PROPOSED WATER MANAGEMENT PLAN

FOR ALAMO LAKE AND

THE BILL WILLIAMS RIVER

Final Report and Recommendations of the Bill Williams River Corridor Technical Committee

ARIZONA GAME AND FISH DEPARTMENT
ARIZONA STATE PARKS DEPARTMENT
U.S. BUREAU OF LAND MANAGEMENT
U.S. BUREAU OF RECLAMATION
U.S. ARMY CORPS OF ENGINEERS
U.S. FISH AND WILDLIFE SERVICE

Submitted to the Bill Williams River Corridor Steering Committee

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BILL WILLIAMS RIVER CORRIDOR RIPARIAN SUBCOMMITTEE
Flow Recommendations for Riparian Resources

I. GOAL AND OBJECTIVES

A. CURRENT STATUS OF MANAGEMENT AREA

The riparian resources along the Bill Williams River have been subjected to several unnatural stresses in the past few decades, severely impacting the native vegetation growing in the riparian corridor (Fenner et al. 1985, Hunter et al. 1987). Although the corridor contains a few remnant cottonwood stands, these native riparian forests have been greatly reduced and are being replaced extensively by non-native salt cedar. Construction of Alamo Dam in 1969 altered the water regime in the river that sustained the riparian vegetation. Restricted flows of sediment-poor water during much of the year, combined with occasional moderately high flows (2,000-3,000 cfs) for extended periods (>60 days) for flood control, have been the primary contributors to the degradation of this riparian system. These altered flows have prevented most natural recruitment of cottonwoods, leaving stands of decadent riparian forests being replaced by more drought-tolerant salt cedar or not replaced at all. Any recruitment of native trees that does occur during high flow years is generally lost when flood flows are quickly scaled back to base flows of 10 cfs or less, and the water table drops too deeply too quickly. Extensive pumping at Planet Ranch has compounded these problems by draining the subsurface hydrologic basin, restricting even more the water available to riparian resources downstream from the ranch. Wildfires in the riparian corridor may also contribute to replacement of cottonwoods and willows by shrubby species such as salt cedar and arrowweed (Busch and Smith 1993). These fires destroy mature native riparian forests, and the lack of subsequent flood flows and sufficient base flows prevents natural recruitment of native trees to replace those lost to fire. The Wildlife Subcommittee report (July 1993) and the letter from Julie Stromberg, President, Arizona Riparian Council (4/21/93) detail the stresses and subsequent degradation of riparian resources along the Bill Williams River corridor. A properly functioning riparian ecosystem could be restored by implementing a flow regime that mimics the pattern of historic (pre-dam) flows.

Properly functioning riparian ecosystems are dynamic, with suitable sites for recruitment and sustained growth varying naturally with each season's water regimes. Through time, the location of specific forest sites may change within a corridor, but the overall health and function of the ecosystem remains. Managing Alamo Dam for riparian resources provides the opportunity to create hydroperiods, including both sufficient base flows and flushing flows, to stabilize and restore a healthy riparian system in the Bill Williams River corridor. While the Riparian Subcommittee emphasized natural variation in recruitment sites for key riparian species, some reaches of the river should receive special consideration for hydrologic concerns. Flows in the Bill Williams National Wildlife Refuge depend largely upon the amount of pumping at Planet Ranch and subsequent depletion of the subsurface hydrologic basin. With pumping at the Ranch, higher releases from Alamo Dam are necessary to provide sufficient base flows to the Refuge. Conversely, sustained high base flows could detrimentally impact resources at sites upstream from the ranch. In addition, the sediment deficiency experienced by, particularly, Banded Canyon (just downstream from the dam) is also of concern. The recommendations provided by the Riparian Subcommittee are designed to balance these concerns, providing longterm recovery goal for riparian resources in the Bill Williams River corridor.

B. RIPARIAN RESOURCES GOAL

The Riparian Subcommittee's goal is to enhance the riparian vegetation at Alamo Lake and the Bill Williams River, using pre-dam flow patterns (timing and shape of Spring and monsoon flows) to promote a healthy, self-sustaining riparian-wetland ecosystem in the Bill Williams River-Alamo Lake corridor.

The Subcommittee decided to focus on restoring riparian resources downstream from Alamo Dam and maintaining the cottonwood gallery forest at the upper end of Alamo Lake (Santa Maria River arm). We decided riparian resources at the reservoir itself were not substantial enough to warrant indepth discussion. Priorities for using water for riparian resources are:

1. ***Maintenance (base) flows***, to stabilize and maintain existing riparian stands;
2. ***Spring flushing flows***, to promote seed bed establishment, recruitment, and germination of key riparian species.
3. ***Fall flushing flows***, to recharge the aquifer and promote additional riparian species.

C. RIPARIAN RESOURCES OBJECTIVES

1. Maintain both <u>area</u> (acreage) and <u>structural diversity</u> of existing vegetation stands dominated by native riparian species, particularly cottonwood/willow stands.

2. Expand coverage and diversity of native riparian stands through natural recruitment.

3. To the extent possible, reduce the dominance of non-native tree species through flow releases and lake levels.

II. <u>ASSUMPTIONS FOR RECOMMENDATIONS</u>

A. HYDROLOGY

1. Dam operation includes the flexibility to store water in times of "surplus" for future (within 12 months) releases that would benefit riparian resources. Water years would be based on those established by the Corps of Engineers, October 1 - September 30.

2. Maximum flows down the river are not constrained by socio-economic factors. The joint resolution by the United States Government and the State of Arizona, dated 15 March 1963, declared that the floodplain below Alamo Dam would be maintained free of encroachment for discharges up to 7,000 cfs.

3. Pumping at Planet Ranch will continue as long as the ranch is privately owned. If Planet Ranch is transferred to Federal ownership, pumping will be significantly reduced. Figure 1 illustrates the effects of pumping at Planet Ranch with releases of 35 cfs from Alamo Dam.

4. A minimum of 18 cfs (measured at the Bill Williams Refuge gauge just below Planet Ranch) is needed to sustain riparian resources within the Refuge. This flow would provide surface flows of at least 1 cfs to Lake Havasu. The Rivers West, Inc. study for the USFWS estimated that a 35 cfs release from Alamo Dam provides flows of 18-20 cfs at the refuge gauge without pumping at Planet Ranch, and 5-10 cfs at the refuge with maximum pumping at Planet Ranch. These estimates are being supported by the USFWS model being developed for this system (Harshman and Maddock, unpubl. report; Harshman, unpubl. report) (see Figure 1).

5. A sustained surface flow in the channel indicates a saturated alluvium (water table is near the floodplain surface).

6. All recommendations by the Riparian Subcommittee assume Alamo Lake is at normal operating range within the water conservation pool (lake elevation ≥1,100 ft. & ≤1,172 ft.), and, therefore, most of the water volume from incoming flows during storm events would be available for release downstream.

B. VEGETATION

1. Cottonwood and willow are key indicator species for riparian systems (e.g. healthy cottonwood-willow stands = healthy riparian system).

2. Cottonwood and willow trees are dormant between approximately December 1 and January 31.

3. Of the key riparian species, cottonwood trees (*Populus fremontii*) are the least tolerant of inundation (sustained flows ≥1,000 cfs). During the growing season (March-October), cottonwood trees may be able to sustain ≤30 days of inundation. From November-February, cottonwood trees may be able to sustain up to 60 days of inundation (Walters et al. 1980, Kozlowski 1984, Kozlowski et al. 1991).

Because of the extreme environment along the Bill Williams River compared to the locales where cottonwoods (*Populus* spp.) have been studied, these inundation tolerances may need refinement through further study. Thus, these tolerance levels should be noted with some degree of uncertainty.

4. Cottonwoods and willows are phreatophytes (Busch et al. 1992), thus, maintaining high water tables is essential for cottonwood and willow vigor during the growing season. Minimum requirements include:

-- any drop in water table should be *≤2 cm/day* (McBride et al. 1988, Mahoney and Rood 1991, Scott and Segelquist 1992);

-- total drop in water table should be ***≤0.5-1 m/growing season*** (J. Stromberg, AZ Riparian Council, letter to AGFD dated 4/21/93);

-- maximum water table depth should be ≤2 m
(Stromberg 1993b; D. Busch, BOR, 1993, pers. comm.).

5. Peak seed dispersal for key riparian species (Ohmart and Anderson 1984):

Cottonwood - March/April (1x/yr)
Willow - April/May (1x/yr)
Salt Cedar - April - late October (June peak) (prolonged/yr)

6. Peak flows in February to early April are good for cottonwood-willow regeneration (based on their seed dispersal). Cottonwoods need flushing flows to prepare seed beds for natural regeneration. Cottonwood regeneration occurs naturally every 5-10 years (Stromberg et al. 1991, 1993; Stromberg 1993a).

7. Flows approximating the pattern of pre-dam conditions are good for maintaining sustainable riparian ecosystems in the desert southwest.

III. WATER OPERATION RECOMMENDATIONS FOR RIPARIAN RESOURCES

A. ALAMO LAKE

1. Purpose:

This recommendation serves to maintain the cottonwood stands at the upper end of Alamo Lake in the Santa Maria River arm. The primary purpose is to prevent salt cedar from further invading cottonwood stands at this site, and from interfering with the natural recruitment of these cottonwoods. This recommendation also proposes minimum lake levels for retaining sufficient water volume to maintain minimum base flows for riparian resources downstream.

2. Recommendation

Maintain Alamo Lake levels between 1,100-1,200 foot msl.

	Optimum	Acceptable	Adverse
Lake level:	1,115-1,171	1,110-1,171	<1,100, >1,200
Months:	Oct. - Sept.	March - Oct.	

3. Limitations

A "bathtub ring" in the Santa Maria Arm depicts the highest historic lake levels at approximately 1,200 feet. Below this line, thick "doghair" stands of salt cedar have invaded and established, creating a solid understory in the cottonwood gallery. Above this line, natural cottonwood recruitment is occurring in the stands, and salt cedar is a minor component. Lake levels above 1,200 feet would detrimentally impact these cottonwood galleries by allowing further displacement of native cottonwood trees with non-native salt cedar.

For downstream riparian resources, minimum lake levels are provided to ensure a sufficient volume of water required to meet at least the *minimum* maintenance flows throughout the year (minimum annual volume = 32,500 ac-ft for Optimum lake level; 14,870 ac-ft. for Acceptable lake level -- see recommendations following). Lake levels ≤1,100 msl mandate maximum releases of 10 cfs. These low flows are not sufficient to sustain riparian resources during the hot Summer months. However, trees may survive these low flows during the cooler Winter months.

B. BILL WILLIAMS RIVER

1. <u>Adverse</u> (accept some impacts to riparian resources)

a. Purpose

This flow regime provides *minimum* base flows to minimally support riparian resources on the river. Base flows *below* this rate, including current dam operations, are considered *adverse* in supporting riparian resources in the Bill Williams River corridor, and would continue to degrade the riparian resources. The recommended flows under this scenario would not restore this corridor to a properly functioning riparian ecosystem, as they do not provide for establishing natural recruitment of native vegetation.

b. Recommendation

Table 1.

Month	No. Days	Flow (cfs/day)	Volume (total Ac Ft)
January	31	10	620
February - September	242	25	12,100
October	31	15	930
November - December	61	10	1,220
TOTAL			14,870 AF/year

c. Limitations

The 10 cfs for winter may not provide sufficient water to the refuge, unless the Planet Ranch aquifer is full. However, during winter the trees are dormant, and may not require as much water. This recommendation provides higher flows in the Summer to account for the high Summer temperatures and increased evapotranspiration, but April-August are also the heaviest times of year for pumping at Planet Ranch (Harshman, unpubl. report). Therefore, these minimum flows may not provide sufficient water to the Bill Williams National Wildlife Refuge, although resources above the ranch could still be supported.

Any flows <u>less</u> than those recommended under this alternative would continue to degrade the existing riparian vegetation in the Bill Williams River corridor. Continued flows over time (> 5 years) under this recommendation would still prevent natural recruitment of cottonwood and willow trees; would continue to subject mature cottonwood and willow trees to water stress; and would allow salt cedar to continue to increase in dominance along the corridor.

2. **Acceptable**

a. **Purpose**

This flow regime would provide sufficient base flows to stabilize the current riparian system as is in the Bill Williams River. Essentially, it would allow what is existing to survive, and would permit stable and predictable conditions for any (mechanical) revegetation projects. These flows would not restore this corridor to a properly functioning riparian ecosystem, as they do not provide for establishing natural recruitment of native vegetation.

b. **Recommendation**

Table 2.

Month	No. Days	Flow (cfs/day)	Volume (total Ac Ft)
January	31	25 - 50	1,550 - 3,100
February - April	89	40 - 500[a]	7,120 - 35,600
May - September	183	50 - 100	18,300 - 36,600
October	31	40 - 60	2,480 - 3,720
November - December	61	25 - 50	3,050 - 6,100
TOTAL			32,500 - 85,120 AF/yr

[a] Flows between 40-200 cfs can be sustained throughout the 2-month period. Flows between 200-500 cfs should be provided in short pulses of 3-5 days.

Sustaining at least the minimum releases provided in this scenario is most critical for stabilizing riparian resources in the Bill Williams River corridor. Therefore, reserving water in Alamo Lake to sustain these minimum flows during the critical release times (hot Summer months) should take priority. The upper limits provided can be flexible up to approximately 200 cfs, or 500 cfs during the early Spring (as noted in the footnote), after which conditions for innundation need to be avoided.

c. **Limitations**

Recommended flows in this regime may provide greater base flows than occurred historically (pre-dam) during certain times of the year. However, an artificial hydroperiod may be required to sustain the remaining riparian resources in this corridor, even in its current state of degradation Construction of Alamo and Parker Dams inundated large stands of native riparian vegetation, and significantly altered flows supporting the remaining stands in the Bill Williams River corridor. These riparian resources have continued to degrade from altered flows from Alamo Dam, pumping at Planet Ranch, and other factors. The recommended flows would partially compensate for riparian habitat losses that have occurred from the various impacts.

The ranges presented in the table are designed to provide flexibility in the dam operations for sustaining riparian resources. Using these recommendations as *guidelines* (most particularly the *minimum* flows), the Corps of Engineers would determine appropriate releases based on current (at the time of the decision) and predicted lake elevations, season, and other operational factors. The Corps would have the flexibility to revise the flows within and among months, seasons, and years based on these recommended ranges. In fact, this may be desirable for the resources to ensure sufficient water in the lake for sustained releases, to vary the water table depth (prevent a "bathtub ring"), and to minimize potential impacts to resources above Planet Ranch (e.g. soil erosion, sustained inundation of plants in the lowest floodplain or river banks) during extended flows at the high end of the range (180-500 cfs).

The minimum 25 cfs in winter allows sufficient water through Planet Ranch to the Bill Williams Refuge, when pumping at the ranch is minimal. In March, higher minimum flows are needed as temperatures start increasing, but also the system can experience higher flows and small pulse flows, as this is the usual time for Spring rains and flowering of cottonwoods. The 50-100 cfs during Summer accounts for high Summer temperatures and increased evapotranspiration in the riparian system, and extensive pumping at Planet Ranch. These figures are based on studies conducted by the Bureau of Land Management (1988), Rivers West, Inc. (1990), and the hydrology model being developed by the USFWS and University of Arizona (Harshman and Maddock, unpubl. report). The Rivers West, Inc. study for the USFWS estimated that a 35 cfs release from Alamo Dam provides flows of 18-20 cfs at the refuge gauge without pumping at Planet Ranch, and 5-10 cfs at the refuge with pumping at Planet Ranch. These figures have been supported by the USFWS model (Harshman and Maddock, unpubl. report; Harshman, unpubl. report) (see Figure 1).

Flows less than the minimums recommended under this alternative may not provide sufficient water to stabilize and maintain current riparian resources, especially with maximum pumping at Planet Ranch. Also, implementing only this recommendation over time (> 5 years) without adding sufficiently high pulse flows to stimulate cottonwood recruitment would prevent increases in diversity or acreage of cottonwood stands. As the mature trees grow older and become decadent, they would eventually be replaced by salt cedar.

3. Optimal

a. Rationale

Periodic "flood" events mimic the pattern of natural flows in the Bill Williams River before the dam. Spring floods would prepare the seed bed (through aggradation and degradation of the banks and terraces), and stimulate natural cottonwood and willow regeneration. Summer monsoon floods would scour the channel, recharge the Planet Ranch aquifer, and possibly flush salts associated with salt cedar. This semiannual pattern also provides for other natural processes adapted to these flushing flow systems that we may not know about.

This recommendation would use natural storm events in the Spring and monsoon to provide the water necessary for these large downstream flushes, with high pulse releases being timed to best benefit the key riparian species (according to their phenology). The higher base flows would take advantage of the ability of the dam to retain water for future (within the year) releases at unnatural rates or at times of the year when water would not have been available prior to the dam.

b. Purpose

This flow regime would 1) stimulate natural recruitment of cottonwood and willow trees on a periodic basis; and 2) provide sufficient base flows to maintain riparian resources on the river. Again, our subcommittee stresses that imitating the *pattern* of pre-dam flows is more important than absolute numbers (cfs) for dam releases, *as long as at least the **minimum** (maintenance) flows are being sustained.*

c. Recommendation

1. *Base flows.*-- Optimum flows for riparian resources along the Bill Williams River would combine base flows provided in the Acceptable recommendation with large "pulse" flows resulting from Spring (January-May) and Summer (August-September) storm events.

2. *Spring flows.*--During the Spring flood season, the Corps of Engineers would determine when water is considered "surplus" in Alamo Lake and in need of releasing. This determination would be based on inflow from storm events and subsequent increases in lake elevation above a target elevation. The decision to release or store water from storm events should be made in the broad context of flow patterns over previous years' storm events. For example, if large releases have not been made in several years (particularly ≥3,000 cfs), and sufficient water is available in the current year, large releases for downstream resources would be implemented. Pulse releases should be timed to best accomodate the phenology (leafing out, flowering, and growing season) of the trees, taking into consideration natural variation from year to year (generally late February to early April). The Corps could revise release schedules, as needed, within a flood season as natural storm events dictate.

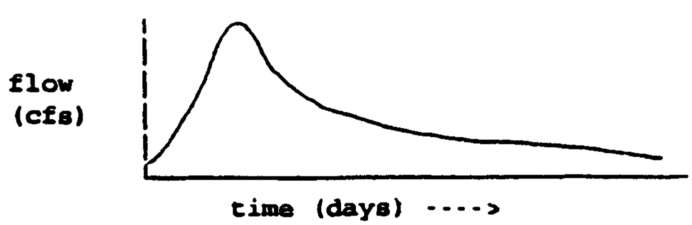
The following guidelines would be used to determine peak flows during natural Spring storm events:

Table 3.

Approx. Interval (years)[a]	Volume H_2O to Flush (000's AF)[b]	Peak Flow (cfs)	Peak Duration[c]	Recession[d]
±3	5-30	1,000-2,000	1-7 days	500->45 cfs over 6 days
±5	30-50	3,000-4,000	5-8 days	500->45 cfs over 20 days
±7	50-75	4,000-5,000	8-10 days	"
±10	75-100	6,000-7,000 (or max cfs)	10-14 days	"
>10	100+	7,000 (or max cfs)	14-30 days	"

[a] "Approximate Interval" reflects the approximate yearly interval we may be able to expect these levels of flows based on U.S. Geological Survey data from the Alamo Dam gauge during 1940-1969 (pre-dam). See Figures 1 and 2.
[b] "Volume H_2O to Flush" denotes the amount of surplus water available in Alamo Lake that the U.S. Army Corps of Engineers needs to remove from the reservoir.
[c] "Peak Duration" includes time necessary to increase flows from base flows to peak flow and return to 500 cfs at approximately 1,000-2,000 cfs per day.
[d] "Recession" refers to the back side of the peak -- that is, drawing out the decrease in flows back to base flows rather than quickly reducing flows back down to base flows (see graph below).

The general idea of this recommendation is to get flows up to the peak flow as quickly as possible (without undo hardship on downstream users), and then draw out the decrease in flows. This simulates, based on pre-dam data, the shape (hydrograph) of these Spring events in a naturally functioning desert riparian system. The hydrograph refers to the way a volume of water is released, including the increase to peak flows, duration at peak flow, and return to base flow. The desired hydrograph is to increase to peak flow as quickly as possible, hold at peak flow as long as recommended, and return slowly to base flow with drawn-out decreases in flow (recession of curve). The hypothetical hydrograph would be as follows:



Drawing out the decrease in flows prevents the water table from dropping too rapidly, which would result in higher mortality of cottonwood seedlings. Sample flow regimes for different water volumes are attached in Appendix A.

Pulse flows would be timed to the natural processes of riparian plants in the corridor, using natural storm events to supply the necessary water, rather than holding to a rigid schedule. The Corps of Engineers would determine at what volume water was considered surplus and in need of discharge.

3. ***Monsoon flows***.--Generally, the Spring events comprise storms with greater volumes of water and longer duration than the Summer monsoon events, although there are years when the Summer monsoon events are larger. Typically, monsoon storms are much flashier, of shorter duration, and lower volumes. To accommodate Fall (August-September) storm events, the following guidelines are recommended:

(a) Ensure sufficient water is stored in the system to ***maintain base flows*** until the following Spring storms, and possibly through the following Summer (in case Spring flows are extremely low). Minimum volume needed = 14,870 ac-ft. per year (see Adverse recommendation). Minimum lake level should be ≥1,110 foot msl, if the lake is to remain ≥1,100 foot msl during the year. This would be determined at the time the decision is being made on whether or not to release a Fall pulse.

(b) Provide a ***monsoon pulse*** approximately *every 3-6 years*, based on natural storm events, but a *at least every 6-7 years*.

(c) Monsoon pulses should occur in *≤7 days, with peak flows ≥1,000 cfs*. Exact peak flows and duration of flows would be determined by the Corps of Engineers, depending on the volume of water to be released. Only a short recession, if any, would be necessary for these flows.

(d) Timing of a monsoon pulse would generally occur in late August - early September, depending on the timing of natural storm events.

c. **Limitations**

The yearly intervals listed in the recommendations table represent approximate intervals of (natural) large Spring storm events based on analyses of pre-dam data (average monthly volumes) at the Alamo gauge from 1940-1969 (see Figures 2 and 3). These intervals also correspond to the timing of natural cottonwood regeneration (Stromberg et al. 1991, 1993; Stromberg 1993a). We recommend the Corps of Engineers use these natural storm events to provide various high-volume releases downstream to promote cottonwood recruitment, timing the pulses to the phenology of the plants (late February - early April). We would expect these large volume releases in approximately the same yearly intervals as suggested by the pre-dam data, but again, it would depend on the timing of natural storm events. *We do not expect these volumes to be released every year, or necessarily at __exactly__ these yearly intervals.* In fact, high volume releases (>3,000) may not be desirable every year, as recruitment in the lower terraces from each previous year may not have a chance to establish. We do, however, request large-volume releases *at least once in every 5-10 years* to rehabilitate the downstream riparian resources. If the Corps does not take advantage of these large-volume Spring releases, cottonwoods cannot naturally regenerate, and the riparian resources downstream will continue to degrade.

The various peak releases relative to volume of water to be discharged should lead to germination sites at varying levels above the base water table, with optimum recruitment zones approximately 0.5-1.0 m above the base water table (J. Stromberg, AZ Riparian Council, letter to AGFD dated 4/21/93). Although at this time, the base water table is unknown for the Bill Williams River, the recommended flow patterns, including the recession, should promote natural regeneration of cottonwoods at acceptable floodplain levels.

If releases are cut off too quickly from peak flows to base flows, the water table supporting the riparian corridor would drop too quickly for cottonwood roots to keep up. This would lead to high mortality of the seedlings, which cannot tolerate a water table dropping at ≥2-3 cm per day (McBride et al. 1988, Mahoney and Rood 1991; Scott and Segelquist 1992). Not only are the flood flows necessary to lay seed beds for germination, but a slowly declining water table is necessary to sustain the seedlings (as well as saplings and mature trees). The recommended 20-day recession is an estimate, made with limited quantitative information on the rate of groundwater decline, and may need to be refined through further study.

According to the literature, the Riparian Subcommittee determined that cottonwoods (*Populus fremontii*) along the Bill Williams River may be "intermediately tolerant" to inundation (Walters et al. 1980, Kozlowski 1984, Koslowski et al. 1991). For these recommendations, we defined inundation as sustained flows ≥1,000 cfs. To prevent stress or death of cottonwoods from extremely high flows, the following guidelines are recommended when releasing ≥1,000 cfs:

Cottonwood Inundation Duration (maximum days)

Dates	Optimum	Acceptable	Adverse
November 1 - February 28	30	60	>80
March 1 - October 31	14	30	>50

Extended inundation (>50 or >80 days, depending on season) should not occur >2 years in a row.

If water must be released for >30 days during the growing season or >60 days during the non-growing season to remove surplus water, a "dry-out" period of ≤300 cfs for ≥30 days should be maintained. The high release/dry-out pattern could be repeated as much as necessary until all surplus water is released.

The monsoon releases do not need to occur every year, although they should be maintained at least every 6-7 years, according to analysis of pre-dam data (see table below). They should not occur in the same years as high Spring releases, unless natural storm events dictate so. If monsoon pulses are completely eliminated, or occur at intervals >6-7 years, many riparian plants that are adapted to these monsoon rains, such as mesquite, may suffer (B. Anderson, 1993, pers. comm.; J. Stromberg, AZ Riparian Council, letter to AGFD dated 4/21/93). These pulses are included to maintain the historic (pre-dam) pattern of flows, thereby providing for the many unknown riparian values that these southwestern riparian ecosystems are adapted to.

Fall Flow Frequencies from 1940-1969 (pre-dam)
Months = August-September
Data Source = U.S.G.S. flow data from Alamo Dam gauge (monthly averages)

Volume of Water (Ac-ft)	Frequency (n/30 yrs)	Approx. Yearly Interval
<1,000	9	<3 yrs.
1,000-2,000	9	±3 yrs.
2,000-3,000	3	±10 yrs.
3,000-5,000	2	±15 yrs.
5,000-10,000	2	±15 yrs.
>10,000	5	±6 yrs.

**All volumes >10,000 ac-ft measured >20,000 ac-ft.

C. DAM MAINTENANCE

The Riparian Subcommittee acknowledges the need to conduct periodic inspections of the dam approximately every 5 years. We recommend drawdown for the bulkhead occur in *April-September, with sustained flows not exceeding 300 cfs* during this time frame. This would maintain sufficient water for the riparian vegetation during the hottest time of the year. Drawdown should be particularly targeted for *June 1-September 30, maintaining flows from 45-300 cfs*, depending on the volume of water that needed to be removed from the lake. The guidelines provided under the Acceptable recommendation could be used to maintain "average" releases between 26-180 cfs. However, since no releases can be made while the bulkhead is in place, we recommend that the actual maintenance begin in *early November*, when temperatures have dropped sufficiently to lower evapotranspiration stress on the trees. Thus, the trees should survive better in the cooler temperatures (and approaching dormancy) with no flows from the dam supporting them.

Maintaining flows at 300 cfs for June-September would flush approximately 73,200 acre-feet from the reservoir. Maintaining flows at 300 cfs for April-September would flush approximately 109,800 acre-feet of water from the reservoir. If >100,000 acre-feet of water needed to be flushed from the reservoir for this maintenance, a pulse in March or April accommodating the excess volume should be provided, then flows should be dropped to 300 cfs for the remainder of the Summer. The peak flow and duration of the pulse should follow the guidelines provided in the "Optimum" recommendation for Spring pulses, extending the recession as long as necessary to remove the water.

D. MONITORING

A *long-term, repeatable* monitoring system should be developed to provide information on the success of the final flow regimes in meeting the resource objectives. Future feedback through monitoring should be used to refine water management prescriptions and flow regimes. The approved final flow regimes should be flexible enough to revise as needed based on resource results. Monitoring methods should include:

1. Establishing *gauges* (including the current Refuge gauge, and others as needed) to monitor downstream flow and groundwater;
2. Monitoring acreage and structural diversity of riparian vegetation with low-elevation (approx. 3,000 ft AGL or ≤1" = 800') *aerial photographs, photo points, and permanent transects* at least every 3 years;
3. Establishing *permanent cross sections* to monitor channel morphology and sediment depletion, aggradation, and degradation;
4. Monitoring *depth to ground water and percent soil moisture* during different releases;
5. Determining *groundwater discharge rates* for the Bill Williams River;
6. Monitoring *plant condition and stress* in low and high water situations, using fluorescence, growth measurements, and other established techniques;
7. Verify the *timing of flowering and seed dispersal* in cottonwoods in this system, including the degree of variation in these processes associated with annual variations in precipitation; and
8. Determining *inundation periods* for cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) trees in the arid southwest. Data are available for the genera *Populus* and *Salix* from more mesic environments, but little hard data is available on these species in highly arid locales.

Several methods and sources could be used to monitor the riparian system. Local agency (BLM, AGFD, BOR, and USFWS) personnel could use established inventory techniques (e.g. AZ Riparian Inventory, Ecological Site Inventory, etc.) to determine "baseline" data, and monitoring would occur during regular, pre-determined intervals thereafter (min. 3-5 years). In addition, graduate students, senior wildlife students, SCA volunteers, or the Water Research Institute may be available to conduct studies along the Bill Williams River, through grants or contracts from the managing agencies. The primary researcher would depend on the technical expertise needed for each research or monitoring project. The agency (or agencies) letting each contract or grant would be responsible for ensuring adequate results from the research project. Monitoring would occur at key areas along the entire river length (e.g. Banded Canyon, Lincoln Ranch, Pitrat Ranch, Planet Ranch, and the Refuge), with inherent flexibility to modify key areas as natural recruitment sites dictate.

E. RESOURCE OUTCOMES

The following outcomes are expected for riparian resources if the Optimum recommendations are implemented:

1. Maintain current acreage of riparian vegetation, particularly cottonwood-willow stands (although stands may not necessarily always be located in the same place, due to the dynamic nature of riparian ecosystems);
2. Promote natural regeneration of cottonwood and willow, thereby increasing acreage and structural diversity (natural age class and size distributions) of cottonwood-willow stands;
3. Provide for aquifer recharge and channel maintenance to support riparian resources at various floodplain levels; and
4. Provide for vegetation species keyed to monsoon flows.

F. BENEFITS

1. Natural cottonwood and willow regeneration will maintain existing stands and expand acreage and structural diversity of riparian vegetation
2. Channel restoration and maintenance
3. Recharge of Planet Ranch aquifer
4. Reduced fire hazard by increasing fuel moisture and humidity
5. Potentially reduced salt cedar encroachment
6. Structurally diverse cottonwood-willow gallery forests
7. Improved habitat for wildlife (especially neotropical migrants)
8. Regular flushing of salts associated with salt cedar
9. Aesthetically better recreation experience
10. Restoration of a self-sustaining, *dynamic* system
11. Provide a physical setting for artificial restoration/revegetation efforts

G. ADVERSE IMPACTS

1. Possible undesirable lake level fluctuations
2. Damage to access and utility facilities
3. Flooding of some farms may occur with high flows
4. Some wetland/marshes may be altered
5. During extended drought periods, riparian resources downstream may need to temporarily pre-empt reservoir resources
6. Construction of Alamo Dam has left the Bill Williams River corridor without a system for replacing sediments. Erosion of sediments without replacement has occurred since operation of the dam began, and will continue no matter what operational tactics are used. Recommending flushing flows higher than those previously released from the dam may accelerate erosion in some locations, particularly the Banded Canyon (immediately below the dam). Conversely, sites downstream from the canyon may not be in such a predicament Prior to the dam, flows through the Bill Williams River reached ≥25,000 cfs during some storm events. These flows, depending on duration, likely scoured large amounts of sediment in the Bill Williams River corridor. Because the releases from the dam cannot exceed 7,000 cfs, some down-canyon sites may actually be experiencing a <u>reduction</u> in sediment loss from these reduced flows. The hydrologic basin under Planet Ranch may also buffer scouring and sediment loss in the Refuge as it buffers downstream flows. Monitoring

channel morphology, particularly the Banded Canyon, will be important as these recommendations are implemented to assess the impacts these flows have on sediment loss.

H. OPERATIONAL CONSTRAINTS

The following operational constraints for Alamo Dam were identified within the riparian resources recommendations:

1. No instantaneous releases between approximately 70-150 cfs due to structure of dam gates
2. Minimum lake level at 1,100 foot msl for bald eagles
3. Need to try to maintain lake level within water conservation pool (≤1,172 foot msl)
4. No discharges >7,000 cfs, unless the dam is modified
5. No storage of water within the reservoir for >1 year
6. Required inspection and maintenance approximately every 5 years
7. For large releases (>1,000 cfs), increases in releases to peak flows should be ≤1,000 cfs per day to reduce downstream property damage and maintain public safety (J. Evelyn, U.S. Army Corps of Engineers, pers. comm.)

All operational constraints were incorporated into the riparian resource recommendations.

IV. <u>INFORMATION NEEDS AND DEFICIENCIES</u>

A. For informed recommendations:

1. With no inflows into the Planet Ranch aquifer, how long can an outflow (into the Refuge) be maintained (assuming the aquifer is full to begin with)? Without pumping at Planet Ranch? With pumping at Planet Ranch?

2. Lag time between dam release and downstream effects/flow (e.g. If you release water from the dam on Day 1, how long does it take for the water to reach the Pitrat Ranch? Planet Ranch? The Refuge?).

3. What does a release at the dam mean at select downstream points (e.g. If you release 25 cfs from the dam, what is the flow at Pitrat Ranch? Above Planet Ranch? At the Refuge gauging station?)?

4. How far in advance does the Corps of Engineers know about their exact maintenance schedules? How much flexibility is there in when they are scheduled?

**Questions #1-3 may be answered at least in part by the hydrology model being developed by the USFWS and University of Arizona.

B. Monitoring and future research needs

As identified in the Monitoring section of the recommendations, the following research and monitoring efforts are needed to better understand riparian resources along the Bill Williams River corridor:

1. Are we meeting the minimum needs of the resources?
2. Is there excess water in the system (downstream? in the lake?) from our flow regimes?
3. Monitor channel morphology, soil moisture, and riparian vegetation (area, structural diversity, and plant condition) changes based on our flows.
4. Research the relationship between adequate soil moisture, ground water, and surface flow in this system. Determine groundwater discharge relationship using aerial photographs taken during various dam releases (known available = 1987, 300 cfs; 1993, 1500 cfs, 1993, 7000 cfs), and other appropriate techniques (**This is an important one**).
5. Determine the inundation tolerance of cottonwood, willow, and possibly salt cedar trees in the Bill Williams River corridor (**This is also an important one**).
6. Is there a way to pass sediments from above the dam to the system below the dam to reduce sediment deficiency in the long term?

Use this resource information to <u>evaluate</u> the success of the flow regimes and, if necessary, to <u>modify</u> the dam operations/releases. This is to ensure that we (as management agencies) are meeting the resource objectives agreed upon by the Technical Committee, subcommittees, and agencies.

V. ISSUES, CONCERNS, AND OPPORTUNITIES

The Riparian Subcommittee believes the Technical Committee has an opportunity to restore valuable riparian resources within the Bill Williams River corridor. Although during some extreme years, the reservoir resources may have to suffer at the expense of the downstream resources, we believe this is an acceptable trade-off, considering the amount of degradation that has occurred in the riparian corridor during the last 20 years. We view it as a type of mitigation for the riparian resources that have been lost or severely impacted since the dam was constructed and efforts began focusing on reservoir opportunities.

Because of the extent of the degradation, it may take a few "cycles" of these recommendations to bring the system back into some resemblance of a properly functioning riparian ecosystem. Any perceived losses or detrimental impacts will be offset by the benefits of natural recruitment of cottonwoods, higher water tables and recharge of the aquifer, channel scouring and maintenance, and a healthier, dynamic riparian ecosystem. Using varying peak flows ranging from 1,000-7,000 cfs should promote regeneration at various levels within the floodplain. Under sustained low flows, recruitment occurs in the river channel and gets wiped out with the subsequent year's floods. With only the highest flows, recruitment occurs in the highest floodplains that quickly dry up with a (rapidly) receding water table. Observations from the high flows of Winter 1993 indicate the river channel can sustain the 7,000 cfs flows without undue degradation of the resources, and that, in fact, these high flows actually benefitted the downstream resources. Combining the high flows with retaining a higher water table should provide positive results in a relatively short time frame.

Our subcommittee was concerned that the final flow regimes agreed upon by the Technical Committee would be "set in stone", regardless of the resulting impacts to the resources at Alamo Lake and the Bill Williams River. We did not want to the see the recommendations to the Corps of Engineers for operating the dam to be absolute, especially as these flows are, for the most part, predicted ranges of what will be good for the resources. *The pattern of the flows is more important than the actual numbers, as long as at least the minimum (maintenance) flows are being sustained.* The recommended minimim flows (cfs) are most critical for stabilizing the riparian corridor, and maintaining the riparian resources in the longterm. We realize flow schedules such as those we recommended will require greater coordination and flexibility in how the dam is operated. However, we believe these flows are necessary to stabilize and improve the valuable riparian resources that have been so heavily impacted in past years.

Flushing flows should be timed to the natural processes of the riparian plants, using natural storm events to provide the water, rather than holding to a rigid schedule. For example, the excessive rain we had in January-February 1993 caused the trees to leaf out in early February, rather than March. Not only did they break dormancy early, they also flowered early. Flushing flows should be timed to account for these natural variations. We hope the Corps of Engineers understands the flexibility inherent in our recommendations, provided the minimum flows are maintained.

Along with this, our subcommittee emphasized monitoring the resources, after the system has been implemented, to evaluate the success of our recommendations. We felt a strong need for some flexibility in the dam operations to modify flows, if necessary, as indicated by the changes in the resources.

VI. REFERENCES AND DATA SOURCES

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APPENDIX A

**Spring Flow Recommendations:
Sample Calculations**

APPENDIX A

Spring Flow Recommendations: Sample Calculations

<u>Table 3</u> (see page 8). Recommendations for release of surplus water during Spring (January-May) storm events.

AF to flush	Peak Flow (cfs)	(includes stepping up & down) Peak Duration	Recession
5-30k	1,000-2,000	1-7 days	500->45 cfs over 6 days
30-50k	3,000-4,000	5-8 days	500->45 cfs over 20 days
50-75k	4,000-5,000	8-10 days	"
75-100k	6,000-7,000 (or max cfs)	10-14 days	"
100k+	7,000 (or max cfs)	14-30 days	"

Table A-1. Volume of water needed for recession (back side of hydrograph), using the conversion factor of 1 cfs/day = 2 ac-ft.

1 cfs/day = 2 ac-ft

Long recession:

Flow (cfs)	No. days	Ac-Ft
500	1	1,000
480	1	960
460	1	920
440	1	880
420	1	840
400	1	800
380	1	760
360	1	720
340	1	680
320	1	640
300	1	600
280	1	560
260	1	520
240	1	480
220	1	440
200	1	400
180	1	360
160	1	320
150	1	300
50	1	100
TOTAL:	20	12,280 AF

Short recession:

Flow (cfs)	No. days	Ac-Ft
500	1	1,000
400	1	800
300	1	600
200	1	400
150	1	300
50	1	100
TOTAL:	6	3,200 AF

The following tables (A-2 through A-6) illustrate sample flow regimes for flushing various volumes of water according to the guidelines provided above. They are not meant to be "written in stone" release patterns, only *examples* on how to implement the guidelines. These estimated volumes of water do not account for the effects of evaporation.

Table A-2. 5-30k to release, peak flow 1,000-2,000 cfs, short recession.

Sample Calculation #1a:

Flow (cfs)	No. days	Ac-Ft	
1,000	1	2,000	
(then begin recession)	1 day	2,000 AF	
		+ 3,200 AF	(recession)
		5,200 AF	

Sample Calculation #1b:

Flow (cfs)	No. days	Ac-Ft	
1000	1	2,000	
2000	2	8,000	
1000	1	2,000	
(then begin recession)	4 days	12,000 AF	
		+ 3,200 AF	(recession)
		15,200 AF	

Sample Calculation #1c:

Flow (cfs)	No. days	Ac-Ft	
1000	1	2,000	
2000	5	20,000	
1000	1	2,000	
(then begin recession)	7 days	24,000 AF	
		+ 3,200 AF	(recession)
		27,200 AF	

Table A-3. 30-50k to release, peak flow 3,000-4,000 cfs, long recession.

Sample Calculation #2a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	5 days	18,000 AF
		+ 12,280 AF (recession)
		30,280 AF

Sample Calculation #2b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	4	24,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	8 days	36,000 AF
		+ 12,280 AF (recession)
		48,280 AF

Sample Calculation #2c:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	7 days	32,000 AF
		+ 12,280 AF (recession)
		44,280 AF

Appendix A (continued)

Table A-4. 50-75k to release, peak flow 5,000 cfs, long recession.

Sample Calculation #3a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	2	16,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	8 days	40,000 AF
		+ 12,280 AF (recession)
		52,280 AF

Sample Calculation #3b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	8 days	50,000 AF
		+ 12,280 AF (recession)
		62,280 AF

Sample Calculation #3c:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	2	20,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	10 days	60,000 AF
		+ 12,280 AF (recession)
		72,280 AF

Appendix A (continued)

Table A-5. 75-100k to release, peak flow 6,000-7,000 cfs, long recession.

Sample Calculation #4a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
5,000	1	10,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	10 days	64,000 AF
		+ 12,280 AF (recession)
		76,280 AF

Sample Calculation #4b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	1	10,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	11 days	72,000 AF
		+ 12,280 AF (recession)
		84,280 AF

Sample Calculation #4c:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
5,000	1	10,000
7,000	1	14,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	11 days	78,000 AF
		+ 12,280 AF (recession)
		90,280 AF

Table A-6. 100k+ to release, peak flow 7,000 cfs, long recession.

Sample Calculation #5a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	1	10,000
6,000	1	12,000
7,000	1	14,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	11 days	98,000 AF
		+ 12,280 AF (recession)
		110,280 AF

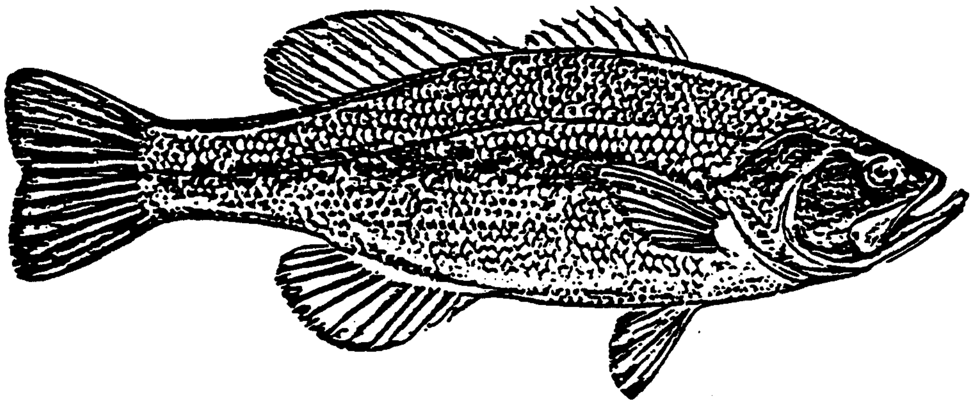
Sample Calculation #5b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
5,000	1	10,000
7,000	6	84,000
5,000	1	10,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	14 days	128,000 AF
		+ 12,280 AF (recession)
		140,280 AF

APPENDIX E.

FISHERIES SUBCOMMITTEE REPORT

BILL WILLIAMS RIVER CORRIDOR
Fisheries Subcommittee
Final Recommendations



Prepared By:
Fisheries Subcommittee
Chairman: Brad Jacobson

Revised: February 24, 1994

Acknowledgements

I would like to thank the members of the Bill Williams River Corridor Fisheries Subcommittee for their assistance in putting together the following subcommittee report. This effort involved fitting meeting into their busy work schedule with very little advanced notice along with returning comments on short turn around schedule. The individuals that were members of this subcommittee were Al Doelker, Havasu Resource Area of the Bureau of Land Management; Carvel Bass, Operations Branch of the U. S. Army Corps of Engineer; Tom Burke, Boulder City Office of the U. S. Bureau of Reclamation; Dave La Pointe, Lake Havasu State Park of Arizona State Parks; and Chuck Minckley, Parker Fisheries Resource Office of the U. S. Fish and Wildlife Service.

Table of Contents

BILL WILLIAMS RIVER CORRIDOR
Fisheries Subcommittee
Recommendations

I. **Goal and Objectives:**

A. Goal:

Develop a water level management prescription for maximizing the fisheries at Alamo Lake and the Bill Williams River below the dam.

B. Objectives:

1. Identify a lake level management prescription for Alamo Lake and a flow regime for the Bill Williams River below the dam which would maximize the various fisheries during optimal water years (wet years).

2. Identify a lake level management prescription for Alamo Lake and a flow regime for the Bill Williams River below the dam which would maximize the various fisheries during acceptable water years (wet enough to maintain the lake elevation).

3. Identify a lake level management prescription for Alamo Lake and a flow regime for the Bill Williams River below the dam which would maximize the various fisheries during adverse water years (not wet enough to maintain the lake elevation).

II. **Assumptions made, and limitations considered, in developing recommendations:**

A. Recommendation Number 1 [Operate Alamo Dam for maximizing the fisheries for the lake, river below the dam, and maintain the river below Planet Ranch during optimal water years].

1. Lake:

a. Water availability would be such as to allow for operating the lake elevation at a high and low operation zone, thus maintaining high productivity. Fluctuation between the two operation zones would occur on a 3 to 7 year cycle.

b. If the lake elevation remains constant or fluctuates frequently the productivity would decline.

c. The timing of the fluctuation would effect the health of the fishery.

d. Spawning will occur during the months of March - May (water temperatures between 60°F and 65°F).

e. Optimum operation elevations selected assumes, that sedimentation hasn't changed the bottom profile to render current information invalid.

2. River below the dam (dam to 6 miles below the dam):

a. Management for the river below the dam will emphasize maintenance of the existing warmwater fishery or establishing a native fish fishery. [The Arizona Game & Fish Department proposal of managing for a cold water trout fishery in the Rawhide Wilderness Area below Alamo Dam is contrary to existing regulations. Therefore, the concept for establishing a trout/native fish fishery was dropped out of this report.]

1) If promoting the existing warmwater fishery, releases from the dam should be stabilized as much as possible.

2) If promoting the native fish fishery, releases from the dam should be patterned after natural events as closely as possible.

d. That releases can be maintained and that the dam can be regulated to achieve the desired releases.

e. That lake elevations are adequate for providing the release needs without changing the lake operation from optimal to acceptable.

3. River below Planet Ranch:

a. Water will reach the lower end of the Bill Williams River corridor.

b. Planet Ranch pumping will decrease in the future.

B. Recommendation Number 2 [Operate Alamo Dam for maximizing the fisheries for the lake, river below the dam, and maintain the river below Planet Ranch during acceptable water years].

1. Lake:

a. Water inflow would only allow for operating the lake at the lower operation zone.

b. If the lake elevation remains constant or fluctuates frequently the productivity would decline.

c. The timing of the fluctuation would effect the health of the fishery.

d. Spawning will occur during the months of March - May (water temperatures between 60°F and 65°F).

e. Low operation zone selected assumes, that sedimentation hasn't changed the bottom profile to render current information invalid.

f. The population dynamics of the lake fishery would be maintained as is indicated in the 1990-1992 lake surveys.

2. River below the dam (dam to 6 miles below the dam):

a. If promoting the existing warmwater fishery, releases from the dam should be stabilized as much as possible.

b. If promoting the native fish fishery, releases from the dam should be patterned after natural events (higher releases January - March with declining flows after March, with a monsoon spike later on in the year if a monsoon occurs).

c. That releases can be maintained below the dam and that the dam can be regulated to achieve the desired releases.

d. That lake elevations are adequate for providing release needs without changing lake operation from acceptable to adverse.

3. River below Planet Ranch:

a. Water will reach the lower end of the Bill Williams River corridor.

b. Planet Ranch pumping will decrease in the future.

C. Recommendation Number 3 [Operate Alamo Dam for maximizing the fisheries for the lake, river below the dam, and maintain the river below Planet Ranch during adverse water years].

1. Lake:

a. Inflow to the lake will not be adequate to maintain lake elevation with in the lower operation zone on an annual basis.

b. Inflow to the lake will be adequate to restore lake elevation to the lower operation zone once every 3 years.

2. River below the dam (dam to 6 miles below the dam) and River below Planet Ranch:

   a. If the lake elevation is above the 1,110ft. minimum, releases should be maintained at a minimum of 25cfs..

   b. If the lake elevation is at or below the minimum acceptable level, only legally mandated water right releases will be made.

D. Generalized assumption.

The preferred Operation Zones were selected from the elevations where changes in the lake level would result in minimum change in surface acres of the lake that are less than 6 meters (19.68ft) deep. This was determined from the Alamo Lake capacities table.

III. Water operation recommendations that maximize fisheries opportunity during optimal, acceptable, and adverse water years:

A. Purpose:

To provide the Bill Williams River Corridor Technical Committee with water operation recommendations that would maximize the different fisheries during various water years (optimal = wet years, acceptable = normal years, adverse = dry years).

B. Recommendations:

1. **Recommendation Number 1 [Operate Alamo Dam for maximizing the fisheries for the lake, river below the dam, and maintain the river below Planet Ranch during optimal water years].**

Alamo Lake

The Bill Williams River Corridor consists of Alamo Lake which provides water for the riverine portions between Alamo Dam and Lake Havasu. The Alamo Lake bass fishery has historically been one of the premier largemouth bass fisheries in the state of Arizona. For the purpose of maximizing the lake fishery it would require the use of two different operating zones to maintain the lake in a highly productive state. These operating zones should be rotated back and forth on a five to seven year cycle. The high water operation would only be possible during optimal water years. The low water operation zone would be the primary operation zone (Fig. 1).

a. Primary Operation Zone would consist of the following operational criteria:

   1. Low operation zone would range between the lake elevations of 1,110ft. and 1,125ft. above mean sea level. At these elevations a 15ft. fluctuation would not change the available acres of habitat less than 6 meters (19.68ft.) deep to any great extent (Fig. 1).

   2. Prior to the start of the spawning season the lake elevation should be at or near the top of the operating zone (1,125ft. msl) on or before March 15th. This sets the stage for the start of another years operation which provides a pool of water for the down stream releases through the remainder of the year.

   3. During the spawning season (March 15th - May 31st) the lake elevation should not fluctuate more than 2 inches per day (up or down). Zero fluctuation is preferred. The 2 inch per day fluctuation is the maximum rate of change in order to maintain a 0.5 suitability index or better for the above mentioned spawning season. Zero fluctuation during the spawn is the ideal, producing the highest possible suitability index of 1.0. If during the spawning season a storm event occurs where outflow can't match inflow, reestablish the zero to 2 inch per day fluctuation for the remainder of the spawning season after the storm has passed. [Try to minimize the number of days that large fluctuations occur.]

   4. During the growing season (June 1st - September 30th) lake elevation should not drop more than 4 meters (13.12ft.). For survival of the fry it is generally more important to have an increasing water level for the stimulation of plankton blooms. This would equal a maximum weekly fluctuation of 23cm (9 inches) per week.

   5. If the lake elevation reaches the 1,110ft. elevation, releases from the dam will only be made for legally mandated water rights.

   6. If during any time of the year a storm event occurs which causes the fluctuations to be outside of the prescribed fluctuation for that period the prescription will not be re-initiated until control has be reestablished. If releases have

to be made they should be made as fast as possible to reduce the time that extreme fluctuations occur.

b. The secondary operation zone (high elevation) will consist of the following operational criteria:

1. Operation would consist of any twenty foot range above the upper elevation of the primary operation zone (1,125ft. msl) (Fig. 1).

2. The ideal zone would be from 1,190ft. to 1,210ft. This is the only higher elevation where fluctuation does not change the available acres of habitat less than 6 meters (19.68ft.) deep to any great extent.

3. Prior to the start of the spawning season the lake elevation should be at or near the top of the operating zone being used on or before March 15th. This sets the stage for the start of another years operation which provides a pool of water for the down stream releases through the remainder of the year.

4. During the spawning season (March 15th - May 31st) the lake elevation should not fluctuate more than 2 inches per day (up or down). Zero fluctuation is preferred. The 2 inch per day fluctuation is the maximum rate of change in order to maintain a 0.5 suitability index or better for the above mentioned spawning season. Zero fluctuation during the spawn is the ideal, producing the highest possible suitability index of 1.0. If during the spawning season a storm event occurs where outflow can't match inflow, reestablish the zero to 2 inch per day fluctuation for the remainder of the spawning season after the storm has passed. [Try to minimize the number of days that large fluctuations occur.]

5. During the growing season (June 1st - September 30th) lake elevation should not drop more than 4 meters (13.12ft.). For survival of the fry it is generally more important to have an increasing water level for the stimulation of a plankton bloom. This would equal a maximum weekly fluctuation of 23cm (9 inches) per week.

6. If the lake elevation reaches the lower margin of the selected operating zone, releases from the dam will only be made for legally mandated water rights.

7. If during any time of the year a storm event occurs which

causes the fluctuations to be outside of the prescribed fluctuation for that period the prescription will not be re-initiated until control has been reestablished. If releases have to be made they should be made as fast as possible to reduce the time that extreme fluctuations occur.

Bill Williams River
[Dam to 6 Miles Below the Dam]

Historically the Bill Williams River was a typical desert river which demonstrated the characteristic of lots of water for short periods of time and little or no water for long periods of time. This was all changed with the establishment of Alamo Dam. The area from the dam down stream for approximately 6 miles now contains water on a year round basis. Fisheries emphasis for this area is to maintain water in this reach to support the existing fishery with the possibility at a later date of looking into developing a native fish fishery. The native fish involved in the fishery would be desert sucker, sonora sucker, roundtail chub, and longfin dace.

c. Release patterns requested for the existing warmwater fishery:

1. Releases averaging 50 cfs per week or greater for the period of June through September. With this release there would be sufficient water in the summer months to prevent any temperature or oxygen problem from occurring.

2. Releases of 25 cfs or greater for the period of October through May. During the cooler months there isn't any possible problem with temperature or oxygen which would allow for lower releases.

3. All releases should be stabilized to hold the surges at a minimum when possible.

4. If the lake elevation reaches the lower margin of the selected operating zone releases from the dam will only be made for legally mandated water rights.

d. Release patterns requested for the development of a native fish fishery:

1. The native fish fishery releases from the dam should be patterned after natural events (higher releases January - March with declining flows after March).

2. If the lake elevation reaches the lower margin of the selected

operating zone, releases from the dam will only be made for legally mandated water rights.

Bill Williams River
[Planet Ranch to Lake Havasu]

The management of the lower river will simply be an effort to promote a native fish fishery if possible. The native fish involved in the fishery would be desert sucker, sonora sucker, roundtail chub, and longfin dace. That portion of the Bill Williams River below Planet Ranch is the primary area where permanent water exists on a year round basis. The amount of water present will depend on the amount of releases from Alamo Dam and the amount of pumping at Planet Ranch.

e. Release patterns requested for the lower river would be as follows:

1. Release enough water from Alamo Dam to maintain a minimum of 25 cfs flows in the Bill Williams River below Planet Ranch on a year round basis.

2. If the lake elevation reaches the lower margin of the selected operating zone, releases from the dam will only be made for legally mandated water rights.

Resource Outcome for Recommendation # 1

Under this recommendation the fisheries resource in the lake would fluctuate between increased production during the high water elevation operating period and the recharging of the nutrient levels (re-vegetation or previously inundated) during low water operating periods.

The riverine sections below the dam would be managed for maximizing the fisheries and recreational opportunity by providing both a stable flow regime for the existing fishery below the dam and possibly provide an area for establishing a native fish fishery that doesn't exist at this time.

Without a working computer model, exactly what the outcome would be below Planet Ranch is not known. There are too many variables that are unknown at the present time. The desired outcome would be the establishment of a native fish fishery on the lower end of the Bill Williams River also.

Benefits Resulting from Recommendation # 1

Fisheries:

1. This operational pattern would improve the largemouth bass and catfish population dynamics of the lake fisheries. During the years that the lake elevation is held at the secondary operation zone the populations would increase in size and condition.

2. This operational pattern would result in increases for all other species of fish as well, resulting in possibly making it easier for the foraging bald eagles.

3. This increase in the sport fisheries would result in an increase in the economy of the area.

4. This operational pattern would provide an improved sport fish fishery and a possible native fish fishery that currently doesn't exist.

Others:

1. This operational pattern would result in the recharge of the entire Bill Williams River Corridor aquifer.

2. This operational pattern would result in an increase of the overall biodiversity of the entire Bill Williams River Corridor.

Impacts Resulting from Recommendation #1

1. There would be possible eagle nesting problems during the high water level operation period. This would only be true if low elevation nests were reestablished.

2. Depending on the elevation there may be operation problems for the state park.

3. The improved fishery below the dam may cause an increase in human impacts to the area.

4. It may affect the operation of the Dam by establishing operation zones that may be outside of current Dam operations.

2. **Recommendation Number 2 [Operate Alamo Dam for maximizing the fisheries for the lake, river below the dam, and river below Planet Ranch during acceptable water years].**

Alamo Lake

Operation for optimizing the largemouth bass fisheries in the lake during normal water years should work toward maintenance and stabilization of the bass population at acceptable levels. This would consist of operating the lake continually at the low water operation zone (Fig. 1). Long term operation under this operational plan (10 plus years) will result in a slow decline in the productivity of the system. For the best results the criteria used below for spawning and growing seasons should occur each year, but once every other year would be acceptable.

This recommendation differs from recommendation # 1 in that there is only one Operation Zone; the spawning season has been shortened; and the growing season has been lengthened.

a. Lake operating zone:

1. Low operation zone would range between the lake elevations of 1,110ft. and 1,125ft. above mean sea level. At these elevations a 15 ft. fluctuation would not change the available acres of habitat less than 6 meters (19.68ft.) deep to any great extent (Fig. 1).

2. Prior to the start of the spawning season the lake elevation should be at or near the top of the operating zone (1,125ft. msl) on or before March 15th. This sets the stage for the start of another years operation which provides a pool of water for the down stream releases through the remainder of the year.

3. During the spawning season (April 1st - May 15th) the lake elevation should not fluctuate more than 2 inches per day (up or down). Zero fluctuation is preferred. The 2 inch per day fluctuation is the maximum rate of change in order to maintain a 0.5 suitability index or better. Zero fluctuation during the spawn is the ideal, producing the highest possible suitability index of 1.0. If during the spawning season a storm event occurs where outflow can't match inflow, reestablish the zero to 2 inch per day fluctuation for the remainder of the

spawning season after the storm has passed. [Try to minimize the number of days that large fluctuations occur.]

4. During the growing season (May 15th - September 30th) lake elevation should not drop more than 4.6 meters (15.1ft.). For survival of the fry it is generally more important to have an increasing water level for the stimulation of a plankton bloom. This would equal a maximum weekly fluctuation of 23cm (9 inches) per week.

5. If the lake elevation reaches the 1,110ft. elevation, releases from the dam will only be made for legally mandated water rights.

6. If during any time of the year a storm event occurs which causes the fluctuations to be outside of the prescribed fluctuation for that period the prescription will not be re-initiated until control has be reestablished. If releases have to be made they should be made as fast as possible to reduce the time that extreme fluctuations occur.

Bill Williams River
[Dam to 6 Miles Below the Dam]

Historically the Bill Williams River was a typical desert river which demonstrated the characteristic of lots of water for short periods of time and little or no water for long periods of time. This was all changed with the establishment of Alamo Dam. The area from the dam down stream for approximately 6 miles now contains water on a year round basis. Fisheries emphasis for this area is simply to maintain water in the 6 mile area to support the existing fishery with the possibility at a later date of looking into developing a native fish fishery. The native fish involved in the fishery would be desert sucker, sonora sucker, roundtail chub, and longfin dace.

b. Release patterns requested for the existing warmwater fishery:

1. Releases averaging 50 cfs per week or greater for the period of June through September. With this release there would be sufficient water in the summer months to prevent any temperature or oxygen problem from occurring.

2. Releases of 25 cfs or greater for the period of October through May. During the cooler months there isn't any possible problem with temperature or oxygen which would allow for lower releases.

3. All releases should be stabilized to hold the surges at a minimum when possible.

4. If the lake elevation reaches the 1,110ft. elevation, releases from the dam will only be made for legally mandated water rights.

c. Release patterns requested for the development of a native fish fishery:

1. The native fish fishery releases from the dam should be patterned after natural events.

2. If the lake elevation reaches the lower margin of the selected operating zone, releases from the dam will only be made for legally mandated water rights.

Bill Williams River
[Planet Ranch to Lake Havasu]

The management of the lower river will simply be an effort to promote a native fish fishery if possible. The native fish involved in the fishery would be desert sucker, sonora sucker, roundtail chub, and longfin dace. That portion of the Bill Williams River below Planet Ranch the primary area where permanent water exists on a year round basis. The amount of water present will depend on the amount of releases from Alamo Dam and the amount of pumping at Planet Ranch.

e. Release patterns requested for the lower river would be as follows:

1. Release enough water from Alamo Dam to maintain a minimum of 25 cfs flows in the Bill Williams River below Planet Ranch on a year round basis.

2. If the lake elevation reaches the lower margin of the selected operating zone releases from the dam will only be made for legally mandated water rights.

Resource Outcome for Recommendation # 2

Under this recommendation the fisheries resource in the lake would remain strong, largemouth bass recruitment would be good, and nutrient levels will be stable at first and then slowly decline if this operation continues for an extended period of time.

The riverine sections below the dam would be managed for maximizing the fisheries and recreational opportunity by providing both a stable flow regime for the existing fishery below the dam and possibly provide an area for establishing a native fish fishery that doesn't exist at this time.

Without a working computer model, exactly what the outcome would be below Planet Ranch is not known. There are too many variables that are unknown at the present time. The desired outcome would be the establishment of a native fish fishery on the lower end of the Bill Williams River also.

Benefits Resulting from Recommendation # 2

Fisheries:

1. This operational pattern would promote a stable largemouth bass and catfish fisheries in the lake.

2. This operational pattern would result in stabilization of all of the other species of fish, including the forage base for the nesting bald eagles.

3. This stabilization of the sport fisheries would result in stabilization of the economy in the area.

4. This operational pattern would provide an improved sport fish fishery and a possible native fish fishery that currently doesn't exist.

Others:

1. This operational pattern may result in the recharge of the entire Bill Williams River Corridor aquifer.

2. This operational pattern would result in an increase of the overall biodiversity of the entire Bill Williams River ecology of the system.

3. The consistent water elevation of the lake would assist the state park in their operation and development of the area.

4. The consistent water elevation of the lake would benefit the eagles in that they would not have to have as many alternate nest sites. (Artificial nesting sites could also be established)

Impacts Resulting from Recommendation #2

1. As is common with all reservoirs the quality of the fishery will decline with time because of a continual decline in lake productivity.

2. The eventual decline in the lake fishery will result in a decline in the economy for the area.

3. **Recommendation Number 3 [Operate Alamo Dam for maximizing the fisheries for the lake, river below the dam, and river below Planet Ranch during adverse water years].**

Because of the nature of the area there will be periods of time when the watershed receives very little water. During those years it is imperative to strive to protect the lake fisheries (don't continue to drain the lake for reasons other than fisheries). In drought years all operation for down stream activities, other than legally mandated releases, should be discouraged (Fig. 1.).

This recommendation differs from recommendation # 2 in that operation zone should be met at least once every 3 years; growing season constraints have been dropped; and riverine constraints have also been dropped.

Drought Operation

a. Strive to operate the lake under the criteria set up under the low water operation zone at least once every 3 years to insure spawning success at least once every 3 years.

b. During the other years maintain the lake elevation as high as possible.

c. During the spawning season (April 1st - May 15th) the lake elevation should not fluctuate more than 2 inches per day (up or down). Zero fluctuation is preferred. The 2 inch per day flucuation is the maximum rate of change in order to maintain a 0.5 suitability index or better. Zero fluctuation during the spawn is the ideal, producing the highest possible suitability index of 1.0. If during the spawning season a storm event occurs where outflow can't match inflow, reestablish the zero to 2 inch per day fluctuation for the remainder of the spawning season after the storm has passed. [Try to minimize the number of days that large fluctuations occur.]

d. If the lake elevation reaches the 1,110ft. elevation, releases from the dam will only be made for legally mandated water rights.

e. If the lake elevation is below the 1,110ft. msl. mark and a storm event occurs, 25% of that storm event should be released for down stream fisheries needs. The remaining 75%

of the storm should be retained in the lake.

Resource Outcome for Recommendation # 3

Under this recommendation the lake fisheries would be sustained through the low water years with little concern for the river other than the legally mandated water rights.

Benefits Resulting from Recommendation # 3

1. Maintain the fisheries in the lake.

2. Maintain the economy associated with the fishery.

Impacts Resulting form Recommendation # 3

1. If the lake elevation dropped below the 1,110ft. level there would be an effect on the operation of the park.

2. There could be a negative effect on the nesting eagles in the area as it pertains to forage.

3. There would be a decline in the existing fisheries in the lake.

4. There would be a possible adverse effect on the fisheries in the riverine sections of the system.

5. There would be a decline in the economy in the area.

IV. Information Needs and Deficiencies:

During the course of the discussions several needs and deficiencies were brought out. The list is as follows:

A. Need for establishing some type of gaging station on the lower end of the Bill Williams River below Planet Ranch in order to fill the void in flow information at the bottom end of the system.

B. Surveys are needed to establish a base line for the current fisheries and other aquatic organisms in the riverine sections.

C. It was not known what releases would be required to establish a surface flow on the Bill William River below planet ranch (25cfs, 10cfs or ????).

D. What pool size would be required in the lake in order to maintain a surface flow in the river below Planet Ranch and still keep the lake at an elevation above 1,110ft.

E. Temperature information on the lake to determine the effects of various storm events.

F. The entire process would have been easier if a hydrological model had been available for use by the various subcommittees during their effort to come up with the various flow requirements.

V. Issues, Concerns, and Opportunities Regarding Water Management for the Fisheries Resources:

A. The importance of the Alamo Lake fisheries.

B. The importance of the fisheries resource as it relates to the nesting bald eagles.

C. The issue of trout in the artificial cold water riverine system below the dam as it pertains to the wilderness.

D. The issue of park operation and maintenance.

E. The issue of recharging the aquifers below the dam.

F. Flood control issues and concerns.

G. The issues associated with the development and maintenance of riparian area along the river.

H. The potential of increased public use on the lake and in the area below the dam.

I. Problems associated with the enforcement of the various regulations in the area, above and below the dam.

J. The etched in stone "1,100ft elevation" !!!!!!!

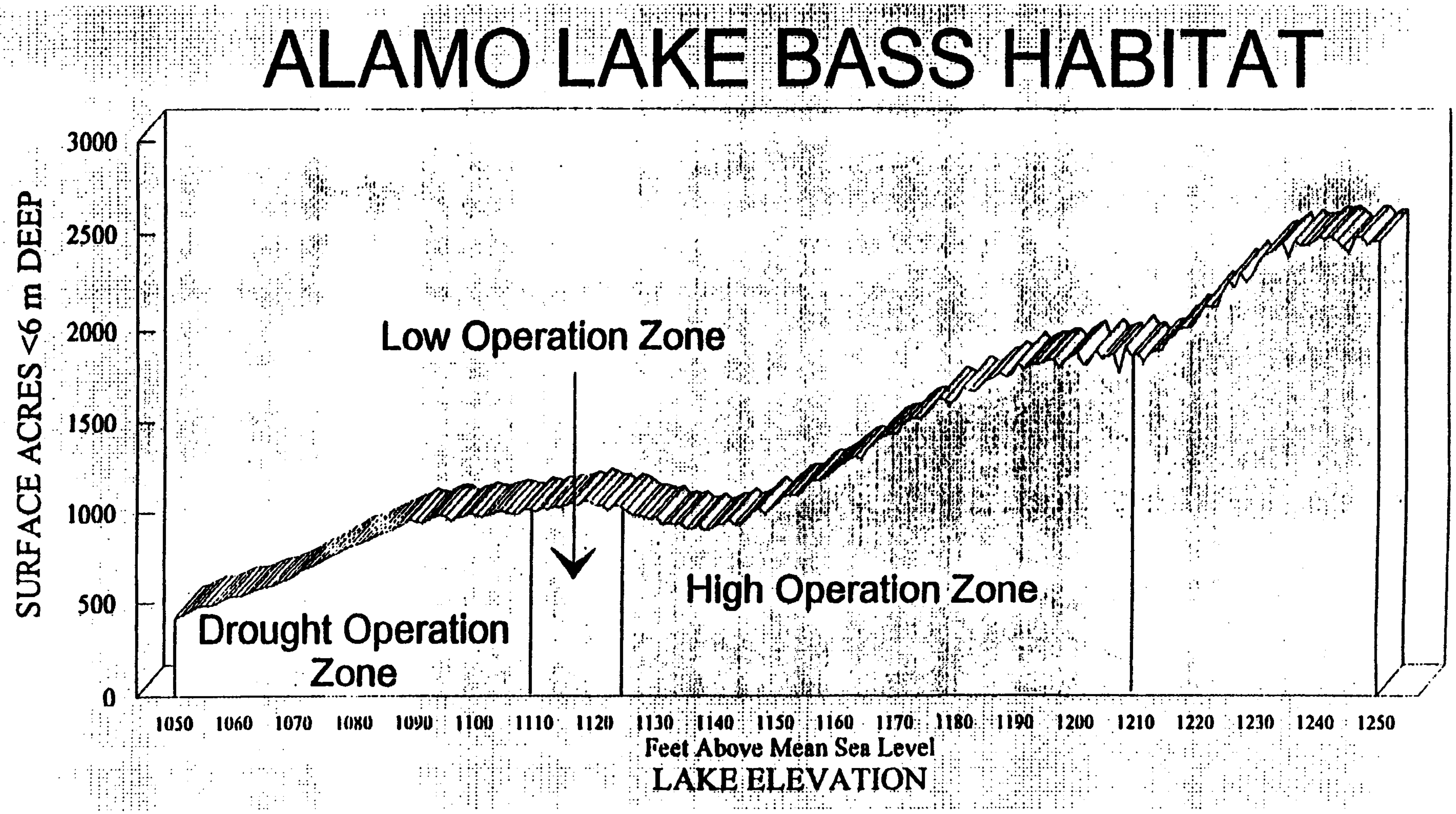


Figure 1: Alamo Lake largemouth bass operation zones:

SUMMARY OF SPAWNING CRITERIA

	WET WATER YEARS	NORMAL WATER YEARS	DRY WATER YEARS
Lake Elevations:	Low Zone : 1,110 - 1,125ft. msl High Zone: Above 1,125ft. msl Preferred High Zone: 1,190 - 1,210ft, msl	Low Zone : 1,110 - 1,125ft. msl every year for best results; once every other year would be acceptable	Low Zone : 1,110 - 1,125ft. msl at least once every 3 years
Season Dates:	March 15 - May 31	April 1 - May 15	April 1 - May 15
Lake Fluctuations:	Maximum of 2 inches per day (Zero fluctuation is the best)	Maximum of 2 inches per day (Zero fluctuation is the best)	Maximum of 2 inches per day (Zero fluctuation is the best)

SUMMARY OF GROWING SEASON CRITERIA

	WET WATER YEARS	NORMAL WATER YEARS	DRY WATER YEARS
Lake Elevations:	Low Zone : 1,110 - 1,125ft. msl High Zone: Above 1,125ft. msl Preferred High Zone: 1,190 - 1,210ft, msl	Low Zone : 1,110 - 1,125ft. msl	No Requirement
Season Dates:	May 16 - Sept. 30	May 16 - Sept. 30	No Requirement
Lake Fluctuations:	Maximum Weekly fluctuation of 9.5 in.	Maximum Weekly fluctuation of 9.5 in.	No Requirement

ATTACHMENT I

All comments were appreciated and taken into consideration. The types of comments that were received were both general and specific. Several of the suggestions were made in the new report that is enclosed with this memorandum. Comments that were more in the form of questions will be addressed in the remainder of this memorandum.

Comment # 1:

Currently a suggested maximum elevation change is 2 inches per day with a maximum shift of 4 meters. How does this compare to current operations? It seems like such a shift would greatly affect aquatic macrophytes, which provide both food and cover.

Answer: Any elevation change indeed will have some affect on the aquatic macrophytes. It is recommended that there be zero fluctuation if possible or the maximum of 2 inches per day during the spawning season. Current operations change from year to year. In general, the release patterns have had a tendency to exceed 2 inches per day and macrophyte production has not been a problem in the past.

Comment # 2:

Native fish fishery releases from the dam should be patterned after natural events. This I am sure will benefit native fishes, but will also benefit non-natives.

Answer: You are correct in your assumption.

Comment # 3:

Is there enough water in Alamo to support the proposed flows to begin with? And with what probabilities can we expect normal, wet, and dry years?

Answer: For the fisheries recommendations there is enough water. If water availability starts to become a concern the operation of the dam shifts to the next recommendation. Once the water elevation reaches 1,110ft. msl the dam is closed to maintain the lake.

As for the probability of expecting the different water years your guess is as good as mine.

Comment # 4:

In the fisheries technical report there are many references to the possibility of native fish reintroduction below the dam, however there is nothing stated about water temperature being a limiting factor for this effort.

Answer: Temperatures have been collected with various water releases from the dam and it was determined that it would not be a factor. Therefore, there was no mention of temperature in the report.

Comment # 5:

Define hydrologic conditions or parameters that constitute "optimal water years" (wet years), "acceptable water years" and adverse water years". Are these designations based on peak discharge levels into alamo or on lake elevations?

Answer: I am not quit sure how to respond to this question. I would like to see, at least for the fisheries, all reference to the different water years dropped. In fisheries, the state of the resource is dependent of the stability of the lake and the use of different lake elevations during various years. The elevations that were selected in the fisheries report are ones that appeared to be feasible. They are not the only ones or even the best ones, they are the most acceptable ones for fisheries under existing constraints.

Comment # 6:

Identify adverse conditions and limitations within each of the recommendations (i.e., minimum and maximum allowable rates, beyond which adverse impacts to the resource are likely).

Answer: These rates that you request are in each recommendation. Minimum = "0" fluctuation Maximum = "2 inches per day" for the spawning season. There are similar criteria was established for the growing season.

Comment # 7:

The sections for recommendations # 1, 2, and 3 are highly repetitive thus adding unnecessarily to the length of the document and making it difficult to determine the generally minor changes between the recommendations. A better approach might be to keep recommendation #1 as is, but for recommendations #2 and 3 summarize the changes from #1 and delete the redundant sections.

Answer: This could be done easily as you mentioned. The reason it wasn't is that it was felt that each one sould be able to stand alone. I will go ahead and include a statement in Bold for recommendation #2 and 3 that will indicate the differences.

Comment # 8:

On Page 4, D. Provide justification for the use of the 6 meter figure. Don't most bass spawn at 1-2 m depths?

Answer: When looking at just the spawning season you are basically correct with your 1-2 meters comment. However, the 6 meters figure is referring to the water area that the bass use the entire year not just during the spawning season.

Comment # 9:

On Page 5, a.1. Provide justification for the 1,110ft. minimum range. How is this better for the fishery than the existing 1,100ft. level?

Answer: This question was basically answered under comment # 5. In general any elevation that provides more surface acres of water that is less than or equal to 6 meters deep is better. An elevation of 1,110ft. is better than 1,100ft. as 1,100ft. is better than 1,090ft.

Comment # 10:

On Page 5, a.6. This recommendation could be highly debated. If a substantive flood event occurs that raises the lake significantly, wouldn't it be better to use the new lake elevation to establish the high operation zone?

Answer: Yes, if the lake has been down for several years and there is a commitment from the Corps of Eng. to maintain that higher elevation for three to seven years if water availability permits. This would establish a new low water elevation for those years which is higher than 1,125ft.

If the lake elevation rose 10 or more feet in a few days, how would it benefit the fisheries to release these waters as soon as possible to the original elevation?

Answer: I am not sure where you came up with this question. What is said is that once the storm event is over reestablish the prescribed fluctuation rates. The rates will depend on the time of year that the storm event occurred. **"If releases have to be made (for other than fisheries reasons) they should be made as fast as possible to reduce the time that extreme fluctuations occur."** There is no mention of returning to the original elevation following a storm event.

Should the seasonality of flooding events be considered in determining how rapidly waters are released from the dam?

Answer: This is basically answered in the bold print above. In short "YES" but that is the Corps of Eng. call not the BWRC Fisheries Subcommittee's.

Comment # 11:

Page 6, b.2. This recommendation fails to account for the Corps Flood Control pool operation criteria.

Answer: You are correct. This is a fisheries recommendation and it simply states that the zone between 1,190ft. and 1,210ft. elevations would be "ideal". Just above there in b.1. it is stated that any 20 foot range above the upper elevation of the primary operation zone (1,110ft. - 1,125ft.) would be OK.

Page 6, b.2. The logic behind the selection of the 1,190ft to 1,125ft. range is unclear and appears ill-advised particularly during the spawning season. For acres of habitat to remain relatively stable during a 35 foot fluctuation would mean that bottom slopes in water <6 meters would be relatively steep.

Answer: You have your elevation numbers backwards and the area that we are looking at is a 65ft. area not a 35ft. area of which we are only targeting 20ft of it in there somewhere (depending on water availability when implementing the secondary operation zone).

As for the logic, in order to stimulate the productivity in the lake one has to inundate areas that have been high and dry for a period of years. Therefore any 20ft. operation zone higher than the primary operation zone would accomplish that end.

Comment # 12:

Page 14,e. Specify what is intended by 25% and 75% of storm events. Is this based on total storm inflow volume? Over what period of time should downstream releases occur and water be retained in the lake?

Answers: The intent is to use 75% of any particular storm event to build the lake back up to the operating zone and 25% of the storm event to keep water in the system below. This is based on total volume of each storm. The down stream releases and periods should be made in accordance with other down stream requests.

Comment # 13:

Page 14, Recommendation #3, Benefit #1 "Sustain a fisheries in the lake." and Impact #3 "There would be a decline in the existing fisheries in the lake." appear contradictory.

Answer: Maybe the word should be maintain instead of sustain. The word change will be made in the text. As far as the contradiction, there is none. The implication is that the fisheries will be maintained but the population numbers will be smaller.

Comment # 14:

How does the Corps of Eng. know what scenario they are in?

Answer: They will know by the amount of water they are able to maintain during the year. If during the year they are not able to maintain the lake elevations in the Primary Operation Zone they are in the Drought Operation Scenario. If they receive a large inflow and they have been operation under Drought or Primary Operation Scenario for a period greater than 3 years they should start operation under the Secondary Operation Scenario of Recommendation # 1. If the Corps of Eng. have been operating under the Secondary Operation Scenario of Recommendation # 1 for a period of 3 to 7 years if is possible that it is time to return to the Primary Operation Zone of Recommendation # 1. In short the availability of water will indicate what Scenario to operate under and when a change should be made.

APPENDIX F.

WILDLIFE SUBCOMMITTEE REPORT

Report

Bill Williams Corridor Planning Technical Committee:

Subcommittee for:

Threatened and Endangered Species

Neotropical Migratory Birds

Other Sensitive Species

Waterfowl

and Other Wildlife

~~June~~ JULY 1993

ADDENDUM TO THE JUNE 1993 WILDLIFE SUBCOMMITTEE REPORT
MAY 3, 1994

SECTION 7 CONSULTATION

Section 7 consultation is appropriate for any situation where dam operations may affect listed species such as the bald eagle and Yuma clapper rail. Changes to the Corps of Engineers Operating Manual would require consultation where listed species may be affected. Deviation from the Operating Manual could also require consultation.

High lake levels which inundate bald eagle nests (the current lowest elevation nest is approximately 1135 feet) would be addressed through Section 7 Consultation between the U.S. Fish and Wildlife Service and Army Corps of Engineers.

The Bald Eagle Protection Act and Migratory Bird Treaty Act also prohibit take of bald eagle nests. As with requirements of the Endangered Species Act, any parties involved in possible destruction of nests should coordinate with the Fish and Wildlife Service, outside of the Technical Committee forum, to ensure their responsibilities are met.

ADDITIONAL REQUIREMENTS FOR MAINTAINING THE BALD EAGLE

The Wildlife Subcommittee does not recommend construction of artificial nest structures at Alamo Lake. Suitable nest trees are available in the lower reaches of the Big Sandy and Santa Maria Rivers. These cottonwood trees are well within the distance bald eagles would fly to forage at the lake. Also, the live cottonwood trees may provide thermal protection and shelter that snags on the lake do not. Further, nests located up either of the rivers would remove eagle nesting activities from potential disturbance by human activity at the lake. Finally, the recent construction of a cliff nest near the confluence area indicates these eagles are capable of adapting to the inevitable loss of cottonwood snags for nesting in the upper lake. It has been suggested that construction of artificial foraging perches around the lake (e.g. simple wooden poles) may be important replacements for the decaying cottonwood snags, which are used extensively for this purpose.

I. Introduction

The Bill Williams River Corridor (BWRC) subcommittee for threatened and endangered species, neotropical migratory birds, other sensitive species, waterfowl, and other wildlife (Wildlife Subcommittee) was charged with identifying management objectives and habitat requirements for these species at Alamo Lake and the BWRC. The Wildlife Subcommittee was also charged with identifying potential habitat restoration, maintenance and enhancement opportunities through various lake level management prescriptions and stream flow regimes.

The Wildlife Subcommittee met on April 6 and May 18, 1993, to discuss recommendations for flow regimes that would best benefit the species groups it was requested to consider. The group began by reviewing its assigned goals. The broad scope of the Wildlife Subcommittee's assigned concern prompted the group to discuss a priority system, should water flow needs of various species groups ever conflict (*e.g.* waterfowl versus endangered species). However, the group ultimately found little or no conflict between habitat needs and optimal flow regime needs of threatened and endangered species, neotropical migratory birds, other sensitive species, waterfowl, and other wildlife. Further, the Wildlife Subcommittee determined that the greatest net benefit for all species and species groups would be gained through a single management strategy (see "Executive Summary," below). Ultimately, what few management priorities exist are imposed by law [*e.g.* the Endangered Species Act of 1973, as amended (ESA)]. Therefore, the Wildlife Subcommittee defined no species management priority system.

II. Executive Summary

The Wildlife Subcommittee determined that overall, all threatened and endangered species, neotropical migratory birds, other sensitive species, waterfowl, and other wildlife would best benefit from the creation and maintenance of a healthy riparian ecosystem along the Bill Williams River corridor below Alamo Dam. The Wildlife Subcommittee determined that only under extreme, prolonged drought conditions would water management needs of species at Alamo Lake conflict with maintenance of a healthy Bill Williams River riparian ecosystem. The Wildlife Subcommittee believes the recommendations of the Riparian Subcommittee will benefit all species and species groups within its assigned scope of concern. The Wildlife Subcommittee therefore endorses the Riparian Subcommittee's "preliminary flow recommendations for riparian resources." The Wildlife Subcommittee determined that, for the optimum benefits for all wildlife species, management should emphasize the habitat that makes the area special southwestern lowland riparian habitat.

A primary concern in the past has been management of the lake level with regard to the bald eagle (*Haliaeetus leucocephalus*). The Wildlife Subcommittee reiterates, but clarifies, previous recommendations to maintain a minimum elevation of 1100' for bald eagles. Considerable flexibility is available within this recommendation (See "Threatened and Endangered Species," below). The Wildlife Subcommittee recommends that, following runoff events, water collected in Alamo Lake be released gradually, in a manner which maintains but does not damage riparian habitat, and also not with an intent to return Alamo Lake to previous, perhaps minimum levels.

III. Discussion: Riparian Habitats and Wildlife

Large scale losses of southwestern wetlands have occurred, particularly cottonwood-willow riparian habitats [Carothers 1977, Rea 1983, Johnson and Haight 1984, Katibah 1984, Johnson *et al.* 1987, General Accounting Office (GAO) 1988, Szaro 1989, Dahl 1990, State of Arizona 1990]. The effects these losses have had on riparian-obligate wildlife in the Lower Colorado River Valley are extensive (Anderson and Ohmart 1984 and

1990, Hunter *et al.* 1987a, Ohmart *et al.* 1988, Rice *et al.* 1980 and 1983). These losses are due to urban encroachment, water diversion and impoundment, channelization, livestock grazing, off-road vehicle and other recreational uses, and hydrological changes resulting from numerous other land uses. However, despite abundant documentation of the importance of riparian habitats to native wildlife, recovery efforts are often slow, and some destruction continues.

Since the 1930s, the large cottonwood-willow forests along the Lower Colorado River have largely disappeared. Although greatly reduced, the Bill Williams River contains the last extensive native riparian habitat in the lower Colorado River area. However, construction of Alamo Dam in 1968 altered water flows in the Bill Williams River, consequently affecting downstream vegetation, especially recruitment of cottonwood and willow trees (Fenner *et al.* 1985). Although other factors, such as groundwater pumping and wildfires, have contributed to the decline of native vegetation, a proper flood regime could override these factors and begin to restore the riparian habitat.

Tamarisk (*Tamarix* sp.), an introduced species better able to survive the altered flow conditions, is rapidly replacing the native riparian vegetation. It is well documented that many native wildlife species do not use tamarisk (also called saltcedar). It is believed that tamarisk may not provide the essential thermal protection of native, broader-leaved species (Hunter *et al.* 1987b, Hunter *et al.* 1988). Also, tamarisk may support a significantly different insect fauna (Kerpez and Smith 1987), which could affect occurrence of insectivorous birds. Some avian species will apparently nest in tamarisk at higher elevations, but not at lower elevations like the BWRC. Further, tamarisk supports a generally lower level of biological diversity overall, compared with native riparian vegetation. At upper Alamo Lake, tamarisk may be outcompeting cottonwoods, which are important as potential bald eagle nest sites.

Destabilization of stream courses by flash flooding is required for significant reproduction and recruitment in Fremont cottonwood (Asplund and Gooch 1988, Stromberg *et al.* 1991). Historically, the riparian vegetation in the Bill Williams watershed was subject to flash-flooding events which coincided with seed dispersal in February-March. Flash floods created large, unshaded, moist alluvial deposits, ideal for the establishment of cottonwood and willow seedlings (Asplund and Gooch 1988, Reichenbacher 1984, Stromberg *et al.* 1991). Both are fast-growing trees which produce large quantities of seeds capable of wide dispersal. However, seeds lose viability within one to five weeks after dispersal (Fenner *et al.* 1984). The seeds need a suitable moist substrate at or soon after dispersal, and moist soil conditions must persist until seedling roots grow to depths where moisture is more constantly available than near the surface (Asplund and Gooch 1988, Fenner *et al.* 1984, Mahoney and Rood 1991). If these conditions are not met, opportunities for the invasion of saltcedar increase, and the opportunities for cottonwood-willow recruitment is essentially lost.

Although cottonwood and willow are dependent upon flooding for successful reproduction, prolonged inundation during the growing season can be detrimental. Roots of riparian trees are unable to draw in soil nutrients or oxygen when inundated for a period of months (Hook and Crawford 1978). There is a shortage of information on exact lengths of time that cottonwood and willow can be inundated before mortality actually occurs, but many sources (published and personal communications) suggest a period of one or two months as a limit that should be adhered to (see Reichenbacher 1984, Hunter *et al.* 1987a; B. W. Anderson, Revegetation and Management Center, Blythe, CA; D. Patten and J. Stromberg, Arizona State University Center for Environmental Studies; C. Hunter, FWS, Atlanta; D. Busch, Bureau of Reclamation, Boulder City, NV, pers. comm.). Effects of prolonged inundation may not be immediate; trees may be weakened and die over a period of years. Due to the stress of prolonged inundation, trees may be particularly susceptible to insect infestation or drought. Unnaturally prolonged high flows may also expose, undermine, and/or scour roots, or otherwise weaken trees, to the point that they fall down. In any event, the riparian habitat on the BWRC has already been compromised to such an extent that at this point and in the future, we should err on the side that benefits riparian habitats.

Benefits of a healthy riparian ecosystem to wildlife, from the bottom of the food chain up, cannot be understated. Cottonwood-willow habitat supports the highest arthropod biomass for more taxa than any other habitat in the area across all seasons (Ohmart *et al.* 1988). In mid-June, Apache cicada emerge in riparian vegetation, which coincides with peak breeding period for many bird species in cottonwood-willow communities. Invertebrate taxa are among the most prevalent food items found in the diets of vertebrates (Minckley 1979). An example of the importance of this food source is provided by the yellow-billed cuckoo (*Coccyzus americanus*), 40% of whose diet may consist of cicadas (Rosenberg *et al.* 1991).

Approximately 32 species of reptiles and amphibians also occur in aquatic and/or riparian habitats in the BWRC area, almost all highly dependent upon the large insect population for food (Ohmart *et al.* 1988). An equal number of mammal species are found in the area and occur in riparian habitat (See Section VI).

Riparian habitats are also likely to be of value to species that are not riparian obligates. Riparian areas may serve as travel corridors, water sources, and areas where these non-riparian species occur in higher abundance.

IV. Threatened and Endangered Species

The following are species currently listing under the authority of the ESA. For each species or species group, a brief discussion is provided regarding habitat/flow regime needs.

Fish

Bonytail chub	(*Gila elegans*)
Razorback sucker	(*Xyrauchen texanus*)
Humpback chub	(*Gila cypha*)
Colorado squawfish	(*Ptychocheilus lucius*)

These "big river fishes" are now and may historically have been associated with the Bill Williams River, primarily in the delta area or historic Bill Williams/Colorado confluence area. However, availability of above-ground flow in the Bill Williams River may provide important recovery opportunities. Therefore, rehabilitation and maintenance of riparian habitat is important.

Desert pupfish	(*Cyprinodon macularius*)
Gila topminnow	(*Poeciliopsis occidentalis*)
Woundfin	(*Plagopterus argentissimus*)

These small fishes have been reduced to very small, widely dispersed populations throughout their former ranges. They are generally tolerant of higher salinity, temperature, and/or turbidity. The Bill Williams River may provide important recovery habitat for these fishes. Therefore, rehabilitation and maintenance of riparian habitat is important.

Birds

Brown pelican (*Pelecanus occidentalis*) Occurs as an uncommon transient, chiefly along lower Colorado River, potentially along Bill Williams River and at Alamo Lake.

Yuma clapper rail (*Rallus longirostris yumanensis*): Occurs primarily in Bill Williams River delta area, which is near the northern edge of its range. This delta area is of minor importance in maintaining the species; 21

birds found in 1972, 21 in 1993, generally 6-15 in recent years. The delta habitat is influenced primarily by the level of Lake Havasu, which is not affected by flows from Alamo Dam.

Bald eagle (*Haliaeetus leucocephalus*): Nests at Alamo Lake [Alamo Breeding Area (BA)], on Bill Williams River below Alamo Dam (Ives BA), and until 1988, on the Big Sandy River just above Alamo Lake (Chino BA). Since its discovery in the mid-1980s, this "Alamo Lake complex" has been consistently successful in producing fledgling bald eagles. Since 1990, the Alamo complex has contributed approximately 20% of Arizona's annual eagle reproduction (Hunt *et al.* 1992, Beatty 1992, Beatty unpubl. data). The success of the Alamo Complex has been significantly facilitated by intensive management, including closure areas, rescue operations and other direct intervention (Hunt *et al.* 1992, Beatty 1992, Beatty unpubl. data).

The primary foraging habitat for all BAs in the Alamo Complex is Alamo Lake. The primary need is availability of adequate foraging habitat. The shallow water fishery of upper Alamo Lake, with numerous hunting perches and abundant fish is the most intensively used foraging habitat in the Alamo Complex. Lower lake levels may reduce the lake area sufficiently to impact food availability, and/or increase territorial interactions among eagles. At extreme high water, the lake can inundate the bald eagle nests and potential nest trees on upper Alamo Lake. As of 1993, Alamo BA and one Ives BA nests on the upper lake ranged from approximately 1135' to 1145'. These nests may no longer exist. Nest inundation occurred in 1993, resulting in take of the active eagle nest (eggs were rescued from the nest). Subsequently, the Alamo bald eagles built a new nest on a cliff, above any potential lake level. Further, cottonwood and willow trees are available on the Big Sandy and Santa Maria rivers above the lake, for potential alternate nests. These areas may be superior nest sites. They are removed from human activity on the lake, and the cottonwood snags on the lake are likely to fall soon. As a result, high water at Alamo Lake is no longer a serious concern for management of bald eagles, unless a nest is in danger of inundation. The primary concern remains the availability of foraging habitat.

The FWS has recommended a <u>minimum</u> lake level of 1100', to provide adequate foraging habitat (USFWS 1988). The Wildlife Subcommittee recommends that the FWS's recommendation of a <u>minimum</u> lake level remain in effect. In the past, this minimum level has apparently been misinterpreted as a target lake level, or a maximum lake level for bald eagle management. The 1100' elevation is a <u>minimum</u> recommended level; any lake level above 1100' is acceptable for bald eagles, as long as an eagle nest is not inundated. If a nest is to be inundated, the Corps of Engineers should exercise their options under sections 7 or 10 of the ESA. However, as siltation continues in the upper lake, this minimum recommended level may have to be revised. Finally, the Wildlife Subcommittee recommends that the Corps of Engineers resolve questions regarding effects of dam operations (both routine and emergency) on bald eagles through the ESA section 7 consultation process. Maintenance of a riparian ecosystem would also benefit the bald eagle, by providing alternate foraging habitat and nest trees (the latter important above Alamo Lake on the Big Sandy and Santa Maria Rivers.

Peregrine falcon (*Falco peregrinus*): This species is observed regularly at Alamo Lake, and more recently, along the Bill Williams River below Alamo Dam. Although surveys have found no nest sites yet (Tibbitts and D. Ward 1990, L. Ward 1993), the regional recovery of this bird makes it likely that it does or will soon breed in the area. However, the only critical habitat needs are available nesting cliffs and a prey base. These are currently available at Alamo Lake and the BWRC under all conditions, with the possible exception of prolonged, extreme drought. The peregrine is known to nest far from surface water in the Southwest, especially in woodland and chaparral habitats where jays, piciformes and other prey are abundant (Tibbitts and D. Ward 1990, L. Ward 1993). However, in very arid regions like west-central Arizona, it is likely to be more strongly tied to presence of water, probably because the associated prey abundance. Therefore, maintenance of a riparian ecosystem would likely benefit the peregrine falcon.

Plants

No listed plants are known to occur in the Bill Williams River corridor.

Reptiles and Amphibians

No listed reptiles or amphibians are known to occur in the Bill Williams River corridor.

Mammals

No listed mammals are known to occur in the Bill Williams River corridor.

V. Neotropical Migratory Birds

In recent years, concern has been raised over declines in birds which breed in northern latitudes and winter in the neotropics - neotropical migratory birds. General areas of concern include availability and condition of breeding, wintering, and migration-route habitats. Although conclusive research is pending, riparian habitats are believed to be disproportionately important to neotropical migrants during migration (D. Krueper, BLM, pers. comm.). Riparian habitats in general are known to support relatively high densities and diversity of breeding birds, including many neotropical migrants. Southwestern riparian habitats are known to support some of the greatest density and diversity of breeding birds in North America. Given that approximately 5% of the land area in the Southwest is riparian habitat, these areas are extremely important to bird communities. Loss of the cottonwood-willow riparian forests has had widespread impact on the distribution and abundance of bird species associated with that forest type (Hunter *et al.* 1987b, Hunter *et al.* 1988, Rosenberg *et al.* 1991). Therefore, rehabilitation and maintenance of the BWRC riparian habitat is important. A list of neotropical migratory birds known and/or likely to use the Bill Williams River corridor and Alamo Lake is attached (See Appendix A). Breeders and sensitive species are highlighted. For discussion of specific sensitive neotropical migrants, see Section VI, below.

VI. Other Sensitive Species

Fish

Colorado roundtail chub	(*Gila robusta*)
Gila sucker	(*Catostomus* sp.)
Gila mountain sucker	(*Catostomus discobulus* ssp.)
Longfin dace	

Availability of above-ground flow in the Bill Williams River may provide important recovery opportunities. Therefore, rehabilitation and maintenance of riparian habitat is important.

Birds

Loggerhead shrike (*Lanius ludovicianus*) (FWS Category 2 - No AGFD designation) Not a riparian obligate, but may occur in greater abundance in riparian areas. With declines in northern portions of its range, special management considerations are warranted.

Vermilion flycatcher (*Pyrocephalus rubinus*) (No FWS or AGFD designation). Rare and local resident, has declined substantially due to loss of habitat, closely associated with cottonwoods. Rehabilitation and maintenance of riparian habitat is important.

Elf owl (*Micrathene whitneyi*) (No FWS or AGFD designation; CA endangered) Rare breeder in BWRC area. Requires large trees (cottonwood, sycamore, or large mesquite) or large cacti (saguaro) for nesting.

Southwestern willow flycatcher (*Empidonax traillii extimus*): (FWS Category 1 - AGFD Endangered) The FWS was petitioned to list this species, and has made a positive 90-day finding on the petition (USFWS 1992). The southwestern willow flycatcher is a riparian obligate species, nesting in dense thickets of cottonwood-willow, *Baccharis*, boxelder and similar vegetation. Rehabilitation and maintenance of riparian habitat is important.

Black rail (*Laterallus jamaicensis*) (FWS Category 2 - AGFD endangered, CDFG threatened) Permanent resident in BWRC in small numbers.

Yellow-billed cuckoo (*Coccyzus americanus occidentalis*) (FWS Category 3c - AGFD threatened, CDFG endangered) Recent investigation (Franzreb and Laymon 1993) renews support for recognizing the "western" subspecies, which enhances concern for cuckoos in the BWRC. Largest remaining population of breeders on lower CO are on BWR. Confined to extensive stands of cottonwood. Cicadas are 40% of their diet.

Gilded flicker *Colaptes auratus meamsii* Fairly common on BW, rare everywhere else. Associated with saguaros and cottonwoods.

Brown crested flycatcher (*Myiarchus tyrannulus*) A species of "special concern" in California. Cottonwoods and/or other larger riparian trees are necessary for nest cavities; this flycatcher also feeds heavily on cicadas. Rehabilitation and maintenance of riparian habitat is important.

Bell's vireo (*Vireo bellii arizonae*) Riparian species; more abundant and widespread formerly. Rehabilitation and maintenance of riparian habitat is important.

Common black-hawk (*Buteogallus anthracinus*) Riparian species; rehabilitation and maintenance of riparian habitat is important.

Brown-headed cowbird (*Molothrus ater*) A brood parasite, which is impacting many songbirds, some to the degree of becoming a threat to their continued existence (Mayfield 1977, Brittingham and Temple 1983). In particular, cowbird parasitism is identified as a threat to the southwestern willow flycatcher (Harris 1991, USFWS 1992). management strategies to reduce this threat include: reducing and recovering fragmented riparian habitat; removing livestock and livestock concentration areas from riparian habitat and surroundings; cowbird trapping programs.

Belted kingfisher (*Ceryle alcyon*) AGFD candidate species. Information indicates wintering only, but breeding is theoretically possible. Rehabilitation and maintenance of riparian habitat is important.

Plants

Cottonwood (*Populus* sp.) Fundamental component of southwestern riparian ecosystems, reduced throughout range. Rehabilitation and maintenance of riparian habitat is important.

Willow (*Salix* sp.) Fundamental component of southwestern riparian ecosystems, reduced throughout range. Rehabilitation and maintenance of riparian habitat is important.

Reptiles and Amphibians

Rana yavapaiensis: pools, permanent water, floods OK, no bass.

Bufo microscapus:

Gila monster (*Heloderma suspectum*): Tends to occur in greater numbers in riparian areas. Rehabilitation and maintenance of riparian habitat is important.

Desert tortoise (*Xerobates agassizi*) (FWS Category 2 - AGFD Candidate) Not a riparian obligate, but impacts may be occurring due to uses within BWRC and adjacent uplands. Potential impacts include recreation, and livestock and burro use, which may significantly compete with tortoise for food.

Chuckwalla (*Sauromalus obesus*) (FWS Category 2) Not a riparian obligate, but impacts may be occurring due to uses within BWRC and adjacent uplands. Potential impacts include recreation, and livestock and burro use, which may significantly compete for food.

Garter snakes (*Thamnophis* spp.) Rehabilitation and maintenance of riparian habitat is important.

Mammals

Bats: Various bat species are likely to occur in the BWRC, including: spotted bat, red bat, hoary bat, California leaf-nosed, and others. In virtually all cases, bat populations could be expected to benefit from the rehabilitation and maintenance of riparian habitat.

Bighorn sheep (*Ovis canadensis*): Not a riparian obligate, but impacts may be occurring due to uses within BWRC and adjacent uplands. Potential impacts include recreation, and livestock and burro use, which may significantly compete for food. BWRC almost certainly used as a water source. Rehabilitation and maintenance of riparian habitat is important.

Invertebrates

VII. Waterfowl

Although there may be some limited nesting within the BWRC and Alamo lake, the Wildlife Subcommittee considered waterfowl to occur primarily as migrants and winter residents. Currently, approximately 90% of the Canada geese (*Branta canadensis*) wintering on the lower Colorado River use the Cibola National Wildlife Refuge. This concentration likely increases the probability of a disease outbreak, and increases the potential extent of such an outbreak. A wider distribution of wintering geese along the lower Colorado River and tributaries is therefore desirable. The most feasible opportunity to achieve at least a partial redistribution appears to be on the Planet Ranch, which may be acquired by the Bill Williams National Wildlife Refuge. The cultivated acreage there is currently believed to be approximately 2300 acres of alfalfa. By supplementing alfalfa with wheat, this could be reduced to 400 acres, thus reducing ground water pumping by approximately 83% and still providing sufficient forage for 5000 to 6000 geese. Attracting that number of geese would require designation of a disturbance-free (no entry) roosting area within the delta during the winter (*e.g.* November 15-March 1). Such a restriction would also result in an increase in duck numbers. It would take several years following implementation of management practices to realize the increase in waterfowl use.

Conversion of 25% of the crop at Planet ranch to wheat would slightly reduce demands on groundwater, and benefit several avian species, especially following dry winters when the seeds of desert annuals are scarce. White-winged doves nesting in the riparian zone would be a major beneficiary. The value of the area to geese would not be sufficiently reduced. Developing a moist soil management unit at Planet Ranch would increase the diversity and abundance of birds using that portion of the ranch. However, as the habitat diversity is increased, management may become more complex for the managing agency.

The Wildlife Subcommittee recommends maximizing the shallow-water area of upper Alamo Lake (3" to 6" deep) during the spring and summer. This will result in maximum forage availability for wintering waterfowl, primarily ducks. However, without designation of a "no entry" zone, use of the lake by geese is likely to be minimal. Maintaining a base surface flow through the BWRC, as recommended by the Riparian Subcommittee, will also benefit various duck species.

VIII. Other Wildlife

For this broad category, the Wildlife Subcommittee's determination was again that rehabilitation and maintenance of riparian habitat is important. Riparian habitats are particularly rare in western Arizona. Operation of Alamo Dam on the Bill Williams River provides opportunity for maintaining a healthy, biologically diverse riparian ecosystem in this otherwise very arid region.

The Wildlife Subcommittee discussed several "other wildlife" species, and several management opportunities, in particular:

Livestock grazing: Given the importance of the BWRC riparian habitat, effects of livestock grazing warrant discussion. Present and historic overuse by livestock has been a major factor in the degradation and modification of riparian habitats in the western United States. These effects include changes in plant community structure, species composition and quantity, often linked to more widespread changes in watershed hydrology (Rea 1983, GAO 1988). Water quality may also be impacted, through increased erosion, siltation, and fecal material. Livestock grazing in riparian habitats typically results in reduction of riparian vegetation (especially palatable broadleaf plants like willows and cottonwood saplings), and is the most common cause of riparian degradation (Carothers 1977, Rickard and Cushing 1982, Cannon and Knopf 1984, Klebenow and Oakleaf 1984, GAO 1988, Clary and Webster 1989, Schultz and Leininger 1990). Linear riparian habitats in arid regions are particularly vulnerable to fragmentation. As shady, cool, wet areas providing abundant forage, they are disproportionately preferred by cattle, over the surrounding xeric uplands (Ames 1977, Valentine et al. 1988). The Wildlife Subcommittee recommends that land management agencies review livestock grazing management plans in the Bill Williams River watershed, with the above concerns in mind.

Burros: Feral burros are abundant in the Alamo Lake-BWRC region. Especially in combination with livestock, burros are having negative effects on the riparian habitat, water quality, and adjacent uplands. These impacts are likely to include excessive grazing and browsing of native plants, resulting in changes in the structure, quantity, and species composition of vegetation in riparian habitats and adjacent uplands. Water quality may be impacted, through increased erosion, siltation, and fecal material. The Wildlife Subcommittee recommends that land management agencies review burro/allotment/herd management plans, or similar plans, with the above concerns in mind.

Recreational Impacts: Various reaches of the BWRC receive recreational use which may be impacting important riparian habitat. Specifically, four-wheel-drive and off-road vehicle use is virtually uncontrolled in many areas. The Wildlife Subcommittee recommends that land management agencies review the areas where such use is allowed, with these concerns in mind.

Beaver: Beavers may be an important component of the riparian ecosystem, by creating small ponds with associated still water, shallow marsh and deep pools. However, they may face competition for young willows, from livestock and burros. Beaver may then resort to girdling and killing the remaining larger cottonwoods.

Quail:

Doves:

Javalina:

Muskrat:

Ringtail, skunk, bobcat, grey fox, raccoon, badgers.

Feral hogs at upper Alamo Lake. How do they compete with javalina?

Invertebrates
Terrabid beetles
Gastropods

IX. Management Priorities for Species Groups

The Wildlife Subcommittee recommends that the BWRC Planning Technical Committee compile, review, and synthesize existing management plans, mandates and responsibilities which are in effect at Alamo Lake, Alamo Dam, and the BWRC. Some of these mechanisms may set priorities for, or supersede, management recommendations developed by the Planning Technical Committee. These mechanisms include:

Endangered Species Act of 1973, as amended (sections 7, 9 and 10).

Bureau of Land Management's Allotment Management Plan

BLM's Burro (Herd) Management Plan

BLM's Wilderness Management Plan

Migratory Bird Treaty Act

BLM Management Plan for Planet Ranch

AGFD Alamo Lake Wildlife Area Management Plan

Alamo Lake State Park Management Plan

Comprehensive Management Plan for Lower Colorado River Refuges

Alamo Lake, Arizona, Reconnaissance Study. U.S. Army Corps of Engineers

X. Information Needs

1. To update prescriptions for maintaining habitats related to lake levels, updated lake volume data are needed. Current figures come from 1973, so they do not include significant sedimentation from the 1979, 1983 and 1993 flood events. As the lake fills in with sedimentation, higher lake levels will be necessary to maintain shallow-water habitats.

2. More specific data are needed on mortality rates of inundated cottonwood, willow and other riparian vegetation.

3. Monitoring of riparian habitats is necessary to determine the effects, if any, of any flow regimes implemented.

4. Surveys and inventories should be completed for species of special concern (e.g. endangered species), to determine presence, habitat use, and recovery opportunities.

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APPENDIX G.

RECREATION SUBCOMMITTEE REPORT

BILL WILLIAMS RIVER CORRIDOR
Recreation and Access Subcommittee Recommendations

Prepared by:
Recreation and Access Subcommittee
Chairman: William Ballinger

Revised: February 1, 1994

Acknowledgements

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BILL WILLIAMS RIVER CORRIDOR
Recreation Use and Access Subcommittee Recommendations

Introduction:

The Bill Williams River Corridor Recreation and Access Subcommittee was formed for the purpose of discussing the recreational needs and activities at Alamo Lake and in the Bill Williams Corridor and the necessity to place lake levels and river flows in perspective. Activities on Alamo Lake are quite different, both in scope and in kinds of activities, to those on the Bill Williams River Corridor so each will be discussed separately.

Alamo Lake:

In terms of user-days, the overwhelming bulk of recreational activity at Alamo Lake is fishing for largemouth bass. While some shore fishing occurs, the majority of this fishing activity is done from motor powered watercraft. Most of the other activities, i.e. camping, picnicking, etc. are done in conjunction with fishing (Figure 1). Consequently, recreation at Alamo Lake is highly dependent upon visitors being able to launch their watercraft in a safe and convenient manner. Recreation is also highly dependent upon the quality of the fishery. Lake levels need to be maintained in a manner to continue quality fishing, to allow for use of boat launching facilities, and below levels that would inundate the campground and infrastructure of Alamo Lake State Park.

Other recreational activities include hunting (deer, quail and waterfowl during open seasons), hiking, horseback riding, photography, bird watching, and nature study. Some water skiing and personal watercraft activity also occurs, but on a very minimal scope.

The future recreational activity pattern is not likely to change drastically. Fishing will continue to be the primary activity. However, as the population continues to increase, the number of people seeking outdoor recreation will result in increased visitation to the area, and the "secondary" recreational activities listed above will increase in scope.

Bill Williams River:

Below the dam, there is light but steady recreational activity that is presently limited due to access problems. The wide range of recreational activities range from visitors looking for a wilderness experience and a sense of solitude while hiking, backpacking, or floating through the two wilderness areas, to hiking, fishing, quail and waterfowl hunting, off-highway vehicle use. Most of this use occurs during the more moderate climate periods. Stream floating by canoe, kayak, or rubber boat is almost non-existent due to difficulty in getting the watercraft to the stream and undependable stream flows.

As more private land is acquired by public agencies, recreational use of the Bill Williams corridor will steadily increase. In comparison to the scope of use at Alamo Lake, it is doubtful that this recreational use will ever be considered as "heavy".

Present access problems below the dam, due to current dam operations, continue to inhibit recreational activities, even during moderate climate periods and times of optimum stream flows. Public access is also limited throughout the remainder of the river corridor because existing access routes go across private lands. However, current Federal acquisition efforts should improve opportunities for legal public access to the Bill Williams River corridor in the future.

With this background information in mind, the recreation and access subcommittee present the following goals, objectives and recommendations for Alamo Lake and the Bill Williams River Corridor below Alamo Dam.

I. Goal and Objectives:

A. Goal:

Recommend dam operation prescriptions, under various weather patterns, to maximize recreational opportunities along the Bill Williams River Corridor, including Alamo Lake.

B. Objectives:

1. Maximize fishing, boating, and camping opportunities at Alamo Lake under various water conditions.

2. Maximize recreational opportunity along the riparian corridor below Alamo Dam by establishing water release patterns which mimic a more "natural" stream system.

II. **Assumptions made, and limitations considered, in developing recommendations:**

A. The following assumptions and limitations concerning dam operations were considered:

1. The lake elevation will be lowered to the 1,100' msl on the average of once every 5 years in order to inspect the dam.

2. The dam operation will go into flood control operation prescriptions if the lake elevation exceeds 1,171' msl.

3. Releases from the dam are not possible between 25 cfs and 147 cfs or above 7,000 cfs. The maximum authorized flood control release from Alamo Dam is 7000 cfs, and is unlikely to be exceeded.

4. It is possible for the dam to be operated at the lake elevations listed in the various recommendations below.

B. The following assumptions and limitations concerning recreation at Alamo Lake were considered:

1. Recreation activities, particularly fishing, boating, and camping at the State Park, decrease as the lake surface and fishable shoreline decreases.

2. Recreation use of the lake increases as the quality of the fishing experience increases.

3. Historical recreation use patterns will remain the same. Most use will occur during the Spring and Fall (Figure 2), on week-ends, and most State Park visitors camp at least one night.

4. Higher lake elevations than listed in the body of this report could possibly provide more recreational opportunity if the existing facilities on the Lake were modified. Therefore, the existing facilities could be a limiting factor.

C. The following assumptions and limitations concerning recreation opportunities along the Bill Williams River were considered:

1. In general, recreation opportunities along the Bill Williams River Corridor can and will vary with the flow regime.

2. The two wilderness areas below the dam will continue to be managed to provide for preservation of the areas wilderness character and opportunities for solitude, and primitive and unconfined types of recreation. Motor vehicles, motorized equipment, bicycles, and hang-gliders are not permitted.

3. Presuming the Federal acquisition or exchange of State and private land in the river corridor, will occur. The recreation opportunities in the area will change. Legal public access to the river and potential development of recreation facilities will promote an increase in the variety of opportunities and the amount of recreation use in the river corridor.

4. Recreation opportunities in the Wildlife Refuge are subject to Refuge mandates and regulations. However, wildlife viewing, hunting, sightseeing, and other recreation opportunities in the Refuge are expected to increase with the improvement of riparian/wildlife habitat.

5. Scenic float trips are possible with flows of 300-7000 cfs and likely to increase as legal public access is available.

6. Water releases for the Bill Williams River Corridor, under various weather condition, will result from the product produced by the other subcommittee reports. Primarily from the fisheries and riparian reports.

III. **Water operation recommendations that optimize recreational opportunities on Alamo Lake and along the Bill Williams River Corridor:**

A. Purpose:

Identify desired recreation needs and access for Alamo Lake and the Bill Williams River Corridor and determine water-related (lake level, stream flow) constraints and opportunities.

B. Recommendations:

All recommendations in this report will be based on maximizing recreational opportunity and access availability under the existing locations of the facilities. Recommendation # 1 will refer to optimal operations, recommendation # 2 will refer to acceptable operations, and recommendation # 3 will refer to what would be considered adverse operations.

1. **Recommendation Number 1:**
   Prescription for operating Alamo Dam that would maximize recreational opportunity on the lake and in the Bill Williams River Corridor (Optimal Scenario).

   a. Operate Alamo Lake in such a way that both existing boat ramps are within the optimal operating range. Operation would be between 1,115' and 1,125' msl. This elevation not only maximizes the functionality of both boat ramps it also maximizes access and opportunity at other locations around the lake.

   b. Following seasonal inflow, if lake elevations reach the 1,144' msl to 1,154' msl releases should be made as fast as possible until the lake elevation is below 1,144'msl. At these elevations the grade on all of the roads and surrounding terrain are too flat for launching boats. Resulting in NO BOAT LAUNCHING ACCESS.

   c. If releases are schedule in excess of 300 cfs recreational opportunity for river floating below the dam would be maximized if the releases incorporate a week-end.

Resource Outcome for Recommendation # 1

Maximization of the recreational opportunity at Alamo Lake and along the Bill Williams River Corridor below Alamo Dam would result from operating Alamo Dam under this recommendation.

Benefits Resulting from Recommendation # 1

Alamo Lake and River Corridor Below Alamo Dam:

1. This operational pattern would provide the stability in the system that would allow for long term planning of park facilities.

2. This operational pattern would provide the stability in the system that would allow for the development of facilities and access in areas off of the park.

3. In maximizing the recreational opportunity and access there would be an increase in the economy for the area.

4. The public would be assured of being able to launch their boats all year round.

5. This operational pattern would provide an additional form of recreation that has not been utilized to any great extent at the present time (floating /rafting).

6. In promoting an additional recreational opportunity there would be an increase in the economy for the area.

Impacts Resulting from Recommendation # 1

Alamo Lake and River Corridor Below Alamo Dam:

1. There may be a potential for an increase in human impacts to the different areas.

2. The increase in recreation may cause problems for the park until budget, staff, and facilities are improved to handle the increase in recreation.

3. Increased recreation may also cause an increased impact on the fisheries and riparian resources which will cause a change in the current regulations for the area.

2. **Recommendation Number 2:**
Prescription for operating Alamo Dam that would be acceptable for providing recreational opportunity on the lake and on the Bill Williams River Corridor .

a. Operate Alamo Lake in such a manner that boat launching is possible. There are three operational elevation windows outside of the optimum range which will provide boat launching capabilities. Two are above the optimum and one is below the optimum. If at all possible operations at the higher elevations is better.

1) Elevations 1,154' msl to 1,178' msl will provide boat launching from a dirt ramp facility that is located below the main campground.

2) Elevations 1,125' msl to 1,144' msl will provide boat launching from the main boat ramp and the Cholla ramp when between 1,125' msl and 1,130' msl.

3) Elevations 1,094' msl to 1,115' msl will provide boat launching from the Cholla boat ramp and the main boat ramp when between 1,108' msl and 1,115' msl.

b. Following seasonal inflow, if lake elevations reach the 1,144' msl to 1,154' msl releases should be made as fast as possible until the lake elevation is below 1,144' msl. At these elevations the grade on all of the roads and surrounding terrain are too flat for launching boats. Resulting in NO BOAT LAUNCHING ACCESS.

c. If releases are schedule in excess of 300 cfs recreational opportunity for river floating below the dam would be maximized if the releases incorporate a week-end.

Resource Outcome for Recommendation # 2

Recreational opportunity would remain at the current levels for Alamo Lake and the Bill Williams River Corridor below Alamo Dam.

Benefits Resulting from Recommendation # 2

Alamo Lake and River Corridor Below Alamo Dam:

1. This operational pattern would provide the stability in the system that would allow for long term planning of park facilities.

2. This operational pattern would provide the stability in the system that would allow for the development of facilities and access in areas off of the park.

3. Recreational opportunity and access there would remain the same as it is at the present time which would stabilize the economy for the area at the present level.

4. The public would be assured of being able to launch their boats all year round.

5. This operational pattern would provide an additional form of recreation that has not been utilized to any great extent at the present time (floating /rafting).

6. In promoting an additional recreational opportunity there would be an increase in the economy for the area.

Impacts Resulting from Recommendation # 2

Alamo Lake and River Corridor Below Alamo Dam:

1. There may be a potential for an increase in human impacts to the different areas.

2. The increase in recreation may cause problems for the park until budget, staff, and facilities are improved to handle the increase in recreation.

3. **Recommendation Number 3:**

Prescription for operating Alamo Dam that would be used only during adverse conditions for providing recreational opportunity on the lake and on the Bill Williams River Corridor during dry years.

a. If possible, operate Alamo Lake in such a manner that one ramp is functional during the two high use periods of the year.

Spring = March, April, May

Fall = September, October, November

The elevation for the months involved with the high use periods would be any elevation > 1,094' msl. If it isn't at least at that elevation none of the presently existing ramps are functional.

b. If releases are schedule in excess of 300 cfs recreational opportunity for river floating below the dam would be maximized if the releases incorporate a week-end.

c. If the lake elevations reaches 1,100' msl or less only legally mandated releases will be made.

Resource Outcome for Recommendation # 3

Recreational opportunity would decrease below the current levels for Alamo Lake and the Bill Williams River Corridor below Alamo Dam.

Benefits Resulting from Recommendation # 3

Alamo Lake and River Corridor Below Alamo Dam:

1. NONE !!

Impacts Resulting from Recommendation #3

Alamo Lake and River Corridor Below Alamo Dam:

1. There would be a decline in the economy for the area.

2. Park visitation would decline

3. The resources , both fisheries and riparian would decline.

IV. Information Needs and Deficiencies:

During the course of the discussions several needs and deficiencies were brought out. This list is as follows:

A. At the present time there isn't any data on recreational usage of that area below Alamo Dam or the other portions of the Bill Williams River Corridor. This information is desired for formulating recreational plans for the area in the future. Data should include information on recreation types and levels of use; access points and modes of access; recreation time and frequency. Locations of particular interest include the area below the dam; Rawhides Mountain and Swansea Wilderness Areas; Lincoln and Planet Ranches; the El Paso pipeline; and the Bill Williams Refuge. The effect of the road closure in the Wildlife Refuge on recreation is also unknown.

B. Information needs to be compiled for exploring ways to provide boat launching facilities between the 1,144' msl to 1,154' msl elevation.

C. There is a deficiency in legal access to the Bill Williams River Corridor below the dam. Information needs to be complied for the purpose of exploring ways to provide better access in some areas and restricted access for other areas.

V. Issues, Concerns, and Opportunities Regarding Water Management for Recreations:

A. If an operation elevation is chosen between 1,144' msl and 1,154' msl an additional boat launching facility would be required. The location and terrain around the existing launch ramps will not allow for modifications.

B. Inundation of the sewage facilities will occur if the lake elevation reaches 1,214' msl.

C. Inundation of the current developed facilities will occur if the lake elevation reaches 1,200' msl.

D. Continual lake level fluctuations are bad for the appearance of the lake. This will increase the size of the "bath tub ring" which in turn degrades the visual esthetics of the recreational resources.

E. If releases are required, large releases over a short duration are better. This type of release will reduce the amount of shoreline erosion and maintenance of the existing boat ramps.

F. The location of existing facilities should not dictate where the ideal operating elevations is. If an elevation is selected that is in conflict with the existing facilities the existing facilities can be changed or even relocated if necessary.

G. There is a concern about the lack of access to areas below the dam.

H. Explore the possibility of modifications to the bulkhead gate so it can be installed or removed mechanically, without the use of divers and a crane. This could lessen the down time and cost for dam inspections and maintenance.

I. Schedule dam inspections when the lake elevations is down to eliminate the need to make releases for the sole purpose of making an inspection. This should be done even is it hasn't been 5 years since the last inspection.

J. When scheduling a dam inspection, schedule it during low recreational periods (June, July, August, December, or January).

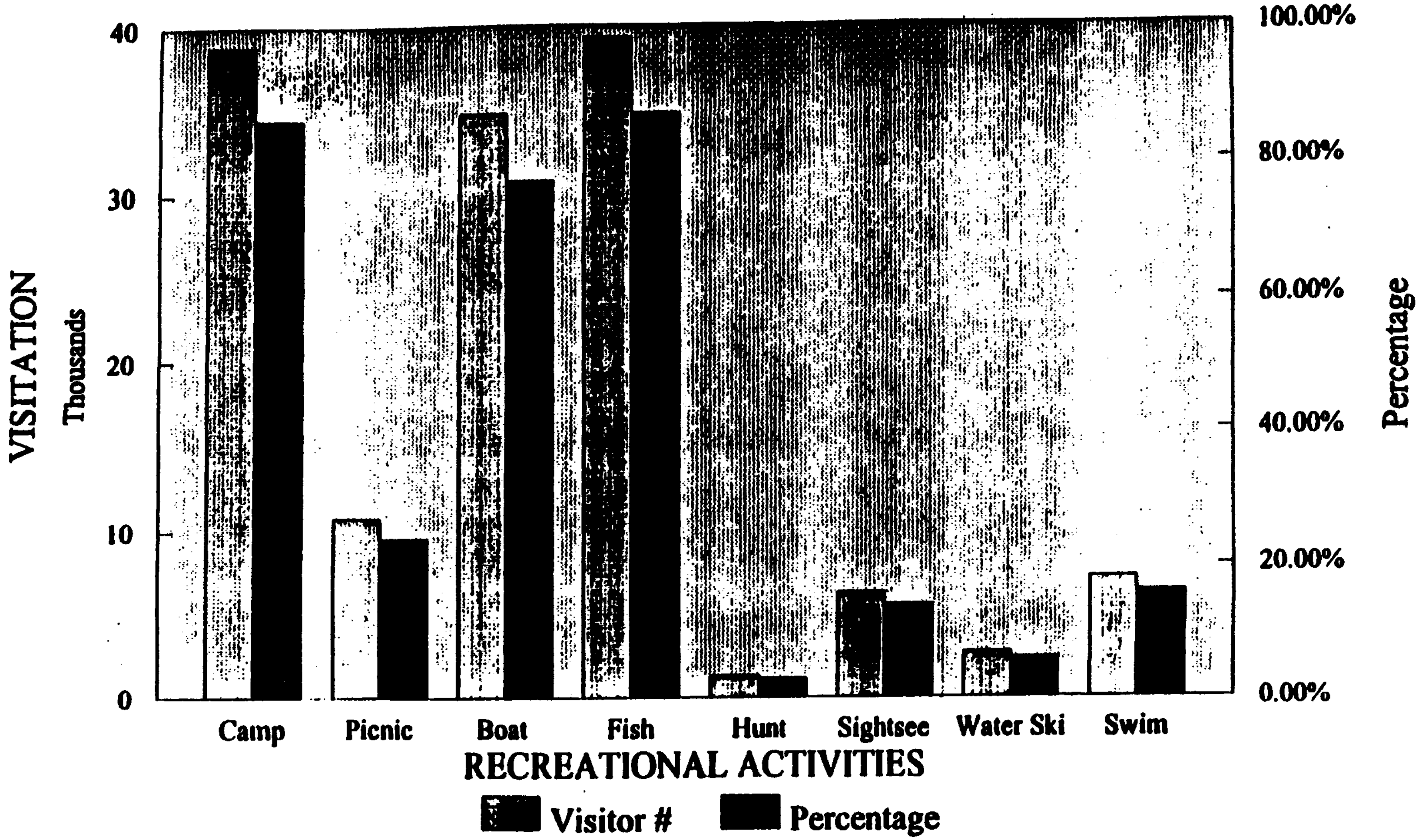

Figure 1: The average Park visitation numbers and percentage of use for the different recreational activities at Alamo Lake [1990, 1991, and 1992].

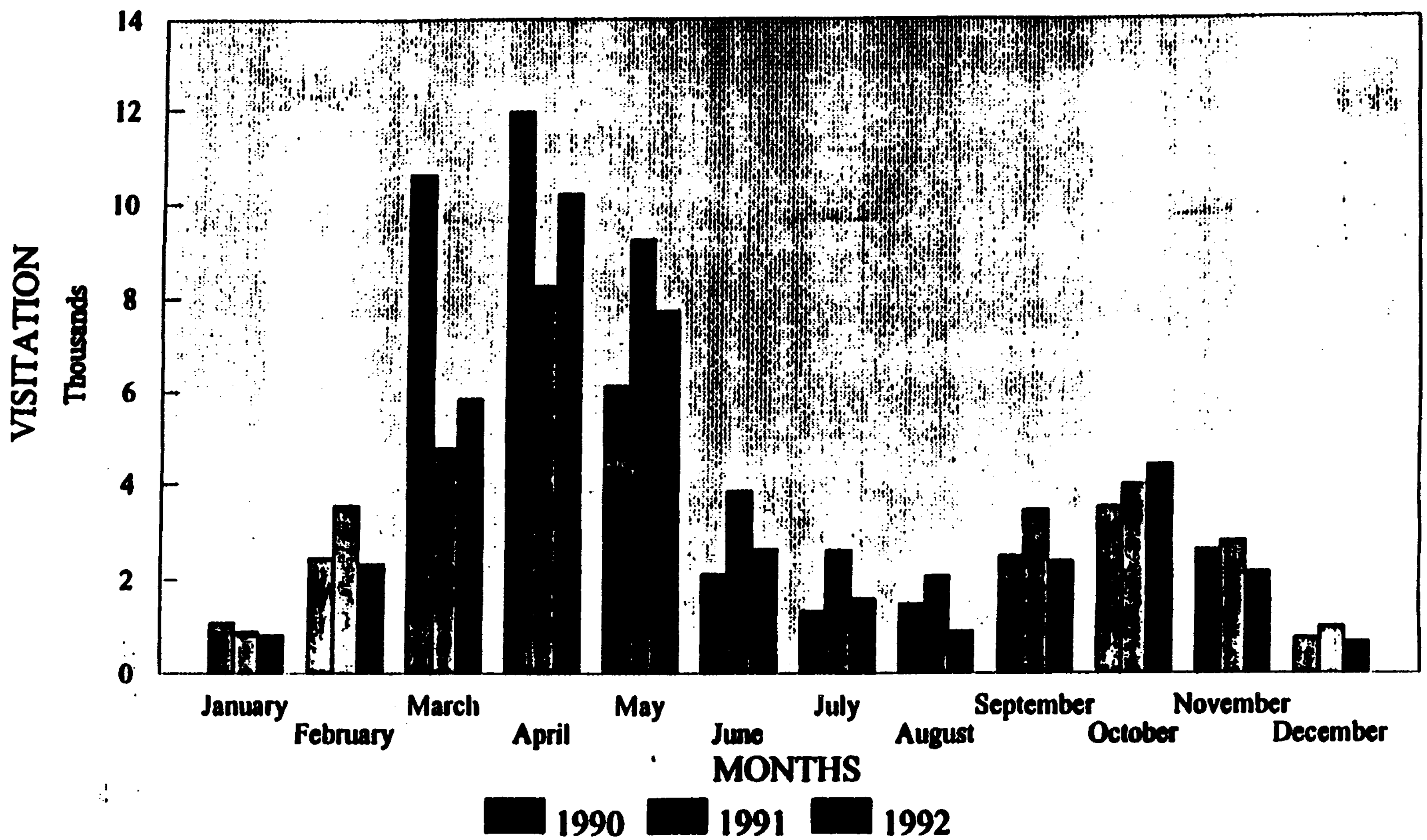

Figure 2: Alamo Lake State Park visitation by month for the years of 1990, 1991, and 1992.

DAM OPERATION SUMMARY
[Recreation and Access Oriented]

	OPTIMAL OPERATIONS	ACCEPTABLE OPERATIONS	ADVERSE OPERATIONS
Desirable Lake Elevations:	1,115' to 1,125' msl Main & Cholla Ramps are at the optimum.	1,154' to 1,178' msl Dirt ramp is functional 1,125' to 1,144' msl Main ramp is functional 1,094' to 1,115' msl Cholla ramp is functional	If possible, > 1,094' msl during high use periods. Spring [March, April, May] Fall [September, October, November]
Undesirable Lake Elevations:	1,144' to 1,154' msl No boat launching is available.	1,144' to 1,154' msl No boat launching is available.	1,144' to 1,154' msl No boat launching is available.
River Flow Requirement:	If releases are > than 300 cfs , incorporate a week-end into the release period.	If releases are > than 300 cfs , incorporate a week-end into the release period.	If releases are > than 300 cfs , incorporate a week-end into the release period.

APPENDIX H.

RESERVOIR OPERATIONS SUBCOMMITTEE REPORT

BILL WILLIAMS RIVER CORRIDOR TECHNICAL COMMITTEE

RESERVOIR OPERATIONS SUBCOMMITTEE

ALAMO DAM AND LAKE

SUMMARY OF PRESENT OPERATING CONDITIONS AND OPERATING CONSTRAINTS

APRIL 1994

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INTRODUCTION

Alamo Dam was authorized by the Flood Control Act of 22 December 1944 (Public Law 534, 78th Congress, 2nd Session) and construction was completed by the Corps of Engineers in 1968. The project had been recommended for approval by the Chief of Engineers in his report dated 11 April 1944, published as a part of the project document (House Document No. 625, 78th Congress, 2nd Session). The act approved construction of Alamo Dam (see figure 1) as a multiple purpose project as recommended in House Document No. 625.

The recommended project purposes were flood control for the lower Colorado River, as an initial objective, and ultimate project development to include water conservation, hydropower and recreation. In order to assess the water conservation and hydropower benefits, the Corps entered into an agreement with the U.S. Bureau of Reclamation (USBR) to evaluate the potential of these purposes. The USBR concluded that, through coordinated operation of Alamo Dam with USBR dams on the Colorado River, a net average annual increase in water supply for the Colorado river system of 4,500 acre-feet would be realized. However, the USBR concluded that hydropower benefits were negligible.

Subsequent to initial authorization, Alamo Dam became subject to the stipulations of the Fish and Wildlife Coordination Act of 1958 (Public Law 85-624), the Federal Water Project Recreation Act -- Uniform Policies (P.L. 89-72), the National Environmental Policy Act of 1969 (P.L. 91-190), the Clean Water Act of 1977

(P.L. 95-217), and the Endangered Species Act of 1973 (Public Law 93-205). Alamo Dam is therefore operated to conform with objectives and specific provisions of the authorizing legislation, as well as with all subsequent Congressional acts that are applicable.

RESERVOIR STORAGE ALLOCATIONS AND OPERATING PLAN

The reservoir storage allocations, critical elevations, and release schedules for Alamo Dam and Reservoir are presented in figure 2. Alamo Dam is currently operated for the authorized purposes of recreation, water conservation, and flood control. The current storage versus elevation relationship is detailed in figure 3.

The authorized top of recreation pool is 1070 feet. Releases below this elevation are made to satisfy existing water rights. Based on examination of low flow records from 1891-1962, the State of Arizona has decreed that matching outflow to inflow up to a 10 cfs maximum would satisfy these water rights. In the absence of releases for other purposes, matching of inflow up to the 10 cfs release schedule for water rights requirements will be made from the recreation, water conservation, and flood control pools.

Water conservation releases from the existing water conservation pool (between reservoir elevations 1070 and 1171.3 feet) are coordinated with operation of the U.S. Bureau of Reclamation's (USBR) Hoover, Davis, and Parker Dams on the lower Colorado River. Coordination of operation is essential to achieve maximum flood control, water supply, and hydropower benefits along the lower Colorado River. The current reservoir regulation plan limits the magnitude of water conservation releases to a maximum of 2,000 cfs.

Since there are presently no contracts for water stored in the conservation pool, there is no established conservation release. Current reservoir operation when in the water conservation pool is to completely evacuate the conservation pool before the flood control season, provided Alamo Dam releases can be used to meet consumptive use demands on the Colorado River. The available capacity on the Colorado River is governed by the USBR's ability to integrate Alamo Dam releases to fulfill water use requirements. If Alamo Dam releases from the water conservation pool cannot be fully utilized, then releases are curtailed, even though water is carried over into the flood season. The waters of the Bill Williams River are State of Arizona waters until they reach the Colorado River, at which time they become subject to the laws and agreements governing the distribution and use of Colorado River waters.

The maximum authorized flood control release from Alamo Dam is 7,000 cfs, as specified in the Alamo Dam General Design Memorandum, dated April 1964, and in the Reservoir Regulation Manual. In a joint resolution by the United States Government and the State of Arizona, dated 15 March 1963, the State of Arizona gave assurances to the United States that the floodplain below Alamo Dam would be maintained free of encroachment for discharges up to 7,000 cfs. An excerpt from that resolution states that the State of Arizona will "Limit man-made encroachment on the existing hydraulic capacity of the Bill Williams River channel downstream from Alamo Dam to permit maximum releases of 7,000 cubic feet per second from the reservoir." Within the flood control pool, releases of 7,000 cfs will be made as a first priority. However, these releases may be reduced in magnitude to achieve system flood control objectives on the Colorado River. For example, if Colorado River dams are making large flood control releases, it may be appropriate to reduce or stop temporarily flood control releases from Alamo Dam in the interest of minimizing flood damages. As shown in figure 2, the reservoir flood control space is between elevations 1171.3 and 1235 feet (spillway crest). If in a flood event the reservoir water surface were to rise above elevation 1235 feet, the outlet gates are gradually closed, until elevation 1244.5 feet is reached. At that elevation, the outlet gates are completely closed and the spillway is discharging 7,000 cfs. If the reservoir water surface rises above elevation 1244.5 feet, the outlet gates are opened as rapidly as necessary to prevent further increase in reservoir water surface elevation. During falling stages in the reservoir water surface elevation, the outlet gate operation is followed in reverse order.

SUMMARY OF CURRENT OPERATING CONSTRAINTS

The following sections describe the current constraints surrounding the operation of Alamo Dam and Reservoir.

Constraints Resulting from the Endangered Species Act.

Since 1982, pairs of Southern Bald Eagles, an endangered species, have been nesting in the vicinity of Alamo Lake. As a result of a U.S. Fish and Wildlife Service letter to the Corps, dated 25 March 1988, Alamo Lake is not drawn down below elevation 1100 feet. This letter points out that elevation 1100 feet provides the minimum pool area necessary to provide sufficient foraging area for the nesting eagles. Although the eagle nesting season is from December through mid-June, it is necessary to keep the elevation above 1100 feet throughout the year. This is due to the relatively high probability of a low runoff season that would not return the elevation to 1100 feet. The ability to maintain the lake elevation at 1100 feet depends on sufficient inflow to offset reservoir evaporation, plus water rights release requirements of 10 cfs or inflow, whichever is less.

Outlet Works Capabilities and Limitations

Description. The outlet works consist of three pairs of 5.5-foot wide by 8.5-foot high slide gates. Each pair of gates consist of a service gate and an emergency gate set, which is upstream from the service gate. The service gate is used for discharge regulation; the emergency gate is used to shut off flow in case the service gate malfunctions or requires maintenance. In addition, the outlet works includes a butterfly valve for discharging low flows. The butterfly valve has a computed discharge rate at maximum opening of 88-105 cfs, depending on reservoir pool elevation.

Maximum Gate Setting. Operational criteria for the outlet gates restrict the maximum gate setting to 80 per cent of the 8.5-

foot vertical dimension of the gates, which is 6.8 feet. Limiting the maximum gate setting to 80 per cent of its full opening ensures that, hydraulically, the control of the rate of flow through the outlet is always at the gate itself. At larger settings, it is possible for the control point to actually shift downstream, or even oscillate between the gate and a downstream location (slug flow condition). As a result of this criteria, the minimum elevation within the water conservation pool at which 7,000 cfs can be released (due to hydraulic head requirements) is 1148.4 feet (refer to figure 4).

Minimum Gate Setting. Pursuant to an inspection and subsequent rehabilitation of the outlet gates in 1990, criteria have been established which limit the gates from being set to less than 0.5 foot opening. The inspection determined that at settings of less than 0.5 foot, high flow velocities would result in cavitation damage to the gate lip and the tunnel invert seal. In addition, the flows would, most likely, contain sediment particles that would further abrade the gate lip and invert seal. The minimum release using one service gate open to 0.5 feet is about 147 cfs at elevation 1070, and 173 cfs at elevation 1100 feet (refer to figure 5)

Rate of Release Change. The three 5.5-foot wide by 8.5-foot high service gates can be raised, one at a time, at the rate of 0.5 feet per minute. Since only one gate can be operated at a time, the minimum time necessary to make a 1.0-foot gate change for all three gates is 6 minutes. Normally, when any significant release changes are to be made, a 24-hour advance notification is made to downstream individuals and agencies, and the schedule of making these release changes are coordinated with these entities. In the interest of public safety, changes in the reservoir release rate are made gradually over a number of hours, so as to minimize any sudden changes in flow rate, water velocity, and depth at downstream locations.

Periodic Inspection and Maintenance of Outlet Works

Inspection and maintenance of the emergency gates and the outlet tunnel upstream from the emergency gates necessitates de-watering the outlet tunnel. De-watering is accomplished by first closing all six gates and the butterfly valve, then putting a steel bulkhead gate in place over the outlet tunnel inlet. Installation of the bulkhead gate is accomplished by using an A-frame and cable winch to lower the bulkhead gate into place. Divers are necessary to remove pins securing the bulkhead gate when not in use, and also to clean the steel guides along which the bulkhead gate slides. Once the bulkhead gate is in place, the tunnel is de-watered by opening one pair of emergency and service gates the minimum 0.5-foot setting.

The bulkhead gate was designed to withstand the hydrostatic force as exerted by a reservoir water surface up to elevation 1110 feet. Exceeding this elevation could cause the bulkhead gate to collapse and/or the intake structure concrete supporting the bulkhead gate to fail.

Since no reservoir releases can be made with the bulkhead gate in place, sufficient storage space must be available in the reservoir prior to bulkhead gate installation to contain any inflows without the lake elevation exceeding 1110 feet. It has been determined that the reservoir needs to be drawn down to elevation 1100 feet to provide the required storage space during maintenance periods. The storage space between elevations 1100 and 1110 feet (28,288 acre-feet) is the minimum space required to provide sufficient time to remove the bulkhead gate in an emergency. It takes 1-2 days to remove and secure the bulkhead gate. Records of historical flood events show that reservoir inflow can raise the reservoir water surface elevation from 1100 feet to 1110 feet in less than 1 day.

De-watering of the outlet tunnel for inspection normally occurs every five years. If the inspection reveals that maintenance needs to be performed on the emergency gates and/or outlet tunnel, the tunnel will have to be de-watered.

Inasmuch as possible, the Corps will attempt to minimize impacts upon the various project purposes due to bulkhead gate installation through appropriate scheduling of inspection and/or maintenance. However, should an unforeseen emergency arise that necessitates an inspection and/or possible maintenance, the Corps has the authority, without prior scheduling, to evacuate the reservoir down to elevation 1100 feet and install the bulkhead gate.

AREA-CAPACITY TABLE

An updated area-capacity table for Alamo Lake was prepared in June 1993 (figure 3). The updated table supersedes all previous tables and should be used immediately and until further notice.

The June 1993 table incorporates results from the October 1985 bathymetric survey, plus estimates on sediment accumulation over the 1968-1993 period. It was necessary to incorporate estimates of sediment accumulation, since the bathymetric survey encompassed only those reservoir elevations from the invert (elevation 990 ft.) through elevation 1120 feet. However, sediment was assumed to have accumulated up to elevation 1207 feet, the highest historic reservoir elevation.

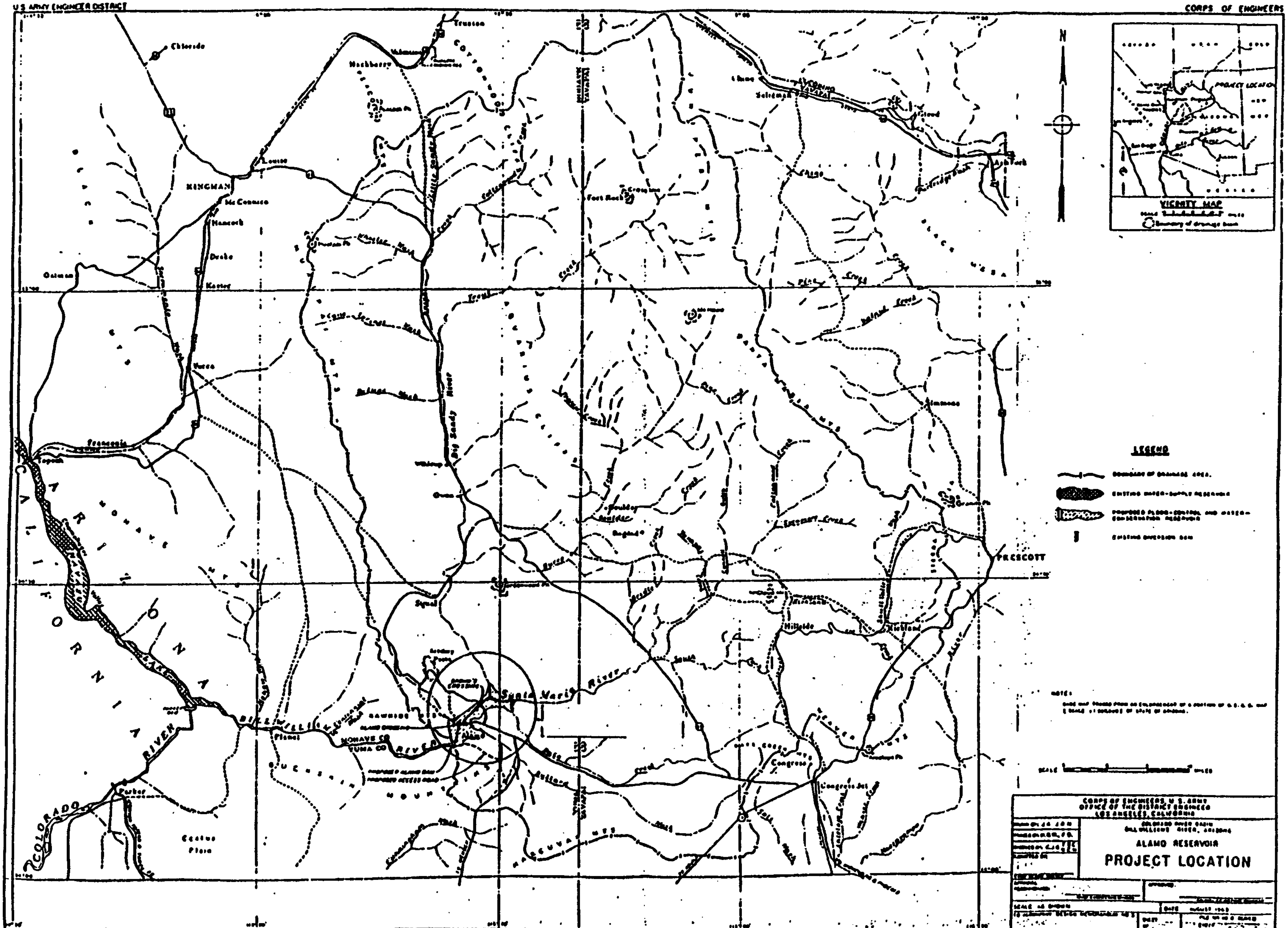
Since the authorizing legislation stipulated 608,000 acre-feet of reservoir storage be allocated for flood control, the revised area-capacity table has changed the bottom of flood control pool elevation from 1174 to 1171.3 feet, in order to insure that the 608,000 acre-feet of flood control space is available.

HISTORIC ALAMO DAM OPERATION

Figures 6-1 through 6-25 present annual water year summaries of reservoir inflow, outflow and reservoir water surface elevation for the historic operation of Alamo Dam from October 1968 through April 1993. Figures 7 through 9 show the same information (inflow, outflow, reservoir stage) consolidated for the entire period (1968-1993) on three separate graphs.

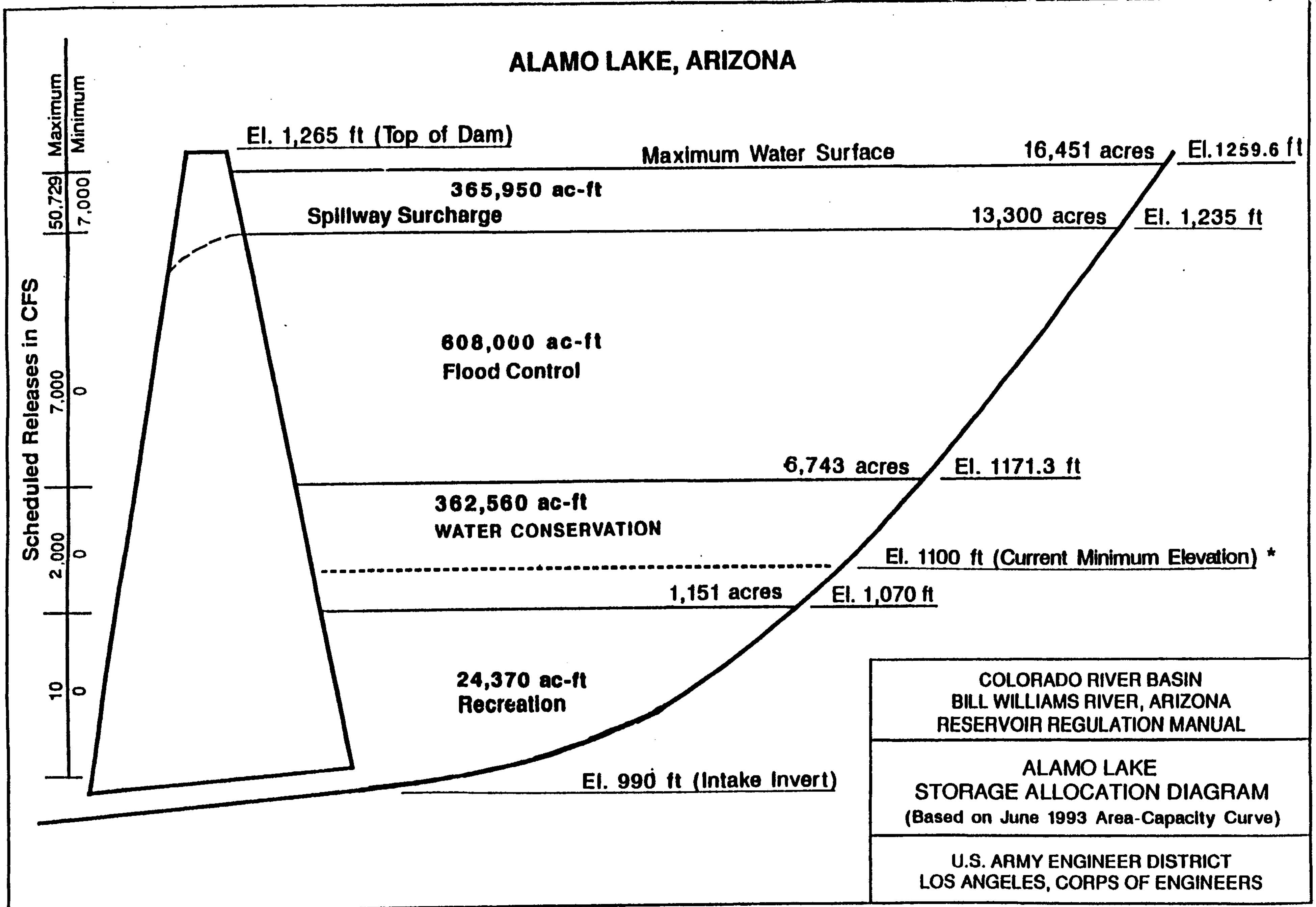
APPENDIX A

(FIGURES)



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
VICINITY MAP
LEGEND
PRESCOTT
KINGMAN
Chloride
Santa Maria River
BILL WILLIAMS
RIVER
Big Sandy River
ARIZONA
CALIFORNIA
COLORADO
RIVER
Congress
Hillside
Yucca
Cactus Plain
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
ALAMO RESERVOIR
PROJECT LOCATION

FIGURE 1



Storage values rounded.

* Required for endangered species.

FIGURE 2

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
990.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
991.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
992.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
993.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
994.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
995.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
996.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
997.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
998.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
999.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1000.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1001.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1002.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1003.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1004.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1005.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1006.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1007.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1008.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
1009.0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Notes:

1. Numbers at the top of each column (.0-.9) are tenths of a foot.
2. Each whole number elevation has an associated capacity row and area row. The capacity row is on the same line as the whole number elevation; the area row is directly beneath

FIGURE 3

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1010.0	0	0	0	0	0	0	1	1	1	1
	0	0	0	0	0	1	1	1	1	1
1011.0	1	1	1	1	2	2	2	2	2	3
	1	1	1	1	1	1	1	2	2	2
1012.0	3	3	3	4	4	4	4	5	5	5
	2	2	2	2	2	2	2	2	2	2
1013.0	5	6	6	6	7	7	7	8	8	8
	2	3	3	3	3	3	3	3	3	3
1014.0	9	9	10	10	10	11	11	12	12	12
	3	3	3	3	3	4	4	4	4	4
1015.0	13	13	14	14	15	15	16	16	17	17
	4	4	4	4	4	4	4	4	4	5
1016.0	18	18	19	19	20	20	21	22	23	23
	5	5	5	6	6	6	7	7	7	8
1017.0	24	25	26	27	28	29	30	31	32	34
	8	8	9	9	10	10	10	11	11	12
1018.0	35	36	38	39	41	42	44	46	48	50
	12	13	14	15	16	16	17	18	19	20
1019.0	52	54	56	59	61	64	67	69	72	75
	21	22	23	24	25	26	27	28	30	31
1020.0	79	82	85	89	93	97	101	105	110	115
	32	34	35	37	39	40	42	44	46	48
1021.0	120	125	130	135	141	147	153	159	166	173
	49	51	53	55	57	60	62	64	66	68
1022.0	180	187	194	202	210	218	227	235	244	253
	71	73	75	78	80	82	85	87	90	92
1023.0	263	272	282	293	303	314	325	336	348	360
	95	98	100	103	106	109	111	114	117	120
1024.0	372	384	397	410	422	435	448	461	474	488
	123	124	125	126	127	129	130	131	132	133
1025.0	501	515	528	542	556	570	584	598	613	627
	134	135	136	138	139	140	141	142	143	145
1026.0	642	656	671	686	701	716	731	746	761	776
	146	146	147	148	149	149	150	151	152	153
1027.0	792	807	822	838	854	869	885	901	917	933
	153	154	155	156	156	157	158	159	160	160
1028.0	949	965	982	998	1014	1031	1047	1063	1080	1097
	161	162	162	162	163	163	164	164	165	165
1029.0	1113	1130	1146	1163	1180	1197	1214	1231	1248	1265
	166	166	167	167	168	168	169	169	169	170

Notes:

1. Numbers at the top of each column (.0-.9) are tenths of a foot.
2. Each whole number elevation has an associated capacity row and area row. The capacity row is on the same line as the whole number elevation; the area row is directly beneath

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1030.0	1282	1299	1316	1333	1351	1368	1386	1403	1421	1439
	170	171	172	173	174	175	175	176	177	178
1031.0	1457	1475	1493	1511	1529	1547	1566	1584	1603	1622
	179	180	181	181	182	183	184	185	186	187
1032.0	1640	1659	1678	1697	1716	1735	1755	1774	1794	1813
	187	188	189	190	191	192	193	194	195	196
1033.0	1833	1853	1872	1892	1912	1933	1953	1973	1994	2014
	197	198	199	199	200	201	202	203	204	205
1034.0	2035	2055	2076	2097	2119	2140	2162	2184	2206	2228
	206	208	210	211	213	215	217	218	220	222
1035.0	2250	2273	2295	2318	2341	2364	2388	2411	2435	2459
	224	225	227	229	231	233	235	236	238	240
1036.0	2483	2508	2532	2557	2582	2607	2633	2659	2685	2711
	242	244	247	249	251	254	256	259	261	263
1037.0	2738	2764	2791	2819	2846	2874	2902	2930	2958	2987
	266	268	271	273	276	278	281	283	286	288
1038.0	3016	3045	3075	3105	3135	3165	3195	3226	3257	3289
	291	293	296	298	301	304	306	309	311	314
1039.0	3320	3352	3384	3417	3449	3482	3515	3549	3583	3617
	317	319	322	325	327	330	333	336	338	341
1040.0	3651	3685	3720	3755	3790	3825	3861	3896	3932	3968
	344	346	347	349	351	353	355	357	358	360
1041.0	4004	4041	4077	4114	4151	4188	4225	4263	4300	4338
	362	364	366	368	369	371	373	375	377	379
1042.0	4376	4414	4453	4492	4531	4570	4610	4649	4689	4730
	381	383	386	388	391	393	396	399	401	404
1043.0	4770	4811	4852	4894	4935	4977	5019	5062	5104	5147
	406	409	412	414	417	420	422	425	428	430
1044.0	5190	5234	5278	5322	5366	5410	5455	5500	5545	5590
	433	435	438	440	443	445	447	450	452	455
1045.0	5636	5682	5728	5774	5821	5868	5915	5962	6010	6058
	457	460	462	464	467	469	472	474	477	479
1046.0	6106	6154	6203	6251	6300	6349	6399	6448	6498	6547
	482	484	485	487	489	491	493	494	496	498
1047.0	6597	6647	6698	6748	6799	6850	6901	6952	7004	7055
	500	502	504	506	507	509	511	513	515	517
1048.0	7107	7159	7211	7263	7316	7368	7420	7473	7526	7579
	519	520	521	522	523	524	525	527	528	529
1049.0	7632	7685	7738	7791	7845	7899	7952	8006	8060	8114
	530	531	532	534	535	536	537	538	539	541

Notes:
1. Numbers at the top of each column (.0-.9) are tenths of a foot.
2. Each whole number elevation has an associated capacity row and area row. The capacity row is on the same line as the whole number elevation; the area row is directly beneath

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1050.0	8168	8223	8277	8332	8386	8441	8496	8552	8607	8663
	542	543	545	547	548	550	551	553	555	556
1051.0	8719	8774	8830	8887	8943	9000	9056	9113	9170	9228
	558	560	561	563	564	566	568	569	571	573
1052.0	9285	9343	9400	9459	9517	9575	9634	9693	9752	9812
	574	576	579	581	583	586	588	590	593	595
1053.0	9871	9931	9991	10052	10112	10173	10234	10295	10357	10419
	597	600	602	604	607	609	611	614	616	618
1054.0	10481	10543	10605	10668	10731	10795	10858	10922	10986	11051
	621	623	626	629	632	634	637	640	643	645
1055.0	11115	11180	11246	11311	11377	11443	11510	11576	11643	11710
	648	651	654	656	659	662	665	668	670	673
1056.0	11778	11846	11914	11982	12050	12119	12188	12257	12327	12397
	676	678	681	683	686	688	690	693	695	698
1057.0	12466	12537	12607	12678	12749	12820	12891	12963	13035	13107
	700	703	705	707	710	712	715	717	720	722
1058.0	13179	13252	13325	13398	13472	13546	13621	13696	13771	13847
	725	728	732	735	739	743	746	750	754	757
1059.0	13922	13999	14075	14153	14230	14308	14386	14464	14543	14623
	761	765	768	772	776	779	783	787	791	794
1060.0	14702	14782	14863	14943	15024	15105	15187	15269	15351	15433
	798	801	804	807	810	813	816	819	822	825
1061.0	15516	15599	15683	15766	15850	15935	16019	16104	16189	16275
	829	832	835	838	841	844	847	850	853	856
1062.0	16361	16447	16533	16620	16708	16795	16883	16971	17060	17149
	860	863	867	870	874	877	881	885	888	892
1063.0	17239	17328	17419	17509	17600	17691	17783	17875	17967	18060
	896	899	903	906	910	914	917	921	925	929
1064.0	18153	18246	18340	18434	18529	18623	18718	18814	18909	19005
	932	935	938	942	945	948	951	954	957	961
1065.0	19101	19198	19295	19392	19490	19588	19686	19784	19883	19982
	964	967	970	973	977	980	983	986	990	993
1066.0	20082	20182	20282	20383	20483	20585	20686	20788	20891	20994
	996	1000	1003	1007	1011	1015	1018	1022	1026	1029
1067.0	21097	21200	21304	21409	21513	21618	21724	21830	21936	22043
	1033	1037	1041	1045	1048	1052	1056	1060	1063	1067
1068.0	22150	22257	22365	22473	22581	22690	22800	22909	23019	23130
	1071	1075	1079	1083	1087	1091	1095	1099	1103	1107
1069.0	23241	23352	23464	23576	23688	23801	23915	24028	24143	24257
	1111	1115	1119	1123	1127	1131	1135	1139	1143	1147

Notes:
1. Numbers at the top of each column (.0-.9) are tenths of a foot.
2. Each whole number elevation has an associated capacity row and area row. The capacity row is on the same line as the whole number elevation; the area row is directly beneath

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1070.0	24372	24487	24603	24719	24836	24953	25070	25188	25307	25426
	1151	1155	1159	1164	1168	1172	1176	1181	1185	1189
1071.0	25545	25664	25784	25905	26026	26147	26269	26391	26514	26637
	1194	1198	1202	1207	1211	1215	1220	1224	1228	1233
1072.0	26761	26884	27009	27134	27259	27385	27511	27637	27765	27892
	1237	1241	1246	1250	1254	1259	1263	1268	1272	1276
1073.0	28020	28148	28277	28406	28536	28666	28796	28927	29059	29191
	1281	1285	1289	1294	1298	1303	1307	1312	1316	1321
1074.0	29323	29456	29589	29723	29857	29991	30126	30261	30397	30533
	1325	1329	1333	1337	1341	1346	1350	1354	1358	1362
1075.0	30669	30806	30943	31081	31219	31358	31497	31636	31776	31916
	1366	1370	1375	1379	1383	1387	1391	1396	1400	1404
1076.0	32057	32198	32339	32482	32624	32767	32910	33054	33198	33343
	1408	1413	1417	1421	1426	1430	1435	1439	1444	1448
1077.0	33488	33633	33779	33926	34073	34220	34368	34516	34665	34814
	1453	1457	1462	1466	1470	1475	1479	1484	1489	1493
1078.0	34963	35113	35264	35415	35566	35718	35871	36024	36177	36331
	1498	1502	1507	1512	1517	1522	1527	1532	1537	1542
1079.0	36486	36641	36796	36952	37109	37265	37423	37581	37739	37898
	1547	1551	1556	1561	1566	1571	1576	1581	1586	1591
1080.0	38058	38217	38378	38539	38700	38862	39024	39187	39350	39514
	1596	1601	1606	1611	1615	1620	1625	1630	1635	1640
1081.0	39678	39843	40008	40174	40340	40507	40674	40842	41010	41179
	1645	1650	1654	1659	1664	1669	1674	1679	1684	1689
1082.0	41348	41518	41688	41859	42030	42201	42373	42546	42719	42893
	1694	1699	1703	1708	1713	1718	1723	1728	1733	1737
1083.0	43066	43241	43416	43592	43768	43944	44121	44298	44476	44655
	1742	1747	1752	1757	1762	1767	1772	1777	1782	1786
1084.0	44834	45013	45193	45374	45555	45737	45919	46102	46286	46470
	1791	1797	1803	1809	1814	1820	1826	1832	1837	1843
1085.0	46654	46840	47025	47212	47399	47586	47774	47963	48153	48342
	1849	1855	1861	1866	1872	1878	1884	1890	1896	1901
1086.0	48533	48724	48915	49108	49300	49494	49687	49882	50077	50272
	1907	1913	1918	1924	1930	1935	1941	1946	1952	1958
1087.0	50469	50665	50862	51060	51259	51457	51657	51857	52058	52259
	1963	1969	1974	1980	1986	1991	1997	2003	2008	2014
1088.0	52460	52663	52866	53069	53273	53478	53683	53889	54096	54303
	2020	2026	2032	2037	2043	2049	2055	2061	2067	2073
1089.0	54510	54718	54927	55137	55347	55557	55768	55980	56193	56406
	2079	2085	2091	2097	2103	2109	2115	2121	2127	2133

Notes:

1. Numbers at the top of each column (.0-.9) are tenths of a foot.
2. Each whole number elevation has an associated capacity row and area row. The capacity row is on the same line as the whole number elevation; the area row is directly beneath

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1090.0	56619	56833	57048	57263	57479	57695	57912	58129	58348	58566
	2139	2144	2149	2154	2160	2165	2170	2176	2181	2186
1091.0	58785	59004	59224	59445	59666	59888	60110	60332	60556	60779
	2192	2197	2202	2208	2213	2218	2224	2229	2235	2240
1092.0	61004	61228	61454	61680	61906	62132	62359	62587	62815	63043
	2245	2250	2254	2259	2263	2268	2272	2277	2281	2286
1093.0	63272	63501	63731	63962	64192	64423	64655	64887	65120	65353
	2291	2295	2300	2304	2309	2313	2318	2322	2327	2332
1094.0	65586	65820	66054	66289	66524	66760	66996	67233	67470	67708
	2336	2341	2345	2350	2355	2359	2364	2369	2373	2378
1095.0	67946	68184	68423	68663	68903	69143	69384	69625	69867	70109
	2382	2387	2392	2396	2401	2406	2410	2415	2420	2424
1096.0	70352	70595	70839	71083	71327	71572	71817	72063	72309	72556
	2429	2433	2438	2442	2446	2450	2455	2459	2463	2467
1097.0	72803	73050	73298	73546	73795	74044	74294	74544	74794	75045
	2472	2476	2480	2484	2489	2493	2497	2502	2506	2510
1098.0	75296	75548	75800	76053	76306	76559	76813	77067	77322	77577
	2515	2519	2523	2527	2531	2536	2540	2544	2548	2553
1099.0	77832	78088	78345	78602	78859	79117	79375	79633	79892	80152
	2557	2561	2566	2570	2574	2578	2583	2587	2591	2596
1100.0	80411	80672	80932	81194	81455	81717	81979	82242	82506	82769
	2600	2604	2608	2613	2617	2622	2626	2630	2635	2639
1101.0	83033	83298	83563	83829	84095	84361	84628	84895	85163	85431
	2643	2648	2652	2657	2661	2665	2670	2674	2678	2683
1102.0	85699	85968	86237	86508	86778	87049	87320	87591	87863	88136
	2687	2692	2696	2700	2705	2709	2713	2718	2722	2727
1103.0	88409	88682	88956	89230	89505	89780	90055	90331	90608	90885
	2731	2735	2740	2744	2748	2753	2757	2762	2766	2770
1104.0	91162	91440	91718	91997	92276	92556	92836	93116	93397	93679
	2775	2779	2784	2789	2793	2798	2803	2807	2812	2817
1105.0	93961	94243	94526	94809	95093	95377	95662	95947	96233	96519
	2821	2826	2831	2835	2840	2845	2849	2854	2859	2863
1106.0	96806	97093	97380	97669	97957	98246	98536	98826	99117	99408
	2868	2873	2878	2883	2888	2893	2898	2903	2908	2913
1107.0	99699	99991	100284	100577	100871	101165	101460	101755	102051	102347
	2918	2923	2928	2933	2939	2944	2949	2954	2959	2964
1108.0	102644	102941	103238	103537	103836	104136	104436	104736	105038	105340
	2969	2975	2981	2986	2992	2998	3004	3010	3015	3021
1109.0	105642	105945	106249	106553	106858	107163	107469	107776	108083	108391
	3027	3033	3039	3045	3051	3056	3062	3068	3074	3080

Notes:

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ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1110.0	108699	109008	109317	109628	109938	110249	110561	110873	111186	111499
	3086	3091	3097	3102	3108	3113	3119	3124	3130	3135
1111.0	111813	112127	112442	112758	113074	113390	113707	114025	114344	114662
	3141	3146	3152	3157	3163	3168	3174	3179	3185	3191
1112.0	114982	115302	115622	115943	116265	116587	116910	117233	117557	117881
	3196	3202	3207	3213	3219	3224	3230	3235	3241	3247
1113.0	118206	118532	118858	119185	119512	119840	120168	120497	120827	121157
	3252	3258	3264	3269	3275	3281	3286	3292	3298	3303
1114.0	121488	121819	122150	122483	122815	123148	123482	123816	124151	124486
	3309	3314	3319	3324	3329	3334	3338	3343	3348	3353
1115.0	124822	125158	125494	125832	126169	126507	126846	127184	127524	127864
	3358	3363	3368	3373	3378	3383	3388	3392	3397	3402
1116.0	128205	128546	128887	129229	129572	129915	130258	130602	130946	131291
	3407	3412	3417	3421	3426	3431	3436	3440	3445	3450
1117.0	131636	131982	132328	132675	133022	133370	133718	134066	134416	134765
	3455	3459	3464	3469	3474	3478	3483	3488	3493	3497
1118.0	135115	135465	135816	136168	136520	136873	137226	137579	137934	138288
	3502	3507	3512	3518	3523	3528	3533	3538	3544	3549
1119.0	138643	138999	139355	139712	140070	140427	140785	141144	141504	141864
	3554	3559	3564	3570	3575	3580	3585	3591	3596	3601
1120.0	142224	142585	142946	143308	143670	144033	144397	144760	145125	145490
	3606	3611	3616	3621	3626	3631	3636	3641	3646	3651
1121.0	145855	146221	146587	146954	147322	147689	148058	148426	148796	149166
	3656	3660	3665	3670	3675	3680	3685	3690	3695	3700
1122.0	149536	149907	150278	150650	151022	151395	151768	152142	152516	152891
	3705	3710	3715	3720	3725	3730	3735	3740	3745	3750
1123.0	153266	153642	154018	154395	154773	155150	155529	155907	156287	156667
	3755	3760	3765	3770	3775	3780	3785	3790	3795	3800
1124.0	157047	157428	157809	158191	158573	158956	159339	159723	160108	160327
	3805	3810	3815	3820	3825	3830	3835	3840	3846	3851
1125.0	160546	160765	160984	161371	161758	162145	162533	162922	163311	163700
	3856	3860	3864	3869	3873	3877	3882	3886	3890	3895
1126.0	164090	164480	164870	165262	165653	166045	166437	166830	167223	167617
	3899	3903	3908	3912	3917	3921	3925	3930	3934	3938
1127.0	168011	168405	168800	169196	169592	169988	170385	170782	171180	171578
	3943	3947	3951	3956	3960	3965	3969	3973	3978	3982
1128.0	171976	172375	172774	173174	173575	173975	174376	174778	175180	175583
	3987	3991	3995	4000	4004	4009	4013	4017	4022	4026
1129.0	175985	176389	176792	177197	177601	178006	178412	178818	179225	179478
	4031	4035	4040	4044	4048	4053	4057	4062	4066	4071

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COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1130.0	179730	179983	180235	180644	181053	181462	181872	182283	182694	183105
	4075	4080	4084	4089	4093	4098	4102	4107	4111	4116
1131.0	183517	183929	184342	184756	185169	185583	185998	186413	186829	187244
	4120	4125	4130	4134	4139	4143	4148	4152	4157	4161
1132.0	187661	188078	188495	188913	189331	189750	190169	190588	191009	191429
	4166	4171	4175	4180	4184	4189	4194	4198	4203	4207
1133.0	191850	192272	192693	193116	193539	193962	194386	194810	195235	195660
	4212	4217	4221	4226	4230	4235	4240	4244	4249	4253
1134.0	196086	196512	196938	197366	197793	198221	198649	199078	199508	199773
	4258	4263	4267	4272	4277	4281	4286	4290	4295	4300
1135.0	200038	200303	200568	201000	201432	201865	202298	202732	203167	203602
	4304	4310	4315	4320	4326	4331	4336	4342	4347	4352
1136.0	204037	204473	204910	205347	205785	206223	206662	207101	207541	207981
	4358	4363	4368	4374	4379	4384	4390	4395	4400	4406
1137.0	208422	208863	209305	209748	210191	210635	211079	211523	211969	212414
	4411	4417	4422	4427	4433	4438	4443	4449	4454	4460
1138.0	212861	213307	213755	214203	214651	215100	215550	216000	216451	216902
	4465	4470	4476	4481	4487	4492	4498	4503	4508	4514
1139.0	217353	217805	218258	218712	219166	219620	220075	220530	220987	221220
	4519	4525	4530	4536	4541	4546	4552	4557	4563	4568
1140.0	221453	221686	221919	222378	222838	223297	223758	224219	224681	225143
	4574	4579	4585	4590	4596	4601	4607	4612	4618	4623
1141.0	225605	226068	226532	226997	227462	227927	228393	228859	229327	229794
	4629	4635	4640	4646	4651	4657	4662	4668	4673	4679
1142.0	230263	230731	231200	231671	232141	232612	233083	233556	234029	234502
	4685	4690	4696	4701	4707	4712	4718	4724	4729	4735
1143.0	234976	235450	235925	236401	236876	237353	237830	238308	238786	239265
	4740	4746	4752	4757	4763	4769	4774	4780	4785	4791
1144.0	239745	240224	240705	241186	241668	242150	242633	243116	243430	243744
	4797	4802	4808	4814	4819	4825	4831	4836	4842	4848
1145.0	244059	244373	244687	245001	245488	245976	246465	246954	247445	247935
	4853	4859	4865	4872	4878	4884	4890	4896	4902	4908
1146.0	248426	248918	249410	249904	250397	250891	251386	251881	252378	252874
	4914	4920	4927	4933	4939	4945	4951	4957	4963	4970
1147.0	253372	253869	254368	254868	255367	255868	256368	256870	257373	257876
	4976	4982	4988	4994	5001	5007	5013	5019	5025	5031
1148.0	258379	258883	259388	259893	260399	260906	261413	261921	262430	262939
	5038	5044	5050	5056	5063	5069	5075	5081	5087	5094
1149.0	263448	263958	264469	264981	265493	266006	266520	267034	267347	267660
	5100	5106	5112	5119	5125	5131	5137	5144	5150	5156

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1150.0	267973	268286	268599	268912	269431	269950	270470	270990	271512	272033
	5163	5169	5176	5182	5189	5195	5202	5208	5215	5221
1151.0	272556	273079	273602	274127	274652	275178	275704	276231	276759	277288
	5228	5234	5241	5247	5254	5260	5267	5273	5280	5287
1152.0	277817	278346	278876	279408	279939	280472	281004	281538	282073	282608
	5293	5300	5306	5313	5319	5326	5333	5339	5346	5352
1153.0	283143	283679	284216	284754	285292	285831	286371	286911	287452	287994
	5359	5366	5372	5379	5385	5392	5399	5405	5412	5419
1154.0	288536	289078	289622	290167	290712	291257	291803	292350	292667	292984
	5425	5432	5439	5445	5452	5459	5465	5472	5479	5485
1155.0	293300	293617	293934	294251	294803	295355	295908	296462	297017	297572
	5492	5499	5506	5513	5520	5527	5535	5542	5549	5556
1156.0	298128	298684	299242	299800	300359	300918	301479	302039	302602	303164
	5563	5570	5577	5584	5591	5599	5606	5613	5620	5627
1157.0	303727	304291	304855	305421	305987	306553	307121	307689	308258	308827
	5634	5642	5649	5656	5663	5670	5677	5685	5692	5699
1158.0	309398	309969	310540	311113	311686	312260	312835	313410	313986	314563
	5706	5713	5721	5728	5735	5742	5750	5757	5764	5771
1159.0	315140	315719	316297	316878	317458	318039	318621	319203	319524	319845
	5779	5786	5793	5800	5808	5815	5822	5829	5837	5844
1160.0	320165	320486	320807	321128	321716	322304	322893	323483	324074	324666
	5851	5859	5866	5874	5881	5889	5896	5904	5911	5919
1161.0	325258	325851	326444	327040	327635	328231	328827	329425	330024	330623
	5926	5934	5941	5949	5956	5964	5971	5979	5987	5994
1162.0	331222	331823	332424	333027	333629	334233	334837	335442	336049	336655
	6002	6009	6017	6024	6032	6040	6047	6055	6062	6070
1163.0	337262	337870	338479	339089	339700	340311	340923	341535	342149	342764
	6078	6085	6093	6100	6108	6116	6123	6131	6139	6146
1164.0	343378	343994	344611	345229	345846	346465	347085	347705	348044	348384
	6154	6162	6169	6177	6185	6192	6200	6208	6215	6223
1165.0	348723	349062	349402	349741	350367	350994	351621	352249	352879	353508
	6231	6239	6246	6254	6262	6270	6278	6286	6294	6302
1166.0	354139	354770	355402	356036	356669	357304	357939	358575	359212	359850
	6310	6318	6325	6333	6341	6349	6357	6365	6373	6381
1167.0	360488	361128	361768	362409	363051	363693	364336	364980	365626	366271
	6389	6397	6405	6413	6421	6429	6437	6445	6453	6461
1168.0	366918	367565	368213	368863	369512	370163	370814	371466	372119	372773
	6469	6477	6485	6493	6501	6509	6517	6525	6533	6541
1169.0	373427	374083	374739	375396	376054	376712	377372	378032	378399	378765
	6549	6557	6565	6573	6582	6590	6598	6606	6614	6622

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1170.0	379132	379498	379865	380231	380897	381563	382231	382900	383570	384240
	6630	6639	6647	6656	6665	6673	6682	6691	6699	6708
1171.0	384911	385583	386256	386931	387605	388281	388957	389634	390313	390992
	6717	6726	6734	6743	6752	6760	6769	6778	6787	6795
1172.0	391672	392353	393035	393718	394401	395086	395771	396457	397144	397832
	6804	6813	6822	6830	6839	6848	6857	6866	6874	6883
1173.0	398521	399210	399901	400593	401285	401978	402672	403367	404063	404760
	6892	6901	6910	6919	6927	6936	6945	6954	6963	6972
1174.0	405458	406156	406855	407556	408257	408959	409662	410366	410737	411109
	6980	6989	6998	7007	7016	7025	7034	7043	7052	7061
1175.0	411480	411851	412223	412594	413303	414014	414726	415439	416153	416867
	7070	7078	7087	7096	7105	7114	7123	7132	7140	7149
1176.0	417583	418299	419016	419735	420453	421173	421894	422615	423338	424062
	7158	7167	7176	7185	7194	7203	7212	7221	7230	7239
1177.0	424786	425511	426237	426965	427692	428421	429151	429881	430613	431346
	7248	7257	7266	7275	7283	7292	7301	7310	7319	7328
1178.0	432079	432813	433548	434285	435021	435759	436498	437237	437979	438720
	7337	7346	7356	7365	7374	7383	7392	7401	7410	7419
1179.0	439462	440205	440949	441695	442441	443188	443935	444684	445078	445472
	7428	7437	7446	7455	7464	7473	7482	7492	7501	7510
1180.0	445866	446260	446654	447048	447803	448559	449316	450074	450834	451594
	7519	7528	7538	7547	7557	7566	7576	7585	7595	7604
1181.0	452355	453116	453879	454643	455408	456173	456940	457707	458477	459246
	7614	7623	7633	7642	7652	7661	7671	7680	7690	7699
1182.0	460016	460787	461560	462334	463108	463883	464659	465436	466215	466994
	7709	7718	7728	7738	7747	7757	7766	7776	7785	7795
1183.0	467773	468554	469336	470120	470903	471688	472474	473260	474049	474837
	7805	7814	7824	7834	7843	7853	7862	7872	7882	7891
1184.0	475627	476417	477209	478002	478795	479590	480385	481181	481588	481995
	7901	7911	7921	7930	7940	7950	7959	7969	7979	7988
1185.0	482403	482810	483217	483624	484427	485231	486036	486842	487649	488457
	7998	8008	8017	8027	8037	8046	8056	8066	8076	8085
1186.0	489266	490076	490887	491700	492512	493326	494141	494956	495774	496592
	8095	8105	8114	8124	8134	8143	8153	8163	8173	8182
1187.0	497410	498230	499050	499873	500695	501519	502343	503169	503996	504823
	8192	8202	8212	8222	8231	8241	8251	8261	8270	8280
1188.0	505652	506481	507312	508144	508976	509809	510644	511479	512316	513153
	8290	8300	8310	8320	8329	8339	8349	8359	8369	8379
1189.0	513992	514831	515671	516513	517355	518198	519043	519888	520315	520743
	8389	8398	8408	8418	8428	8438	8448	8458	8468	8478

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SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1190.0	521170	521597	522025	522452	523304	524157	525010	525865	526721	527578
	8488	8497	8506	8515	8524	8533	8542	8551	8560	8569
1191.0	528435	529293	530152	531013	531874	532736	533598	534462	535328	536193
	8579	8588	8597	8606	8615	8624	8633	8642	8652	8661
1192.0	537059	537927	538795	539665	540535	541406	542278	543151	544026	544900
	8670	8679	8688	8697	8707	8716	8725	8734	8743	8753
1193.0	545776	546652	547530	548409	549288	550168	551050	551932	552816	553699
	8762	8771	8780	8789	8799	8808	8817	8826	8836	8845
1194.0	554584	555470	556356	557245	558134	559023	559913	560805	561308	561810
	8854	8863	8873	8882	8891	8901	8910	8919	8928	8938
1195.0	562313	562815	563318	563820	564718	565617	566517	567418	568321	569223
	8947	8957	8966	8976	8986	8995	9005	9015	9024	9034
1196.0	570127	571032	571937	572845	573753	574661	575571	576481	577394	578307
	9044	9054	9063	9073	9083	9092	9102	9112	9122	9131
1197.0	579220	580134	581050	581967	582885	583803	584722	585643	586565	587487
	9141	9151	9161	9171	9180	9190	9200	9210	9219	9229
1198.0	588411	589335	590260	591187	592114	593043	593972	594902	595834	596766
	9239	9249	9259	9269	9278	9288	9298	9308	9318	9328
1199.0	597699	598633	599568	600506	601443	602381	603320	604260	604765	605270
	9337	9347	9357	9367	9377	9387	9397	9407	9417	9426
1200.0	605774	606279	606784	607289	608235	609183	610131	611081	612032	612983
	9436	9445	9455	9464	9473	9482	9491	9500	9509	9518
1201.0	613935	614888	615842	616798	617754	618711	619668	620627	621587	622548
	9527	9537	9546	9555	9564	9573	9582	9591	9600	9610
1202.0	623509	624471	625434	626399	627364	628330	629297	630265	631234	632204
	9619	9628	9637	9646	9656	9665	9674	9683	9692	9701
1203.0	633174	634146	635118	636092	637066	638041	639017	639994	640973	641952
	9711	9720	9729	9738	9748	9757	9766	9775	9784	9794
1204.0	642931	643912	644894	645877	646861	647845	648830	649816	650381	650946
	9803	9812	9821	9831	9840	9849	9859	9868	9877	9886
1205.0	651212	652077	652642	653207	654200	655194	656189	657185	658182	659180
	9896	9905	9915	9925	9935	9945	9954	9964	9974	9984
1206.0	660179	661178	662179	663182	664184	665188	666193	667198	668206	669213
	9994	10003	10013	10023	10033	10043	10052	10062	10072	10082
1207.0	669440	670442	671447	672454	673461	674469	675478	676489	677502	678515
	10030	10041	10053	10065	10077	10089	10101	10113	10125	10137
1208.0	680364	681383	682403	683426	684448	685471	686496	687521	688549	689576
	10191	10200	10210	10220	10230	10240	10250	10260	10270	10280
1209.0	690604	691633	692664	693696	694728	695762	696796	697831	698869	699906
	10290	10300	10310	10320	10330	10340	10350	10360	10370	10380

Notes:

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2. Each whole number elevation has an associated capacity row and area row. The capacity row is on the same line as the whole number elevation; the area row is directly beneath

ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
SURVEYED: MAR. 1963 - MAY 1968; OCT. 1985 (ELEVATION 990-1120 FEET)
COMPUTED JUNE 1993 (SUPERSEDES ALL PREVIOUS TABLES)

ELEV FEET	CAP AREA .0	CAP AREA .1	CAP AREA .2	CAP AREA .3	CAP AREA .4	CAP AREA .5	CAP AREA .6	CAP AREA .7	CAP AREA .8	CAP AREA .9
1210.0	700080	701119	702160	703202	704245	705288	706333	707378	708426	709474
	10390	10400	10410	10421	10431	10442	10452	10463	10473	10484
1211.0	710523	711572	712623	713676	714729	715783	716838	717894	718953	720011
	10494	10505	10515	10526	10537	10547	10558	10568	10579	10589
1212.0	721070	722131	723192	724256	725319	726384	727449	728516	729585	730654
	10600	10610	10621	10632	10642	10653	10663	10674	10685	10695
1213.0	731724	732794	733866	734941	736015	737090	738166	739244	740323	741403
	10706	10717	10727	10738	10748	10759	10770	10780	10791	10802
1214.0	742483	743565	744647	745732	746817	747903	748990	750078	751168	752258
	10812	10823	10834	10845	10855	10866	10877	10887	10898	10909
1215.0	753190	754283	755376	756472	757568	758665	759763	760863	761965	763066
	10920	10931	10943	10955	10967	10979	10991	11003	11014	11026
1216.0	764169	765274	766379	767487	768595	769704	770814	771925	773039	774153
	11038	11050	11062	11074	11086	11098	11110	11122	11134	11146
1217.0	775268	776384	777501	778621	779741	780862	781984	783107	784233	785359
	11158	11170	11182	11194	11206	11218	11230	11242	11254	11266
1218.0	786486	787614	788743	789875	791007	792140	793274	794409	795547	796685
	11278	11290	11302	11314	11326	11338	11350	11362	11374	11386
1219.0	797824	798964	800106	801250	802394	803539	804685	805832	806983	808132
	11398	11410	11422	11435	11447	11459	11471	11483	11495	11507
1220.0	809220	810371	811525	812681	813837	814994	816153	817313	818475	819637
	11520	11532	11544	11557	11569	11582	11594	11607	11619	11632
1221.0	820801	821966	823132	824301	825469	826639	827810	828982	830157	831332
	11644	11657	11669	11682	11694	11707	11719	11732	11744	11757
1222.0	832508	833686	834864	836045	837227	838409	839593	840778	841965	843153
	11769	11782	11795	11807	11820	11832	11845	11858	11870	11883
1223.0	844341	845531	846722	847916	849110	850305	851501	852699	853899	855099
	11895	11908	11921	11933	11946	11959	11971	11984	11997	12009
1224.0	856300	857503	858707	859914	861120	862328	863537	864747	865960	867173
	12022	12035	12048	12060	12073	12086	12098	12111	12124	12137
1225.0	868387	869602	870818	872038	873256	874476	875697	876920	878145	879369
	12150	12161	12173	12185	12196	12208	12220	12231	12243	12255
1226.0	880595	881822	883050	884281	885512	886743	887976	889210	890447	891683
	12266	12278	12290	12302	12313	12325	12337	12349	12360	12372
1227.0	892921	894159	895399	896642	897884	899128	900372	901618	902866	904115
	12384	12396	12407	12419	12431	12443	12455	12466	12478	12490
1228.0	905364	906614	907866	909121	910375	911630	912886	914144	915404	916664
	12502	12514	12525	12537	12549	12561	12573	12585	12597	12609
1229.0	917925	919188	920451	921718	922984	924251	925519	926789	928061	929333
	12620	12632	12644	12656	12668	12680	12692	12704	12716	12728

Notes:

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ALAMO RESERVOIR (CORPS OF ENGINEERS) -- AREA-CAPACITY TABLE
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1230.0	930210	931483	932759	934037	935314	936593	937873	939154	940437	941720
	12740	12751	12762	12773	12784	12795	12806	12817	12828	12839
1231.0	943004	944290	945576	946865	948154	949444	950735	952027	953322	954616
	12851	12862	12873	12884	12895	12906	12917	12929	12940	12951
1232.0	955911	957208	958505	959806	961105	962406	963709	965012	966318	967623
	12962	12973	12984	12996	13007	13018	13029	13040	13052	13063
1233.0	968930	970237	971546	972858	974169	975481	976794	978109	979426	980743
	13074	13085	13097	13108	13119	13130	13141	13153	13164	13175
1234.0	982060	983379	984699	986022	987345	988668	989993	991318	992647	993975
	13187	13198	13209	13220	13232	13243	13254	13266	13277	13288
1235.0	995300	996634	997966	999301	1000635	1001971	1003308	1004647	1005989	1007330
	13300	13313	13327	13341	13355	13369	13383	13396	13410	13424
1236.0	1008673	1010017	1011363	1012712	1014060	1015410	1016761	1018114	1019469	1020825
	13438	13452	13466	13480	13494	13508	13522	13535	13549	13563
1237.0	1022181	1023539	1024899	1026262	1027624	1028988	1030353	1031719	1033089	1034458
	13577	13591	13605	13619	13633	13647	13661	13675	13689	13703
1238.0	1035829	1037201	1038575	1039951	1041328	1042706	1044085	1045465	1046849	1048232
	13717	13731	13745	13759	13774	13788	13802	13816	13830	13844
1239.0	1049617	1051003	1052391	1053782	1055172	1056564	1057957	1059352	1060750	1062147
	13858	13872	13886	13900	13915	13929	13943	13957	13971	13985
1240.0	1063500	1064900	1066301	1067705	1069108	1070513	1071919	1073325	1074735	1076144
	14000	14010	14021	14032	14043	14054	14065	14076	14087	14098
1241.0	1077554	1078965	1080377	1081792	1083207	1084622	1086039	1087456	1088877	1090297
	14109	14120	14131	14141	14152	14163	14174	14185	14196	14207
1242.0	1091718	1093140	1094563	1095989	1097414	1098841	1100268	1101697	1103129	1104559
	14218	14229	14240	14251	14262	14273	14284	14295	14306	14317
1243.0	1105991	1107425	1108859	1110296	1111732	1113170	1114608	1116048	1117490	1118932
	14328	14339	14350	14361	14372	14383	14394	14405	14417	14428
1244.0	1120375	1121819	1123265	1124713	1126160	1127609	1129058	1130509	1131963	1133416
	14439	14450	14461	14472	14483	14494	14505	14516	14527	14538
1245.0	1134870	1136325	1137782	1139241	1140701	1142161	1143623	1145086	1146552	1148017
	14550	14562	14575	14588	14601	14614	14627	14640	14653	14665
1246.0	1149484	1150953	1152422	1153894	1155367	1156840	1158315	1159791	1161270	1162748
	14678	14691	14704	14717	14730	14743	14756	14769	14782	14795
1247.0	1164228	1165709	1167191	1168677	1170162	1171648	1173136	1174625	1176117	1177608
	14808	14821	14834	14847	14860	14873	14886	14899	14912	14925
1248.0	1179101	1180595	1182091	1183589	1185087	1186587	1188087	1189589	1191094	1192599
	14938	14951	14964	14977	14990	15003	15016	15029	15042	15055
1249.0	1194105	1195612	1197120	1198632	1200143	1201655	1203169	1204684	1206202	1207720
	15068	15081	15095	15108	15121	15134	15147	15160	15173	15186

Notes:
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1250.0	1209100	1210619	1212141	1213665	1215190	1216716	1218243	1219772	1221304	1222835
	15200	15213	15227	15241	15255	15269	15283	15297	15310	15324
1251.0	1224368	1225902	1227438	1228976	1230515	1232055	1233596	1235138	1236684	1238229
	15338	15352	15366	15380	15394	15408	15422	15436	15450	15464
1252.0	1239776	1241324	1242874	1244427	1245979	1247533	1249088	1250644	1252204	1253763
	15478	15492	15506	15520	15534	15548	15562	15576	15590	15604
1253.0	1255324	1256886	1258450	1260017	1261583	1263151	1264720	1266291	1267864	1269438
	15618	15632	15646	15660	15674	15688	15702	15716	15730	15744
1254.0	1271013	1272589	1274166	1275747	1277328	1278910	1280493	1282077	1283666	1285253
	15758	15772	15786	15801	15815	15829	15843	15857	15871	15885
1255.0	1286842	1288432	1290024	1291618	1293212	1294807	1296403	1298000	1299601	1301201
	15900	15911	15923	15935	15947	15959	15971	15983	15995	16007
1256.0	1302801	1304404	1306007	1307613	1309219	1310826	1312434	1314043	1315656	1317267
	16019	16031	16042	16054	16066	16078	16090	16102	16114	16126
1257.0	1318880	1320494	1322110	1323728	1325346	1326965	1328585	1330206	1331830	1333454
	16138	16150	16162	16174	16186	16198	16210	16222	16234	16246
1258.0	1335079	1336705	1338332	1339963	1341592	1343223	1344855	1346489	1348125	1349761
	16258	16270	16282	16294	16306	16318	16330	16342	16354	16367
1259.0	1351398	1353036	1354675	1356318	1357959	1359602	1361247	1362892	1364541	1366188
	16379	16391	16403	16415	16427	16439	16451	16463	16475	16487
1260.0	1367400	1369050	1370702	1372356	1374010	1375665	1377321	1378978	1380639	1382299
	16500	16511	16523	16535	16547	16559	16571	16583	16595	16607
1261.0	1383960	1385622	1387285	1388951	1390617	1392284	1393952	1395621	1397294	1398966
	16619	16631	16643	16654	16666	16678	16690	16702	16714	16726
1262.0	1400638	1402313	1403988	1405666	1407344	1409023	1410703	1412384	1414069	1415752
	16738	16750	16762	16774	16786	16798	16810	16822	16834	16846
1263.0	1417437	1419123	1420810	1422501	1424191	1425882	1427574	1429267	1430963	1432659
	16858	16870	16882	16894	16906	16918	16930	16942	16955	16967
1264.0	1434356	1436054	1437753	1439456	1441158	1442861	1444565	1446270	1447979	1449687
	16979	16991	17003	17015	17027	17039	17051	17063	17075	17087
1265.0	1451300									
	17100									

Notes:

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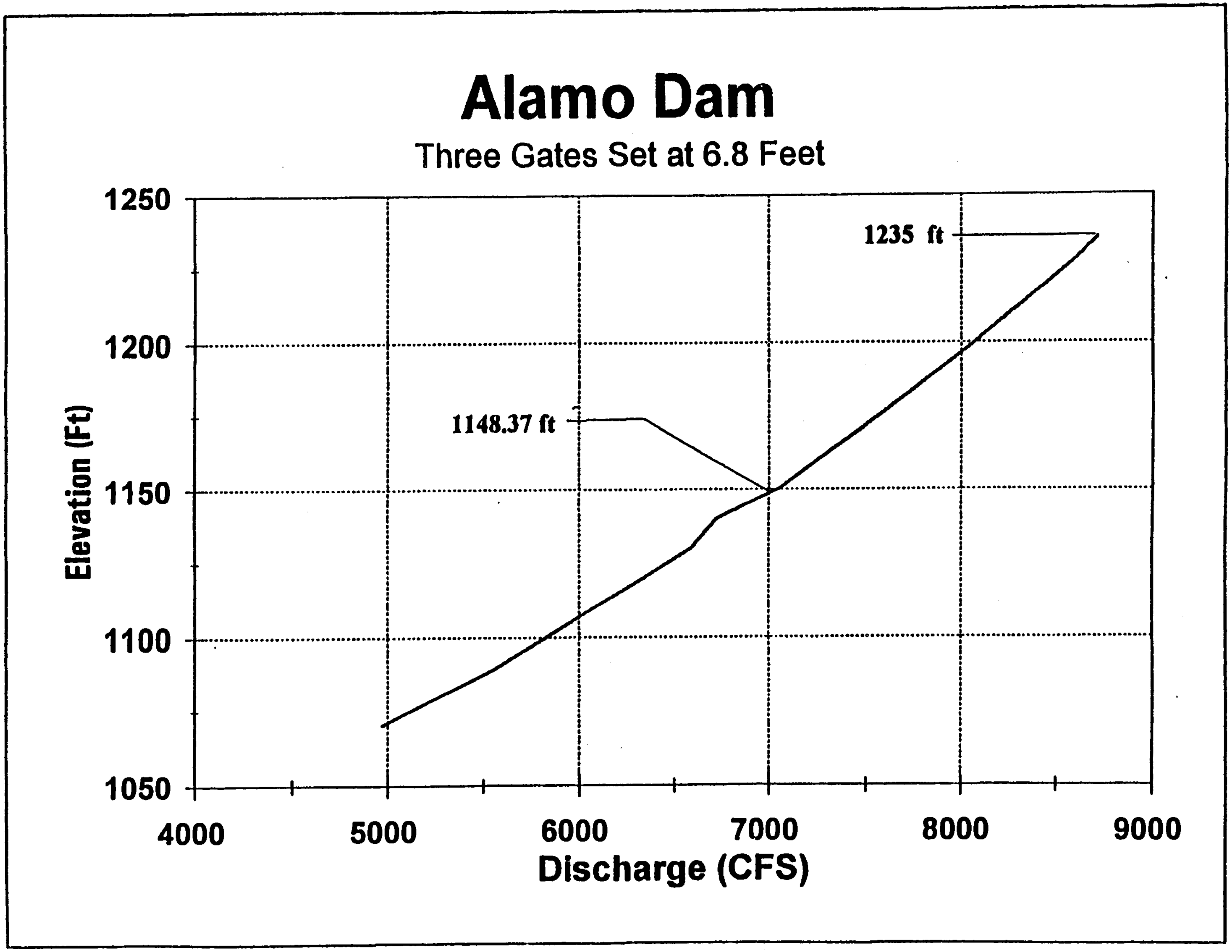

Alamo Dam
Three Gates Set at 6.8 Feet
1250
1200
1150
1100
1050
Elevation (Ft)
4000
5000
6000
7000
8000
9000
Discharge (CFS)
1235 ft
1148.37 ft

FIGURE 4

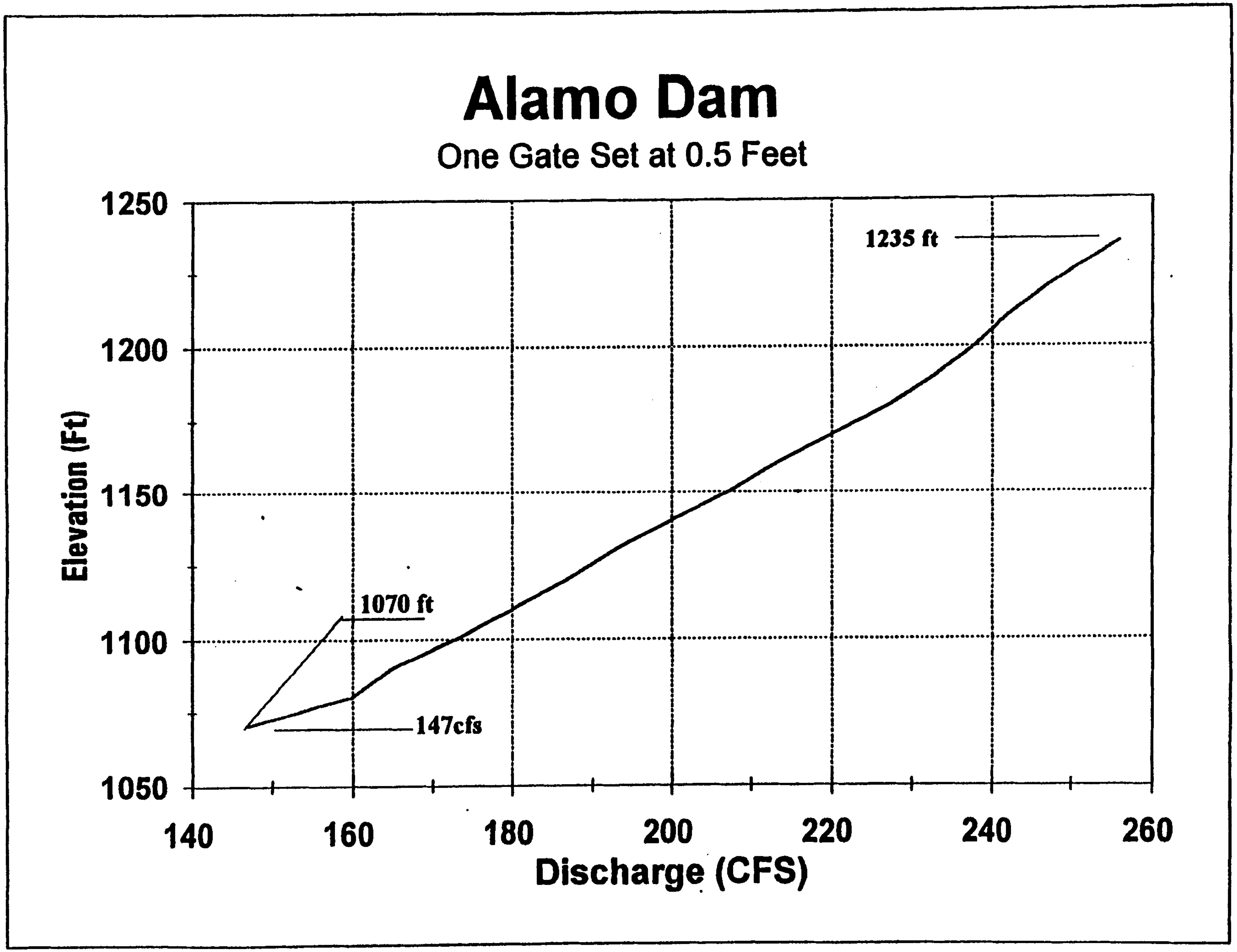

Alamo Dam
One Gate Set at 0.5 Feet
1235 ft
1070 ft
147cfs
Elevation (Ft)
1250
1200
1150
1100
1050
140
160
180
200
220
240
260
Discharge (CFS)

FIGURE 5

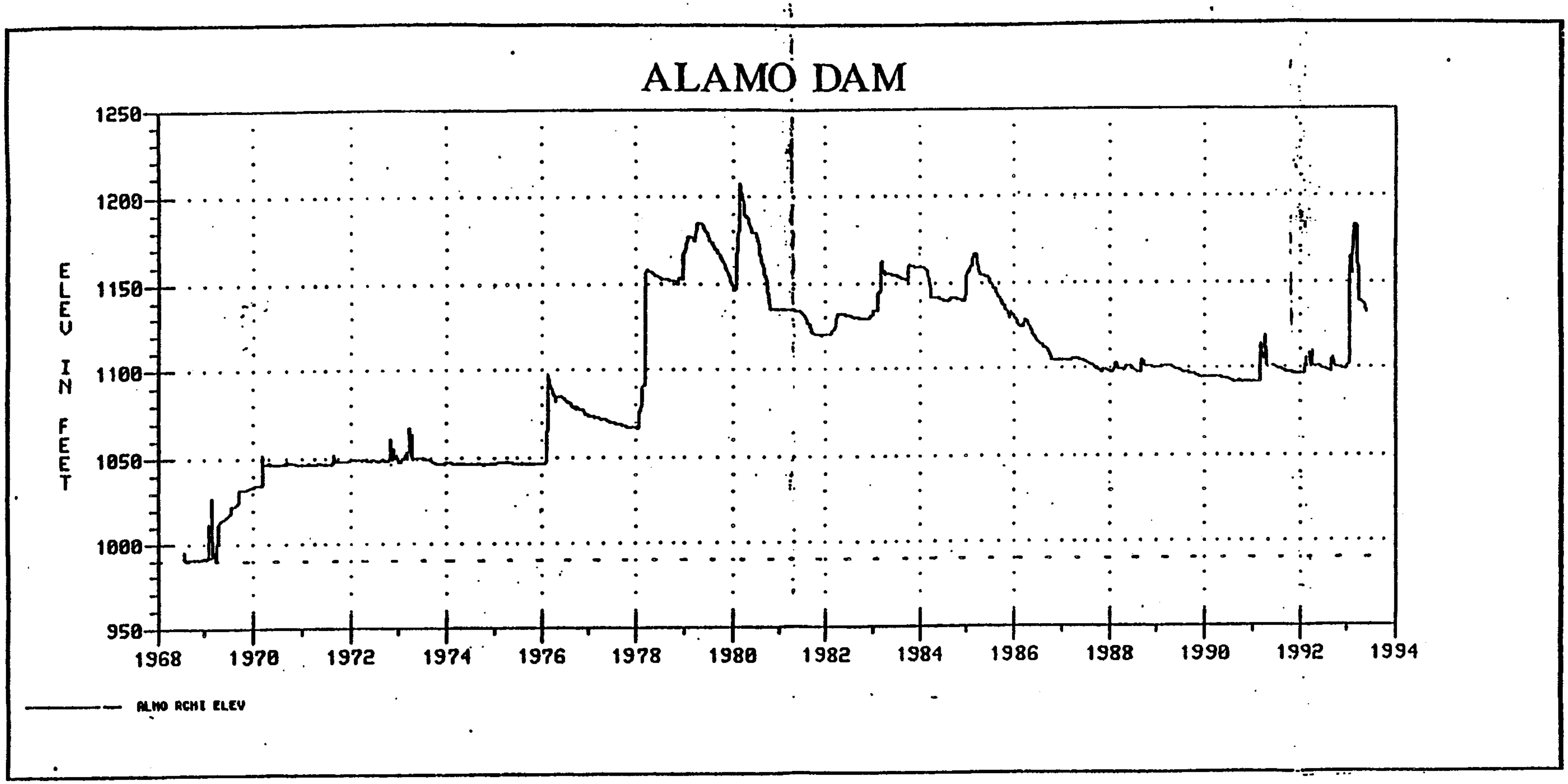
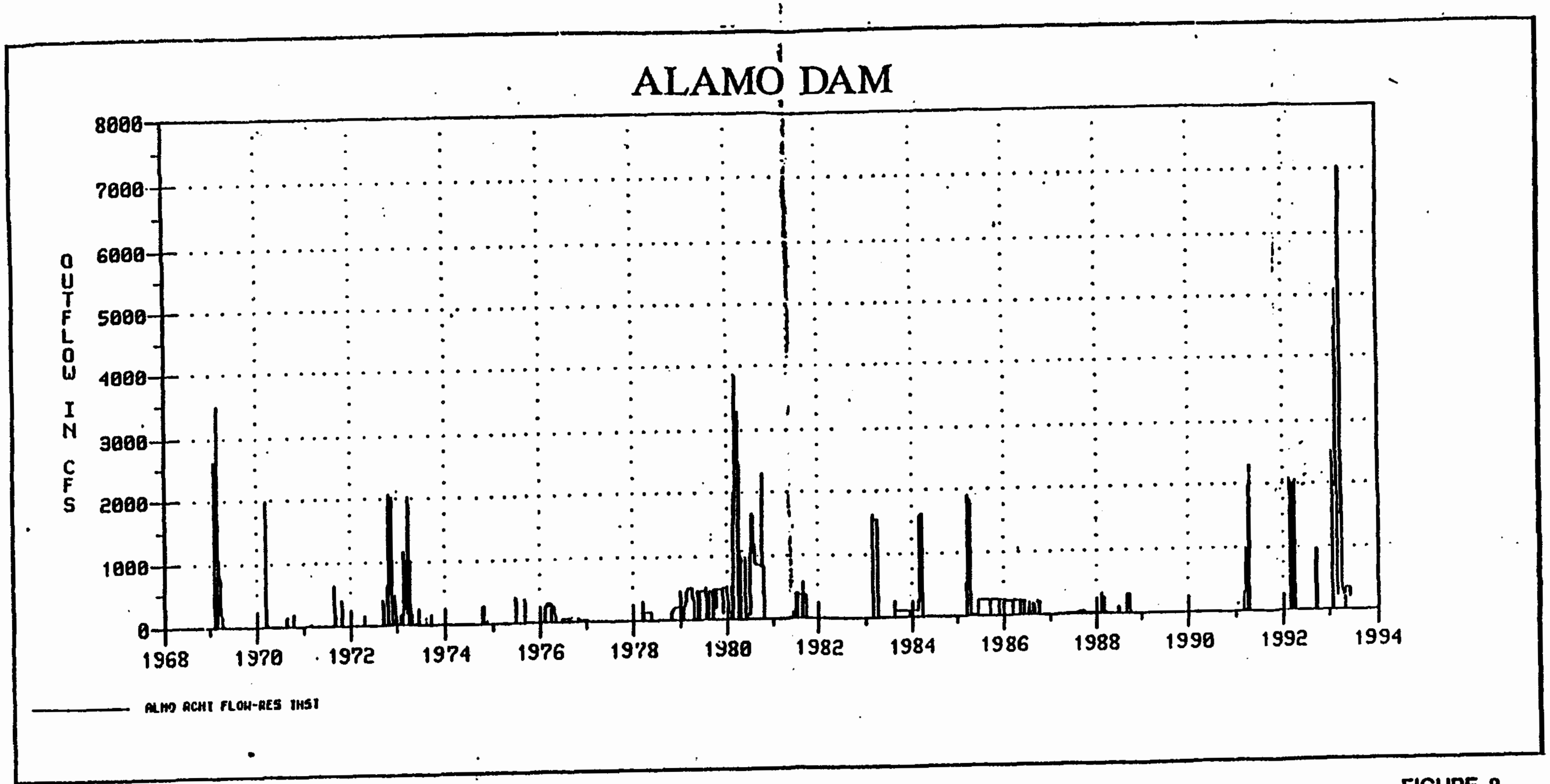

ALAMO DAM
ELEV IN FEET
1250
1200
1150
1100
1050
1000
950
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
ALMO RCHI ELEV

FIGURE 7



ALAMO DAM
OUTFLOW IN CFS
8000
7000
6000
5000
4000
3000
2000
1000
0
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
ALMO ACHT FLOW-RES INST

FIGURE 8

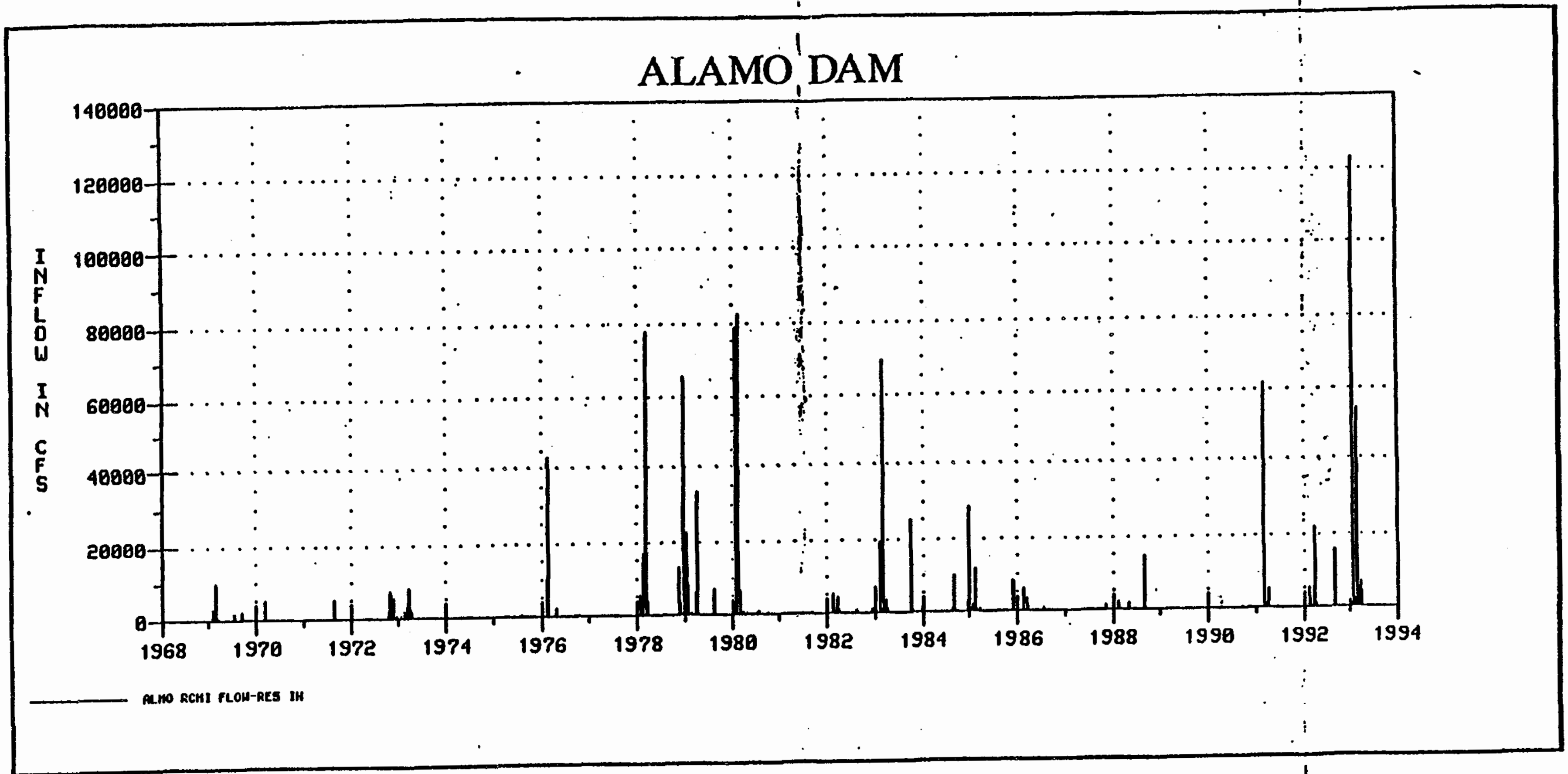

ALAMO DAM
INFLOW IN CFS
140000
120000
100000
80000
60000
40000
20000
0
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
ALMO RCH1 FLOW-RES IN

FIGURE 9

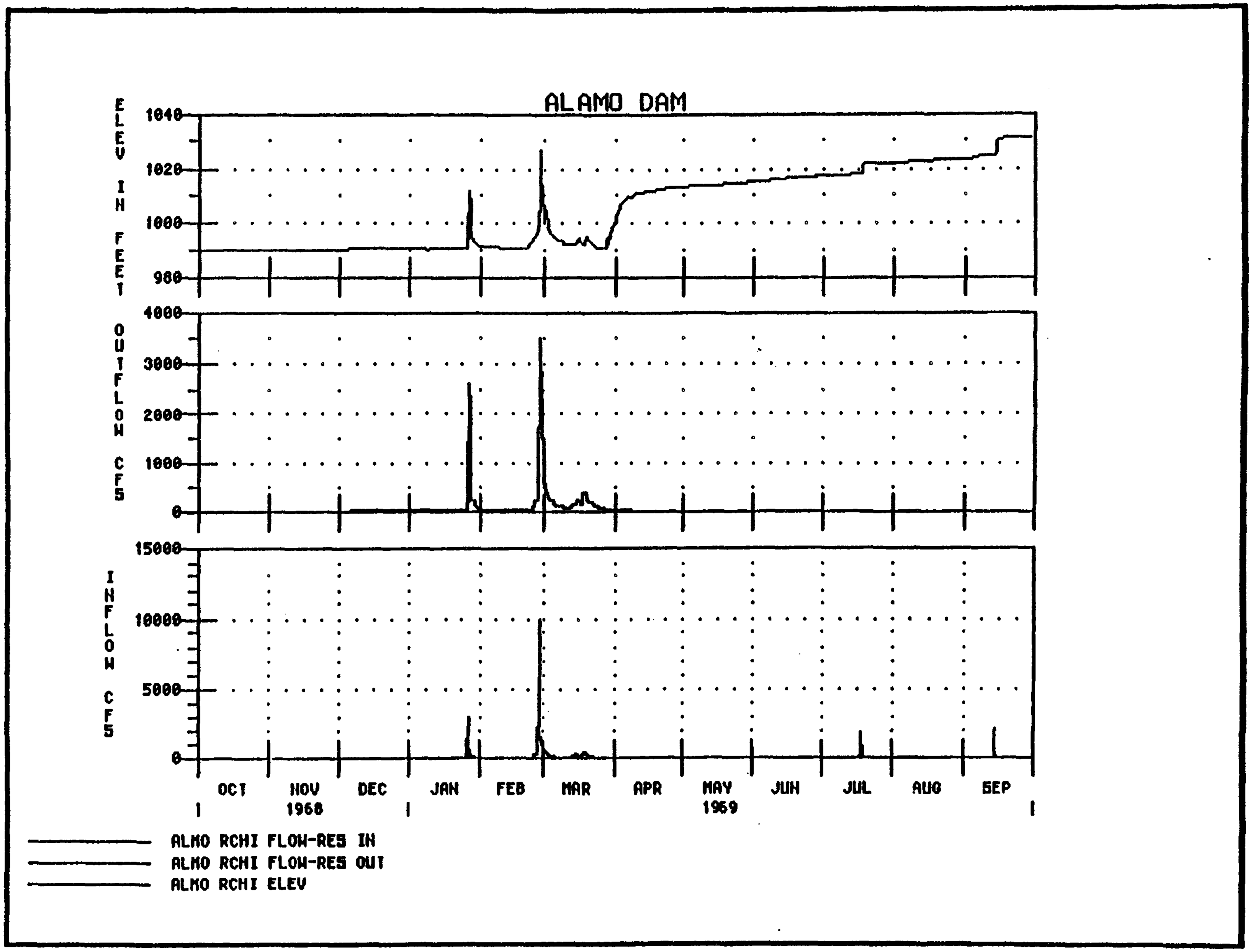

ALAMO DAM
ELEV IN FEET
1040
1020
1000
980
OUTFLOW CFS
4000
3000
2000
1000
0
INFLOW CFS
15000
10000
5000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
1968
1969
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-1

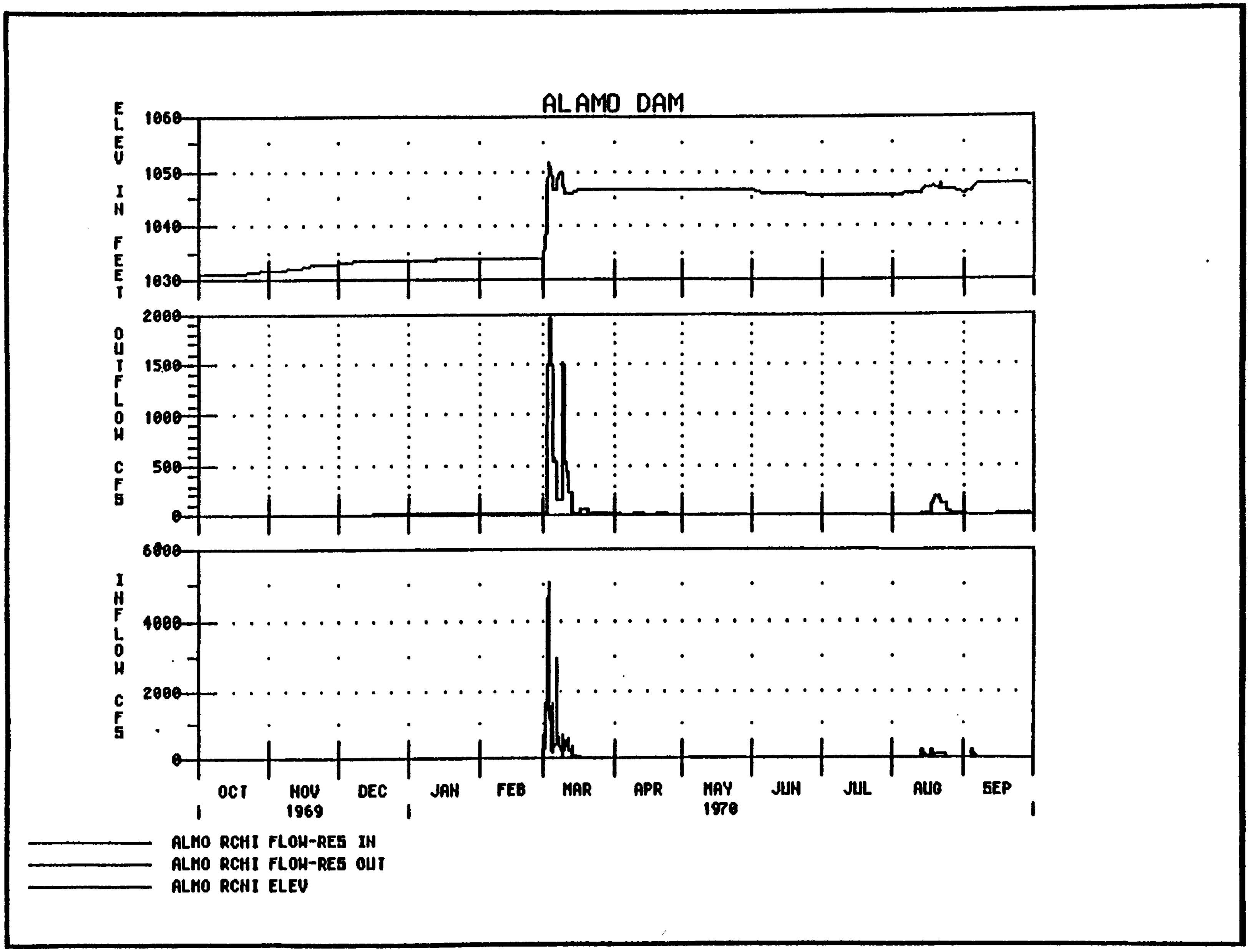

ALAMO DAM
ELEV IN FEET
1060
1050
1040
1030
OUTFLOW CFS
2000
1500
1000
500
0
INFLOW CFS
6000
4000
2000
0
OCT
NOV
1969
DEC
JAN
FEB
MAR
APR
MAY
1970
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-2

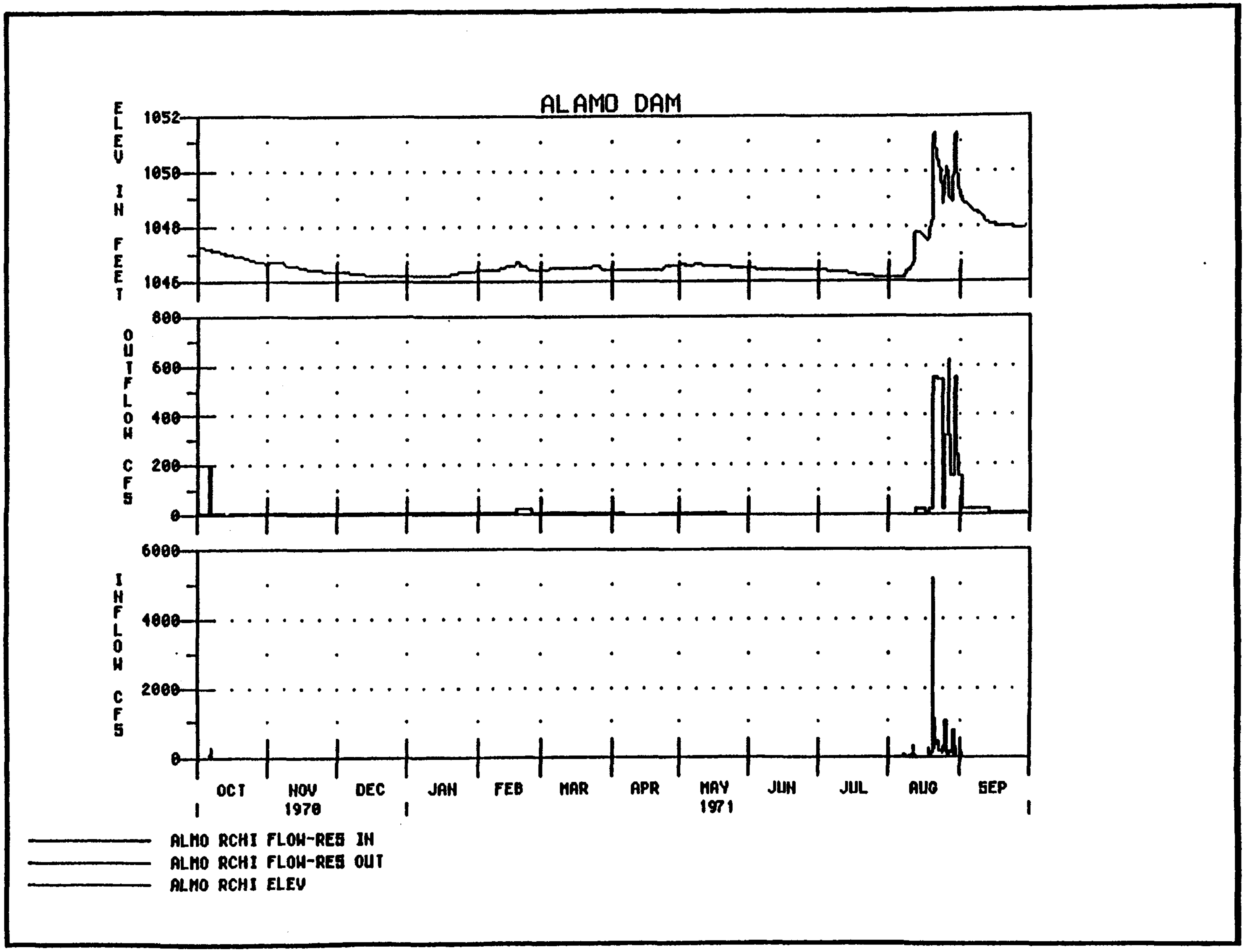
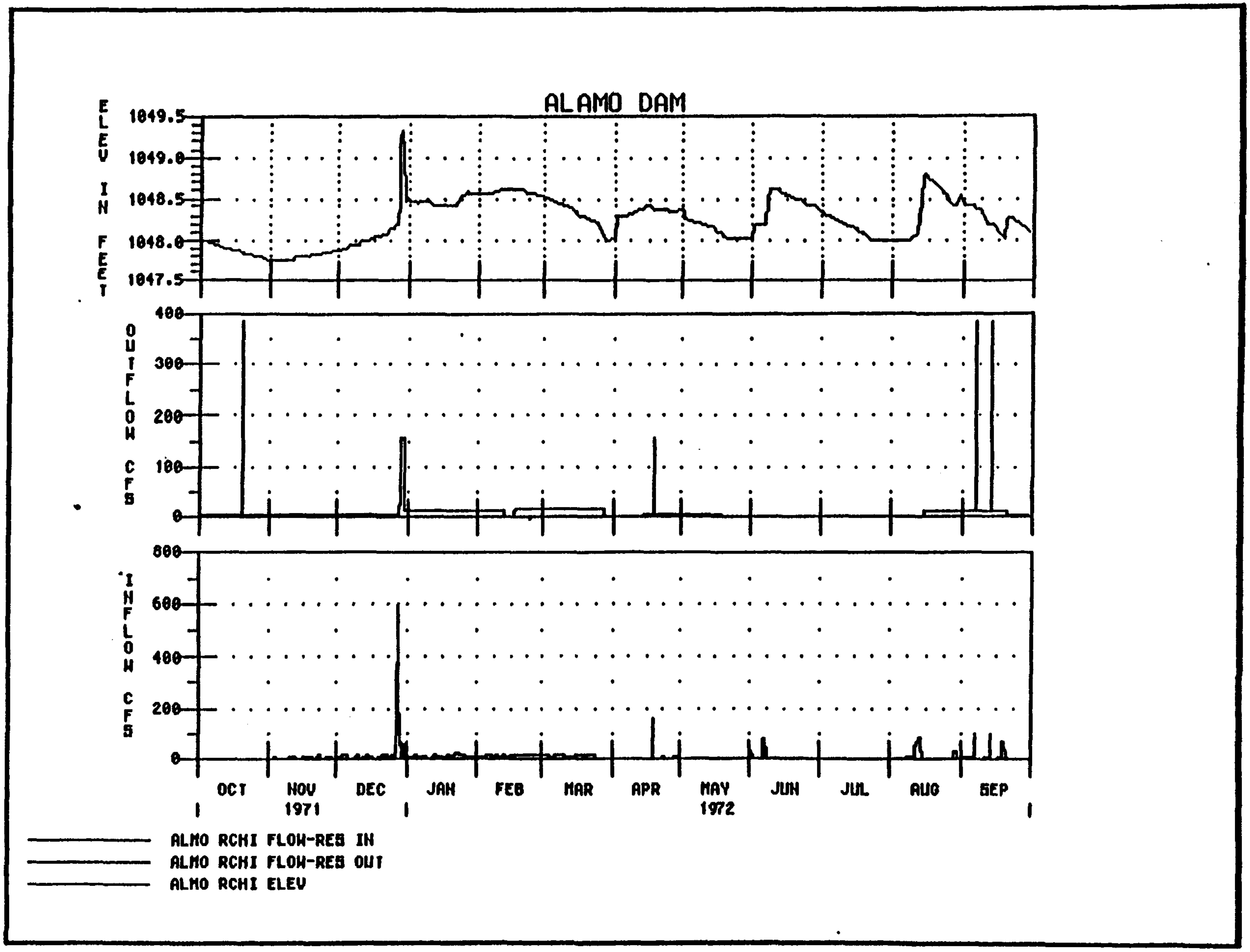
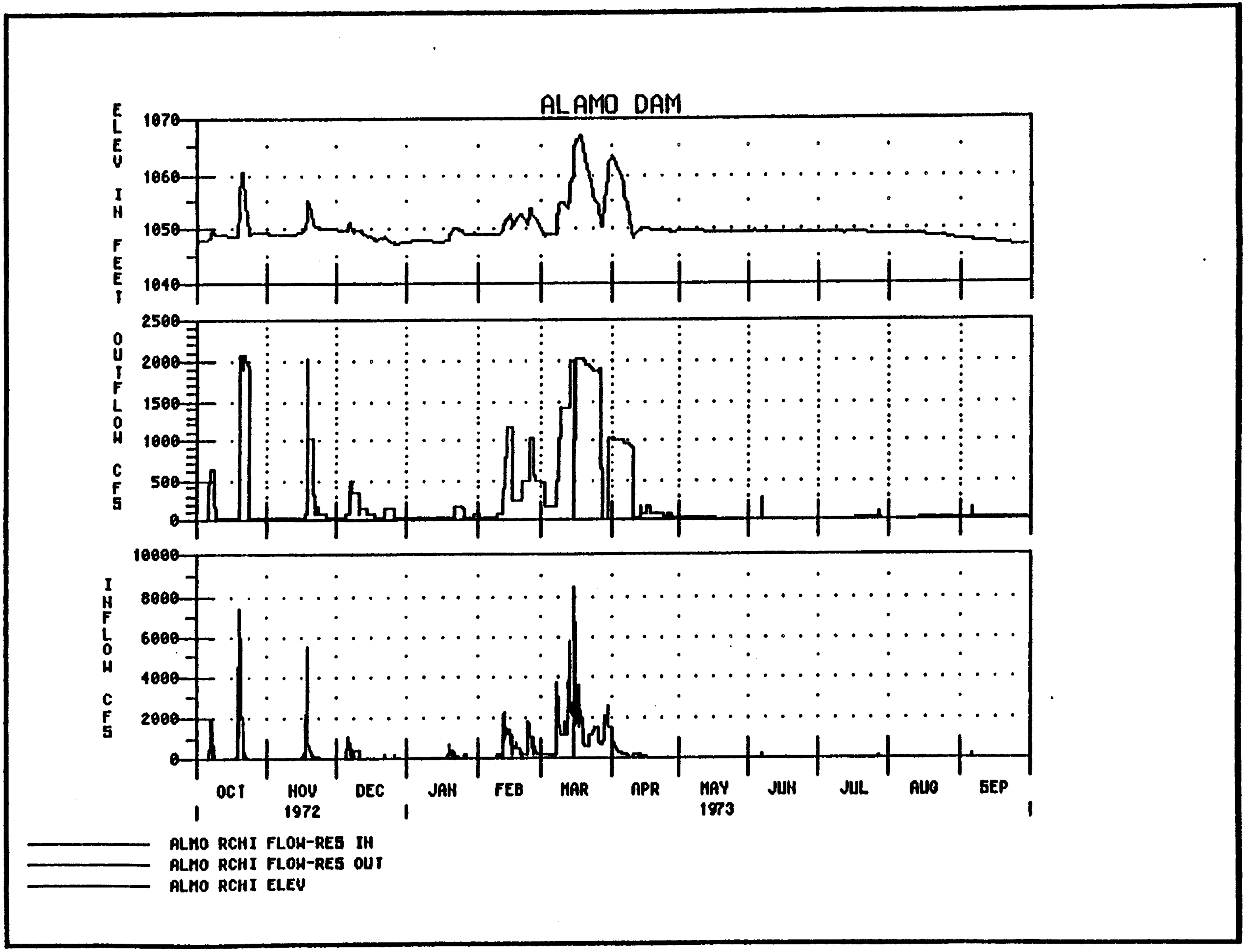

ALAMO DAM
ELEV IN FEET
1052
1050
1048
1046
OUTFLOW CFS
800
600
400
200
0
INFLOW CFS
6000
4000
2000
0
OCT
NOV
1970
DEC
JAN
FEB
MAR
APR
MAY
1971
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-3



ALAMO DAM
ELEV IN FEET
1049.5
1049.0
1048.5
1048.0
1047.5
OUTFLOW CFS
400
300
200
100
0
INFLOW CFS
800
600
400
200
0
OCT
NOV
1971
DEC
JAN
FEB
MAR
APR
MAY
1972
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-4



ALAMO DAM
ELEV IN FEET
1070
1060
1050
1040
OUTFLOW CFS
2500
2000
1500
1000
500
0
INFLOW CFS
10000
8000
6000
4000
2000
0
OCT
NOV
1972
DEC
JAN
FEB
MAR
APR
MAY
1973
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-5

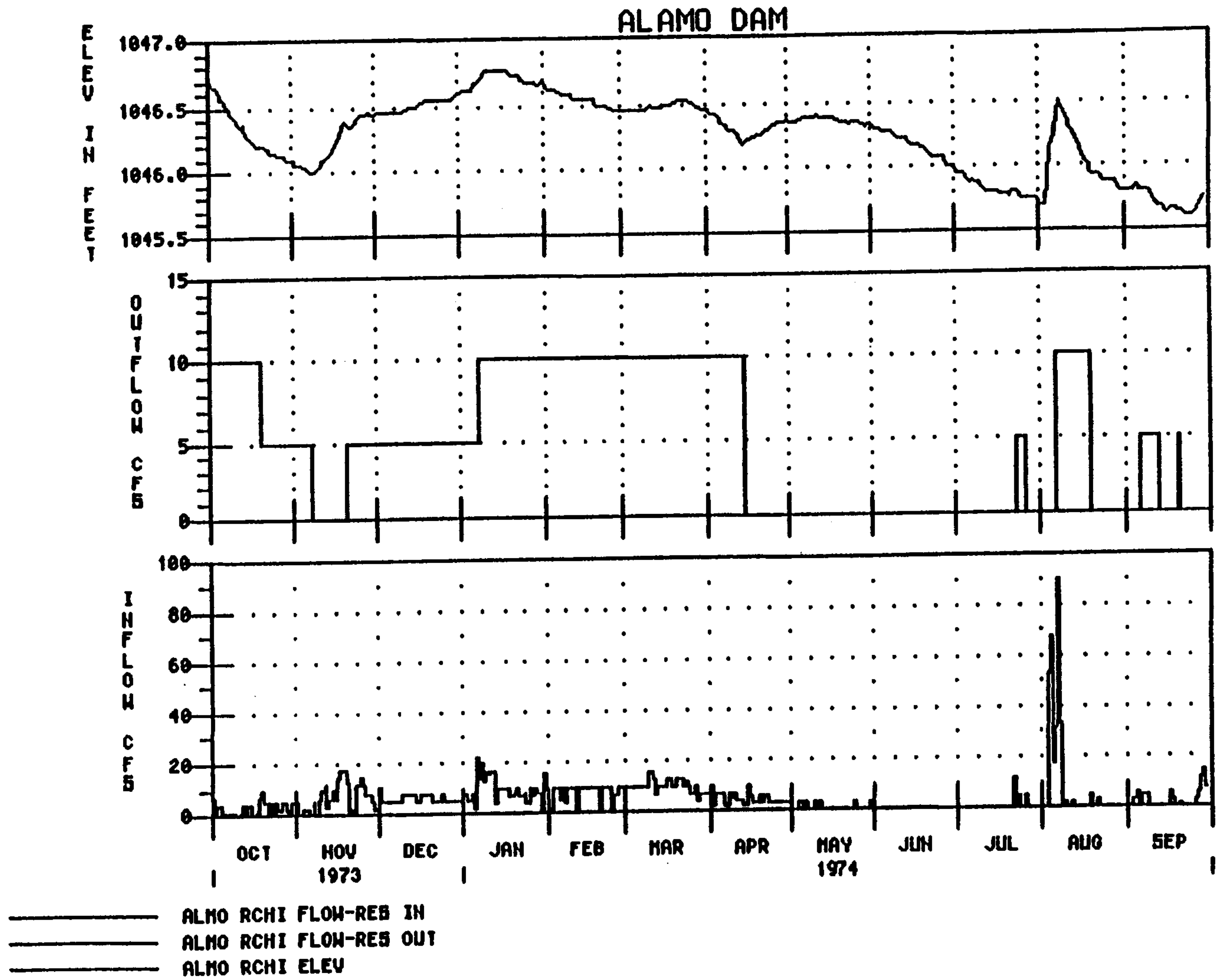

ALAMO DAM
ELEV IN FEET
1047.0
1046.5
1046.0
1045.5
OUTFLOW CFS
15
10
5
0
INFLOW CFS
100
80
60
40
20
0
OCT
NOV
1973
DEC
JAN
FEB
MAR
APR
MAY
1974
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-6

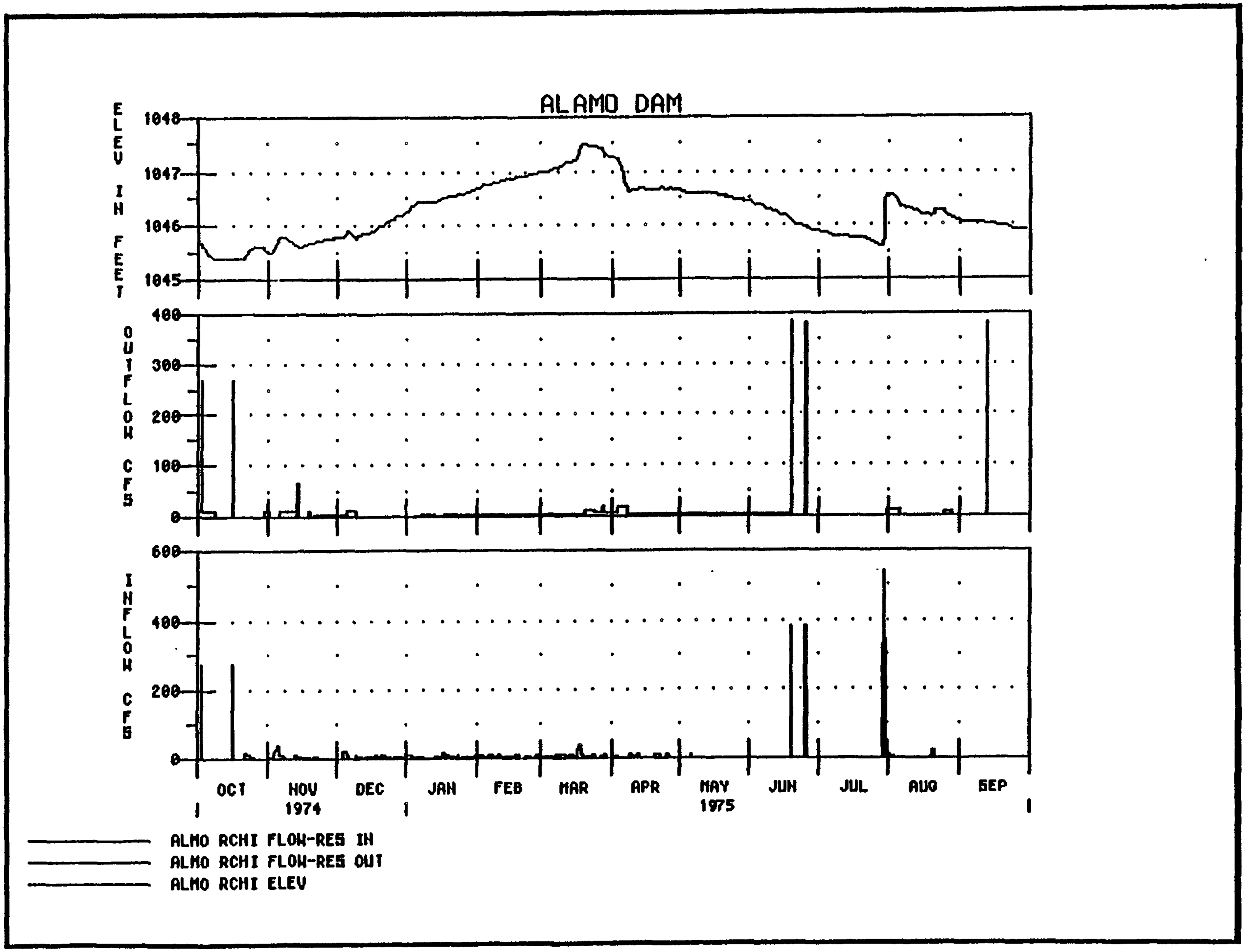

ALAMO DAM
ELEV IN FEET
1048
1047
1046
1045
OUTFLOW CFS
400
300
200
100
0
INFLOW CFS
600
400
200
0
OCT
NOV
1974
DEC
JAN
FEB
MAR
APR
MAY
1975
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-7

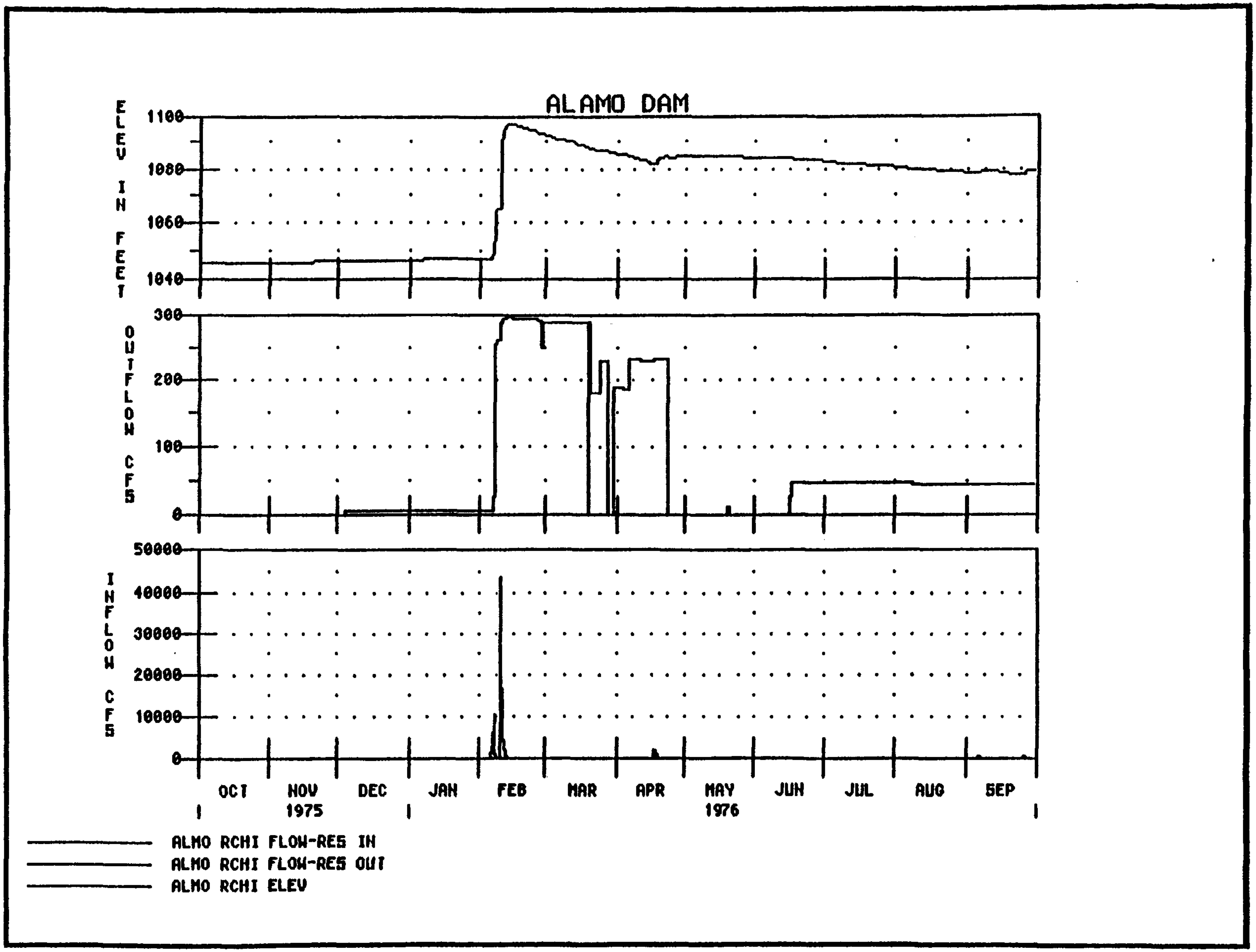
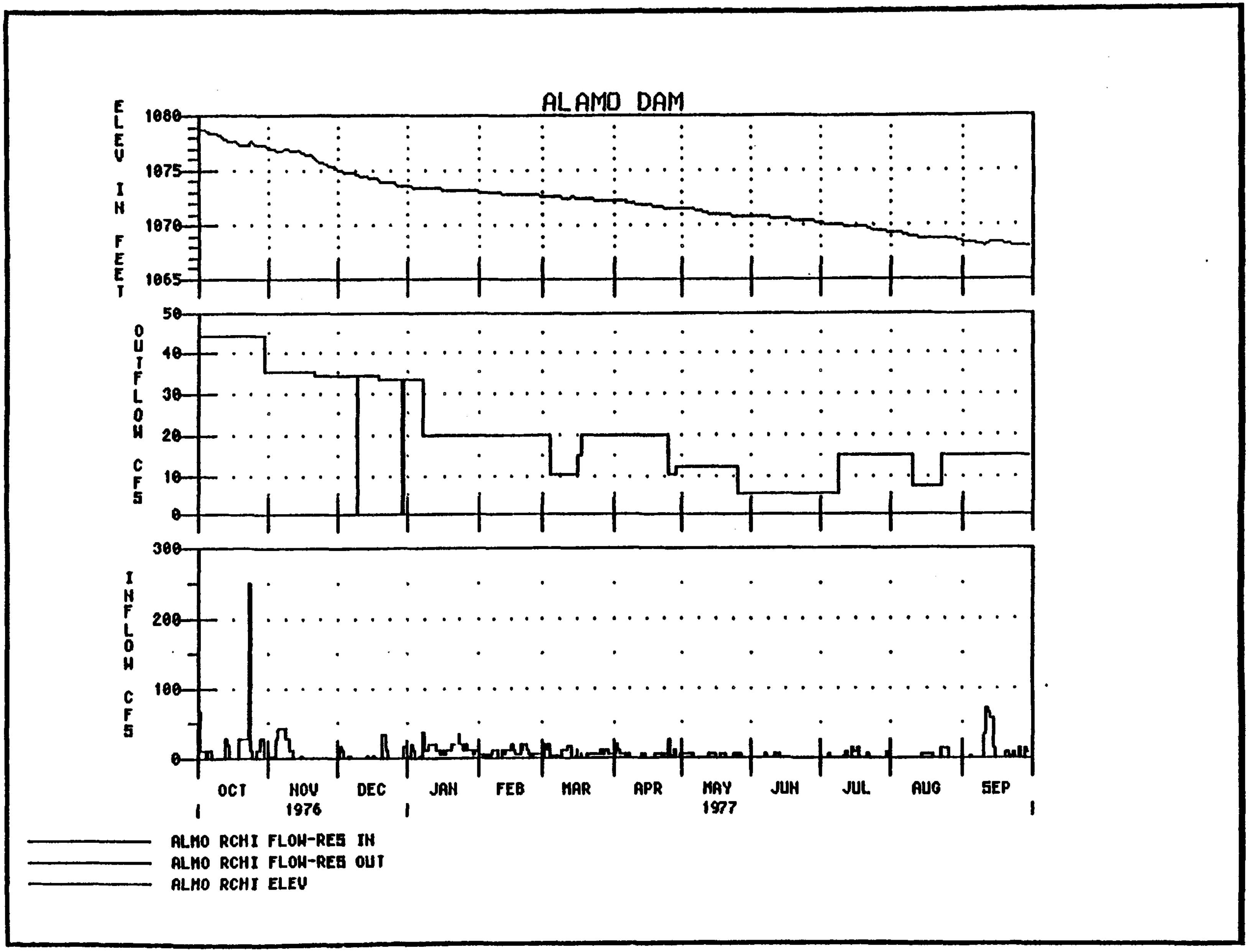
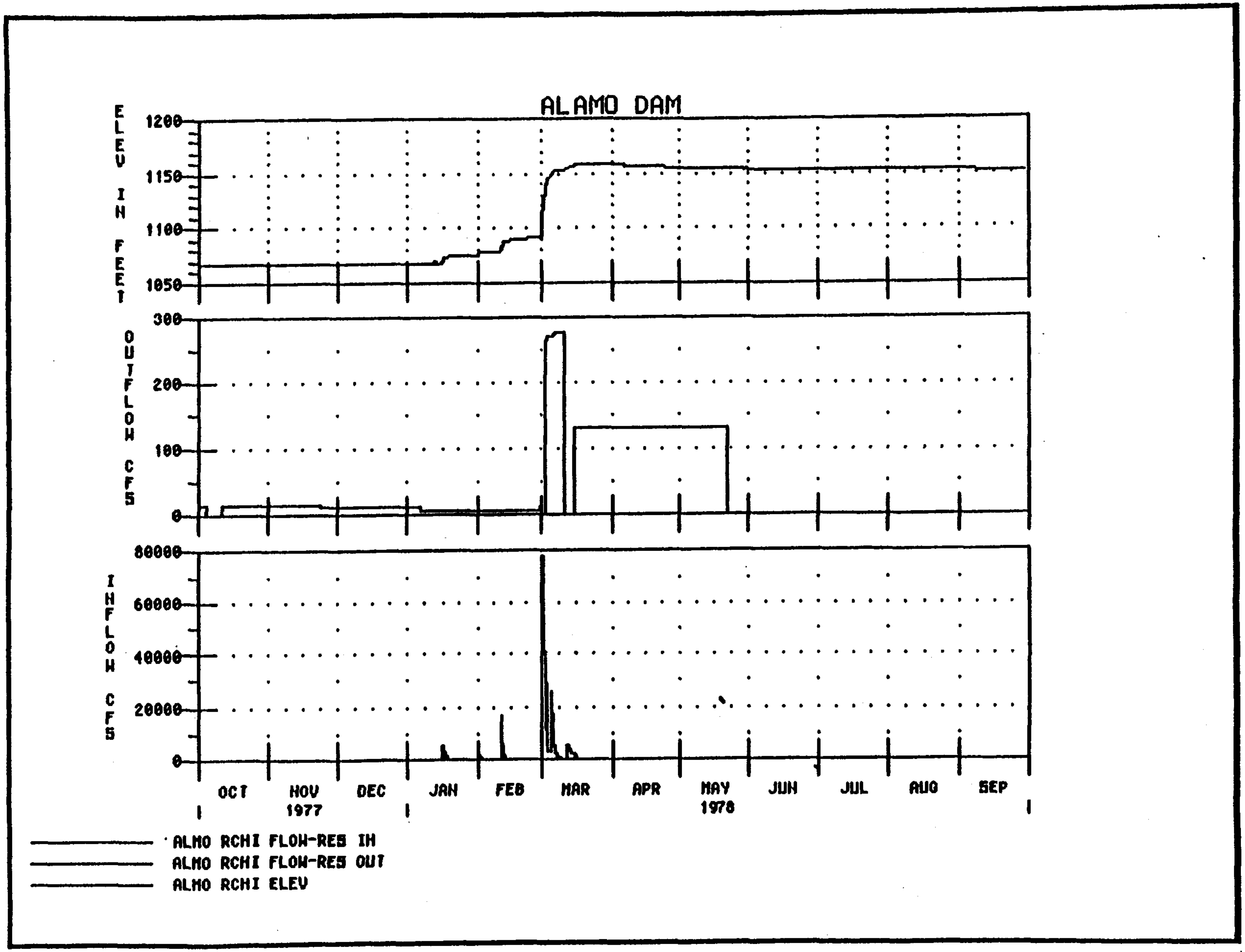

ALAMO DAM
ELEV IN FEET
1100
1080
1060
1040
OUTFLOW CFS
300
200
100
0
INFLOW CFS
50000
40000
30000
20000
10000
0
OCT
NOV
1975
DEC
JAN
FEB
MAR
APR
MAY
1976
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-8



ALAMO DAM
ELEV IN FEET
1080
1075
1070
1065
OUTFLOW CFS
50
40
30
20
10
0
INFLOW CFS
300
200
100
0
OCT
NOV
1976
DEC
JAN
FEB
MAR
APR
MAY
1977
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-9



ALAMO DAM
ELEV IN FEET
1200
1150
1100
1050
OUTFLOW CFS
300
200
100
0
INFLOW CFS
80000
60000
40000
20000
0
OCT
NOV
1977
DEC
JAN
FEB
MAR
APR
MAY
1978
JUN
JUL
AUG
SEP
ALMO RCH1 FLOW-RES IN
ALMO RCH1 FLOW-RES OUT
ALMO RCH1 ELEV

FIGURE 6-10

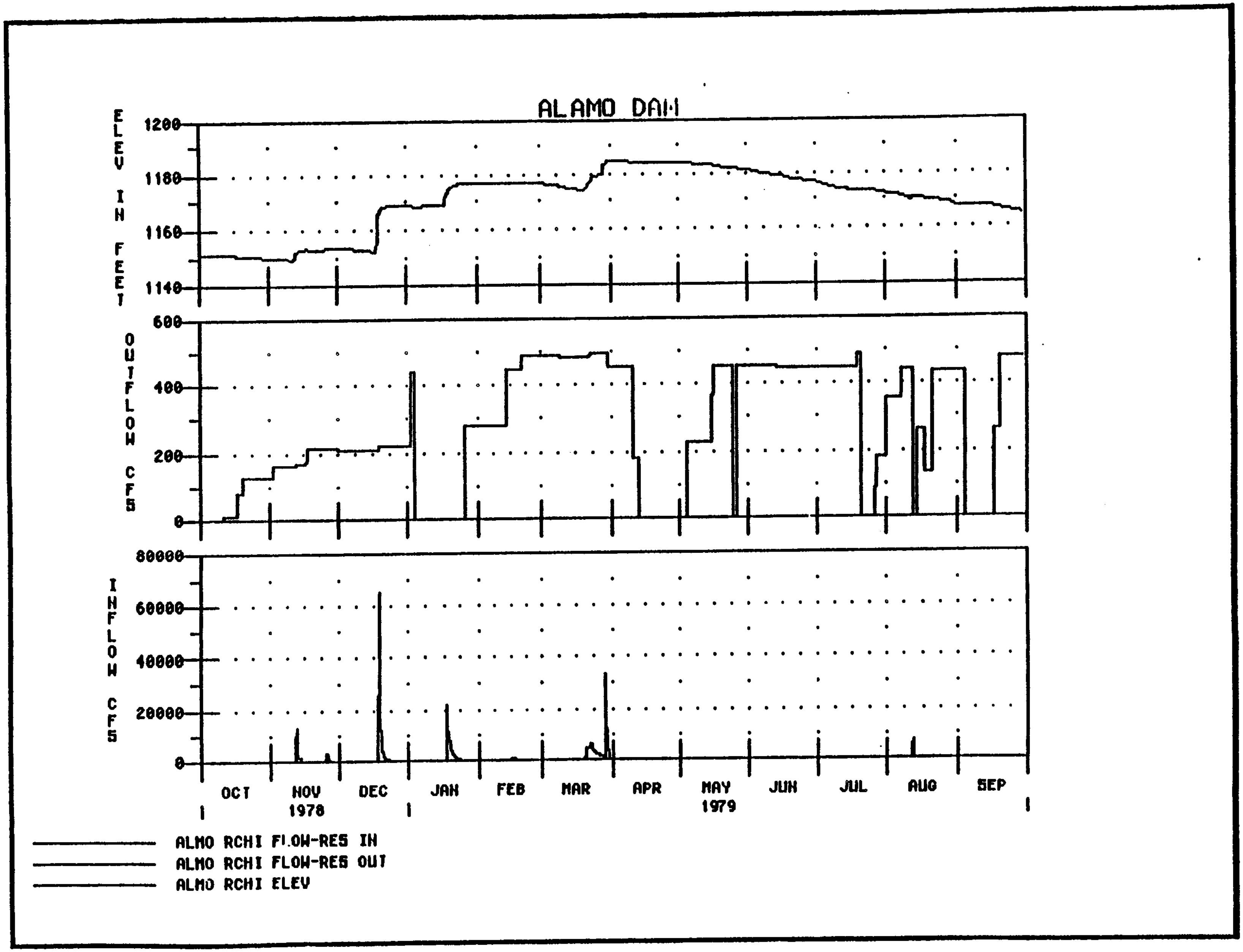

ALAMO DAM
ELEV IN FEET
1200
1180
1160
1140
OUTFLOW CFS
600
400
200
0
INFLOW CFS
80000
60000
40000
20000
0
OCT
NOV
1978
DEC
JAN
FEB
MAR
APR
MAY
1979
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-11

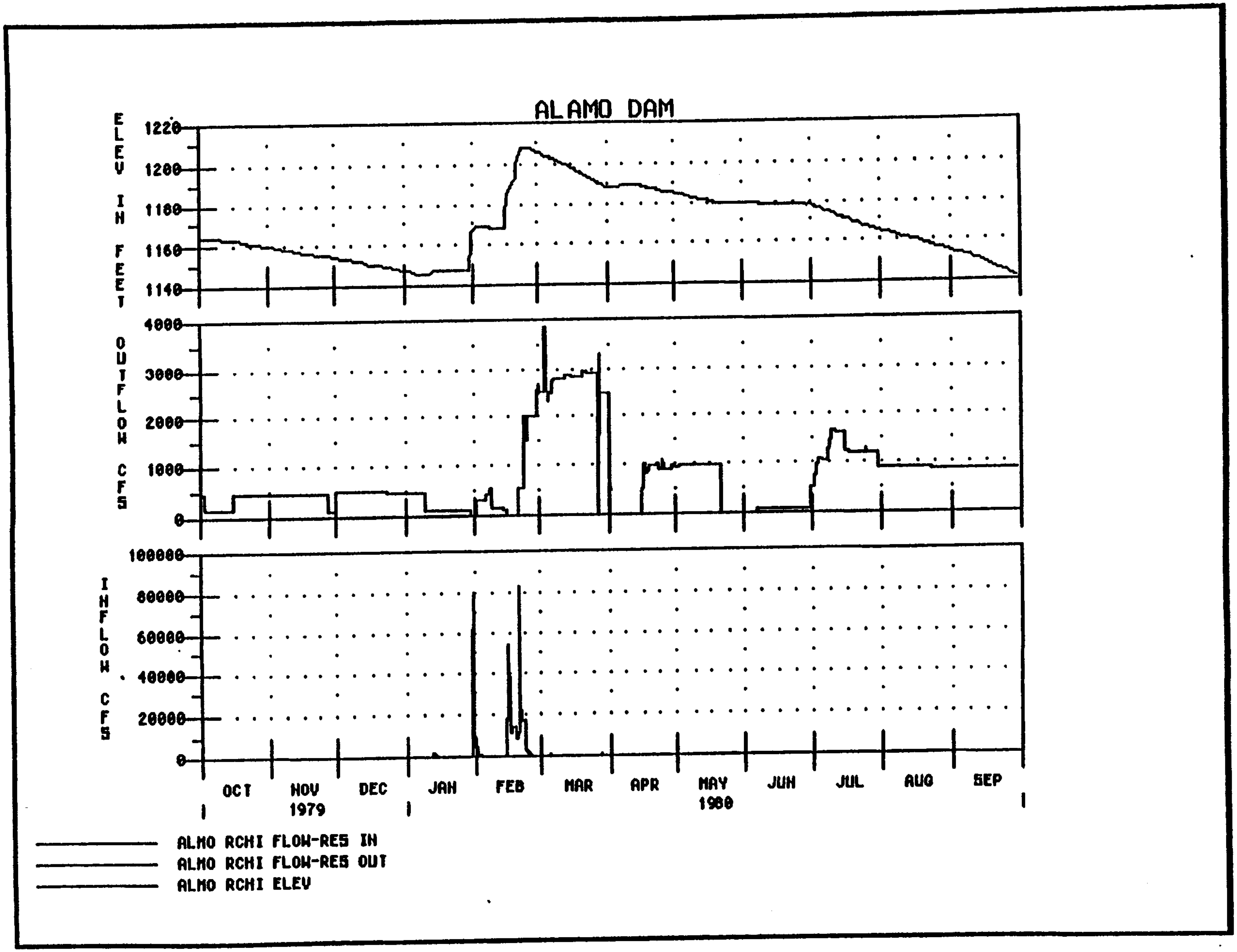
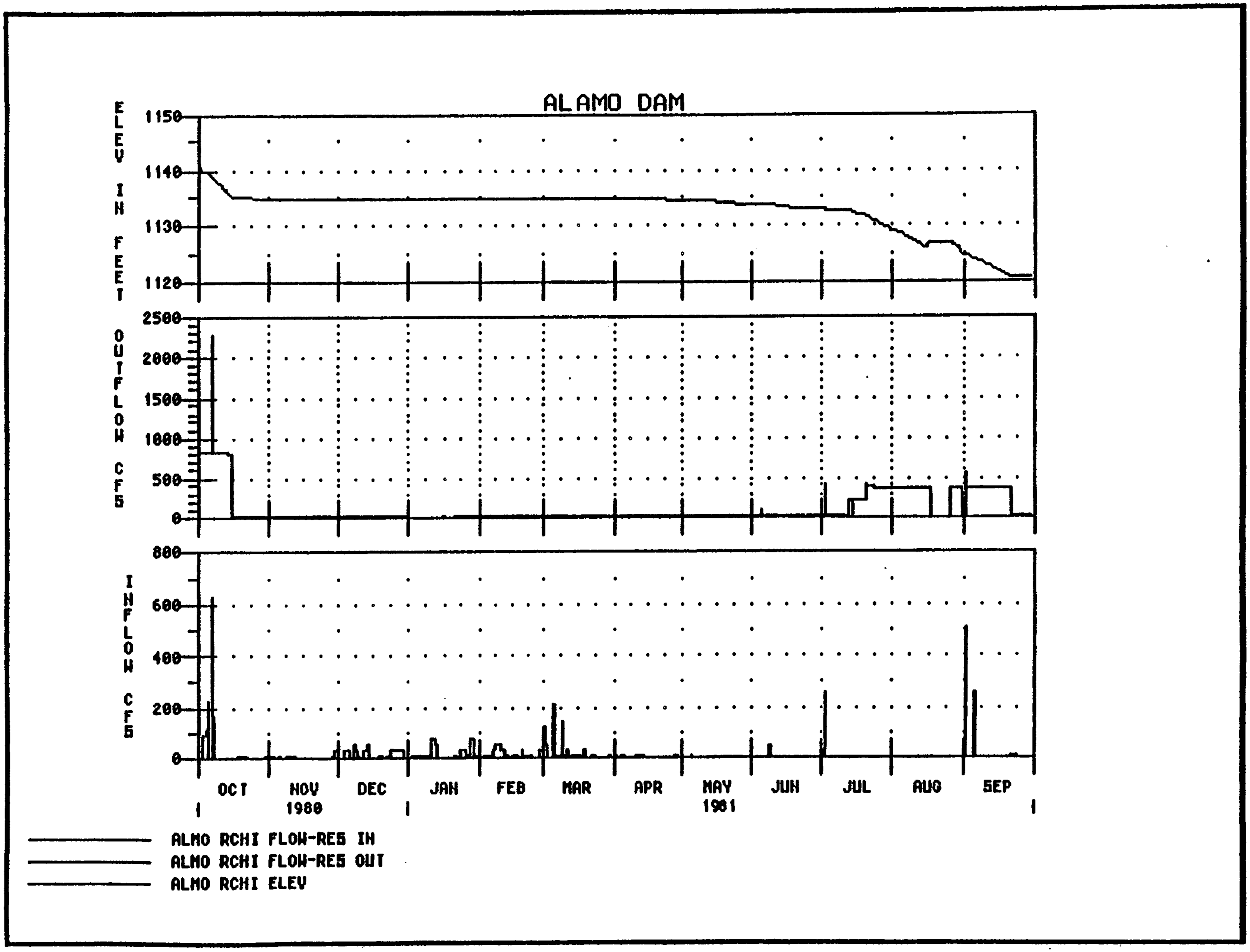

ALAMO DAM
ELEV IN FEET
1220
1200
1180
1160
1140
OUTFLOW CFS
4000
3000
2000
1000
0
INFLOW CFS
100000
80000
60000
40000
20000
0
OCT
NOV
1979
DEC
JAN
FEB
MAR
APR
MAY
1980
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-12



ALAMO DAM
ELEV IN FEET
1150
1140
1130
1120
OUTFLOW CFS
2500
2000
1500
1000
500
0
INFLOW CFS
800
600
400
200
0
OCT
NOV
1980
DEC
JAN
FEB
MAR
APR
MAY
1981
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-13

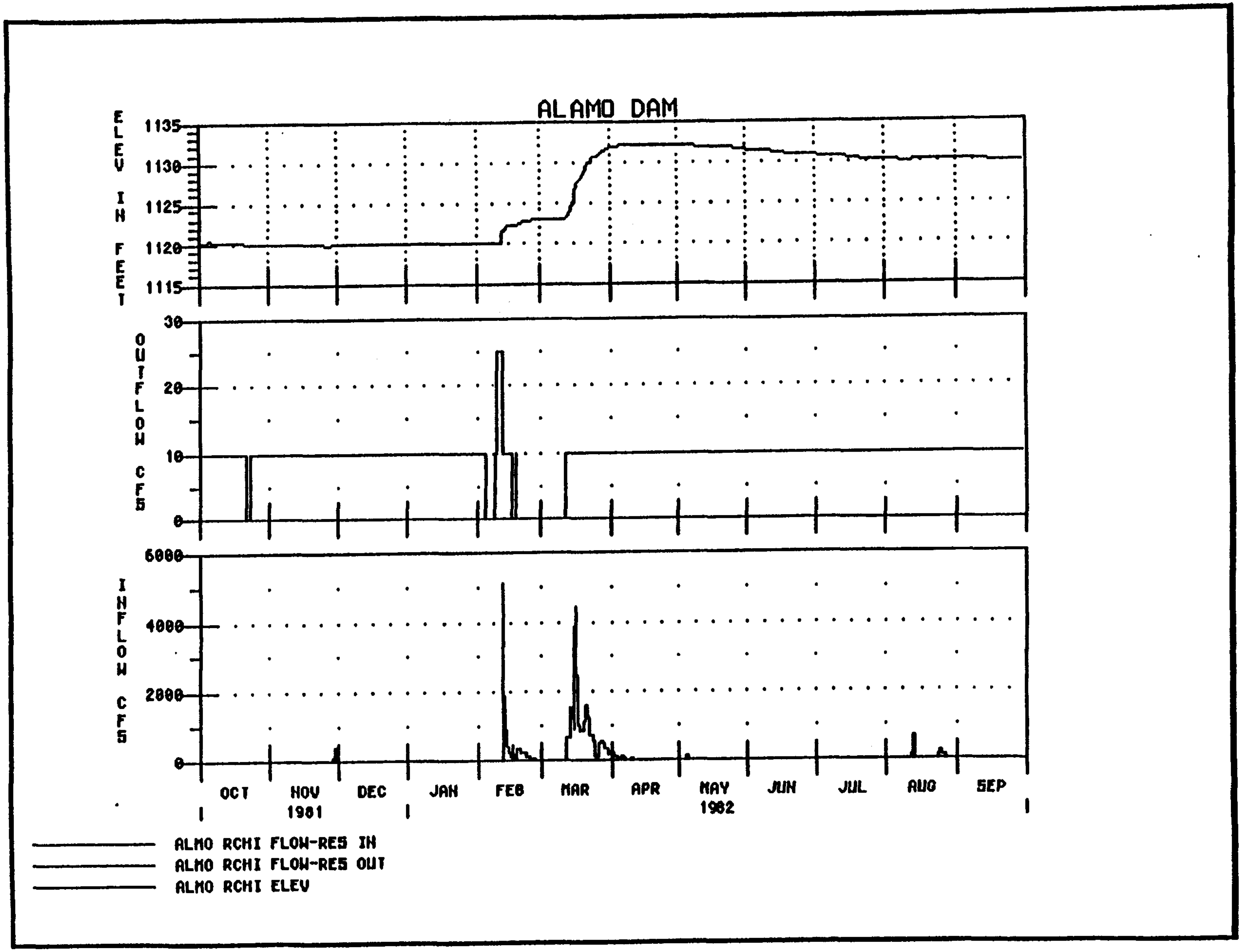
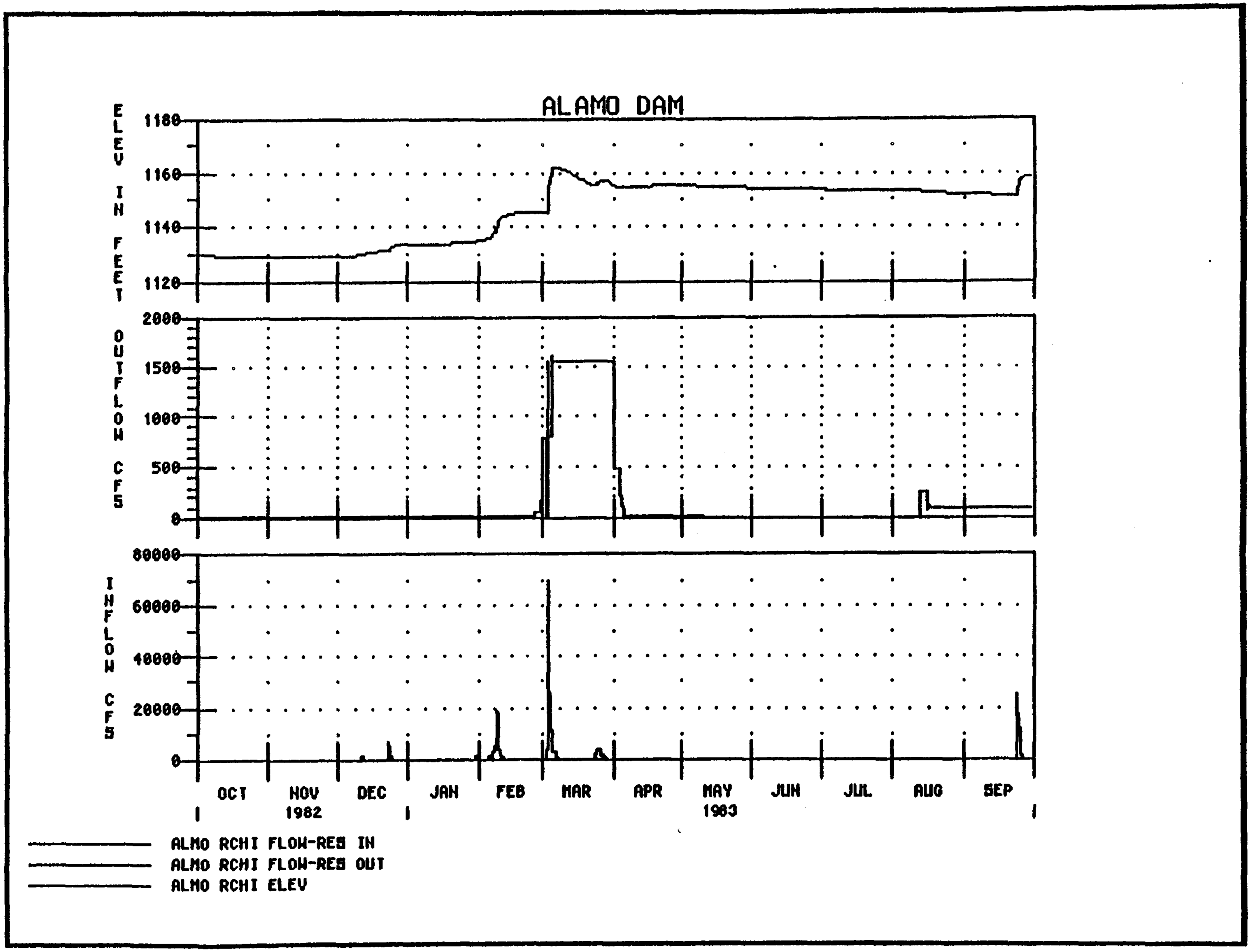
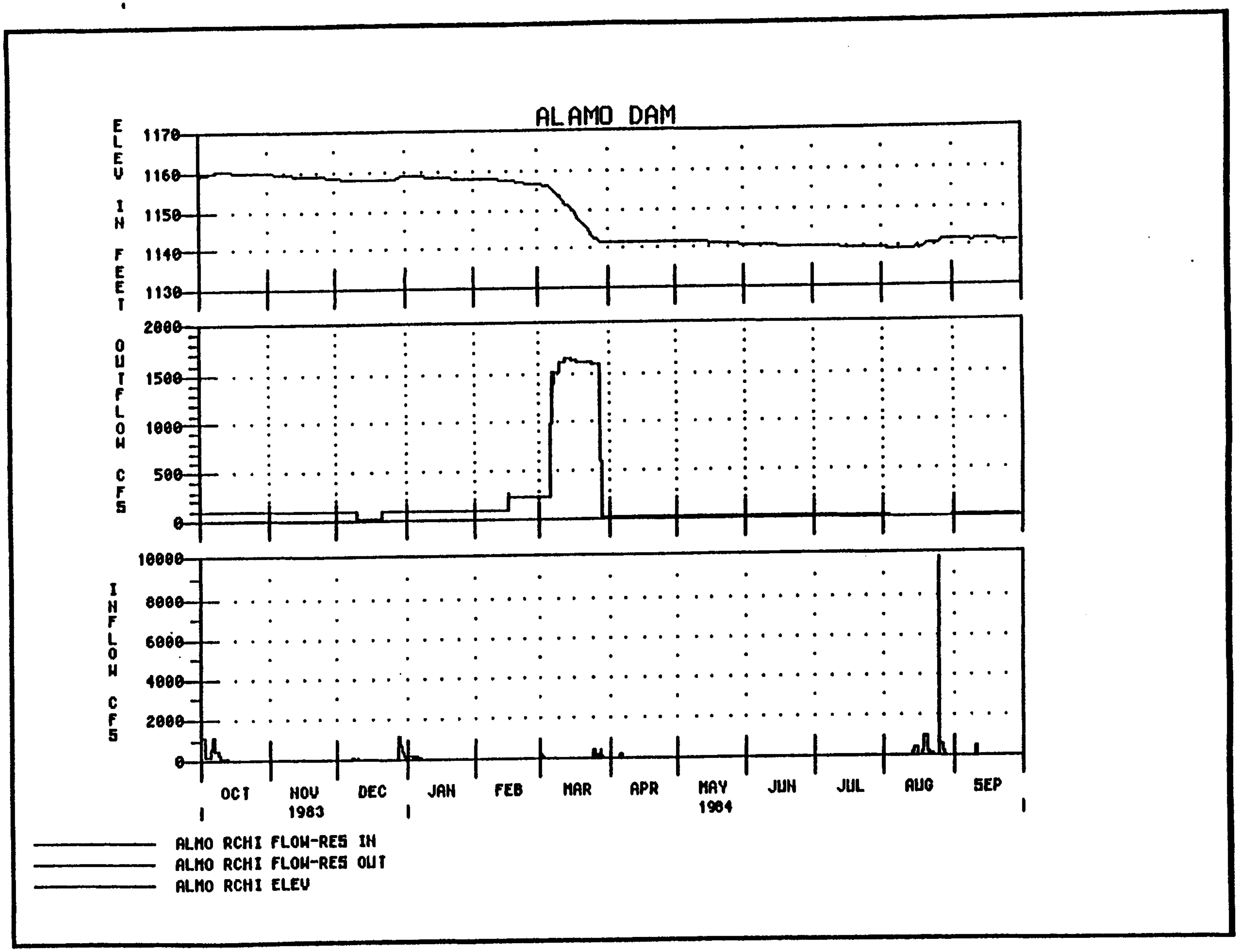

ALAMO DAM
ELEV IN FEET
1135
1130
1125
1120
1115
OUTFLOW CFS
30
20
10
0
INFLOW CFS
6000
4000
2000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
1981
1982
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-14



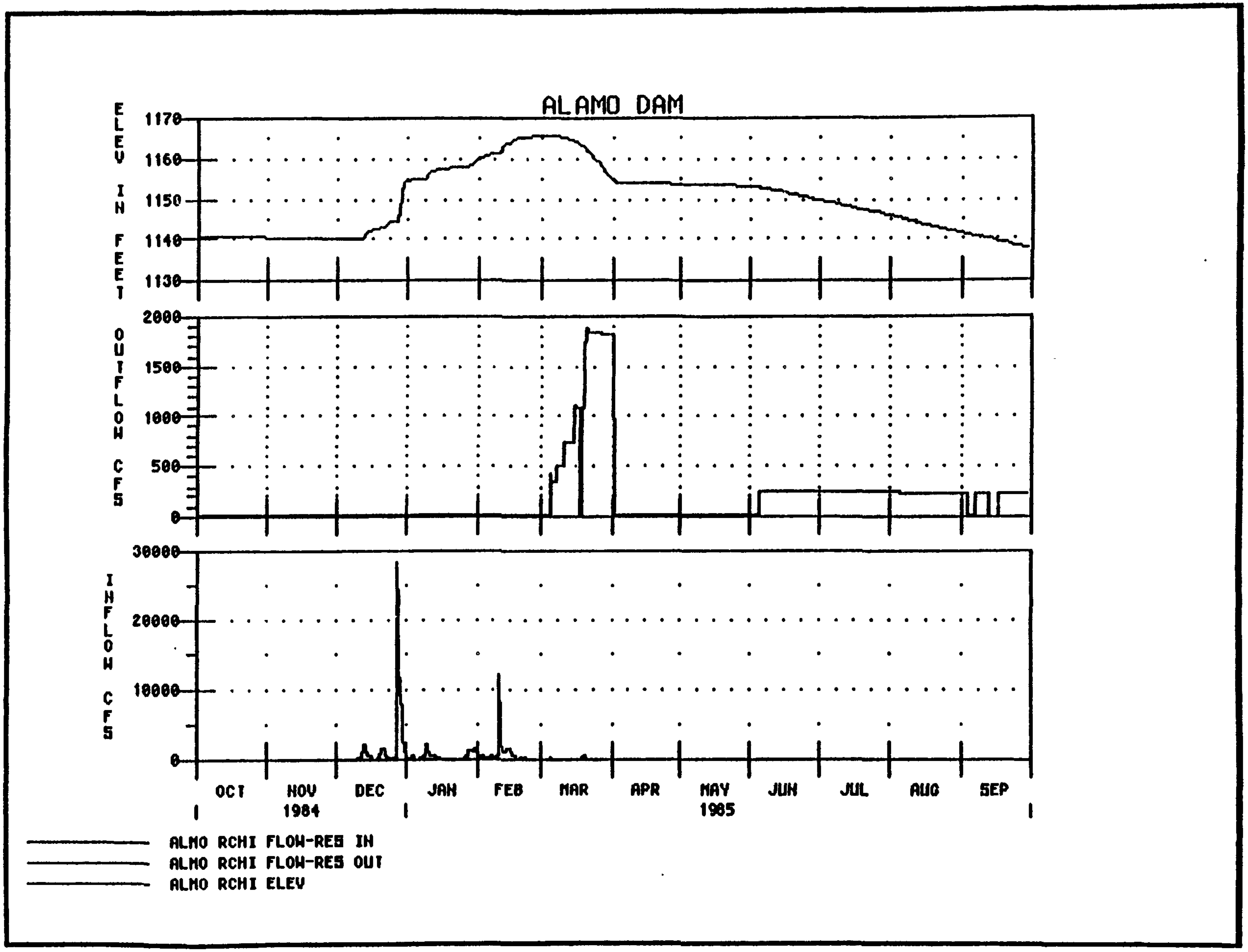
ALAMO DAM
ELEV IN FEET
1180
1160
1140
1120
OUTFLOW CFS
2000
1500
1000
500
0
INFLOW CFS
80000
60000
40000
20000
0
OCT
NOV
1982
DEC
JAN
FEB
MAR
APR
MAY
1983
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-15



ALAMO DAM
ELEV IN FEET
1170
1160
1150
1140
1130
OUTFLOW CFS
2000
1500
1000
500
0
INFLOW CFS
10000
8000
6000
4000
2000
0
OCT
NOV
1983
DEC
JAN
FEB
MAR
APR
MAY
1984
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-16



ALAMO DAM
ELEV IN FEET
1170
1160
1150
1140
1130
OUTFLOW CFS
2000
1500
1000
500
0
INFLOW CFS
30000
20000
10000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
1984
1985
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-17

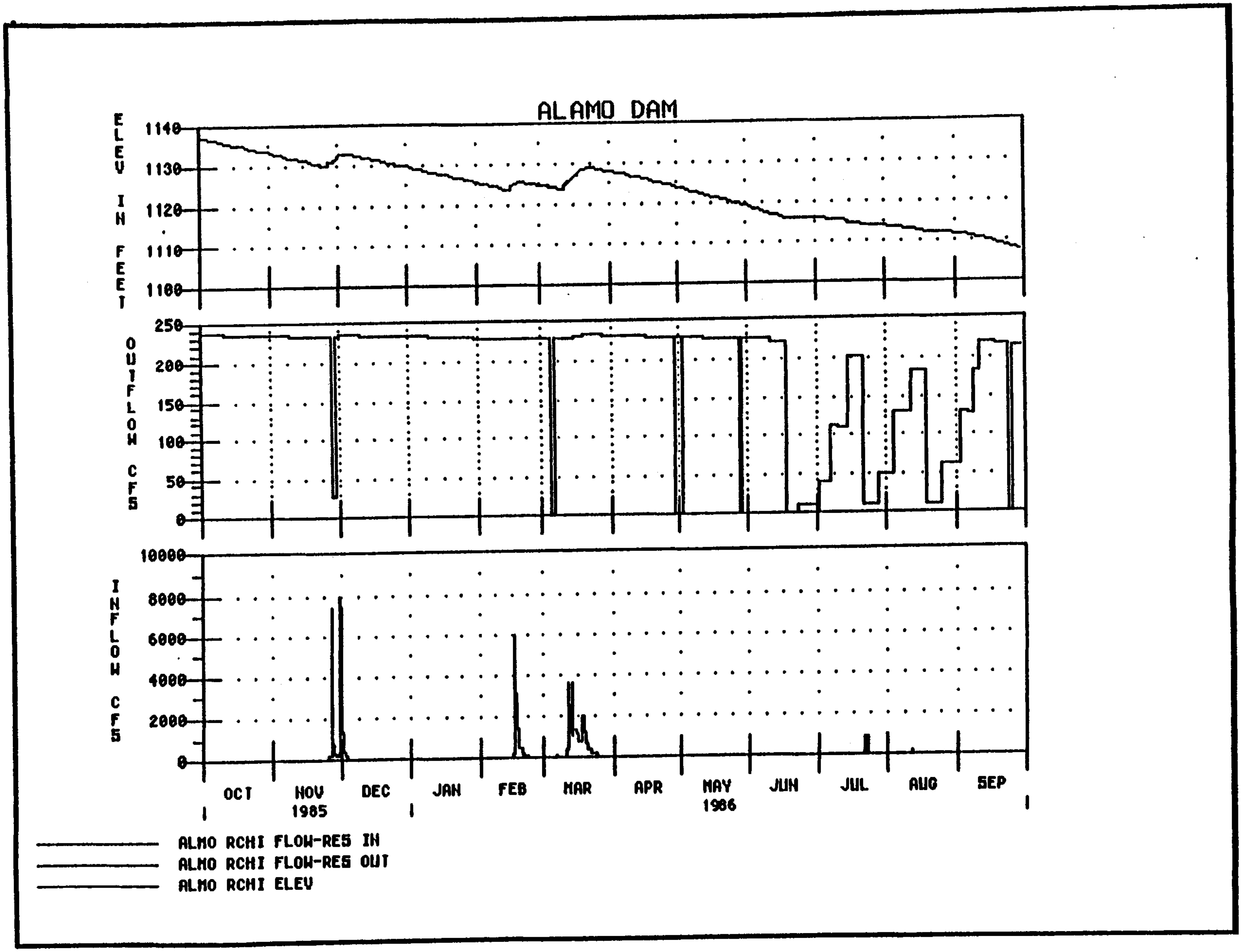

ALAMO DAM
ELEV IN FEET
1140
1130
1120
1110
1100
OUTFLOW CFS
250
200
150
100
50
0
INFLOW CFS
10000
8000
6000
4000
2000
0
OCT
NOV
1985
DEC
JAN
FEB
MAR
APR
MAY
1986
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-18

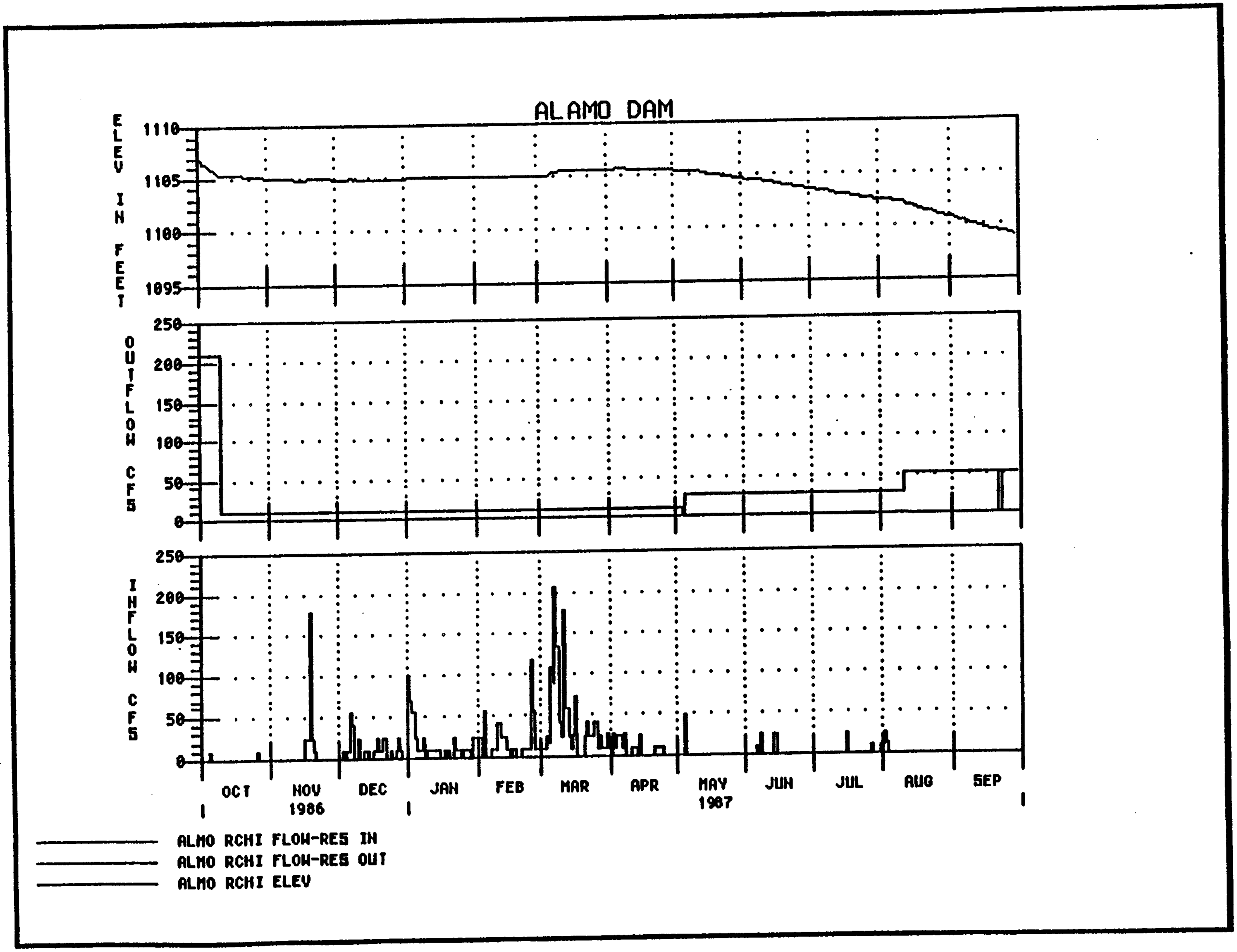

ALAMO DAM
ELEV IN FEET
1110
1105
1100
1095
OUTFLOW CFS
250
200
150
100
50
0
INFLOW CFS
250
200
150
100
50
0
OCT
NOV
1986
DEC
JAN
FEB
MAR
APR
MAY
1987
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-19

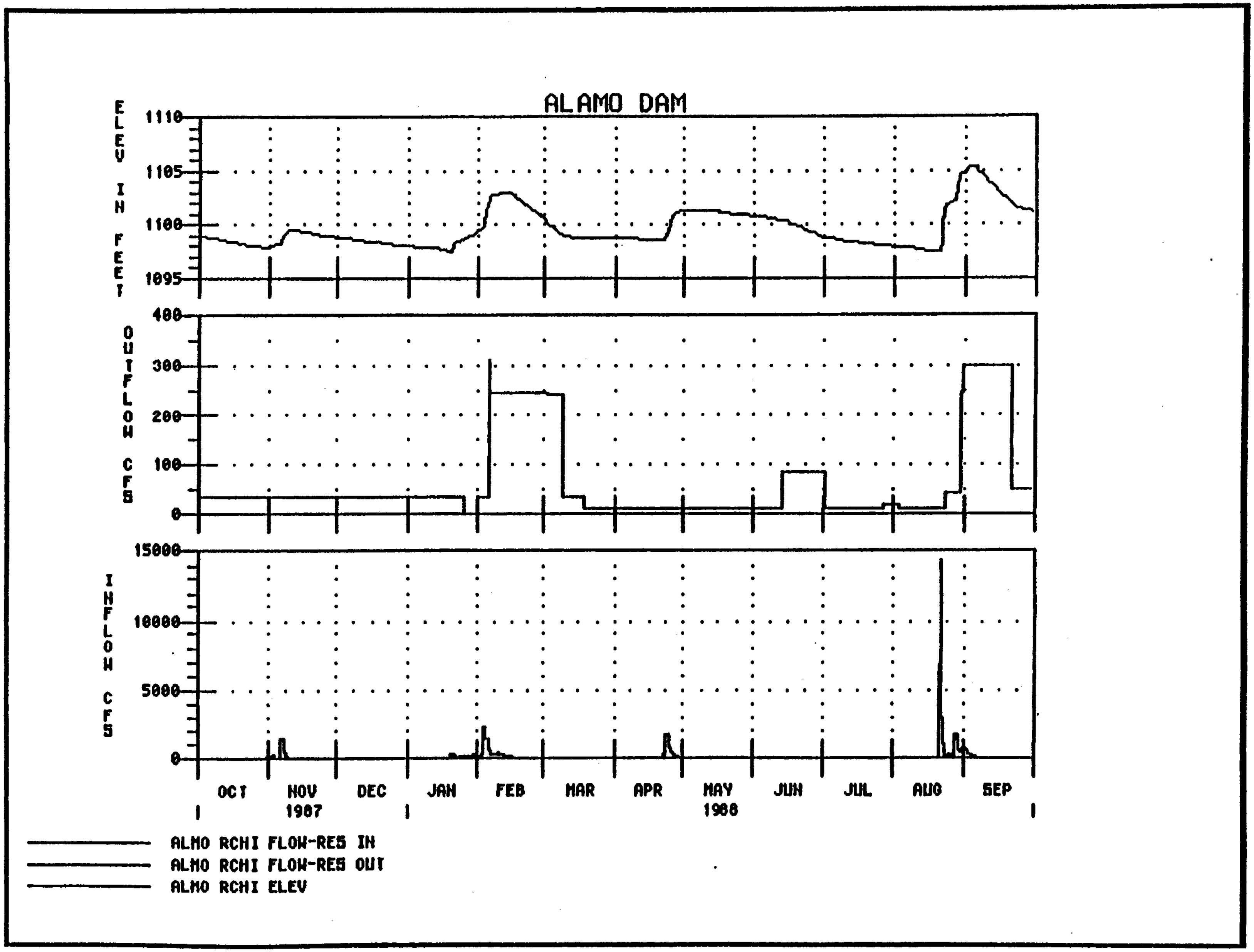
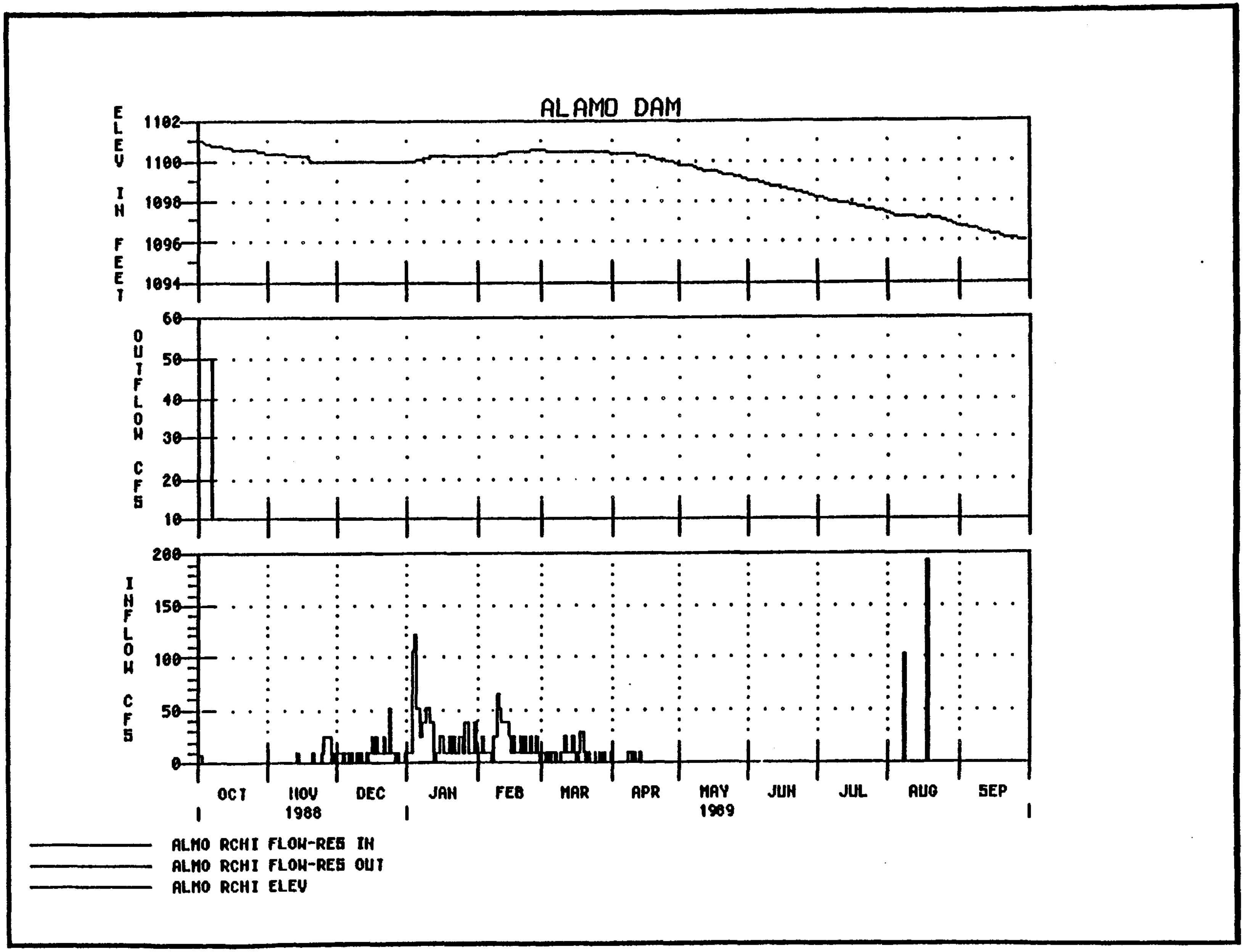
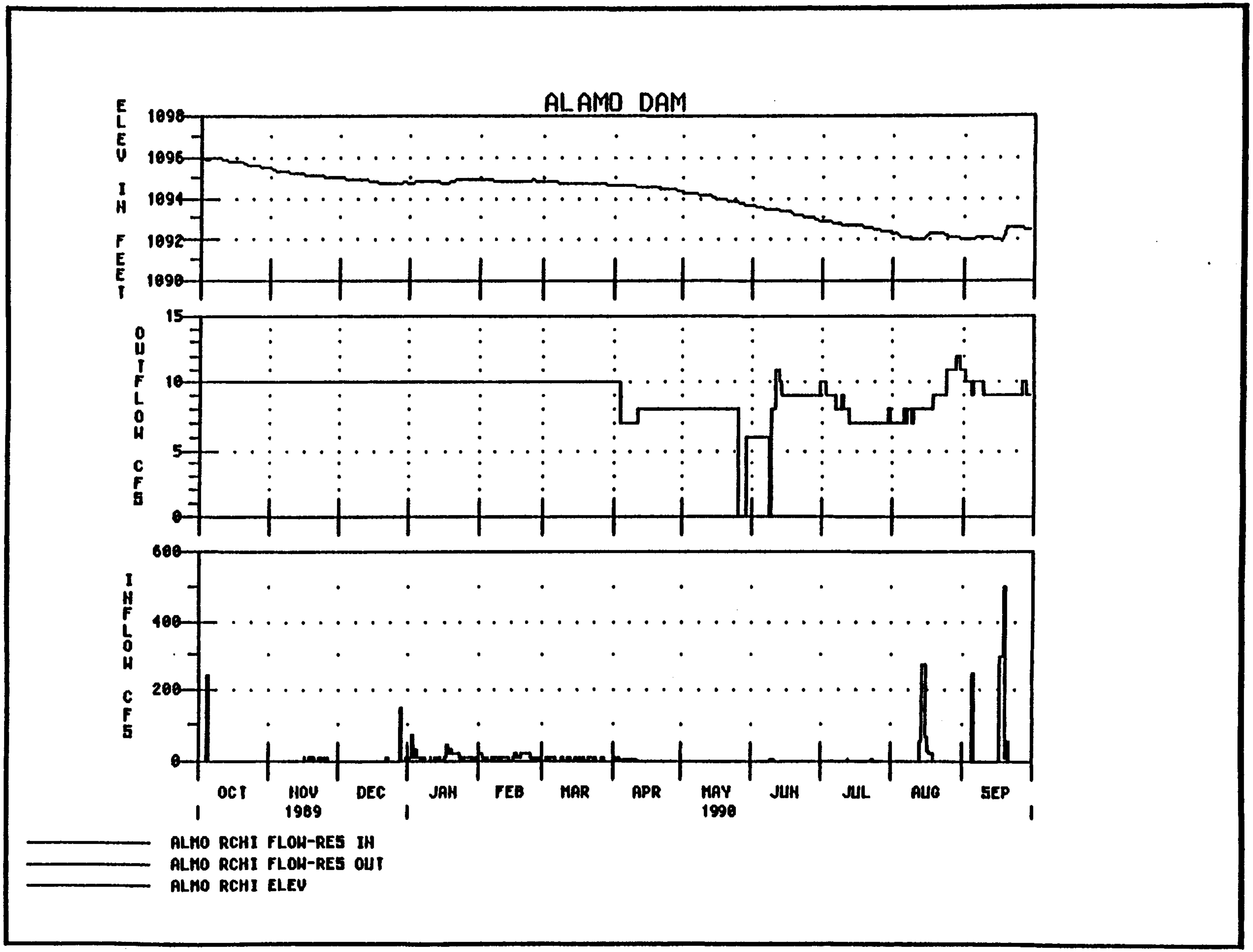

ALAMO DAM
ELEV IN FEET
1110
1105
1100
1095
OUTFLOW CFS
400
300
200
100
0
INFLOW CFS
15000
10000
5000
0
OCT
NOV
1987
DEC
JAN
FEB
MAR
APR
MAY
1988
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-20



ALAMO DAM
ELEV IN FEET
1102
1100
1098
1096
1094
OUTFLOW CFS
60
50
40
30
20
10
INFLOW CFS
200
150
100
50
0
OCT
NOV 1988
DEC
JAN
FEB
MAR
APR
MAY 1989
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-21



ALAMO DAM
ELEV IN FEET
1098
1096
1094
1092
1090
OUTFLOW CFS
15
10
5
0
INFLOW CFS
600
400
200
0
OCT
NOV
1989
DEC
JAN
FEB
MAR
APR
MAY
1990
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-22

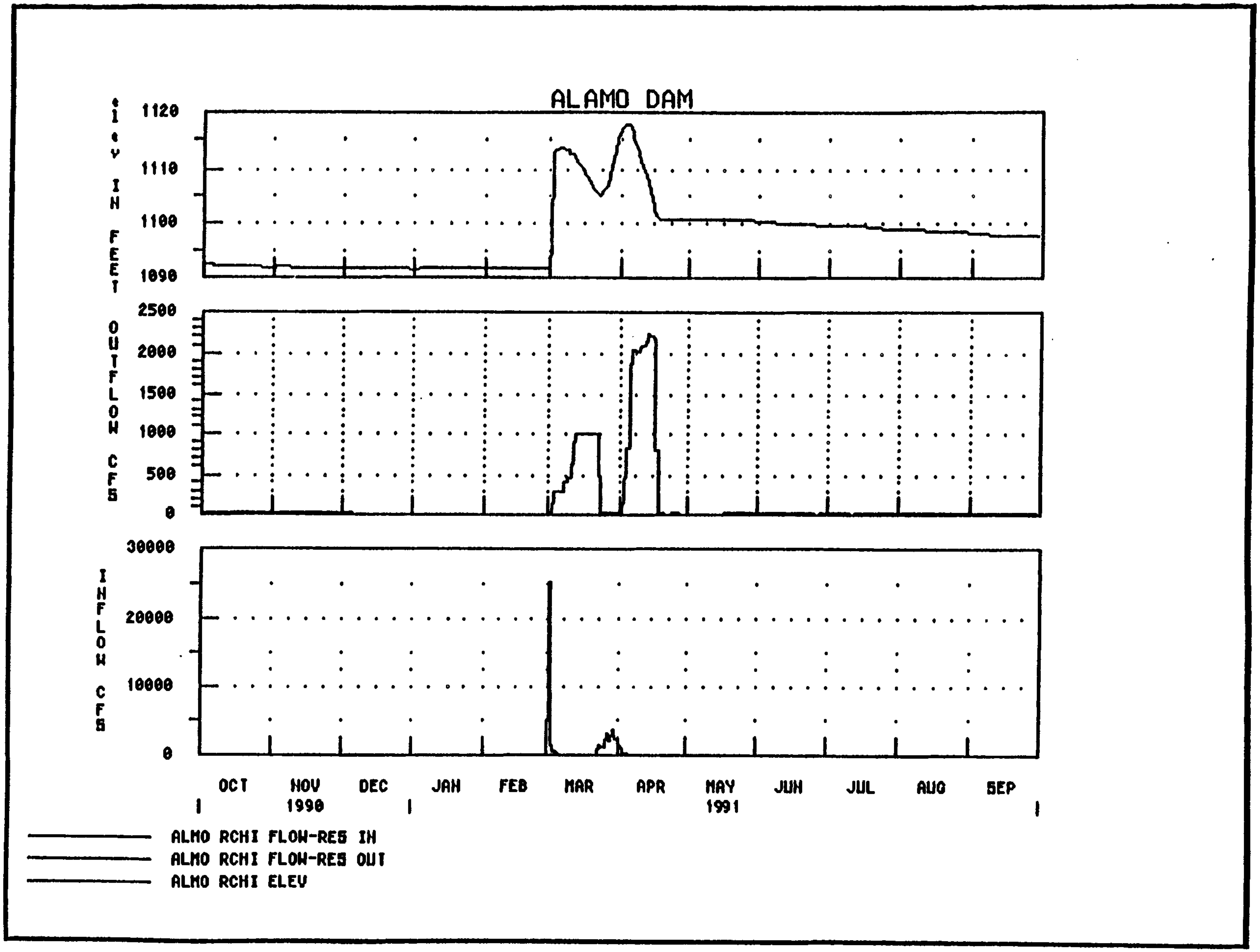

ALAMO DAM
elev IN FEET
1120
1110
1100
1090
OUTFLOW CFS
2500
2000
1500
1000
500
0
INFLOW CFS
30000
20000
10000
0
OCT
NOV
1990
DEC
JAN
FEB
MAR
APR
MAY
1991
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-23

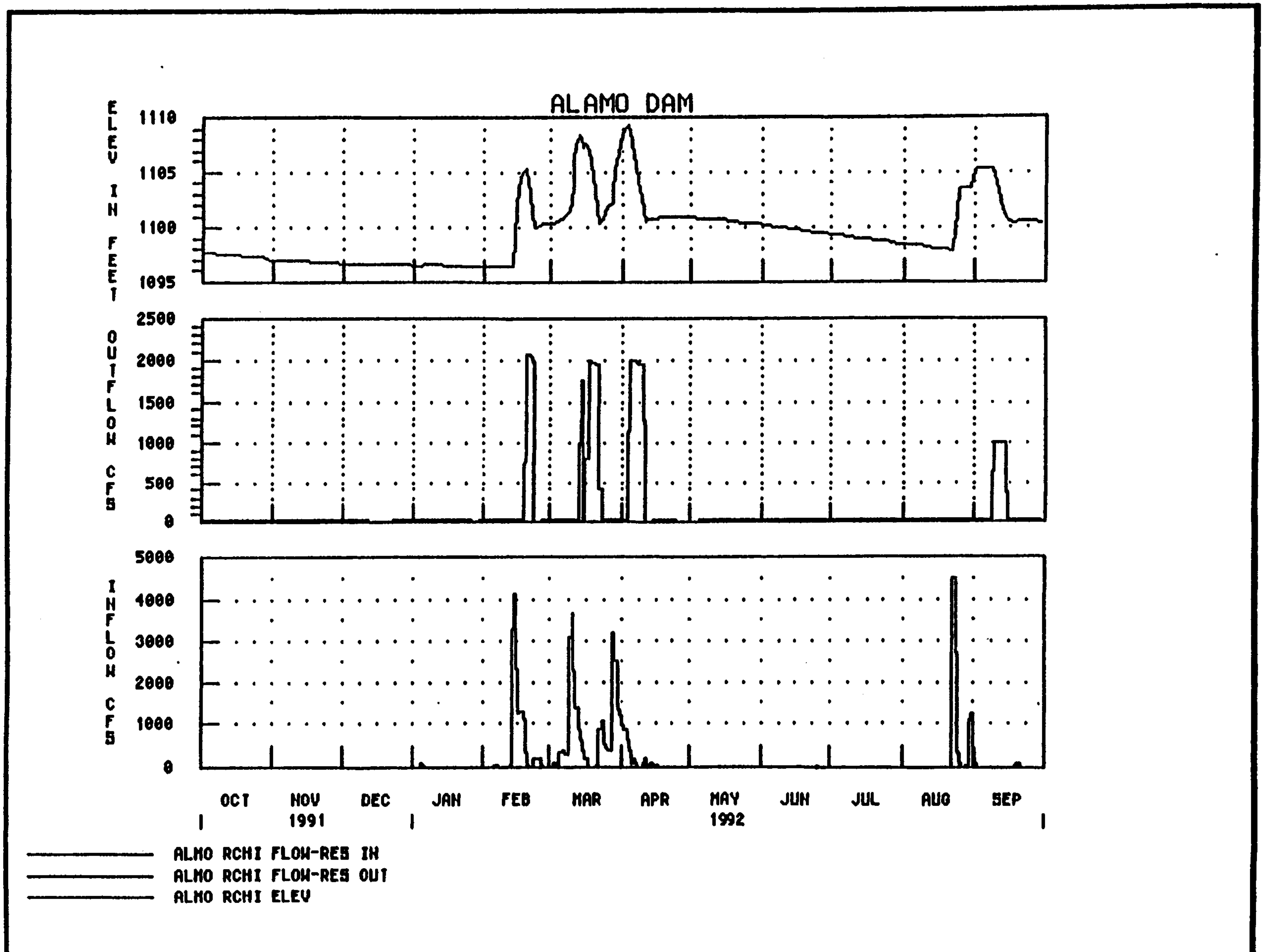

ALAMO DAM
ELEV IN FEET
1110
1105
1100
1095
OUTFLOW CFS
2500
2000
1500
1000
500
0
INFLOW CFS
5000
4000
3000
2000
1000
0
OCT
NOV
1991
DEC
JAN
FEB
MAR
APR
MAY
1992
JUN
JUL
AUG
SEP
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-24

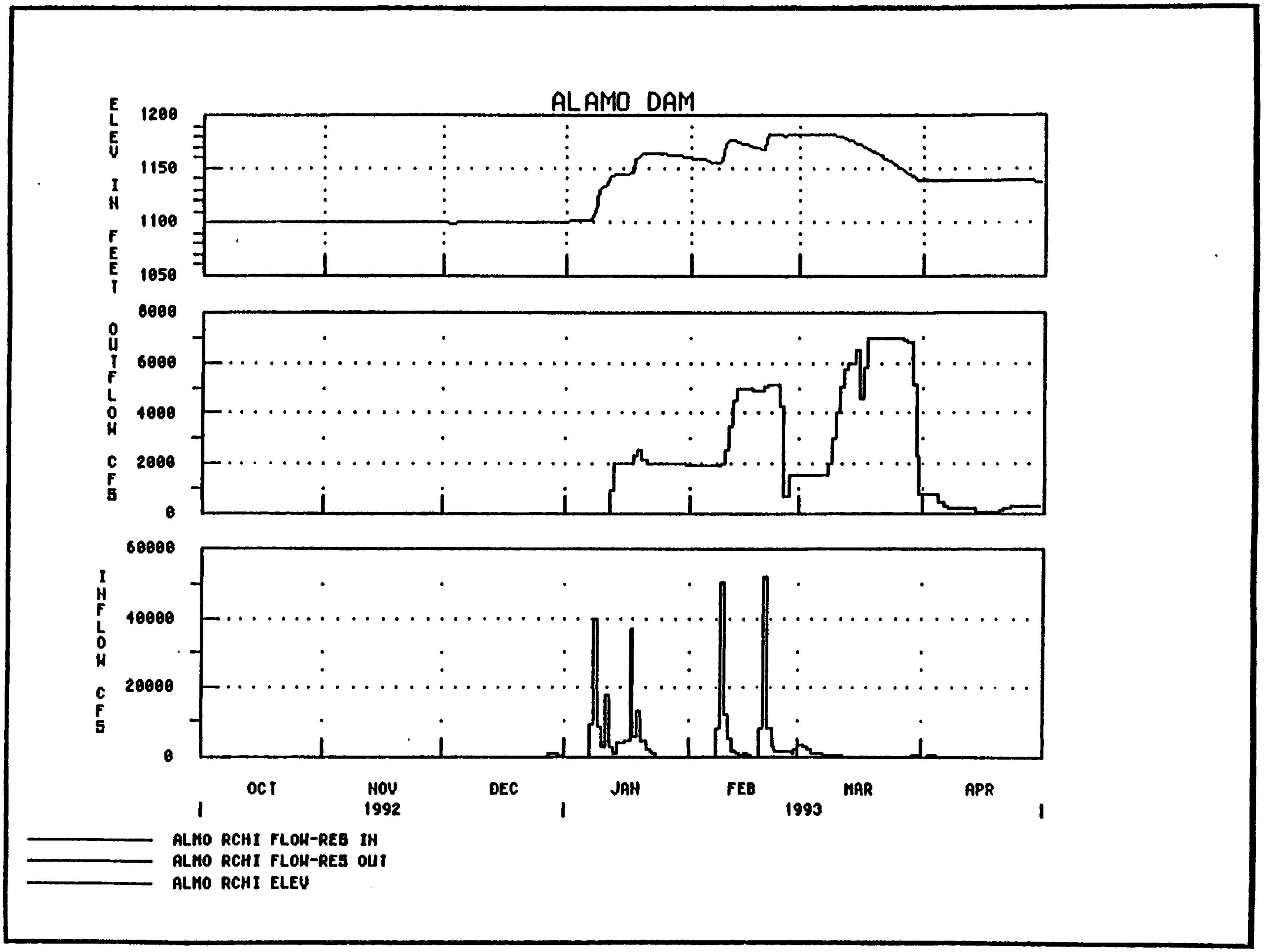

ALAMO DAM
ELEV IN FEET
1200
1150
1100
1050
OUTFLOW CFS
8000
6000
4000
2000
0
INFLOW CFS
60000
40000
20000
0
OCT
NOV
1992
DEC
JAN
FEB
1993
MAR
APR
ALMO RCHI FLOW-RES IN
ALMO RCHI FLOW-RES OUT
ALMO RCHI ELEV

FIGURE 6-25