# CHAPTER III: APPLICATION OF THE WATER BALANCE MODEL

The primary application of the forecast model is to determine the effect of water diversions and changes in climate on the level and salinity of Mono Lake, The general forecast procedure used in each application of the model is shown schematically in Figure 3-l. Because the equation to forecast the end-of-water year lake volume (which is translated into lake level) requires knowing the average annual lake surface area (average of the unknown end-of-water year and initial lake area) an iterative "guessing" procedure must be employed. In each application the initial lake level is the level at the beginning of the water year; the model then calculates the level at the end of the water year which in turn becomes the initial level at the beginning of the next water year. A description of each application's assumptions and results is presented as follows:

## APPLICATION I: HISTORIC (1937-83) ANNUAL LAKE LEVELS ASSUMING THE LADWP AQUEDUCT FACILITIES WERE NEVER BUILT

### PURPOSE:

This application shows what the annual lake elevation would have been had LADWP aqueduct facilities, including the Mono Craters tunnel, never been built in the Mono Basin. The calculated lake level does not strictly represent a "natural" lake level because the water balance is affected by the reservoir regulation of runoff, net reservoir evaporation[l], Virginia Creek inflow, municipal water, and in-basin irrigation.[2]

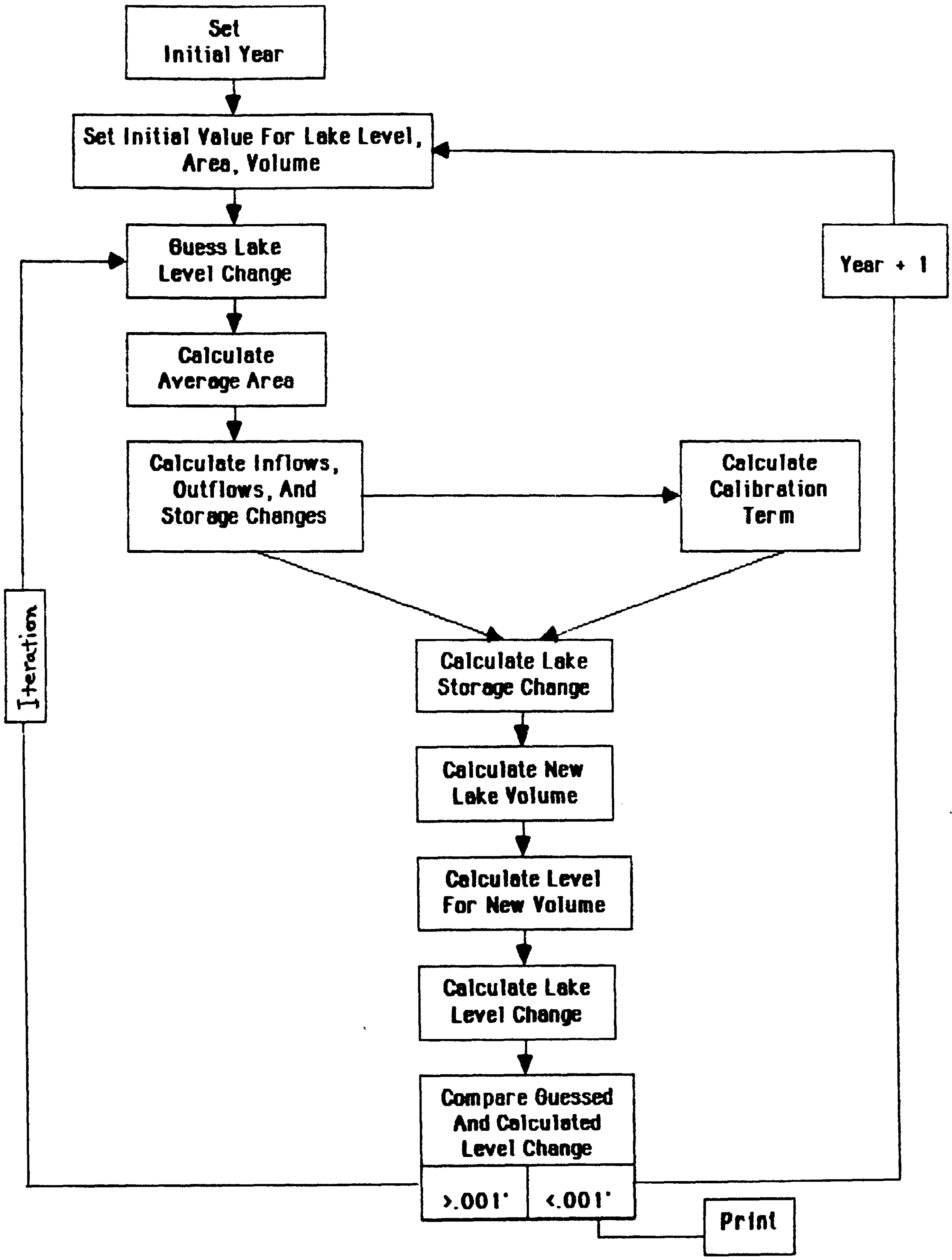


Figure 3-1. Flow Diagram of Forecast Procedure

ASSUMPTIONS:

1. Initial lake level is 6415.04 ft (October 1,1936)

2. The annual values of the Sierra Nevada gaged runoff, ungaged Sierra runoff, Mono Lake precipitation rate, Mono Lake's equivalent freshwater evaporation rate, net municipal inflow, net land surface precipitation, non-Sierra runoff, Virginia Creek inflow, and phreatophyte ET above 6428 ft are equal to their 1937-83 values.

3. The phreatophyte ET below 6428 ft and bare ground evaporation are related to the lake level as explained in Chapter II.

4. Grant Lake Reservoir remains at its pre-1941 size, thus net Grant Lake Reservoir evaporation remains constant at its 1937-40 value of 1000 ac-ft.

5. ET from irrigated land remains constant at its 1937 value of 10,000 ac-ft since it is assumed that there is no irrigated acreage reduction,

6. ET from riparian vegetation remains constant at its 1937 value of 2200 ac-ft since there is no acreage reduction due to LADWP stream diversions.

7. Groundwater storage change is related to the Mono Lake storage change as explained in Chapter II.

8. Grant Lake Reservoir storage change is zero since it is unknown how the reservoir would have been operated.

9. LADWP groundwater export (tunnel make) and LADWP surface water export are zero since no aqueduct facilities are built.

RESULTS:

Table 3-l and Figure 3-2 show the results of this application. Without LADWP export, the lake would be about 47 ft higher than it was in 1983. The lake level under strictly natural conditions (no human interference in the hydrologic cycle) would be about two feet higher,

The results of this application are consistent with the results that might be deduced from the record of lake fluctuations prior to LADWP diversions. For example, in the 39-year period from 1902 through 1940 the lake exhibited a net rise of two ft, going from elevation 6415 ft to 6417 ft. According to the results of this application the lake would have risen in the 42-year period 1937-78 from a measured elevation of 6415 ft to a calculated elevation of about 6419 ft, a net rise of 4 ft. Since the average estimated runoff in the 1902-40 period was nearly equal to the average measured runoff in the 1937-78 period, the calculated elevation change assuming no LADWP export from 1937-78 should be fairly similar to the observed change from 1902-40. The additional 2 ft of net rise that the 1937-78 period exhibited may be attributed to a number of factors including data and model deficiencies, a different sequence of climatic conditions, different evaporation rates, additional in-basin irrigation that probably occurred in the 1902-40 period, and about 17,000 ac-ft of tunnel make (LADWP groundwater export) that occurred at the end of the 1902-1940 period.

TABLE 3-1. Comparison of Observed and Calculated Lake Levels Assuming No Aqueduct Facilities Were Built

| Year | Observed Elevation | Calculated Elevation Without LADWP Export | Difference |
|---|---|---|---|
| 1937 | 6414.97 | 6415.35 | -.38 |
| 1938 | 6418.09 | 6418.01 | .08 |
| 1939 | 6417.66 | 6417.59 | .07 |
| 1940 | 6416.92 | 6417.65 | -.73 |
| 1941 | 6416.99 | 6418.95 | -1.96 |
| 1942 | 6417.50 | 6419.85 | -2.35 |
| 1943 | 6418.05 | 6420.68 | -2.63 |
| 1944 | 6416.61 | 6420.20 | -3.59 |
| 1945 | 6417.16 | 6420.88 | -3.72 |
| 1946 | 6416.95 | 6421.06 | -4.11 |
| 1947 | 6416.33 | 6420.45 | -4.12 |
| 1948 | 6414.06 | 6419.54 | -5.48 |
| 1949 | 6411.92 | 6418.83 | -6.91 |
| 1950 | 6410.08 | 6418.19 | -8.11 |
| 1951 | 6408.22 | 6418.45 | -10.23 |
| 1952 | 6408.73 | 6420.11 | -11.38 |
| 1953 | 6407.60 | 6419.66 | -12.06 |
| 1954 | 6405.28 | 6418.60 | -13.32 |
| 1955 | 6403.18 | 6417.79 | -14.61 |
| 1956 | 6402.15 | 6419.19 | -17.04 |
| 1957 | 6401.14 | 6419.05 | -17.91 |
| 1958 | 6401.57 | 6419.90 | -18.33 |
| 1959 | 6399.80 | 6419.05 | -19.25 |
| 1960 | 6397.60 | 6417.63 | -20.03 |
| 1961 | 6395.57 | 6416.64 | -21.07 |
| 1962 | 6394.00 | 6417.03 | -23.03 |
| 1963 | 6392.76 | 6417.45 | -24.69 |
| 1964 | 6390.54 | 6416.55 | -26.01 |
| 1965 | 6389.06 | 6417.33 | -28.27 |
| 1966 | 6387.42 | 6416.93 | -29.51 |
| 1967 | 6388.72 | 6418.65 | -29.93 |
| 1968 | 6387.16 | 6418.02 | -30.86 |
| 1969 | 6389.49 | 6420.28 | -30.79 |
| 1970 | 6388.02 | 6420.18 | -32.16 |
| 1971 | 6386.13 | 6420.04 | -33.91 |
| 1972 | 6384.29 | 6419.49 | -35.20 |
| 1973 | 6382.78 | 6419.90 | -37.12 |
| 1974 | 6381.07 | 6420.58 | -39.51 |
| 1975 | 6379.39 | 6420.85 | -41.46 |
| 1976 | 6377.75 | 6419.76 | -42.01 |
| 1977 | 6375.60 | 6418.21 | -42.61 |
| 1978 | 6374.99 | 6419.46 | -44.47 |
| 1979 | 6373.44 | 6419.73 | -46.29 |
| 1980 | 6373.87 | 6421.14 | -47.27 |
| 1981 | 6372.37 | 6420.51 | -48.14 |
| 1982 | 6372.77 | 6422.52 | -49.75 |
| 1983 | 6378.58 | 6425.52 | -46.94 |
| 1984 | 6380.12 | 6426.72 | -46.60 |

Note: all elevations are for the end of the water year

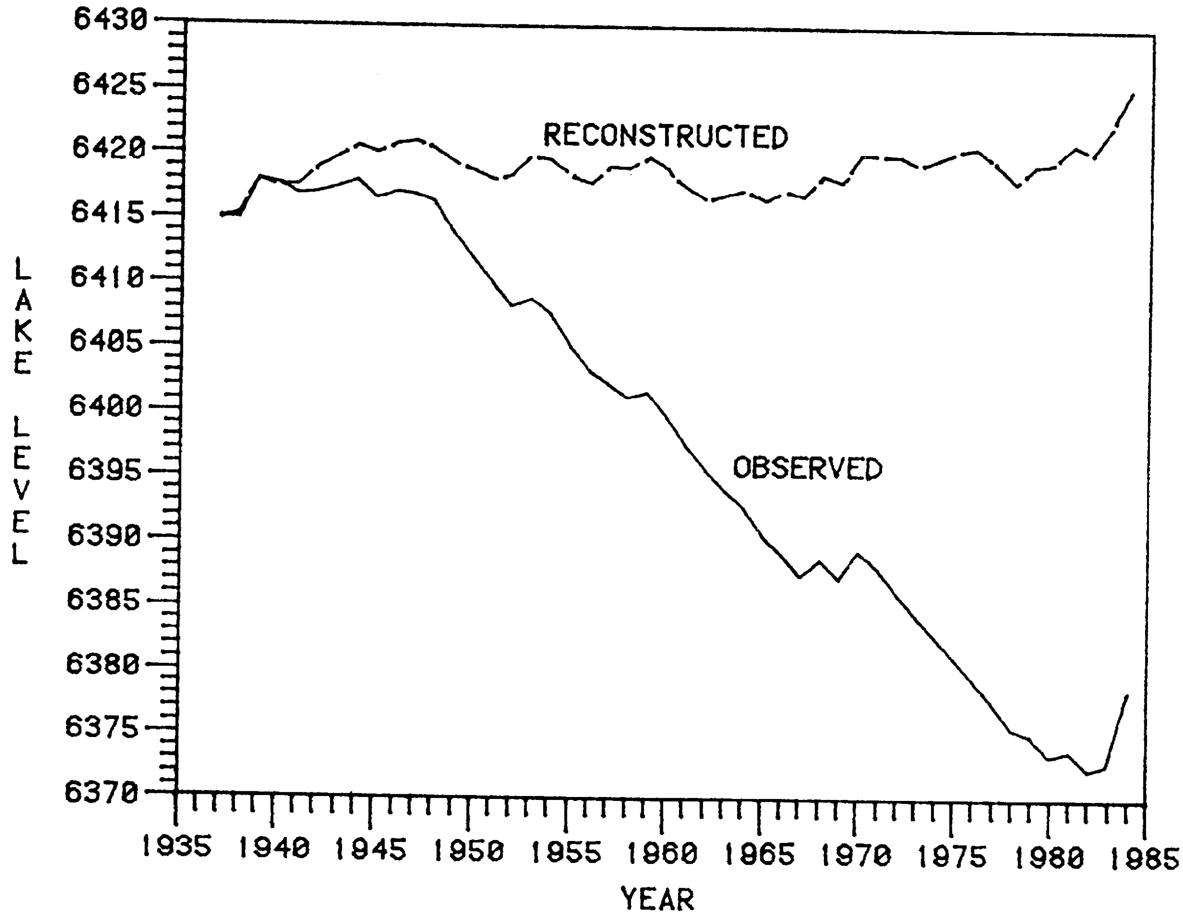


FIGURE 3-2. 1937-83 OBSERVED AND RECONSTRUCTED LAKE LEVELS WITHOUT LADWP EXPORT

COMPARISON TO PREVIOUS RESULTS:

Four previous models (Corley 1970, CADWR 1974, Loeffler 1977, LADWP 1984a) calculate lake elevations assuming that there had been no exports by the LADWP. Table 3-2 compares these calculated lake levels. The reconstructed lake levels of Loeffler and LADWP are lower than this model's primarily because they use evaporation rates that are 7%-9% lower. When these lower evaporation rates are applied to the development of their forecast equation, the total calculated inflow to the lake is 20%-30% less than this model's calculated inflow to the MGWB. CADWR's levels are lower than this model's mainly because they do not add the LADWP groundwater export (tunnel-make) back into lake storage.

## APPLICATION 2: FUTURE LAKE LEVELS AND SALINITY

PURPOSE:

All of the following applications involve forecasting future lake levels or salinities for a range of LADWP surface water export scenarios. The basic assumption in each one is that the hydroclimatic conditions (i.e. the rate of runoff, precipitation, and evaporation) of the 1937-83 base period will occur in the future.

The following assumptions are common to each forecast application. The unique assumptions within each application will be presented separately.

TABLE 3-2. Comparison of Calculated Lake Levels Assuming No Export by LADWP

| Year | Corley (1971) | CADWR (1974) | Loeffler (1977) | LADWP (1984a) | Current Model |
|---|---|---|---|---|---|
| 1970 | 6417.5 | 6414.5 | 6412.0 | 6408.0 | 6420.0 |
| 1972 | | 6414.0 | 6411.0 | 6406.0 | 6419.0 |
| 1975 | | | 6410.0 | 6407.0 | 6420.5 |
| 1979 | | | | 6404.0 | 6419.5 |
| 1983 | | | | | 6425.0 |

All elevations rounded to the nearest half foot (USGS datum).

ASSUMPTIONS:

1. Initial lake level is 6380.12 ft (October 1,1984 level)

2. Sierra Nevada gaged runoff is 149,696 ac-ft/yr (1937-83 average) times the annual runoff index derived from the 1937-83 sequence.

3. Ungaged Sierra runoff is 16,646 ac-ft/yr (average value since 1978) times the annual runoff index.

4. Non-Sierra runoff remains a constant 19,673 ac-ft/yr.

5. Mono Lake precipitation rate is 8 inches per year times the annual precipitation index derived from the 1937-83 sequence.

6. Net land surface precipitation remains a constant 9,000 ac-ft/yr.

7. Virginia Creek inflow remains a constant 1100 ac-ft/yr.

8. Net municipal inflow remains at the 1983 value of 500 ac-ft/yr because the rate of increase in net inflow would be very slow, This is because June Lake and Lee Vining municipal use is becoming more efficient and increased water use outside their service areas will offset increased water use within their service areas.

9. Mono Lake evaporation rate is 3.75 ft per year, adjusted for the lake salinity, times the annual evaporation index derived from the 1937-83 sequence. Due to the lack of data it is assumed that the evaporation rate will not increase at high salinities even though the brine would have a higher heat storage capacity.

10. Grant Lake Reservoir net evaporation is a constant 1500 ac-ft/yr since it cannot be predicted how the surface area will fluctuate.

11. Bare ground evaporation (BGE) from the exposed Mono Lake

11. Bare ground evaporation (BGE) from the exposed Mono Lake bottom depends on the lake level which in turn determines the exposed acreage and evaporation rate,

a) If the lake rises above 6428 ft, there would be no great expanses of bare ground until the lake retreated from a new high stand. As the water table rose, the area around the shoreline --especially around the north and east side-- could become pockmarked with lagoons and new phreatophyte growth. The BGE component will incorporate this new evaporation and evapotranspiration. Although the BGE will undoubtedly vary with the lake level when the lake exceeds 6428 ft there is insufficient information to ascertain the magnitude of the variation; it is thus assumed that the BGE will remain a constant 1850 ac-ft per year, equivalent to the BGE at 6428 ft.[3]

b) If the lake is below 6428 ft the BGE is determined by applying the rates given in Appendix 2-C.

c) If the lake drops below 6368 ft, the shallow rills that are currently visible on the north and east shores will deepen because the land surface gradient dramatically steepens below 6368 ft (relative to the extremely flat gradients above 6368 ft) creating a geomorphic "nick-point" Stine pers comm 1984). As a consequence the exposed land on the north and east shores will be drained by the rills, causing a lowering of the water table. To accomodate these changes the bare ground evaporation rates are adjusted so that below 6368 ft the evaporation rate for newly exposed land will be 0.7 ft and the existing acreage exposed above 6368 ft that evaporates at 1.0 ft per year will gradually convert to acreage that evaporates at 0.1 f t per year. By the time the lake reaches 6334 ft, then, all the acreage above 6368 ft evaporates at 0.1 ft per year. Below 6334 ft the evaporation rate for newly exposed land is assumed to be 0.7 ft per year, while the existing acreage exposed below 6368 ft will gradually convert to acreage that evaporates at a rate of 0.1 ft per year.

12. Irrigated land evapotranspiration (ILET) depends on the amount of land irrigated which in turn depends on the runoff.

a) If the runoff is above 85% of normal, 3500 acres are irrigated and the ET is the 1983 value of 7000 ac-ft/yr.

b) If the runoff is below 60% of normal, it is assumed that the LADWP would reduce their irrigated acreage by about 500 acres, lowering the ET volume to the 1976-77 value of 6000 ac-ft/yr.

c) If the runoff is between 60% and 85% of normal the ET is 6500 ac-ft/yr (the average of "a" and "b" above).

13. Riparian ET (RET) depends on the surface water export by LADWP because the annual export amount largely determines the flow down lower Lee Vining and Rush Creeks, which in turn determines the possible regeneration of riparian vegetation.

a) If the average export rate is between 80,000 and

100,000 ac-ft/yr the RET will be equal to its 1979-83 average value of 700 ac-ft/yr. [4]

b) If the average export rate is under 40,000 ac-ft/yr the RET will be equal to 2200 ac-ft/yr; this assumes that the pre-LADWP riparian acreage will re-establish itself. [5]

c) If the average export rate is between 40,000 and 80,000 ac-ft/yr the RET will be equal to 1,500 ac-ft/yr (average of 2200 and 700 ac-ft/yr from above),

14. Phreatophyte ET above 6428 ft (PETA) remains a constant 1700 ac-ft/yr; if the lake rises above 6428 ft the possible increase in phreatophyte vegetation (due to higher water tables) will be accounted for in the BGE component (see assumption no. 12 above).

15. The phreatophyte ET below 6428 ft (PETA) depends on the lake level which in turn determines the exposed acreage and evaporation rate.

a) If the lake level is between 6428 ft and 6368 ft the PETB is calculated by equation (25) on P. 123.

b) If the lake drops below 6368 ft the relationship between exposed lake area and phreatophyte type, density, area, and therefore water consumption may change for the following reasons: (1) Springs, which flush the soil of salts and thus allow the vegetation to grow, may not continue to follow the lowering lake level downslope. Spring discharge is limited by the extent of the permeable layers and faults that allow water to escape. (2) Land areas near the shoreline will require proportionally more flushing since the lake is getting progressively saltier. (3) The total area of high water table will be reduced because the deep rills that will develop on the north and east shores will lower the water table. A zonal arrangement of vegetation more typical of a wet playa (Horton et al. 1964) could result as the surface layers become less permeable so that only salt-tolerant species such as salt-grass will survive near the shoreline and deeper-rooted phreatophytes such as rabbitbrush and greasewood will survive further upslope. It cannot be ascertained how the relationships will change as the lake declines other than that the species type and density and thus the ET rate will probably change. Therefore, for purposes of forecasting, it is assumed that the total phreatophyte acreage can be estimated by equation (24), but that the acreage that evapotranspires at 2.0 ft gradually decreases until, at 6360 ft, only 20% of the total phreatophyte acreage evapotranspires at 2.0 ft per year; the remaining 80% of phreatophyte acreage evapotranspires at a rate of 0.5 ft per year, This 20%/80% ratio is used for all lake levels below 6360 ft.

16. Groundwater storage change is related to the Mono lake storage change as explained in Chapter II.

APPLICATION 2A: FUTURE LAKE LEVELS USING THE SEQUENCE OF 1937-83 HYDROCLIMATIC CONDITIONS

Purpose: This application calculates the response of the lake to annually varying climatic conditions and both constant and annually varying export levels.

Assumptions: This application uses the sequence of 1937-83 climatic conditions as they actually occurred, which means that the runoff in the first 10 years is above-normal (114% of the 1937-38 average), the runoff in the next 18 years is below-normal, (86% of average), and the last 19 years exhibits a dramatic variation in annual runoff including the lowest and highest of record. For purposes of this application the 47-year sequence is repeated 10 times, for a total of 470 years, so that the equilibrium levels of Mono Lake can be ascertained.

Each forecast uses a different LADWP surface water export scenario. Twelve different export scenarios are tested. The first eleven consist of an annual export amount that is the same in each year. These constant amounts range from zero ac-ft to 50,000 ac-ft at 5,000 ac-ft increments. In all of these scenarios the Grant Lake Reservoir storage change is zero in each year since it is unknown how LADWP would operate their system. The 1937-83 runoff sequence does not allow more than 50,000 ac-ft of export in each year without a change in Grant Lake Reservoir storage. The last (twelfth) scenario assumes the annual export is unrestricted and that the annual amount of export and Grant

Lake Reservoir storage change varies according to the runoff. For 1937-69 runoff values, these two components vary according to the operation simulation given in a LADWP report by Tilleman (1971) which assumes that the second barrel of the Los Angeles Aqueduct was in place during the 1937-69 period.[6] For 1970-83 runoff values the two components (SWEX and GLSE) vary as they actually did during the 1970-83 historic period. The long-term average export in this scenario is close to 100,000 ac-ft/yr. LADWP groundwater export (tunnel-make) remains at a steady-state value of 7270 ac-ft/yr for the first 10 years of the 1937-83 sequence and then assumes the actual 1947-83 values for the next 37 years of the sequence.

Results: The results of this application are purely deterministic forecast, i.e. for the given input (as determined by the assumptions) the lake will respond as calculated (within the error margin of the forecast). The lake level fluctuations in the next 47 years for selected export scenarios are shown in. Figure 3-3. Since the basic assumption -the repeat of 1937-83 hydroclimatic conditions- is highly unlikely, the actual lake response will be different from that calculated. The calculated lake levels, however, are useful for analyzing the timing and scale of short-term lake fluctuations in response to different LADWP export scenarios and annually varying hydroclimatic conditions.

The long-term fluctuations (470 years) are shown in

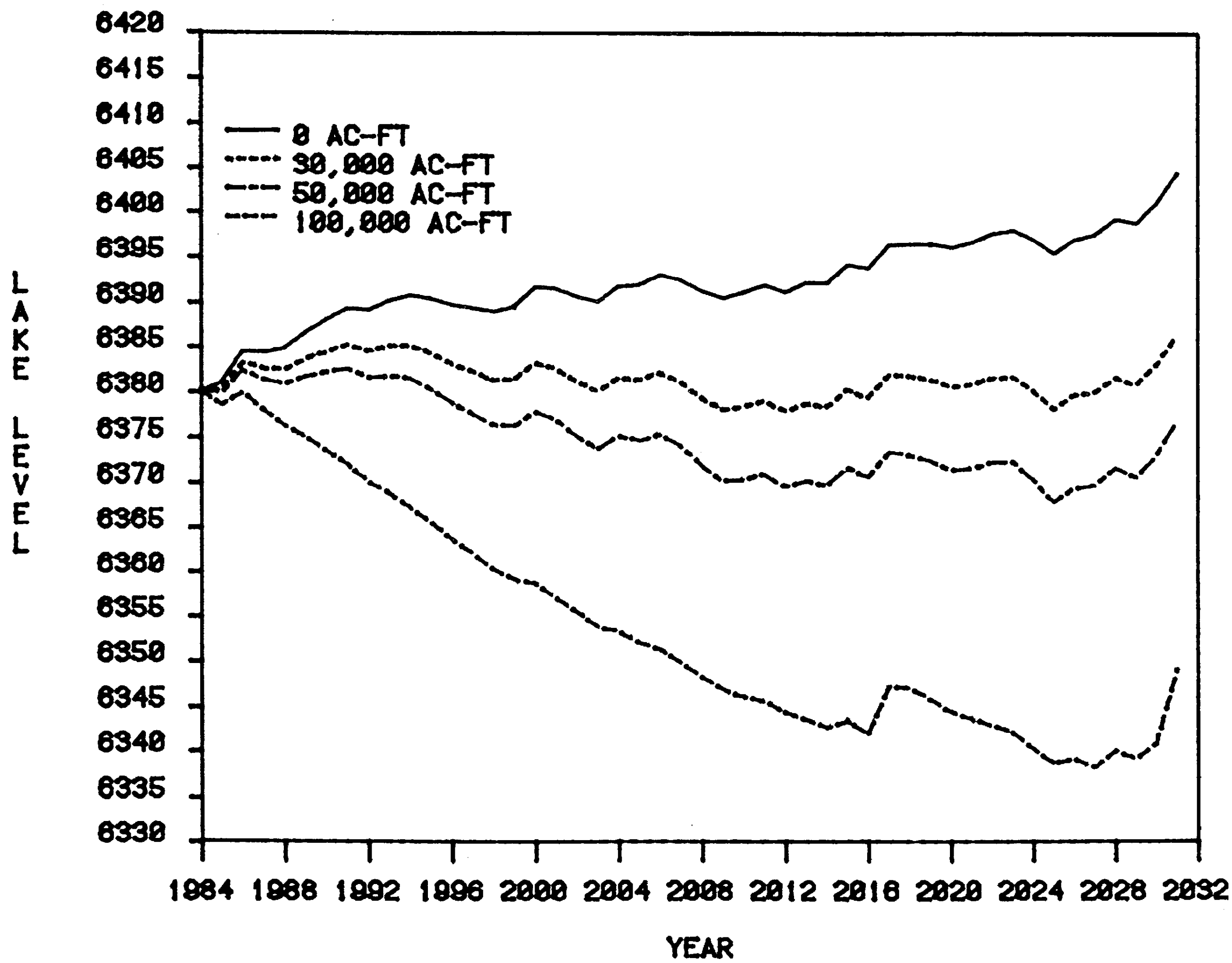


Figure 3-3 Lake Level Fluctuations 1985 - 2031 for Exports of 0, 30, 50 and 100 Thousand ac-ft/yr With Actual Sequence of 1937-83 Hydroclimatic Conditions

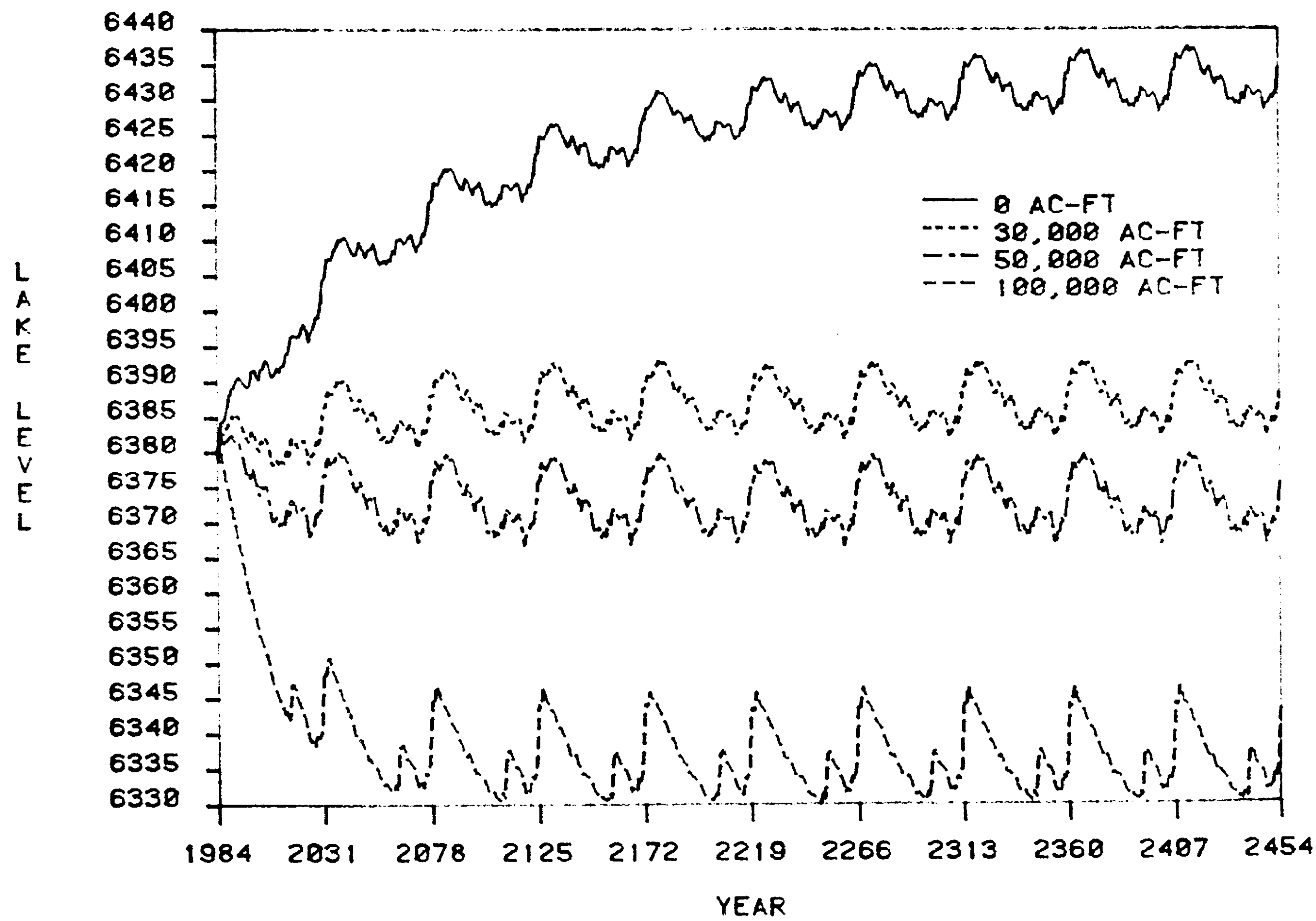


Figure 3-4 Lake Level Fluctuations, 1985-2454, for Exports of 0, 30, 50 and 100 Thousand ac-ft/yr With Repetition of 1937-83 Hydroclimatic Conditions

Figure 3-4. These results are useful for showing the concept of the "dynamic" equilibrium that the lake will achieve for a given set of climatic conditions. The lake will never stabilize; rather, if a given climatic sequence persists long enough -- a highly unlikely event -- it will continuously fluctuate around an equilibrium level within a range of 10 ft (at the zero export level) to 16 ft (at the 100,000 ac-ft export level). When the lake level is artificially depressed by diversions, a wider range of fluctuations occurs because the lake area (and thus the volume of lake evaporation) is so reduced that the occassional very wet year causes a large jump in level,

The long-term fluctuations also suggest what the long-term average inflow (runoff minus export plus net land surface precipitation) into the Mono Groundwater Basin would have to be in order to keep the lake above certain key elevations. For example, in order to keep the lake above 6378 ft (an elevation providing a three foot minimum coverage of the Negit Island landbridge), the long-term average inflow to the MGWB (including net land surface precipitation but excluding precipitation on the lake) must be about 155,000 ac-ft or about 79% of the 1937-83 average.[7] The export reduction that this would require is totally dependent on climatic conditions. If the climate is similar to that experienced from 1937-83 then the long-term export reduction would be about 35,000 ac-ft.[8] The wetter the future climate, the less exports would have to be reduced since the increased inflow from other parts of the basin would sustain the 155,000 ac-ft average annual inflow requirement. It is more useful to identify the inflow which is necessary to keep the lake above a certain level as opposed to identifying the required LADWP export level (and the corresponding level of export reduction) because these latter quantities are wholly dependent on the assumed (1937-83) hydroclimatic sequences occurring in the future. The identified inflow is basically independent of the assumed hydroclimatic conditions to the extent that other sequences of runoff, evaporation, and precipitation do not result in a wider range of fluctuations than the 1937-83 sequences.

Comparison to Previous Results:

None of the previous water balance models forecast future lake levels using varying hydroclimatic conditions. All of the previous models assumed average conditions in each year of the forecast.

APPLICATION 2B: FUTURE LAKE LEVELS USING THE SEQUENCE OF 1937-83 HYDROCLIMATIC SEQUENCES WITH THE 1947-64 CONDITIONS OCCURRING FIRST.

Purpose: The purpose of this application is to show the effect of a different sequence of wet and dry periods than that assumed in Application 2A.

Assumptions: The assumptions for this application are the same as Application 2A except that instead of using the sequence of

1937-83 conditions in the order that they actually occurred, the sequences are rearranged so that the relatively dry 1947-64 conditions occur first, followed by the 1937-46 and 1965-83 conditions. The 1947-64 runoff conditions were about 86% of the 1937-83 average.

Results: Plotting the results of applications 2A and 2B together for selected export scenarios (see Figure 3-5) shows that after nine years the lake levels differ by about nine feet (i.e. those calculated with the 1947-64 conditions first are about nine feet lower than those calculated with 1937-46 conditions first), except in the 100,000 ac-ft scenario in which the difference is only about 4 feet. These results show the effect of different hydroclimatic conditions on short-term lake fluctuations. Although in reality neither the wet or dry sequence will likely repeat itself in the given order, the future conditions could be at least as divergent from the norm as these two initial sequences.

APPLICATION 2C: FUTURE LAKE LEVELS USING THE 1937-83 AVERAGE HYDROCLIMATIC CONDITIONS IN EACH YEAR OF THE FORECAST.

Purpose: This application shows the response of the lake if the average of the 1937-83 conditions are projected into the future.

Assumptions:

1. The runoff, precipitation, and evaporation

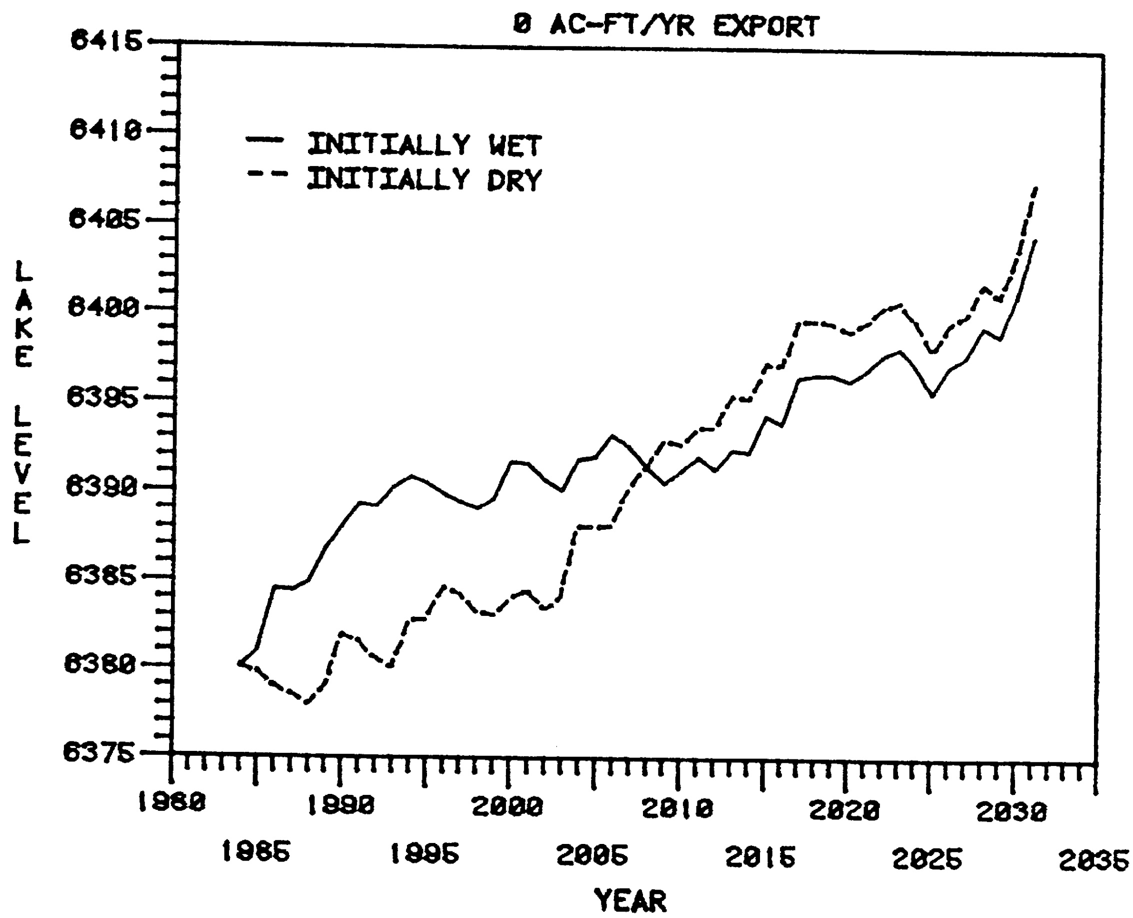


Figure 3-5a Comparison of Lake Level Fluctuations, 1985-2031, Using 1937-83 Hydroclimatic Conditions With Initial Sequence Above Normal (1937-46) and Initial Sequence Below Normal (1947-64)

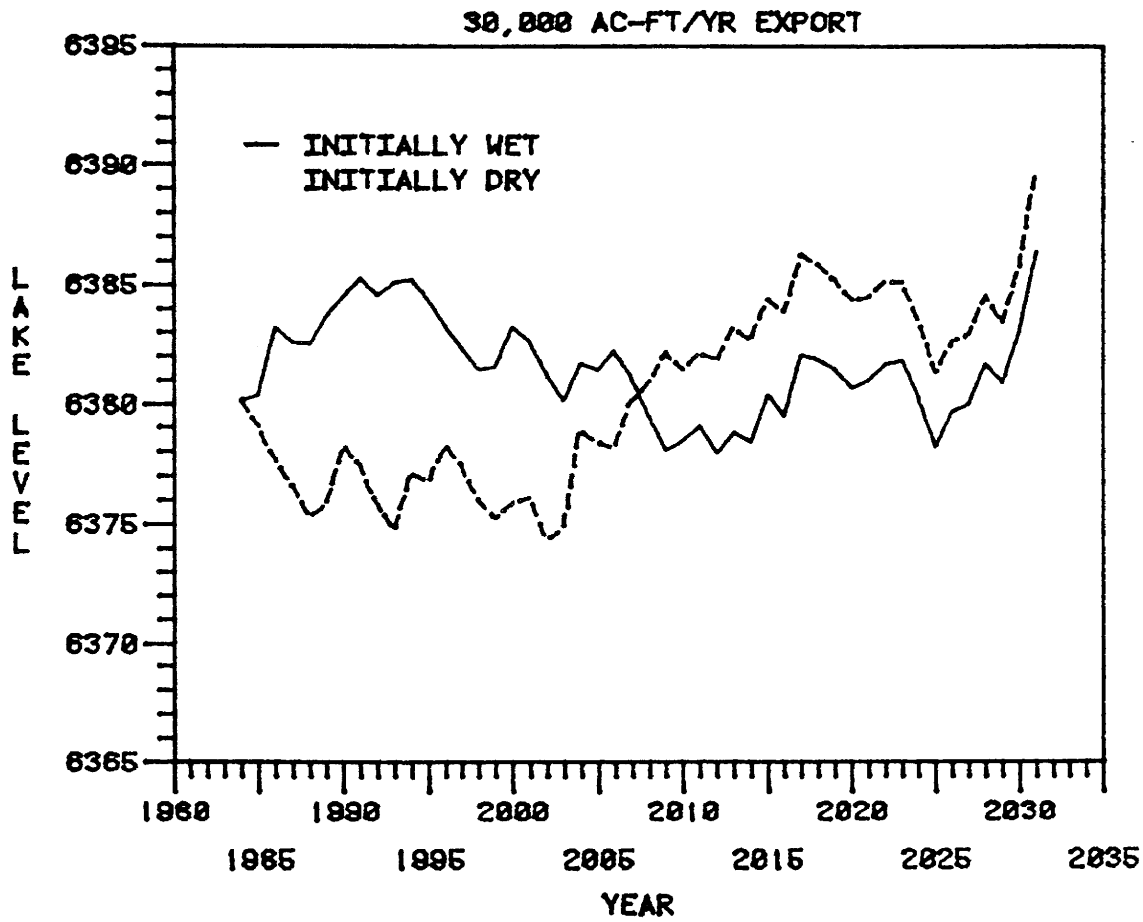


Figure 3-5b Comparison of Lake Level Fluctuations, 1985-2031, Using 1937-83 Hydroclimatic Conditions With Initial Sequence Above Normal (1937-46) and Initial Sequence Below Normal (1947-64)

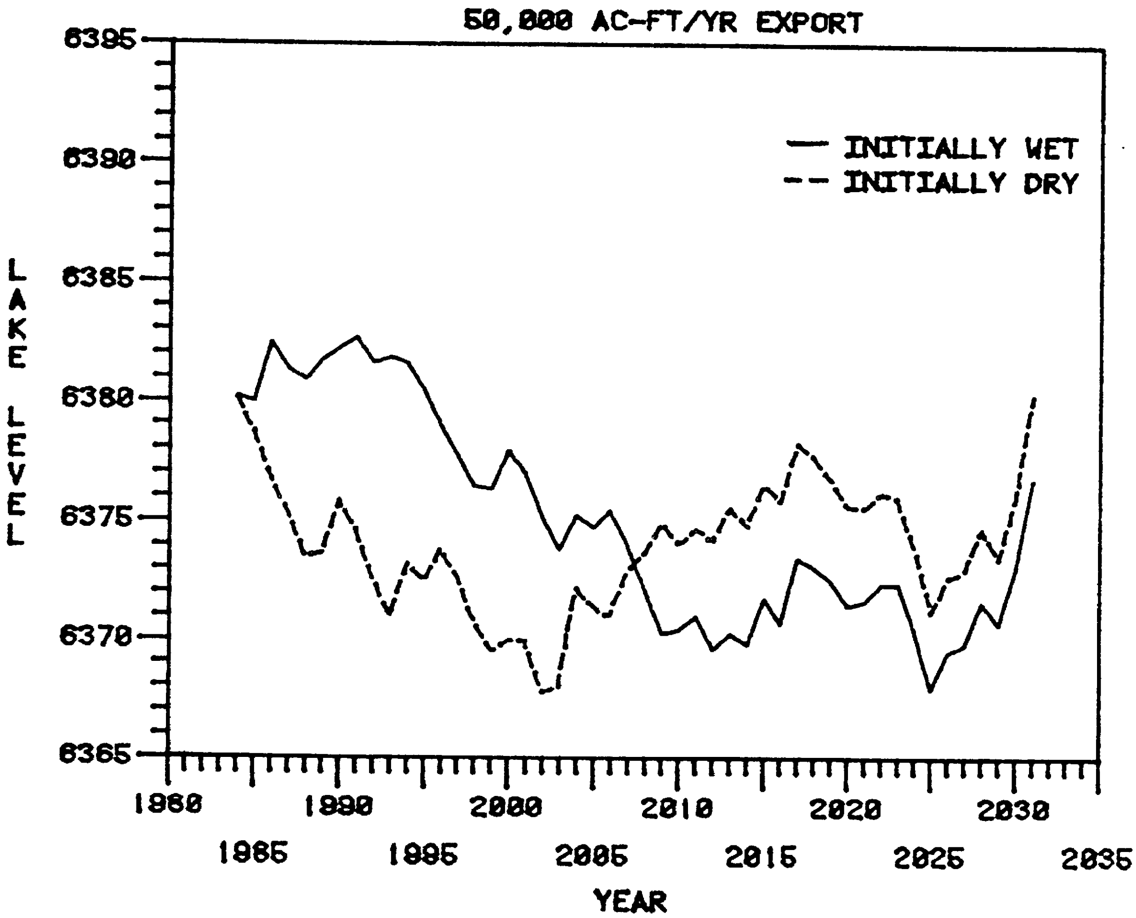


Figure 3-5c Comparison of Lake Level Fluctuations, 1985-2031, Using 1937-83 Hydroclimatic Conditions With Initial Sequence Above Normal (1937-46) and Initial Sequence Below Normal (1947-64)

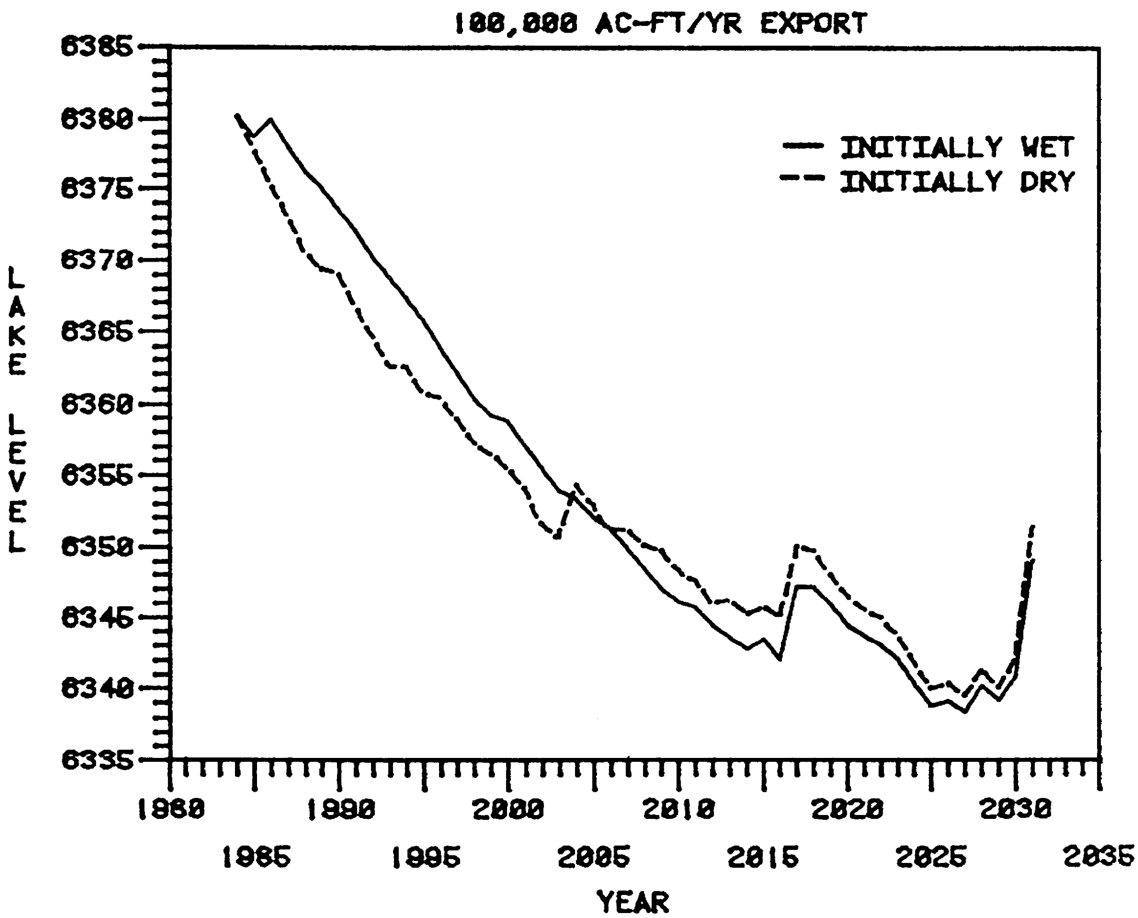


Figure 3-5d Comparison of Lake Level Fluctuations, 1985-2031 Using 1937-83 Hydroclimatic Conditions With Initial Sequence Above Normal (1937-46) and Initial Sequence Below Normal (1947-64)

indices are set equal to their base period average in each year of the forecast (i.e. 1.0 for runoff and precipitation, and .998 for evaporation).[9]

2. The irrigation evapotranspiration is equal to 7000 ac-ft in each year since the runoff is always 100% of average.

3. Each forecast uses a different LADWP surface water export scenario. 21 export scenarios are tested. They range from 0 ac-ft/yr to 100,000 ac-ft/yr at 5,000 ac-ft increments; each scenario assumes a constant annual export amount.

4. Grant Lake Reservoir storage change is zero in each year of each export scenario.

5. LADWP groundwater export (tunnel make) is a constant 7270 ac-ft/yr in each scenario.

Results: The forecasted lake levels for selected export scenarios are shown in Figure 3-6. Although the figure does not show how the lake would respond in any given year, it does show the long-term trend of lake response. An eventual hypothetical stabilization or equilibrium level is reached, in which the inflows exactly balance the outflows and no storage or level change occur. The equilibrium level for each export scenario is plotted in Figure 3-7; the resulting curve in Figure 3-7 can be used to derive the equilibrium level for any given average export rate given the assumed hydroclimatic conditions. In reality the lake will always be fluctuating no matter how "stable" the climate is, and in fact Mono Lake's fluctuations in the past 1000 years suggest significant climatic variation (Stine 1984). The main use of Figures 3-6 and 3-7, therefore, is to

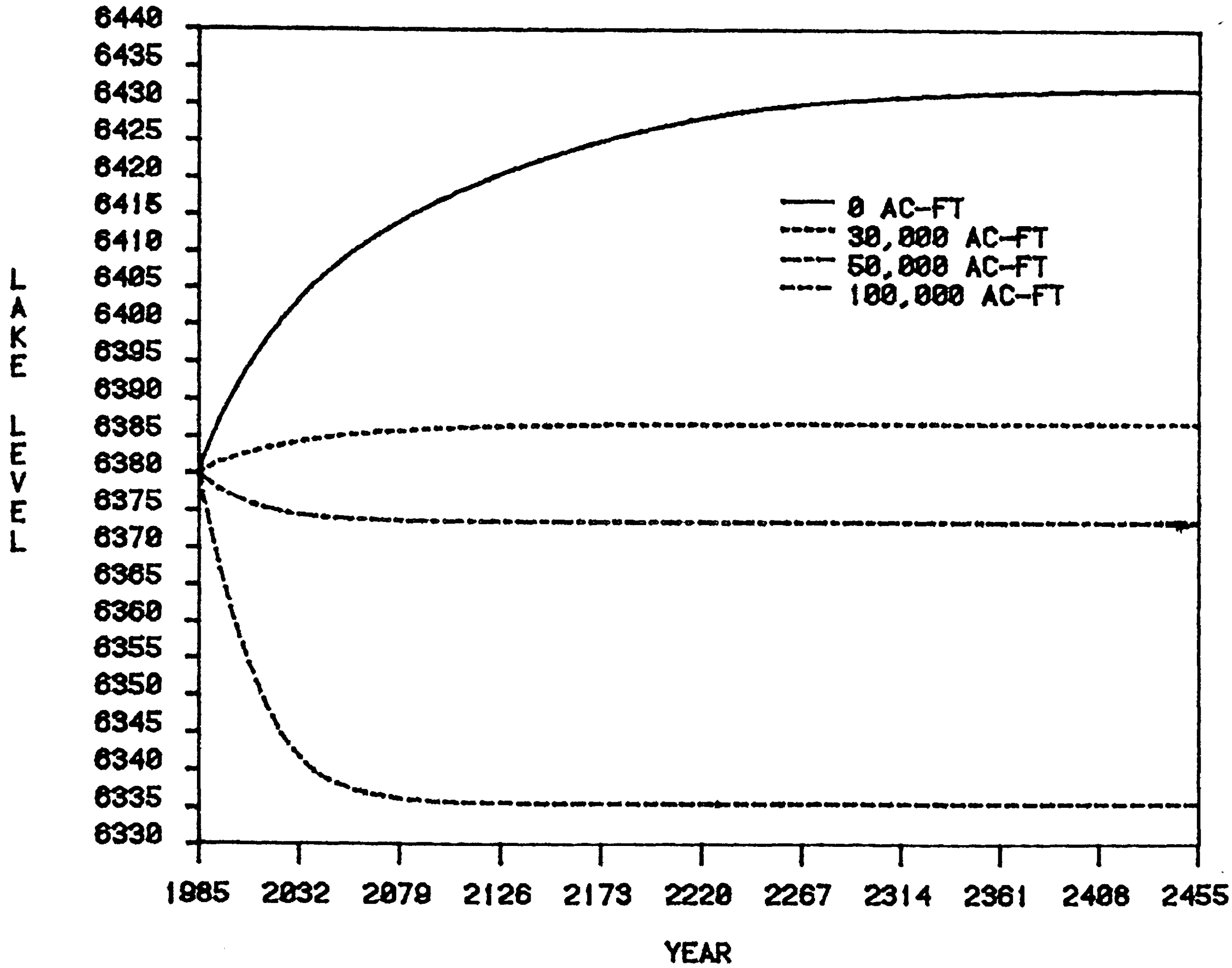


Figure 3-6 Lake Level Fluctuations, 1985-2454, for Exports of 0, 30, 50, and 100 Thousand ac-ft/yr, Using the Average 1937-83 Hydroclimatic Conditions

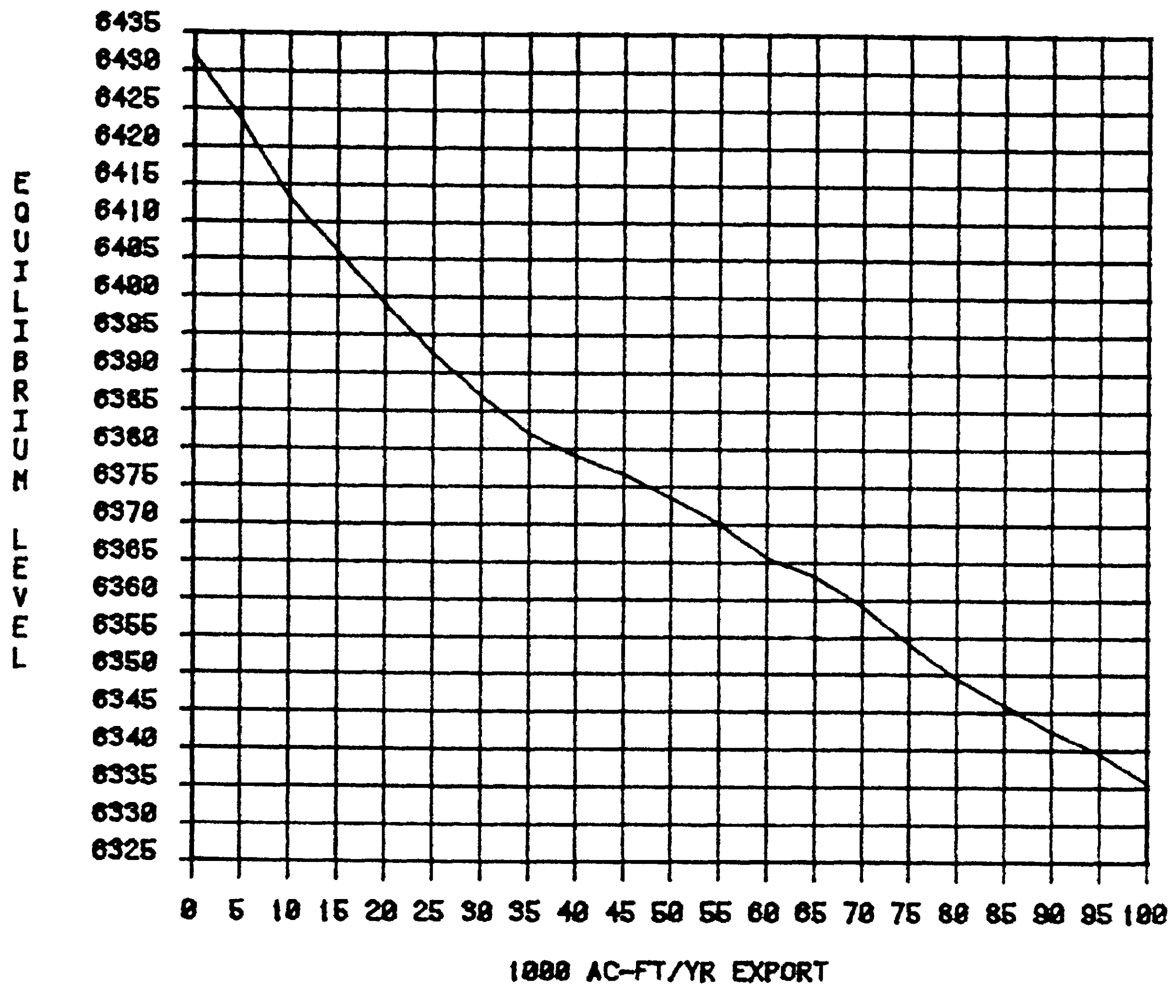


Figure 3-7 Equilibrium Lake Level as a Function of LADWP Surface Water Exports

indicate whether a particular export rate would result in a relatively high or low lake level under the current climate. Under any scenario the lake will rise or fall the fastest in the immediate future with a declining rate of lake level change the further into the future one proceeds. The time it takes to reach an equilibrium level varies with the export amount to the extent that an export scenario merely reflects a particular average inflow amount and associated lake level. The amount of time for an export scenario to reach a lake level where annual changes are less than 0.01 ft ranges from 61 years (40,000 ac-ft export scenario) to over 500 years (5,000 ac-ft scenario).[l0] Not surprisingly, equilibrium levels closer to the present lake level are achieved sooner.

Because the equilibrium level is a theoretical construct determined by unrealistic climatic assumptions, a more useful way of interpreting Figure 3-7 is to translate the export levels into an equivalent average groundwater basin inflow (runoff minus export plus net land surface precipitation but excluding Mono Lake precipitation). Figure 3-8 then shows the average amount of inflow necessary to maintain a particular lake level, assuming that the vegetation and municipal water requirements do not change significantly, The range of fluctuations around the particular level will depend on the climatic sequence.

Comparison to Previous Results: Nine of the previous models are applied to forecasting future lake levels under average

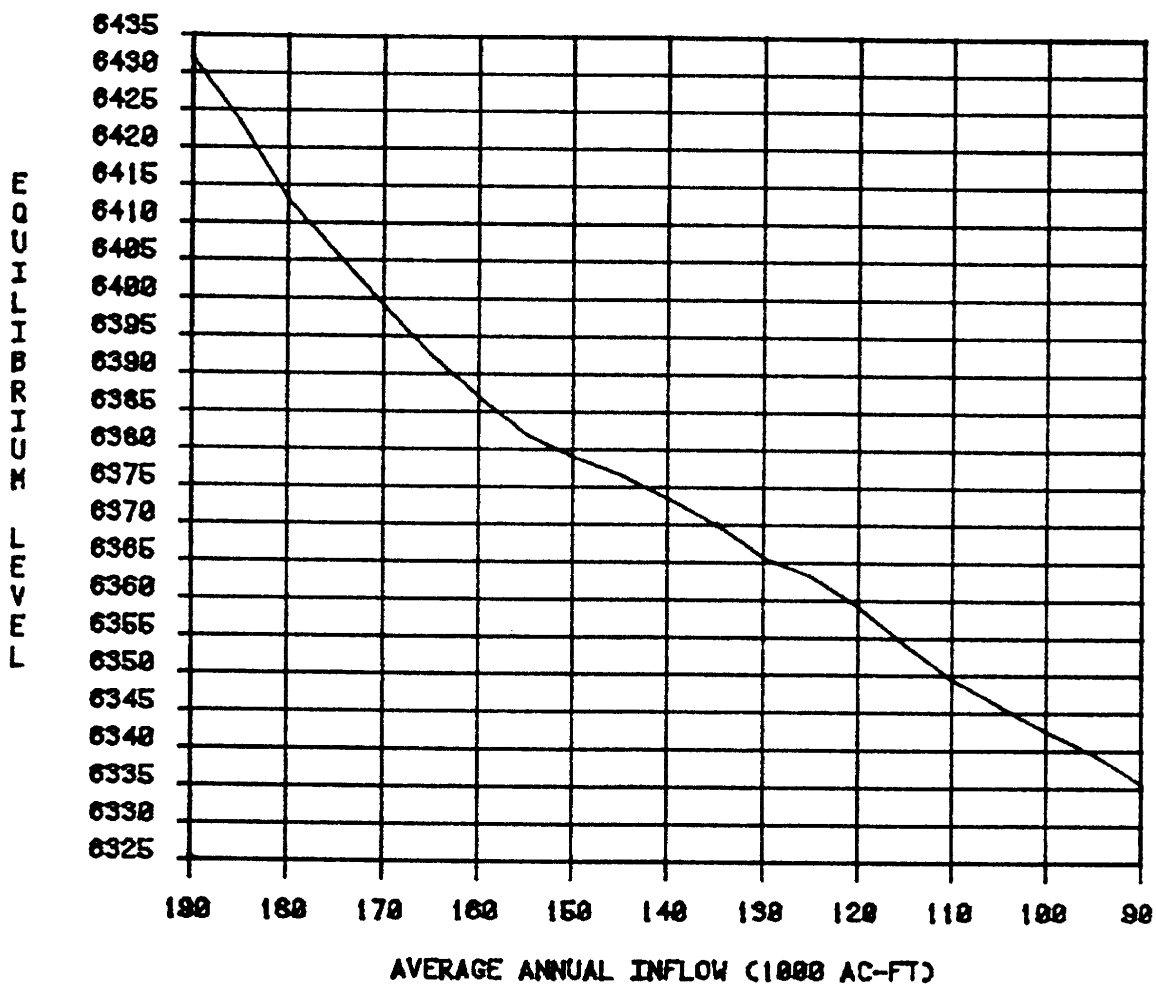


Figure 3-8 Average Annual Inflows to Mono Groundwater Basin Required to Maintain Different Average Lake Levels

conditions of inflow and outflow; four of them examine the effect various LADWP surface water export scenarios would have on future lake levels. Figure 3-9 compares the results derived from this model with those four forecast models. The divergent results are attributable to the different estimates of the future water balance component values by each of the models, particularly the estimates of average inflow and evaporation rates. For example, the LADWP (1984a) model calculates as a residual an average future inflow to the lake of about 124,000 ac-ft assuming no LADWP surface water export; this report's model calculates an average future inflow to the groundwater basin of about 197,000 ac-ft, assumes no surface water export and includes net land surface precipitation, about 15,000-30,000 ac-ft of which Is lost before reaching the lake due to tunnel-make, evaporation and evapotranspiration. LADWP (1984a) uses a 3.4 ft mean annual evaporation rate to estimate Mono Lake evaporation and this model uses a 3.75 ft mean annual rate.

LADWP (1984d) presents a provisionally updated version of the LADWP (1984a) forecast model, using the 1970-82 data aqueduct stream runoff for calibration. The 1970-82 period has 2% greater runoff than the 1941-76 period used to formulate the LADWP (1984a) model. This updated model is applied to forecasting equilibrium levels for different export rates. Those results are plotted along with this model's results in Figure 3-10. For comparison purposes, Figure 3-10 also shows the LADWP's (1984a) results.

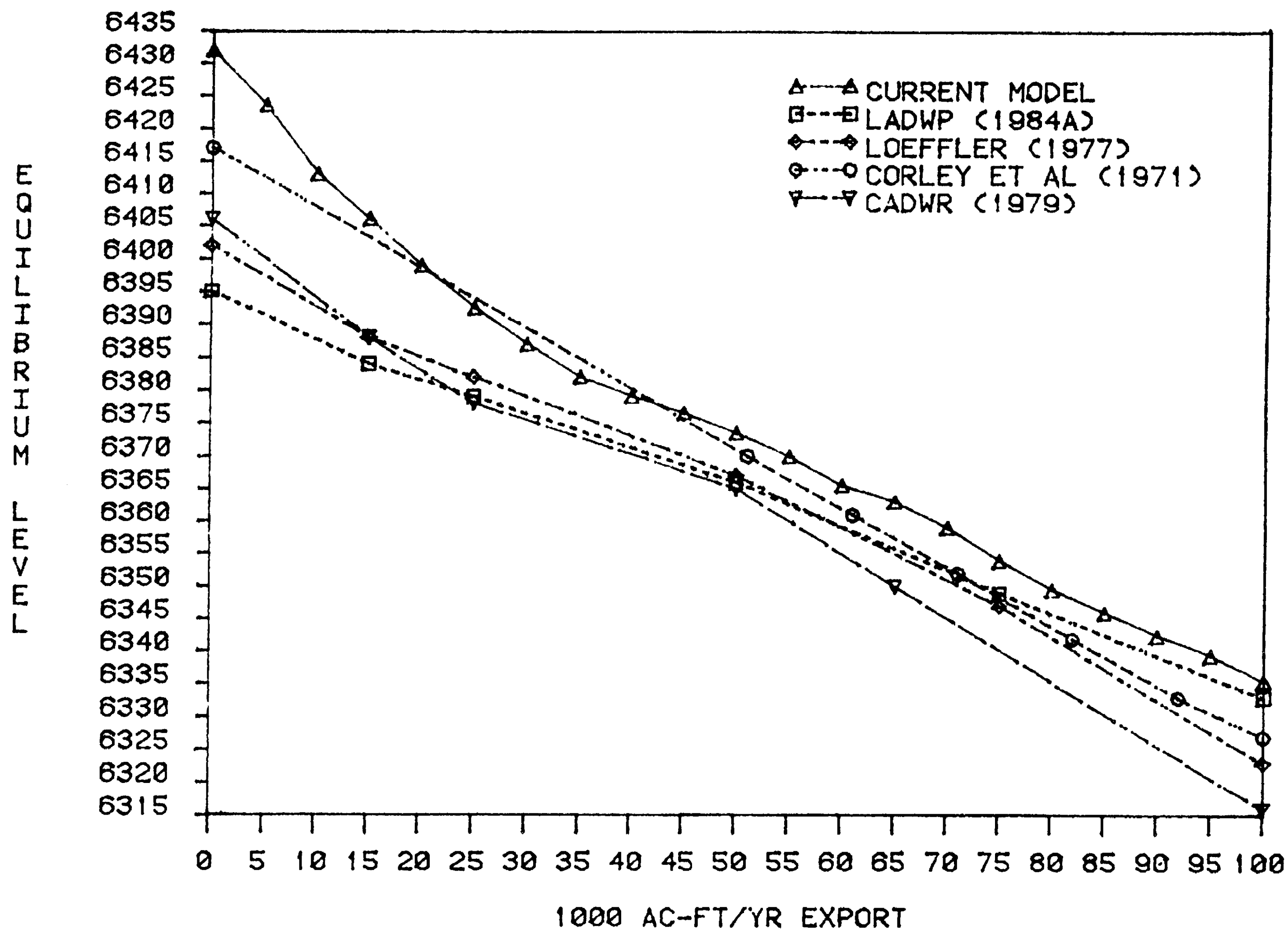


Figure 3-9. Comparison of Equilibrium Lake Level as a Function of LADWP Exports for Five different Forecast Models

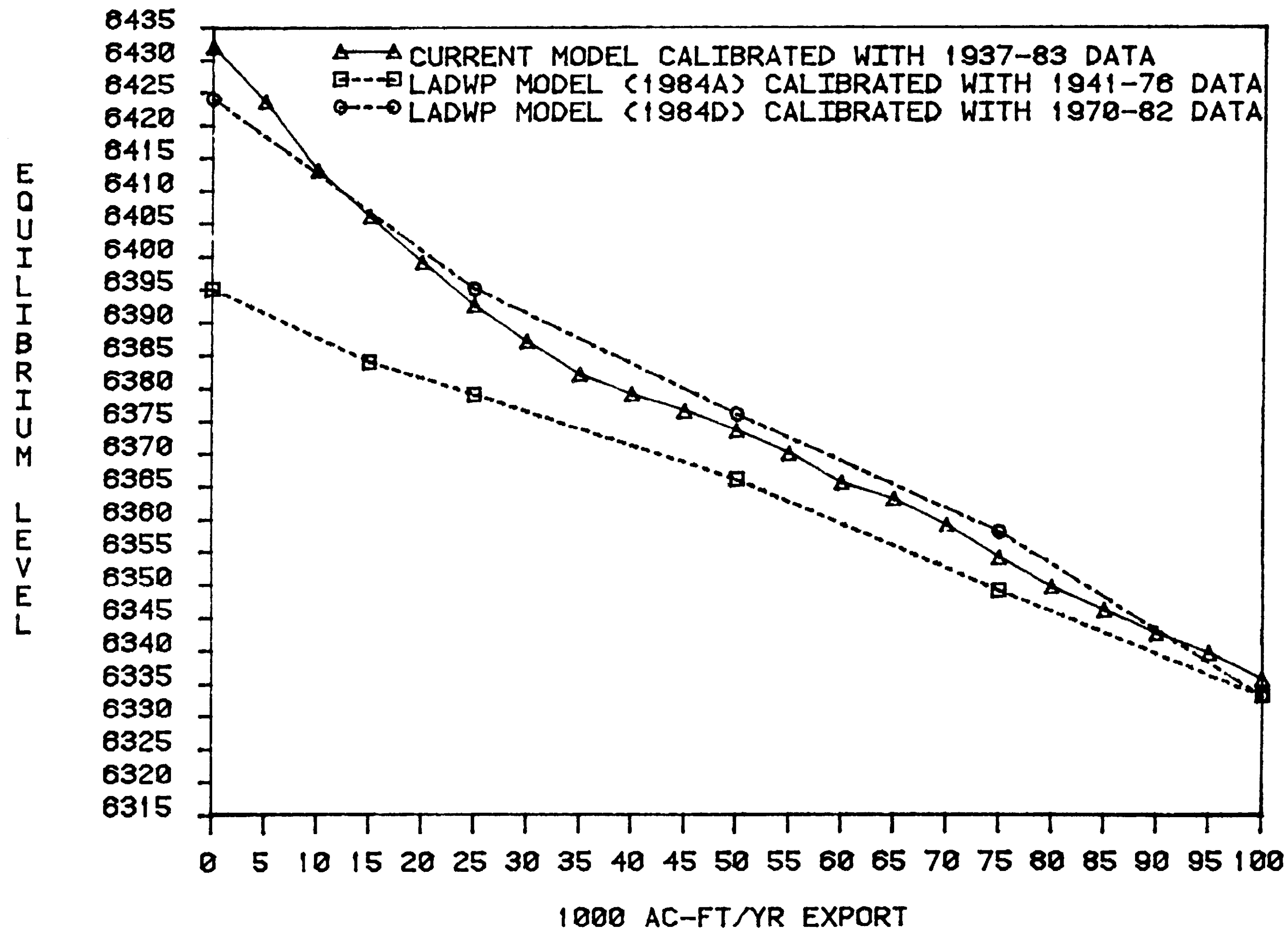


Figure 3-10. Comparison of Equilibrium Lake Levels for LADWP (1984a,d) Models and our Model

Figure 3-10 shows that the equilibrium levels calculated by LADWP (1984d) are significantly higher than those calculated by their (1984a) model. This is because the provisionally updated model calculates a future average inflow to the lake of about 148,000 ac-ft (assuming no export) or about 19% higher than their (1984a) calculated inflow. The reason that the calculated inflow is 19% higher even though the measured runoff is only 2% higher is that the calculated inflow is derived from an equation that is a regression of residually determined inflow values against the measured runoff, excluding Mill Creek (note that the LADWP 1984a model includes Mill Creek; besides the problem of using residual values, the 1970-82 equation is based on only 13 data points, too few to get reliable results.

APPLICATION 2D: FUTURE LAKE SALINITIES USING THE SEQUENCE OF 1937-83 HYDROCLIMATIC CONDITIONS.

Purpose: This application projects the future salinity of Mono Lake. Salinity is related to lake level in a uniform way if one assumes a constant dissolved solids tonnage and the current lake basin morphometry that includes Paoha Island.[ll] The relationship of salinity to lake level is given in Appendix I-C.

Assumptions: This application uses the same assumptions as Application 2A and 2B so that the future salinities can be evaluated when the immediate future hydroclimatic conditions are either somewhat wetter (1937-46 conditions) or drier (1947-64 conditions) than the 1937-83 normal. The model calculates the end-of-water-year salinity as total dissolved solids (TDS) in grams per liter (g/l) with the equation developed by Herbst (pers comm 1984) which converts the model-calculated specific gravity to an equivalent TDS.

Results: The projected salinities in the next 47 years for selected export scenarios using the 1937-83 sequence with both the initially below normal (1947-64) and above normal (1937-46) conditions are shown in Figure 3-11. The salinity values represent the salinity of a uniform, well-mixed lake with the same solids amount as the current lake. They can thus only be used as a rough guide to the future salinities. Data from 1983 and 1984, for example, suggest that if the lake level is low and salinities are high, an abnormally high freshwater inflow (due to releases by LADWP and precipitation) prevents the lake from turning over and mixing in the fall. At lower lake levels and thus higher salinities the lack of lake mixing is even more likely to occur as a result of fall and winter reservoir releases to the lake in the above normal runoff years. Whether this merimictic condition would persist requires a better understanding of the chemical dynamics of Mono Lake. Other complexities in projecting future salinities include Black's (1958) suggestion that sodium bicarbonate could precipitate out before the brine reaches saturation. It is also possible that some solids would precipitate out in shallow areas sooner than they would in the main water mass.

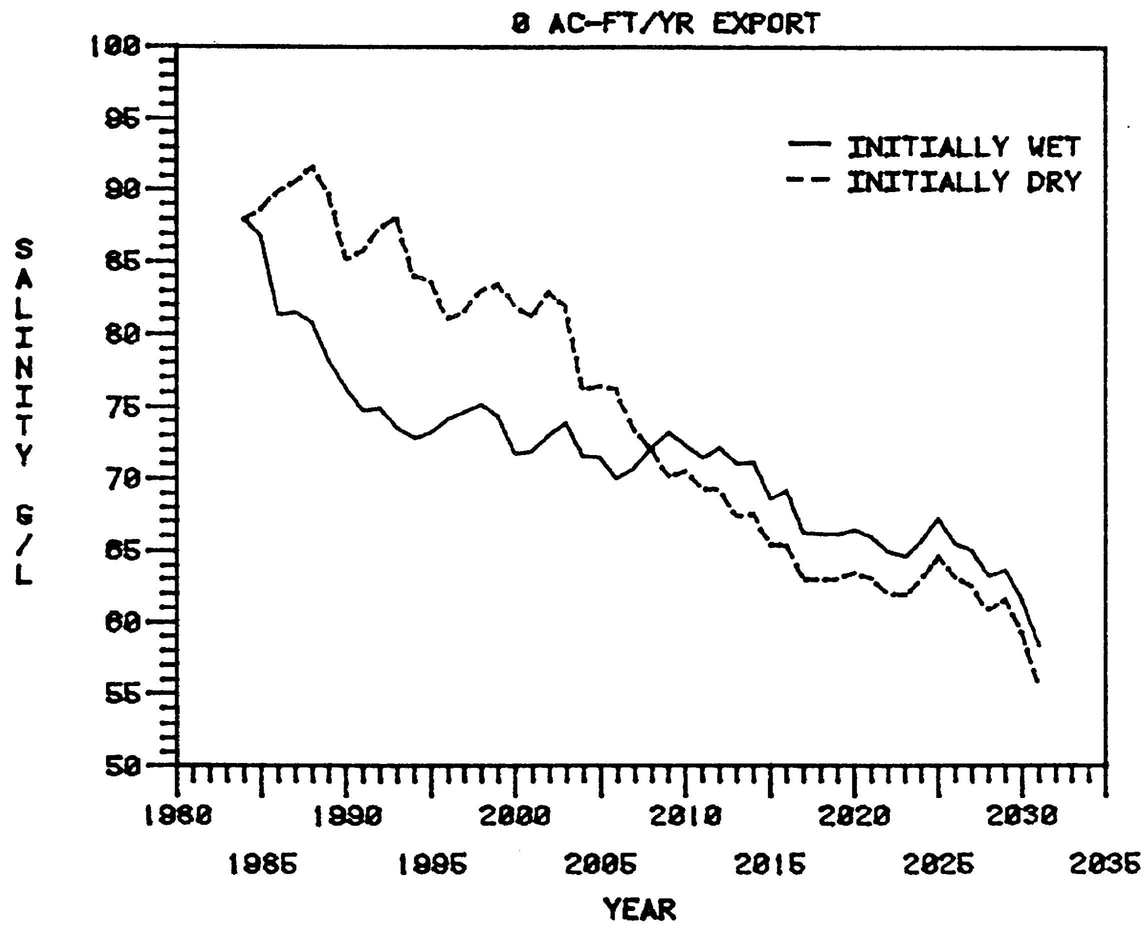


Figure 3-11a Projected Salinity Fluctuations Using 1937-83 Hydroclimatic Conditions With Initial Wet Sequence (1937-46) and Initial Dry Sequence (1947-64)

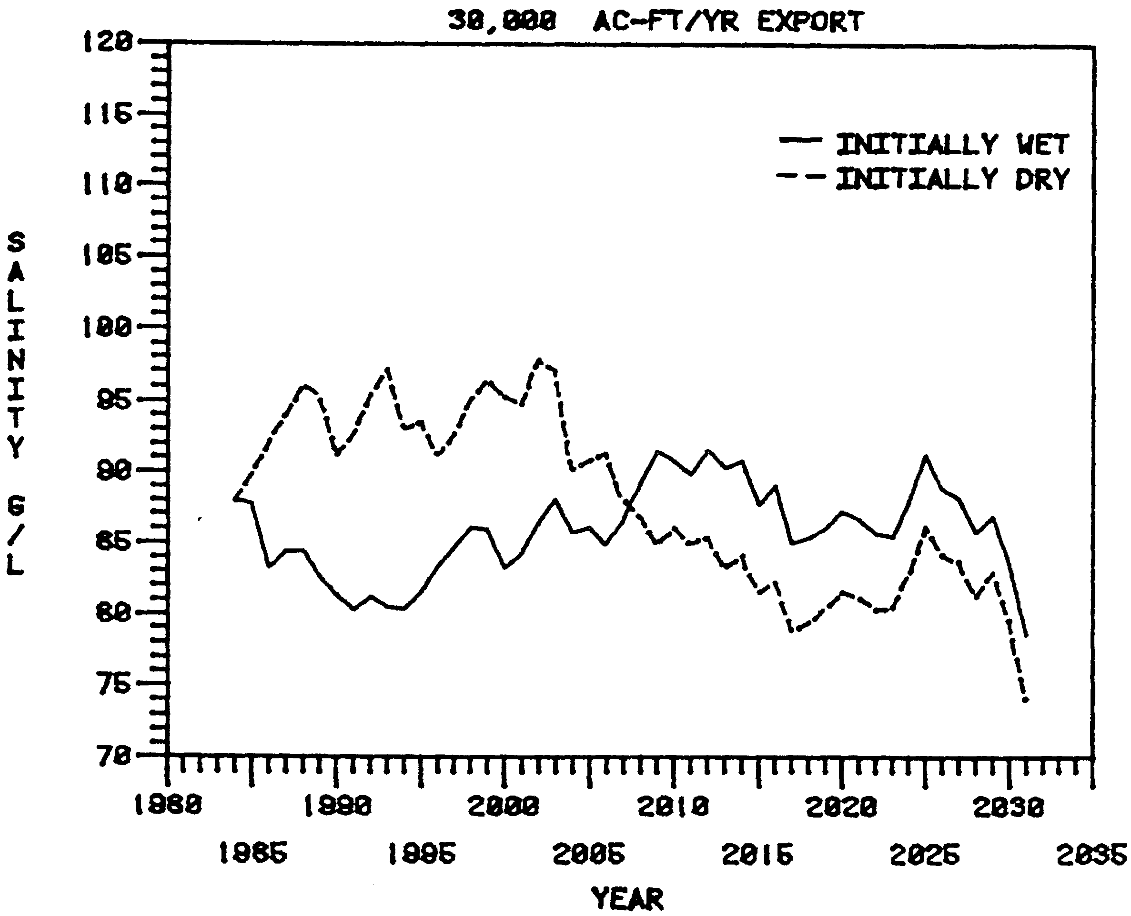


Figure 3-11b Projected Salinity Fluctuations Using 1937-83 Hydroclimatic Conditions With Initial Wet Sequence (1937-46) and Initial Dry Sequence.

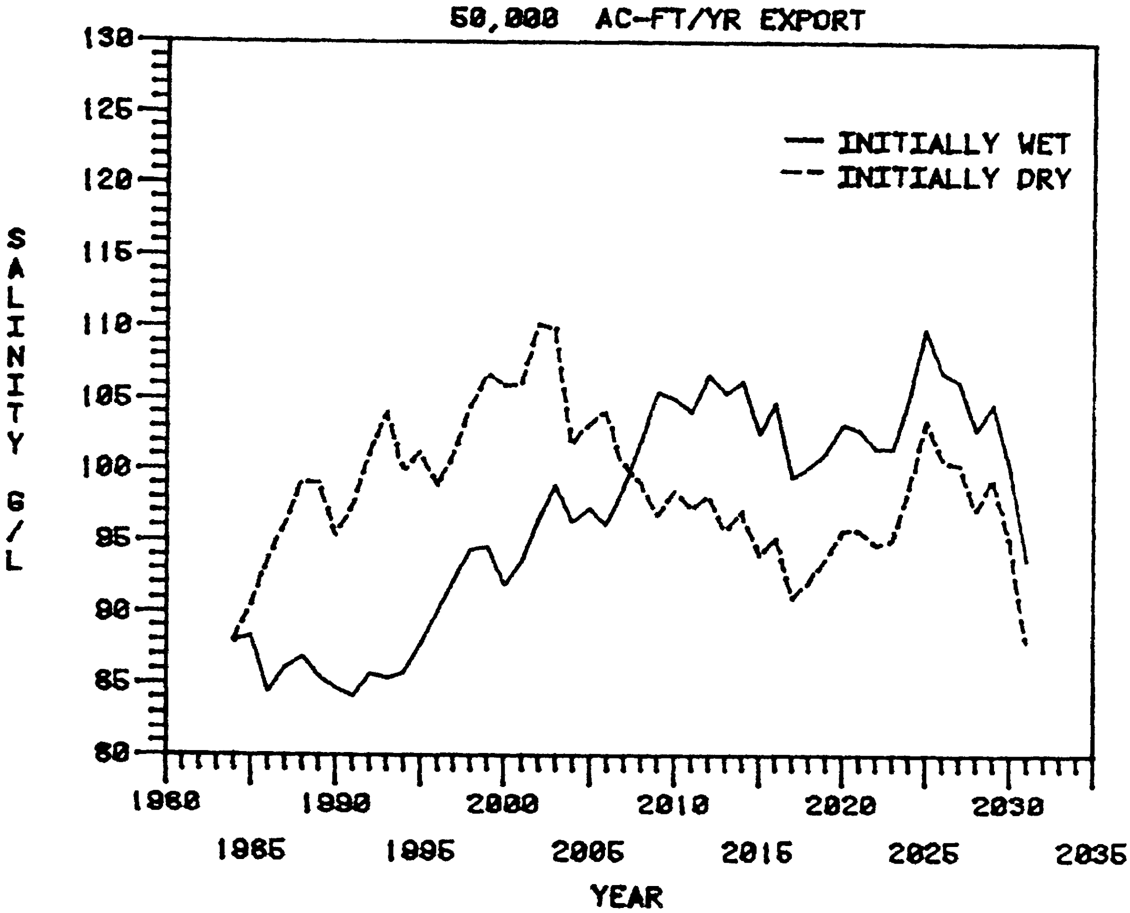


Figure 3-11c Projected Salinity Fluctuations Using 1937-83 Hydroclimatic Conditions With Initial Wet Sequence (1937-46) and Initial Dry Sequence (1947-64)

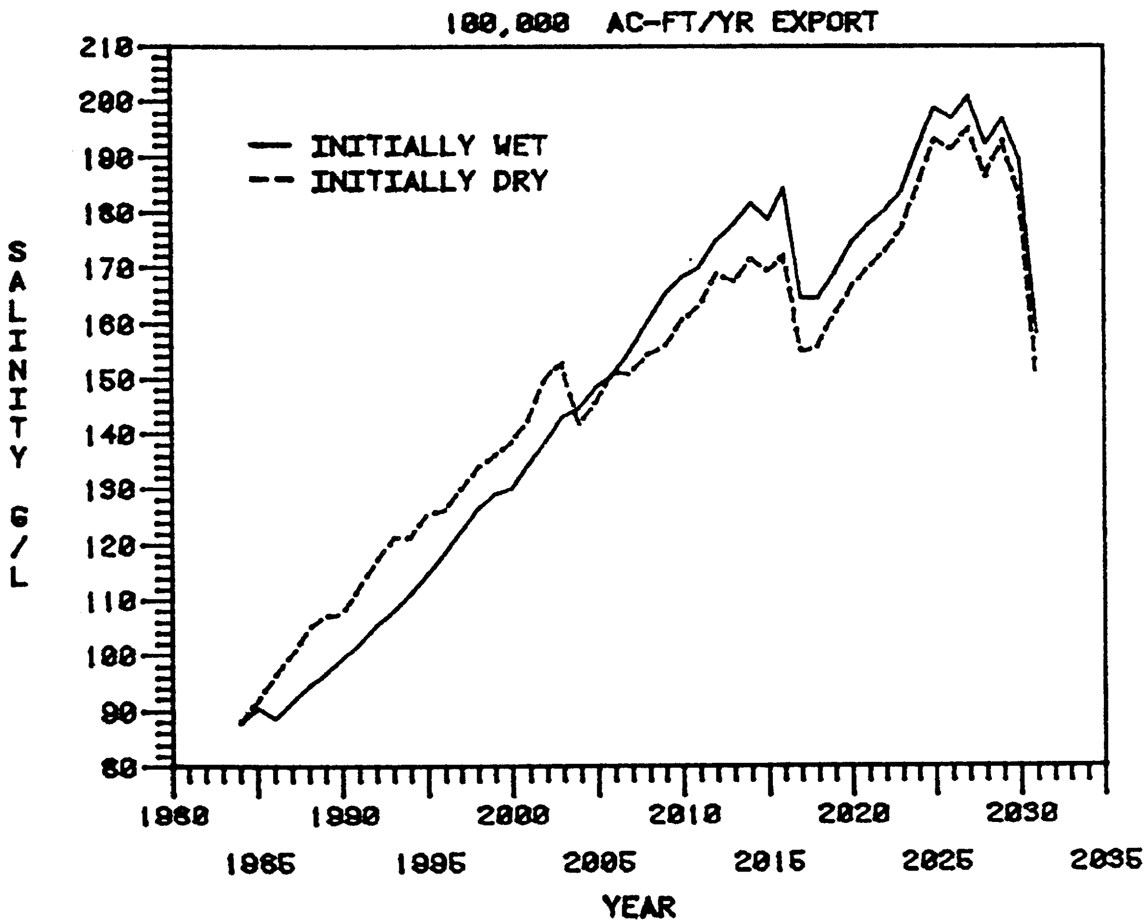


Figure 3-11d Projected Salinity Flucutations Using 1937-83 Hydroclimatic Conditions With Initial Wet Sequence (1937-46) and Initial Dry Sequence (1947-64)

The long-term salinity variations, assuming a repitition of 1937-83 conditions are shown in Figure 3-12. These results are shown mainly to point out the range of salinity fluctuations that a particular export scenario would produce.

Comparison to Previous Results: LADWP (1984a) and Loeffler (1977) forecast salinities assuming average hydroclimatic conditions and 100,000 ac-ft/yr surface water export.

Their results are determined by their forecasted lake levels and the stage/area/volume relationship based on Russell's 1883 bathymetry. Because this model uses a different stage/area/volume relationship, the difference in the corresponding stage/salinity relationships precludes direct comparison of the results. [12]

## APPLICATION 3: DETERMINE THE SENSITIVITY OF MONO LAKE LEVELS TO CHANGES IN COMPONENT VALUES

PURPOSE:

The main purpose of this application is to evaluate the effect that changes in the projected component values due to climatic change, would have on the forecasted lake levels.[l3]

ASSUMPTIONS:

This application uses the same assumptions, including the same calibration terms, as Application 2C (i.e. average

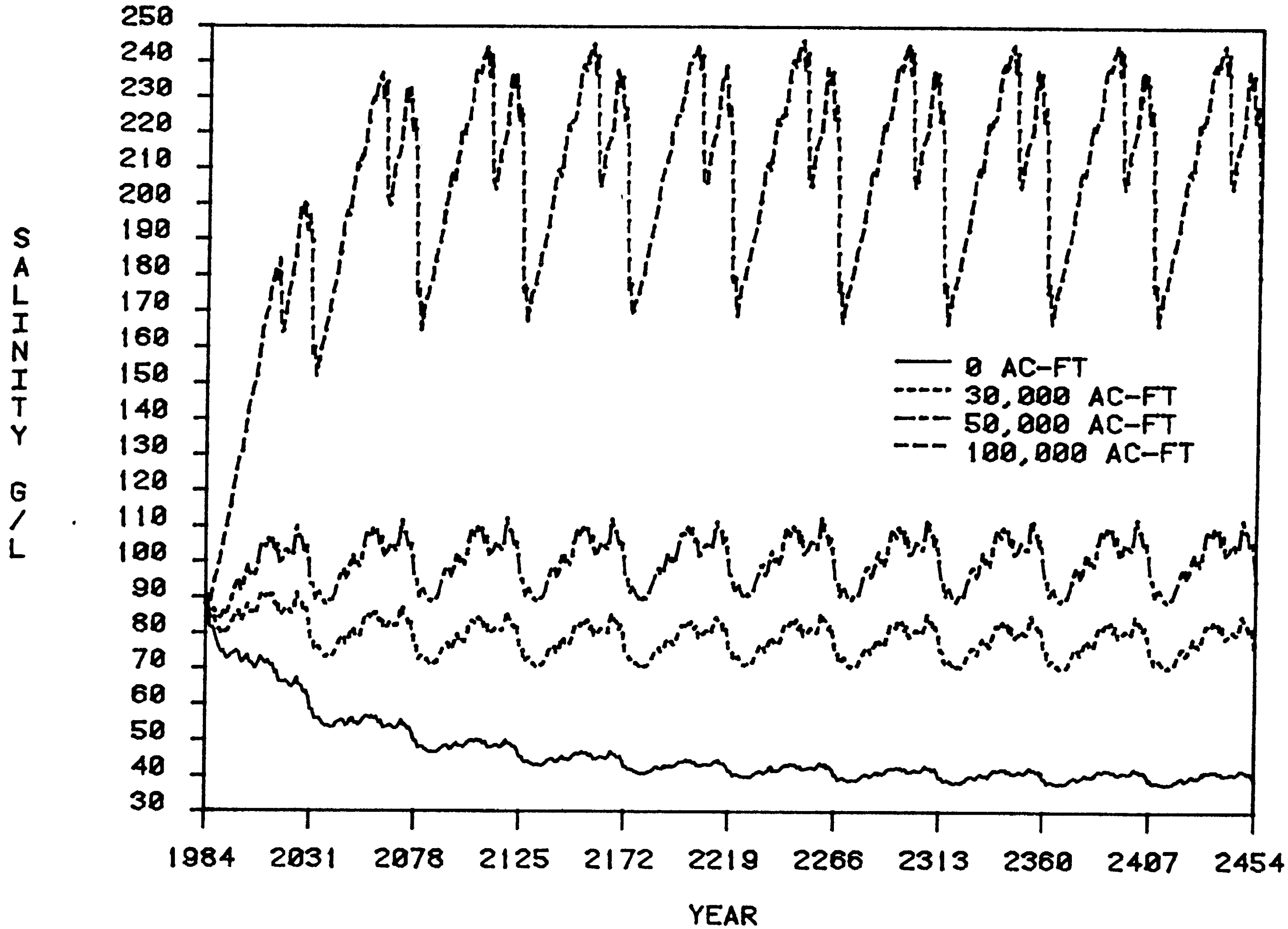


Figure 3-12 Projected Long-Term Salinity Fluctuations, 1985-2454, With Repetition of 1937-83 Hydroclimatic Conditions, For Exports of 0, 30, 50, and 100 Thousand ac-ft/yr

hydroclimatic conditions) except for the one variable value that is changed for the test. Each test involves changing one component variable to a value that is climatically plausible, and then forecasting with the calibrated model. The following tests were made:

1. the evaporation index is changed from .998 to .95 in each year, effectively reducing the annual unadjusted Mono Lake evaporation rate from 45 inches to 42 inches.
2. the runoff index is changed from 1.0 to 0.95 in each year, causing the average runoff to be similar to the 1937-79 average runoff.
3. the error term is arbitrarily increased by 1,000 ac-ft in each year, to reflect possible changes in several different components.

RESULTS:

The annual difference from the expected lake level change initially ranges from about 0.02 ft for test "3" (1,000 ac-ft change) to 0.17 ft for test "1" (.95 evaporation index). Although these annual differences gradually decrease over time, their accumulation can result in a noticeable divergence of the expected lake level in any one year from the lake level calculated for the test. Figure 3-13 shows the relative difference from the expected levels in the short-term (10 years), intermediate-term (47 years), and long-term (470 years) for various export scenarios. Figure 3-13 suggests that a relatively small change in the assumed climatic conditions can cause a noticeable difference in the forecasted lake level in the

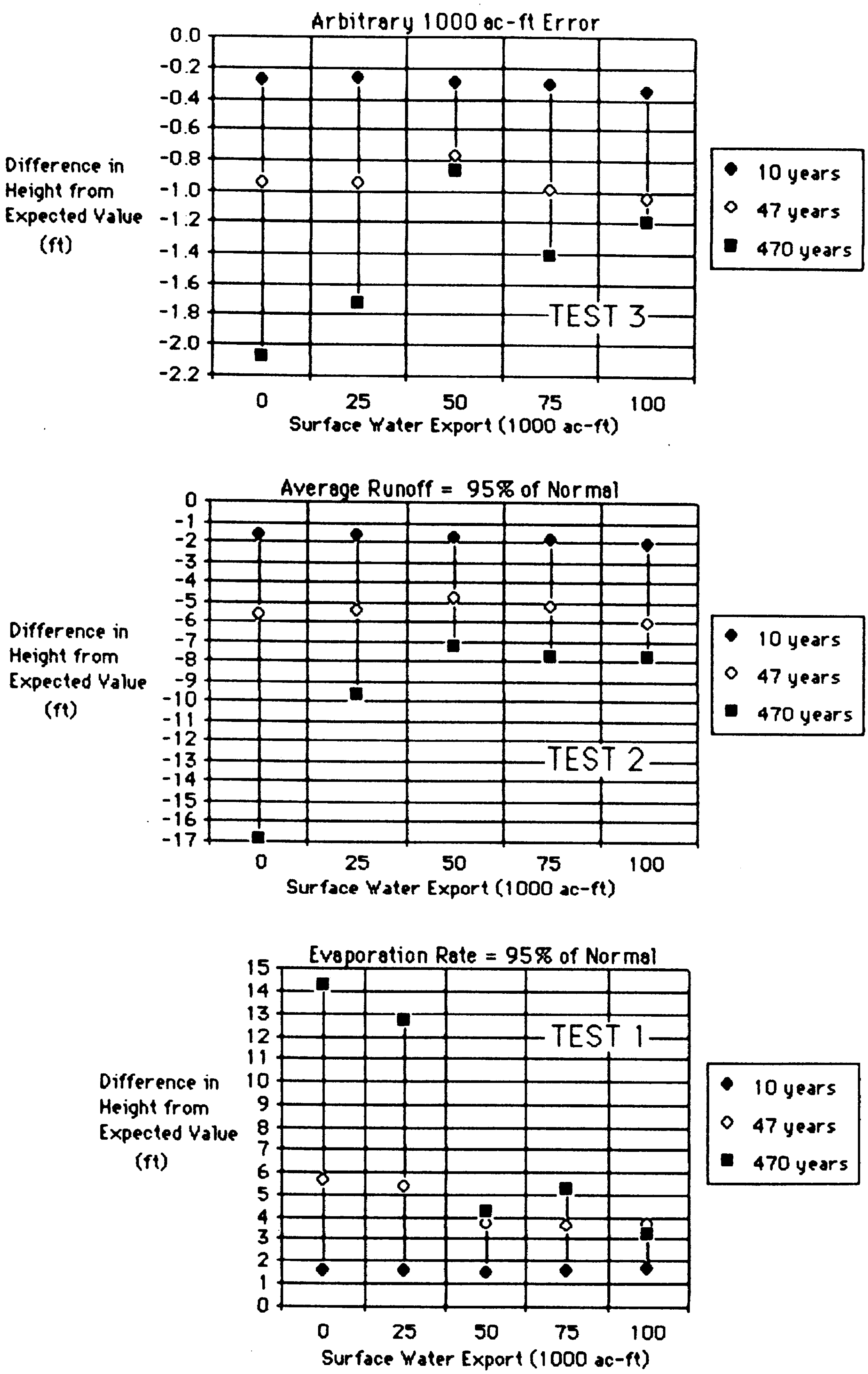


**Figure 3-13**. Sensitivity of Forecasted Lake Levels to Different Component Values

intermediate and long term. Plotting the hypothetical equilibrium level against export rate in Figure 3-14 for each "test" along with the curve for the expected values as generated in Application 2C shows the sensitivity of the lake level over the long term (470 years). Although the differences from the expected lake level are significant over the long-term, one must remember that the longer the forecast the less realistic the result because of the extremely remote possibility of the persistence of the assumed hydroclimatic conditions.

The test for the evaporation index emphasizes the need for accurate estimate of Mono Lake's evaporation rate. The test for the runoff index reiterates the fact that the forecasted equilibrium level for a given export scenario is a function of the assumed hydroclimatic conditions. These conditions should always be clearly specified in any discussion of export reduction and lake level maintenance.

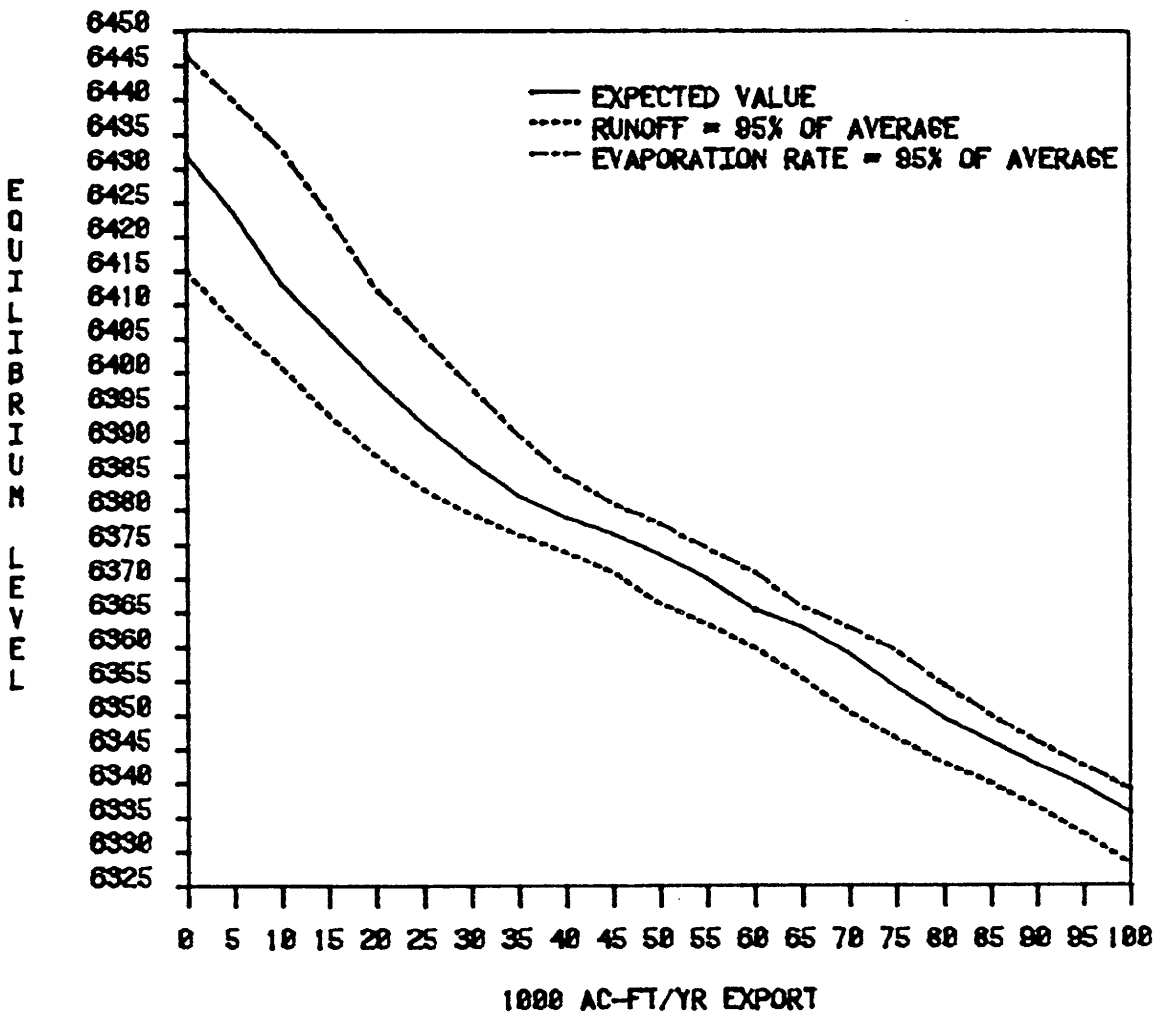


Figure 3-14 Sensitivity of Equilibrium Level to Changes in Component Values as a Function of Export

Footnotes

(1) Since all the reservoirs (except Waugh Lake) are enlargements of natural lakes, only the annual net increase of evaporation over the natural lake evaporation is relevant. The net evaporation increase is less than 400 ac-ft/yr.

(2) Some of the irrigated land would have supported native phreatophytes without artificial irrigation. The net decrease in evapotranspiration if there were no irrigation would be about 4000 ac-ft/yr assuming that about 3000 acres out of the 5000 irrigated in 1937 could still support native phreatophytes.

(3) The annual BGE when the lake is at 6428 ft is equal to 1850 ac-ft or the sum of the evaporation from the 400 ac of lagoon surface area (1500 ac-ft) and the bare ground evaporation from land immediately around the lake shore (350 ac-ft). The land around the lakeshore is assumed to be a "ring" 100 ft wide around the 40 mile circumference of the lake thus encompassing about 500 ac. It is assumed to evaporate at a rate of 0.7 ft/yr. This "ring" of land is affected by seiching and wave run-up and presumably would have relatively high water tables.

(4) If LADWP diversions continue at an average rate of 100,000 ac-ft/yr the RET might stabilize at a slightly lower level assuming, as postulated by Taylor (1980), the riparian acreage on lower Lee Vining and Rush Creeks has not come into equilibrium with the reduced stream flow; since any further declines in acreage would be very small, the corresponding change in the RET would also be very small.

(5) Since the pre-diversion riparian vegetation withstood significant reductions in flow due to irrigation diversions and drought conditions, it is assumed that riparian acreage can withstand some reduction in stream flow due to exports.

(6) LADWP's current operational response to 1937-69 runoff conditions would be somewhat different because aqueduct operational variables such as Owens Valley groundwater pumping, San Fernando Groundwater Basin recharge, and Los Angeles water demand have changed since the 1971 report; since LADWP has not provided more up-to-date operation simulations the Tilleman report is the best data base to use to simulate LADWP's expected exports given 1937-69 runoff conditions.

(7) Precipitation on the lake surface is excluded since the volume of precipitation is a function of the lake area which does not have a meaningful average.

(8) 155,000 ac-ft = 197,107 ac-ft (1937-83 average inflow) minus . 7258 ac-ft (LADWP groundwater export) minus 35,000 ac-ft (average LADWP surface water export). The dynamic equilibrium condition determined by the 1937-83 hydroclimatic sequence and 35,000 ac-ft

of LADWP surface water export always keeps the lake above 6378 ft except in one year -- the equivalent of 1977 runoff conditions -- when the lake drops to 6377 ft. It is possible that the same average inflow but a different, more variable hydroclimatic sequence would cause greater fluctuations in the dynamic equilibrium and thus a lower minimum lake level. If in the short-term future there is a dry period, then a constant 35,000 ac-ft of LADWP export causes the lake to drop below 6375 ft.

(8) 140,000 = 197,107 - 7,258 - 50,000

(9) 0.998 is the 1937-83 evaporation index average because the index relied on non-normalized Tinemaha Reservoir pan measurements for the first seven years.

(10) Even after the annual lake level change is less than 0.01 ft the lake rises slowly for many years ( up to 466 years) until "true" equilibrium is reached, i.e. when there is no change at all. The time it takes to achieve equilibrium is determined by the unique balance between the inflow and outflow components, some values of which are effected by the ever-changing lake area.

(11) Prior to Paoha's emergence about 200 years ago, the lake contained more water and thus had a lower salinity at any given lake elevation (Stine pers comm 1984).

(12) In addition it is unknown what tonnage of salts Loeffler assumed.

(13) This application should not be interpreted to reflect the model's sensitivity to errors in component values. The sensitivity of the forecast to errors in component values is hard to evaluate. A constant component error would change the overall error by a constant amount which would result in a calibration equation with the same coefficients but a constant term different in proportion to the amount of the error. As a result, the forecasted lake levels would be exactly the same, Table 2-14 evaluates the sensitivity of the total inflow or total outflow to component error.