M E M O R A N D U M

December 1, 1994

TO: File

FROM: John J. Whipple, Staff Engineer

SUBJECT: Ute Reservoir Yield Update

ABSTRACT

The determination of water yield from Ute Reservoir was updated based on new information now available. The firm annual yield for the reservoir is estimated to be in the range of 18,000 acre-feet to 22,500 acre-feet per year through the year 2045. This annual yield does not include recovery of about 2,500 acre-feet per year of seepage below Ute Dam. The annual yield can be increased by several thousand acre-feet per year if small occasional shortages in the Ute Reservoir water supply are acceptable to the entities which contract to purchase reservoir water.

INTRODUCTION

The most recent Ute Reservoir yield study conducted by the Interstate Stream Commission (ISC) staff was completed in January 1987. The reservoir yield determined by that study is outdated and needs updating due to changes in circumstances and new data now available. This update of the Ute Reservoir water yield is undertaken at this time for the following reasons:

(1) new storage restrictions on Ute Reservoir were adopted by the U.S. Supreme Court in its December 13, 1993, decree in Oklahoma and Texas v. New Mexico;

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(2) results of the Ute Reservoir sediment survey conducted in November 1992 indicate that the historic average sediment inflow rate to the reservoir has declined relative to previous sedimentation estimates;

(3) current option contracts to reserve the yield from Ute Reservoir for eastern New Mexico communities expire on December 31, 1994, and new water contracts for the reservoir yield are to be negotiated between these communities and the ISC;

(4) construction of works to divert Ute Reservoir water to eastern New Mexico communities has not commenced and will likely not be completed before the year 2005, thereby postponing the anticipated project operation period to the years 2006-2045; and

(5) hydrologic and meteorologic data are now available through the year 1993 to check the critical period and evaluate the water yield for Ute Reservoir.

DATA ANALYSES

Monthly hydrologic and meteorologic data were collected and evaluated for the period 1943-1993. Descriptions of the data available and data analyses performed follow.

Precipitation Data

The monthly precipitation rate at Ute Dam was determined from the following sources:

(1) Ute Dam precipitation data published by the U.S. Department of

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Commerce (USDC)[1], which data are generally available for the period 1965-1979;

(2) Ute Dam precipitation data recorded by the ISC's Ute Dam Caretaker, which data are generally available and reliable for 1980 and the period 1988-1993[2];

(3) Logan precipitation data published by the USWB, which data are generally available for the period 1943-1959; and

(4) Ute Dam precipitation estimates obtained using regression equations relating Ute Dam precipitation to Tucumcari 4 NE[3] precipitation data published by the USDC, which estimates were generally used for the periods 1960-1964 and 1981-1987.

The monthly precipitation at Logan was assumed to be directly transferable to the nearby Ute Dam area. The regression equations relating monthly Ute Dam precipitation to monthly precipitation at the Tucumcari 4 NE station were developed using the USDC and reliable Ute Dam Caretaker data for these sites available for much of the period 1964-1993. The regression equations are as follows:

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[1] The following federal agencies of the USDC have published meteorologic data for weather stations in New Mexico: (a) the U.S. Weather Bureau (USWB) for the period 1943-1965; (b) the Environmental Science Services Administration for the period 1966-August 1970; and (c) the National Oceanic and Atmospheric Administration (NOAA) for the period September 1970-1993.

[2] Ute Dam Caretaker data for other periods is either: (a) published with or without corrections by the USDC; (b) missing; or (c) determined by thorough review to be unreliable.

[3] The Tucumcari 4 NE weather station was published as Tucumcari 3 NE prior to March 1979. However, the weather station location was not changed and the Tucumcari 3 NE data are equivalent to the Tucumcari 4 NE data.

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Ute Dam precip = 0.90 x Tucumcari 4 NE precip (r^2=0.57)

for the months of April-October; and

Ute Dam precip = 1.00 x Tucumcari 4 NE precip (r^2=0.78)

for the months of November-March.

These equations are forced through the origin to avoid overestimating Ute Dam precipitation during months of low precipitation at Tucumcari. The degree of correlation of these equations during months of high precipitation at Tucumcari is not significantly affected by forcing the equations through the origin.

Evaporation Data

The monthly pan evaporation rate at Ute Dam was determined from the following sources:

(1) Ute Dam pan evaporation data published by the USDC[4], which data are generally available for the period 1965-1978;

(2) Ute Dam pan evaporation data recorded by the ISC's Ute Dam Caretaker, which data are generally available and reliable for the periods 1979-1980 and 1988-1993[5];

(3) Ute Dam pan evaporation estimates obtained using a regression equation relating Ute Dam pan evaporation to Tucumcari 4 NE[6] standard class A pan evaporation data published by the USDC, which estimates were generally used for the months of April-October for the periods 1953-1964 and 1981-1987;

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[4] See note 1.

[5] See note 2.

[6] See note 3.

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(4) Ute Dam pan evaporation estimates obtained using a regression equation relating Ute Dam pan evaporation to Conchas Dam pan evaporation data published by the USWB, which estimates were generally used for the months of April-October for the period 1943-1952; and

(5) Ute Dam average monthly pan evaporation rates, which rates were used for the months of November-March for much of the period 1943-1993.

The regression equations relating monthly Ute Dam pan evaporation to monthly class A pan evaporation at the Tucumcari 4 NE and Conchas Dam stations were developed using the USDC and reliable Ute Dam Caretaker data for these sites available for much of the period 1965-1993. The regression equations, with monthly pan evaporation in inches, are as follows:

Ute Dam evap = 0.74 x Tucumcari 4 NE evap + 1.80 (r^2=0.55);

and

Ute Dam evap = 0.66 x Conchas Dam evap + 3.27 (r^2=0.39).

These equations were developed using data for the months of April-October, and the equations are consequently applicable for these months only. The equation relating Ute Dam pan evaporation to pan evaporation at Tucumcari 4 NE is not valid for application to Tucumcari 4 NE pan evaporation data collected prior to June 1952 from non-standard shaped sunken pans. The average monthly pan evaporation rates for Ute Dam for the months of November-March were estimated using the USDC and reliable Ute Dam Caretaker data for Ute Dam available for these months for portions of the period 1965-

1993; and these average pan evaporation rates were used when pan evaporation data for Ute Dam were not available these months.

The monthly gross lake evaporation rate for Ute Reservoir was estimated using a pan coefficient of 0.7 and the monthly pan evaporation rate at Ute Dam. The monthly net lake evaporation rate for Ute Reservoir was determined by deducting the monthly precipitation rate at Ute Dam from the monthly gross lake evaporation rate.

Reservoir Inflow

The monthly inflow to Ute Reservoir under present conditions was determined from the following sources:

(1) historic Ute Reservoir inflow estimates obtained using reservoir water balance calculations, which estimates were made for the period December 1962-1993;

(2) Canadian River at Logan discharge data published by the U.S. Geological Survey (USGS), which data were used for the period 1948-November 1962[7]; and

(3) hypothetical Canadian River at Logan discharge estimates made by the New Mexico State Engineer Office (SEO) to reflect full development of the Tucumcari Project completed beginning 1948, which estimates were used for the period 1943-1947.

The discharge of the Canadian River at Logan was assumed to be the

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[7] Canadian River at Logan discharge data for years prior to 1948 are not representative of reservoir inflow conditions which now exist due to full development of the Tucumcari Project upstream from the Ute Reservoir site beginning 1948. Canadian River at Logan discharge data since closure of Ute Dam on December 13, 1962, are representative of reservoir outflow, not inflow, conditions.

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same as the discharge of the Canadian River at or below the Ute Dam site because there is only about one square mile of intervening drainage between the two locations.

The monthly inflow to Ute Reservoir beginning with closure of Ute Dam in December 1962 was estimated using water balance calculations which included the following factors:

(a) monthly outflow from Ute Reservoir, including dam seepage, releases and spills, as measured by the Canadian River at Logan discharge gage[8];

(b) monthly change in Ute Reservoir contents as determined using capacity tables prepared by the USGS and U.S. Bureau of Reclamation (USBR) and end-of-month reservoir elevation data generally published by the USGS;

(c) monthly mean surface area for Ute Reservoir as determined using area tables prepared by the USGS and USBR and average monthly reservoir elevation data generally estimated from ISC's Ute Dam Caretaker daily reservoir elevation data for the periods 1963-1980, 1985-1986 and 1988-1993 and from USGS published daily Ute Reservoir contents for the period 1981-1984 and 1987[9]; and

(d) monthly net lake evaporation rate for Ute Reservoir as determined using the procedures described previously in this memorandum.

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[8] No significant diversions of Ute Reservoir water have yet been made.

[9] Ute Dam Caretaker records of daily reservoir elevation data are generally missing for the period 1981-1984 and 1987.

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The monthly change in contents and the monthly mean surface area for Ute Reservoir were both estimated using a procedure whereby the lake capacities and areas were incrementally reduced on an annual basis for sediment accumulation as indicated by reservoir sediment surveys conducted in January 1963, December 1975, December 1983 and November 1992. This procedure assumes that no evaporative losses occurred from exposed sediment deposits within the original reservoir site. Subsurface evaporation and phreatophyte evapotranspiration within sediment delta formations are not known, and excluding them from the water balance calculations results in conservatively low estimates of reservoir inflow.

As a check on the reservoir inflows computed using the water balance procedure, reservoir inflows and Canadian River at Logan discharge data were compared to the inflow from Ute Creek alone as measured at the Ute Creek near Logan discharge gage. Ute Creek near Logan discharge data published by the USGS are available for the period 1942-1993, but 1942 is excluded from this comparison because of the extraordinarily large amount of spill from Conchas Reservoir which occurred this year. The ratio of the annual average Canadian River discharge at Logan published by the USGS for the period 1943-1962 to the annual average computed inflow to Ute Reservoir for the period 1963-1993 is 1.75. The ratio of the annual average Ute Creek discharge near Logan for the period 1943-1962 to the annual average Ute Creek discharge for the period 1963-1993 is 1.98. The percentage contribution from Ute Creek to the total runoff of the Canadian River at Ute Dam was about 25 percent for the period 1943-1962 and about 23 percent for the period 1963-1993. The similarities in these ratios and in these percentages indicate that the inflows to Ute Reservoir since closure of Ute Dam, as calculated using the procedure described herein, are reliable for use to determine the yield of the reservoir.

Reservoir inflows for years prior to 1943 were not determined. Rather than adjust the gaged Canadian River at Logan discharge data for these years to reflect full development of the Tucumcari Project, the hypothetical reservoir operation studies used to update the Ute Reservoir yield assumed that the conservation storage capacity of Ute Reservoir would be near full at the beginning of the year 1943. This assumption was made for two reasons: (1) the extraordinarily large Canadian River flows which occurred in 1941-1942 would have spilled Ute Reservoir through much of 1942; and (2) the conservation storage can be maintained near full until diversions to the eastern New Mexico communities commence. Reservoir inflows for the period 1943-1947 were taken from a 1960 SEO water supply study which projected the hypothetical discharge of the Canadian River at Logan for the years 1942-1947 based upon a hypothetical operation of Conchas Reservoir with full Tucumcari Project development. Conchas Reservoir is the Canadian River water supply storage facility for the Tucumcari Project, and Conchas Dam was closed in 1938. The project diversions from Conchas Reservoir and associated return flows to the Canadian River below Conchas Dam and above the Logan gage were assumed to be fully developed beginning 1948.

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Dam Seepage

Streamflow records published by the USGS indicate that the base flow of the Canadian River at Logan was at times negligible prior to closure of Ute Dam in December 1962. Since closure of the dam, the base flow of the Canadian River at Logan is essentially seepage through the dam embankment and foundation. A relationship between dam seepage and reservoir water surface elevation was determined by inspection of a plot for the period 1963-1993 of the monthly gaged discharge for the Canadian River at Logan versus the monthly average reservoir elevation data, which data were estimated as described previously in this memorandum. The resulting seepage rate curve gives a dam seepage rate of about 4 cubic-feet-per-second (cfs) when the reservoir is full to spillway crest.

Sedimentation

The future sedimentation rate for Ute Reservoir was projected using the results of reservoir sediment surveys conducted in January 1963 by the ISC and November 1992 by the USBR. In the period between these surveys, a total of about 28,200 acre-feet of sediment accumulated within the reservoir site below elevation 3790 feet. This amounts to an average annual sediment inflow rate of about 940 acre-feet per year for the period 1963-1992, including any compaction of sediments within the reservoir. The sediment inflow rate for the 1963-1992 period was extrapolated to a long-term average annual sediment inflow rate of 1190 acre-feet per year using the ratio of the annual average Ute Reservoir inflow for the period 1943-1993 to the annual average reservoir inflow for the period 1963-1993. This assumes that sediment inflow to and deposition in Ute Reservoir are directly proportional to water inflow to the reservoir, and that the sediment trap efficiency will continue to be nearly 100 percent. Should extraordinarily large reservoir inflows, such as those which would have occurred in 1941-1942, occur in the future, the hydraulic detention time would be low enough during this event that a 100 percent sediment trap efficiency could not be assumed during the duration of the event. Consideration also of the large runoff which occurred in the years 1941-1942 would result in a long-term average annual sediment inflow rate for Ute Reservoir of approximately 2000 acre-feet per year.

It was assumed that the average annual sediment inflow rate for Ute Reservoir beginning 1993 will be 1190 acre-feet per year. Total sediment deposition volumes in Ute Reservoir at the end of the years 2005, 2025 and 2045 were estimated based on this projected sediment inflow rate and the amount of sediment deposited in the reservoir during the period 1963-1992. The sediment volumes were distributed in the reservoir below elevation 3790 feet using the empirical area-reduction method and a type II sediment area design curve. Selection of the type II design curve was based on the original reservoir topography and reservoir operations, and it was verified by distributing historic sediment deposition volumes and comparing the resultant computed capacity curves with the capacity curves derived directly from the sediment surveys. Distributing sediment to 3 feet above spillway crest allows for

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some sediment deposition in backwater areas at full reservoir storage.

The conservation storage capacity limitations imposed by the decree in Oklahoma and Texas v. New Mexico and the current listed conservation storage capacities of other reservoirs in the Canadian River drainage in New Mexico below Conchas Dam have the effect of limiting the total conservation storage permitted New Mexico in Ute Reservoir to a maximum of 193,240 acre-feet. This total conservation storage in Ute Reservoir includes inactive storage currently maintained above the outlet works sill elevation of 3725 feet. The inactive storage pool in Ute Reservoir will be maintained indefinitely at elevation 3741.6 feet in accordance with the 1962 Memorandum of Agreement between the ISC and the New Mexico State Game and Fish Commission. The inactive storage between elevations 3725 feet and 3741.6 feet is presently considered under the decree to be conservation storage for such purposes as fish and wildlife and recreation.[10] The capacities of the dead storage pool below elevation 3725 feet, the inactive conservation storage pool between elevations 3725 feet and 3741.6 feet, and the active conservation storage pool above elevation 3741.6 feet that are estimated after projecting the sediment volume distributions in the reservoir for specified years are given in the following table.

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[10] It is possible under the decree that this inactive storage may be reclassified at a future date to be for sediment control purposes, which would exempt the inactive storage from being counted against the conservation storage limitation of the decree.

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End of Year	Dead Pool Capacity (acre-feet)	Inactive Conservation Pool Capacity (acre-feet)	Active Conservation Pool Capacity (acre-feet)	Top of Conservation Pool Elevation (feet)
2005	6,700	20,500	172,700	3783.0
2025	1,900	15,000	178,200	3785.6
2045	0	8,500	173,700	3787.0

The conservation storage capacity at the end of year 2045 is limited by the spillway crest at elevation 3787 feet. The elevations of sediment deposits near the dam at the end of 2005, 2025 and 2045 are estimated from the sediment volume distributions to be about 3705 feet, 3715 feet and 3725 feet, respectively.

RESERVOIR SIMULATION MODEL

The reservoir simulation model used to assess the water yield for Ute Reservoir consisted of water balance calculations performed monthly for the study period. The water balance included reservoir storage, inflow, precipitation, evaporation, dam seepage, water demand releases and spills. Bank storage was not accounted. The percentage monthly distribution of the annual water demand was taken from a 1977 USBR water supply study for Ute Reservoir. Spills included physical spills over the Ute Dam spillway at elevation 3787 feet and downstream releases at the maximum safe release rate from Ute Reservoir required by the decree in Oklahoma and Texas v. New Mexico when storage is above the top of the conservation pool. The maximum safe release rate for the Ute Dam outlet works was assumed to be about 360 cfs when the reservoir is full to spillway crest. No releases to meet the demand were made when the reservoir storage was at or below the top of the inactive pool at elevation 3741.6 feet.

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expected to occur during the anticipated project operation period 2006-2045.

The firm yields described above and shown in figures 1 and 2 were derived using surface areas for Ute Reservoir estimated from projected future lake area curves which take into account accumulated sediment deposits through the year of interest. This procedure assumes that no evaporative losses will occur from exposed sediment deposits within the original reservoir site. Subsurface evaporation via capillary action and phreatophyte evapotranspiration rates within sediment delta formations are not known, and excluding them from the reservoir operation simulations tends to result in conservatively high estimates of reservoir water yield. On the other hand, use of conservatively low reservoir inflows in the simulations tends to result in conservatively low estimates of reservoir yield. Whether these factors offset each other is not known. If it was assumed that evaporative losses would occur from exposed delta deposits at the same rate as evaporation from the reservoir water surface, then the annual firm yield for Ute Reservoir would be about 18,000 acre-feet to 19,000 acre-feet per year. This yield was derived using the estimated long-term average sediment inflow rate of 1190 acre-feet per year and surface areas for the reservoir estimated from the original lake area curve developed from the 1963 sediment survey. The sensitivity of the firm yield estimate to the inclusion of evaporative losses from delta deposits is illustrated in figure 3, which shows the yield estimates which result from either excluding

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or including free-water surface evaporation amounts for the sediment delta areas. The thickness of delta deposits may generally exceed 20 feet by the end of the study period.

The annual yield from Ute Reservoir can be significantly increased if water shortages in the reservoir water supply are acceptable. For example, figure 4 illustrates the relatively small sensitivity of the total water shortage amount for the entire 1943-1993 period estimated by the reservoir operation simulations to the annual water yield for Ute Reservoir. If the annual yield for the reservoir is increased by about 3,000 acre-feet per year above the firm yield, the reservoir simulations indicate that only in one year out of fifty would a shortage condition occur. This shortage condition might last for up to ten months and amount to about 60 percent of the annual water yield. The amount of water use out of Ute Reservoir can be maximized if the communities which contract for the reservoir yield are willing to accept small occasional shortages in the reservoir water supply.

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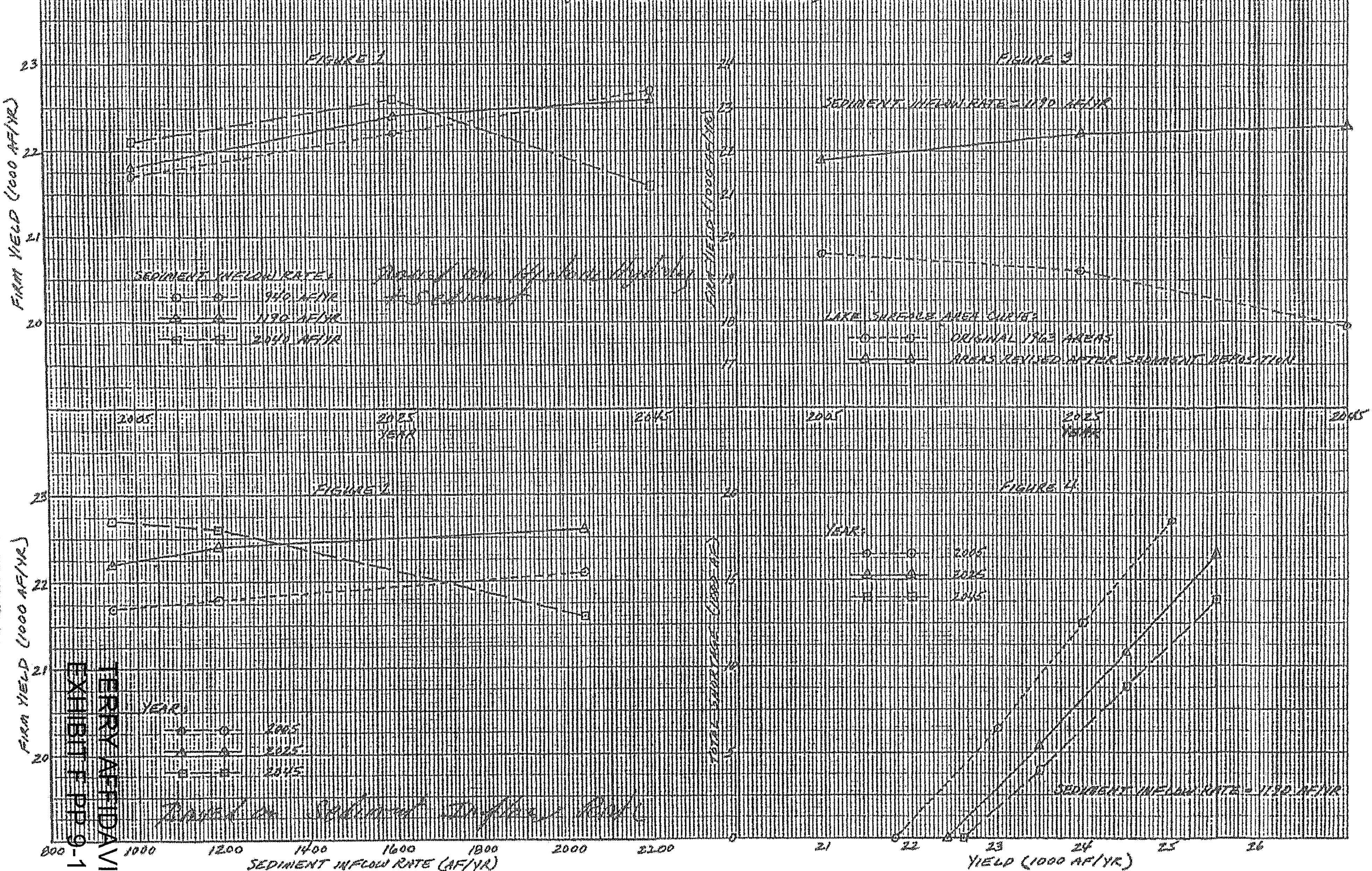
UTE RESERVOIR YIELD STUDY - 1994
(YIELDS EXCLUDING DAM SEEPAGE)



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