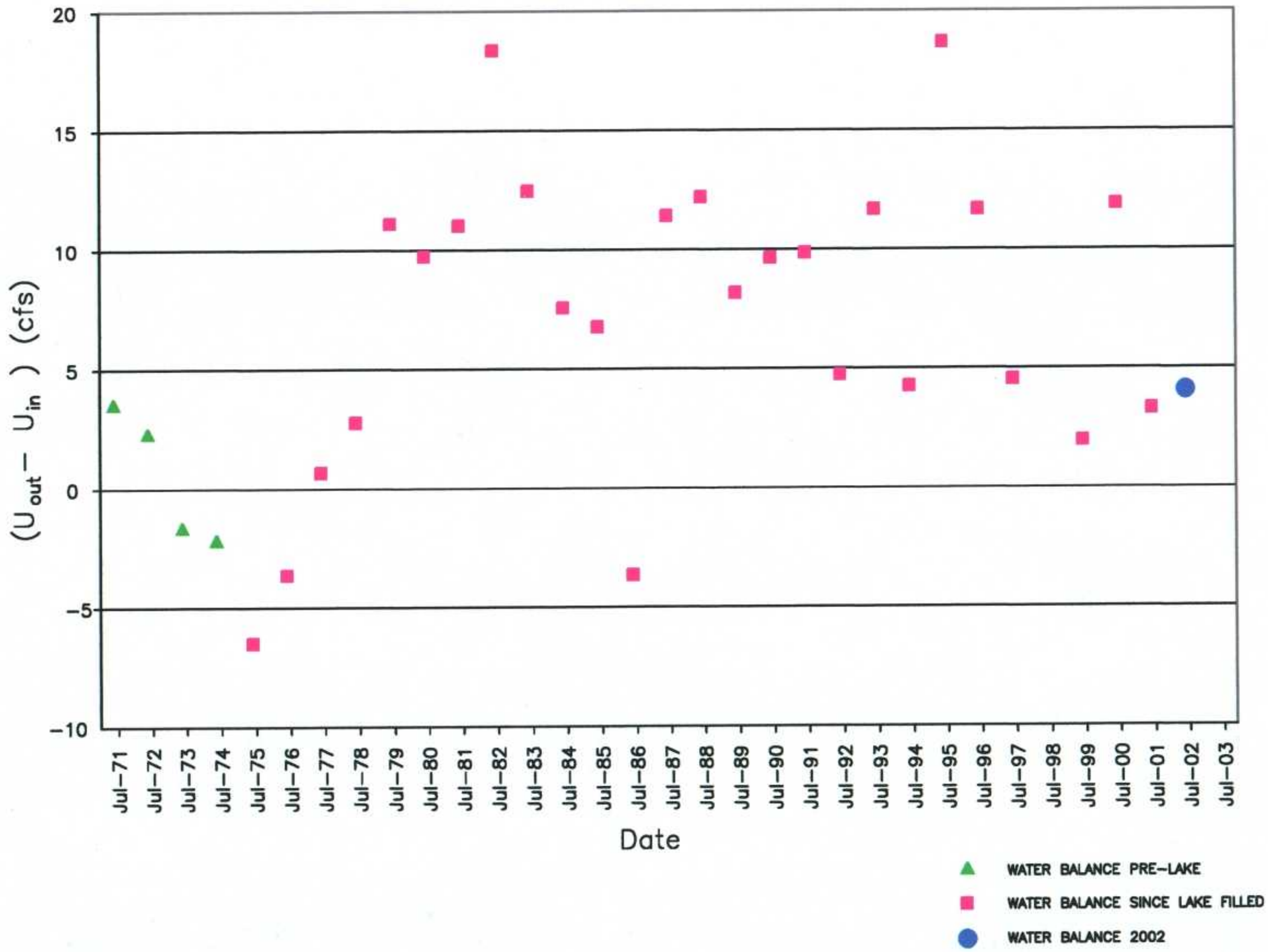
**Possible Inter-Basin Ground-Water Flow in Upper Huntington Canyon**

FIGURE 3




| | | | | | |
|---|---|---|---|---|---|
| HCI HYDROLOGIC CONSULTANTS, INC. — HC TASCA an company | JOB NO. HCI-1787 | DATE: 8/19/02 | **Water Losses from Electric Lake vs. Precipitation** | FIGURE 4 |
| | BY: RLH | DWG FILE: GRAPH4 | | |
| | DRAWN: SAC | PLOT FILE: GRAPH4 | | |
| | CHECKED: | PLOT DATE: 8/22/02 | | |

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|---|---|---|---|
| JOB NO. | HCI−1787 | DATE: | 8/19/02 |
| BY: | RLH | DWG FILE: | GRAPH3 |
| DRAWN: | SAC | PLOT FILE: | GRAPH3 |
| CHECKED: | | PLOT DATE: | 8/22/02 |

**Water Losses from Electric Lake 1971−2002**

FIGURE 5