CLARK CANYON RESERVOIR
2000 RESERVOIR SURVEY

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The Bureau of Reclamation (Reclamation) surveyed Clark Canyon Reservoir in June of 2000 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The data were used to calculate reservoir capacity lost due to sediment accumulation since dam closure in August of 1964. The underwater survey was conducted in June of 2000 near reservoir elevation 5538 feet (project datum). The underwater survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the underwater portions of the reservoir covered by the survey vessel. The above-water topography was determined by digitizing the developed contour lines from the U.S. Geological Survey quadrangle (USGS quad) maps of the reservoir area. The new topographic map of Clark Canyon Reservoir was developed from the combined digitized USGS quad contours and June 2000 underwater measured topography. This study assumed no change from elevation 5540 and above.

As of June 2000, at top of joint use water surface elevation (feet) 5,546.1, the surface area was 5,151 acres with a total capacity of 174,367 acre-feet. Since initial filling in August of 1964, about 4,106 acre-feet of sediment have accumulated in Clark Canyon Reservoir below elevation 5,546.1, resulting in a 2.3 percent loss in reservoir volume. Since 1964, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 114.7 acre-feet.

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by

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Technical Service Center
Denver, Colorado

August 2001

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The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics Group of the Technical Service Center (TSC) prepared and published this report. Stephanie Schwinghammer and Ronald Ferrari of the TSC conducted the hydrographic survey. Ronald Ferrari completed the data processing needed to generate the new topographic map and area-capacity tables. Sharon Nuanes of the TSC completed the final map development. Kent Collins of TSC performed the technical peer review of this documentation.

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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INTRODUCTION

Clark Canyon Reservoir and dam are located in Beaverhead County at the head of the Beaverhead River about 20 miles southwest of Dillon, Montana (fig. 1). Clark Canyon Reservoir as part of the East Beach Unit provides irrigation, flood control, and recreation benefits. The dam and reservoir are operated and maintained by the East Bench Irrigation District.

Clark Canyon Dam was completed in 1964 and is a zoned earthfill structure whose dimensions are (fig. 2):

Hydraulic height[1]	113.9	feet[2]	Structural height	147.5	feet
Top width	36	feet	Crest length	2,950	feet
Crest elevation	5,578.0	feet			

The spillway is located in the left abutment of the dam and consists of an inlet channel, a free overflow crest at elevation 5560.4, a chute with underlying drainage gallery, and a stilling basin. The spillway provides a discharge of 9,530 cubic feet per second (cfs) at reservoir elevation 5571.9

The outlet works, through the left abutment, consists of an approach channel, concrete intake structure, concrete conduit, a gate chamber with four high-pressure gates, an access shaft, shaft house and stilling basin. The discharge capacity of the outlet works is 2,325 cfs at reservoir elevation 5,547.

The total drainage area above Clark Canyon Dam is 2,321 square miles of which 1,751 square miles are considered sediment contributing. Sediments from the remaining drainage area are trapped by Lima Reservoir that has a drainage area of 570 square miles. Clark Canyon Reservoir has an average width of 2.0 miles with a length of around 4.5 miles.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2000 results of the survey of Clark Canyon Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships
- estimate storage depletion caused by sediment deposition since dam closure

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[1]The definition of such terms as "hydraulic height," "structural height," etc. may be found in manuals such as Reclamation's *Design of Small Dams* and *Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs*, or ASCE's *Nomenclature for Hydraulics*.

[2]Elevation levels are shown in feet. All elevations shown in this report are based on the original project datum established by U.S. Bureau of Reclamation which is tied to the National Geodetic Vertical Datum of 1929.

A Real-time Kinematic (RTK) GPS control survey was conducted to establish a temporary horizontal and vertical control point for the reservoir survey. The horizontal control was established in Montana state plane coordinates in the North American Datum of 1983 (NAD83). The RTK GPS control was conducted with the base set on the NGS datum point "Dillon" located in the town of Dillon, Montana. All elevations in this report are reference to the Reclamation project datum that is tied to the NGVD29

The underwater survey was conducted in June of 2000 near reservoir water surface elevation 5,538. The bathymetric survey was run using sonic depth recording equipment interfaced with a differential global positioning system (DGPS) capable of determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates of the survey boat as it was navigated along grid lines covering Clark Canyon Reservoir. The positioning system provided information to allow the boat operator to maintain a course along these grid lines. Water surface elevations recorded by the reservoir gauge (tied to the Reclamation vertical datum) during the time of collection were used to convert the sonic depth measurements to true reservoir bottom elevations. The above-water topography was determined by digitizing the developed contour lines from the U.S. Geological Survey quadrangle (USGS quad) maps of the reservoir area.

The new Clark Canyon Reservoir topographic maps are a combination of the USGS quad contours and underwater survey data. The 2000 reservoir surface areas at predetermined contour intervals were generated by a computer graphics program using the collected reservoir data. The 2000 area and capacity tables were produced by a computer program that uses measured contour surface areas and a curve-fitting technique to compute area and capacity at prescribed elevation increments (Bureau of Reclamation, 1985).

Tables 1 and 2 contain a summary of the Clark Canyon Reservoir sedimentation and watershed characteristics for the 2000 survey. The 2000 survey determined that the reservoir has a total storage capacity of 174,367 acre-feet and a surface area of 5,151 acres at reservoir elevation 5,546.1. Since closure in August of 1964, the reservoir had an estimated volume change of 4,106 acre-feet below reservoir elevation 5,546.1. This volume represents a 2.3 percent loss in total capacity and an average annual loss of 114.7 acre-feet per year.

RESERVOIR OPERATIONS

Clark Canyon Dam operates as part of the East Bench Unit to provide flood control, irrigation water, and recreational use. The June 2000 area-capacity tables show 325,324 acre-feet of total storage below the maximum water surface elevation 5,571.9. The 2000 survey measured a minimum elevation of 5,449.0. The following values are from the June 2000 area-capacity tables:

- 71,882 acre-feet of surcharge between elevation 5,560.4 and 5,571.9.
- 79,075 acre-feet of flood control storage between elevation 5,546.1 and 5,560.4.
- 50,207 acre-feet of joint use storage below elevation 5,535.7 and 5,546.1.
- 123,099 acre-feet of conservation use between elevation 5,470.6 and 5,535.7.
- 1,057 acre-feet of inactive storage between elevation 5,455.0 and 5,470.6.
- 4 acre-feet of dead storage below elevation 5,455.0.

The Clark Canyon Reservoir inflow and end-of-month stage records in table 1, operation period August 1964 through June 2000, show the inflow and annual fluctuation since dam closure. The estimated average inflow into the reservoir for this operation period was 288,963 acre-feet per year. Since 1966, the extreme storage fluctuations of Clark Canyon Reservoir ranged from an elevation of 5,508.7 in 1989 to the maximum recorded elevation of 5,564.7 in 1984.

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in the cabin of a 24-foot trihull aluminum vessel equipped with twin in-board motors. The hydrographic system contained on the survey vessel consisted of a GPS receiver with a built-in radio and an omnidirectional antenna, a depth sounder, a helmsman display for navigation, a computer, and hydrographic system software for collecting underwater data. Power to the equipment was supplied by an on-board generator.

The shore equipment included a second GPS receiver with an external radio and an omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. To obtain the maximum radio transmission range, known datum points with clear line-of-sight to the survey boat were selected. The power for the shore unit was provided by a 12-volt battery.

GPS Technology and Equipment

The hydrographic positioning system used at Clark Canyon Reservoir was Navigation Satellite Timing and Ranging (NAVSTAR) GPS, an all-weather, radio-based, satellite navigation system that enables users to accurately determine three-dimensional position. The NAVSTAR system's primary mission is to provide passive global positioning and navigation for land-, air-, and sea-based strategic and tactical forces and is operated and maintained by the Department of Defense (DOD). The GPS receiver measures the distances between the satellites and itself and determines the receiver's position from intersections of the multiple-range vectors. Distances are determined by accurately measuring the time a signal pulse takes to travel from the satellite to the receiver.

The NAVSTAR system consists of three segments:

- The space segment is a network of 24 satellites maintained in a precise orbit about 10,900 nautical miles above the earth, each completing an orbit every 12 hours.

- The ground control segment tracks the satellites, determining their precise orbits. Periodically, the ground control segment transmits correction and other system data to all the satellites, and the data are then retransmitted to the user segment.

- The user segment includes the GPS receivers which measure the broadcasts from the satellites and calculate the position of the receivers.

The GPS receivers use the satellites as reference points for triangulating their position on earth. The position is calculated from distance measurements to the satellites that are determined by how long a radio signal takes to reach the receiver from the satellite. To calculate the receiver's position on earth, the satellite distance and the satellite's position in space are needed. The satellites transmit signals to the GPS receivers for distance measurements along with the data messages about their exact orbital location and operational status. The satellites transmit two "L" band frequencies (called L1 and L2) for the distance measurement signal. At least four satellite observations are required to mathematically solve for the four unknown receiver parameters (latitude, longitude, altitude, and time); the time unknown is caused by the clock error between the expensive satellite atomic clocks and the imperfect clocks in the GPS receivers.

The GPS receiver's absolute position is not as accurate as it appears in theory because of the function of range measurement precision and the geometric position of the satellites. Precision is affected by several factors--time, because of the clock differences, and atmospheric delays caused by the effect of the ionosphere on the radio signal. Geometric dilution of precision (GDOP) describes the geometrical uncertainty and is a function of the relative geometry of the satellites and the user. Generally, the closer together in angle two satellites are from the receiver, the greater the GDOP. GDOP is broken into components: position dilution of precision (x,y,z) (PDOP), and horizontal dilution of precision (x,y) (HDOP). The components are based only on the geometry of the satellites. The PDOP and HDOP were monitored at the survey vessel's GPS receiver during the Clark Canyon Reservoir Survey, and for the majority of the time they were less than 3, which is within the acceptable limits of horizontal accuracy for Class 1 and 2 level surveys (Corps of Engineers, 1994).

An additional and larger error source in GPS collection is caused by false signal projection, called selective availability (S/A). The DOD implements S/A to discourage the use of the satellite system as a guidance tool by hostile forces. Positions determined by a single receiver when S/A is active can have errors of up to 100 meters. In May of 2000 the use of S/A was discontinued, but the errors of a single receiver are still around $\pm$10 meters.

A method of collection to resolve or cancel the inherent errors of GPS is called differential GPS (DGPS). DGPS is used during the reservoir survey to determine positions of the moving survey vessel in real time. DGPS determines the position of one receiver in reference to another and is a method of increasing position accuracies by eliminating or minimizing the uncertainties. Differential positioning is not concerned with the absolute position of each unit but with the relative difference between the positions of two units, which are simultaneously observing the same satellites. The inherent errors are mostly canceled because the satellite transmission is essentially the same at both receivers.

At a known geographical benchmark, one GPS receiver is programmed with the known coordinates and stationed over the geographical benchmark. This receiver, known as the master or reference unit, remains over the known benchmark, monitors the movement of the satellites, and calculates its apparent geographical position by direct reception from the satellites. The inherent errors in the satellite position are determined relative to the master receiver's programmed position, and the necessary corrections or differences are transmitted to the mobile GPS receiver on the survey vessel.

For the Clark Canyon Reservoir survey, position corrections were determined by the master receiver and transmitted via an ultra-high frequency (UHF) radio link every second to the survey vessel mobile receiver. The survey vessel's GPS receiver used the corrections along with the satellite information it received to determine the vessel's differential location. Using DGPS can result in sub-meter positional accuracies for the survey vessel.

The Sedimentation and River Hydraulics Group conducts their bathymetric surveys using Real-time Kinematic (RTK) GPS. The major benefit of RTK versus DGPS is precise heights can be measured in real time for monitoring water surface elevation changes. The basic outputs from an RTK receiver are precise 3D coordinates in latitude, longitude, and height with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically. The output is on the GPS datum of WGS-84 which the hydrographic collection software converted into Montana's NAD83 state plane coordinate system. The system employs two receivers, like with DGPS, that collect additional satellite data that allows on-the-fly centimeter accuracy measurements.

Survey Method and Equipment

The Clark Canyon Reservoir hydrographic survey collection was conducted June 7 through June 10 of 2000 between water surface elevations 5,537.0 and 5537.9 (Reclamation project datum). The bathymetric survey was run using sonic depth recording equipment, interfaced with an RTK GPS, capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved across closely-spaced grid lines covering the reservoir area. Most of the transects (grid lines) were run somewhat in a north or south direction of the reservoir at a 400-foot spacing. Data was also collected along the shore as the boat traversed between transects. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining the course along these predetermined lines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing.

The 2000 underwater data were collected by a depth sounder that was calibrated by lowering a deflector plate below the boat by cables with known depths marked by beads. The depth sounder was calibrated by adjusting the speed of sound, which can vary with density, salinity, temperature, turbidity, and other conditions. The collected data were digitally transmitted to the computer collection system via a RS-232 port. The depth sounder also produces an analog hard-copy chart of the measured depths. These graphed analog charts were printed for all survey lines as the data were collected and recorded by the computer. The charts were analyzed during post-processing, and when the analog charted depths indicated a difference from the recorded computer bottom depths, the computer data files were modified. The water surface elevations at the dam, recorded by a Reclamation gauge, were used to convert the sonic depth measurements to true lake-bottom elevations.

Clark Canyon Reservoir Datums

Prior to the underwater survey in June 2000, a RTK GPS survey was conducted to establish a horizontal and vertical control point that overlooked Clark Canyon Reservoir. The National Geodetic Survey control point "Dillon" in the town of Dillon, Montana was used as the base station for the control survey. The radio link between Dillon and Clark Canyon Reservoir was intermittent, but control information appeared to be good for the horizontal and close for the vertical measurements. All vertical information in this report was referenced to the reservoir water surface gauge measurements during the time of this survey. The gauge is referenced to the Reclamation project datum that is reported as NGVD29.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Clark Canyon Reservoir was developed from the 2000-collected underwater data and from the USGS quad maps. The upper contours of Clark Canyon Reservoir were developed by digitizing the contour lines of elevation 5,542 and 5,560 from the USGS quad maps that covered the reservoir area. The USGS quad maps were developed from aerial photography dated 1964. There was a small area of the dam and reservoir not covered by the 1964 aerial that did not appear on the Dalys, Montana quad map. For this study, this area was interpolated using available original information. ARC/INFO V7.0.2 geographic information system software was used to digitize the USGS quad contours. The digitized contours were transformed to Montana's NAD 1983 state plane coordinates using the ARC/INFO PROJECT command. The resulting digitized areas from the USGS quad contours compared well with the original contour areas. The original computed surface area for elevation 5542.0 was 4,929 acres compared to the digitized computed area of 4,930.5 acres. The original area for elevation 5560.0 was measured as 5,880 acres compared to the digitized computed area of 5,879 acres.

The elevation 5,542.0 contour that was digitized from USGS quad maps was used to perform a clip of the Clark Canyon Reservoir triangular irregular network (TIN) such that interpolation was not allowed to occur outside the 5,542.0 contour. This complete contour was selected since it was the closest complete elevation to represent the reservoir at the time of the survey which was conducted near reservoir elevation 5,537. This clip was performed using the hardclip option of the ARC/INFO CREATETIN command. Using ARCEDIT, the underwater collected data and digitized contours from the quad maps were plotted. The plot found that the underwater data did not completely lie within this clip, which would require some modifications to include the entire underwater data set. These areas included the north and some on the south shores of the reservoir. It is assumed that most of this occurred due to shoreline erosion caused by the high winds that occur on this reservoir. Using select and move commands within ARCEDIT, the vertices of the 5,542.0 clip were shifted to fit all the collected underwater data.

Contours for the reservoir below elevation 5,542.0 were computed from the underwater data set using the triangular irregular network (TIN) surface modeling package within ARC/INFO. A TIN is a set of adjacent, non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. TIN was designed to deal with continuous data such as elevations. The TIN software uses a method known as Delaunay's criteria for triangulation where triangles are formed among all data points within the polygon clip. The method requires that a circle drawn through the three nodes of a triangle will contain no other point, meaning that sample points are connected to their nearest neighbors to form triangles using all collected data. This method preserves all collected survey points. Elevation contours are then interpolated along the triangle elements. The TIN method is discussed in greater detail in the ARC/INFO V7.0.2 *Users Documentation,* (ESRI, 1992).

The linear interpolation option of the ARC/INFO TINCONTOUR command was used to interpolate contours from the Clark Canyon Reservoir TIN. In addition, the contours were generalized by filtering out vertices along the contours. This generalization process improved the presentability of the resulting contours by removing very small variations in the contour lines. This generalization had no bearing on the computation of surface areas and volumes for Clark Canyon Reservoir since the areas were calculated from the developed TIN. The areas of the enclosed contour polygons developed from the survey data were completed for elevations 5,449.0 through elevation 5,542.0. The contour topography at 5-foot intervals is presented on figures 3 and 4, drawing numbers 699-D-569 and 699-D-570.

Development of 2000 Contour Areas

The 2000 contour surface areas for Clark Canyon Reservoir were computed at 1-foot increments from elevation 5,449.0 to 5,542.0. The 2000 underwater survey measured the minimum reservoir elevation at 5,449.0. These calculations were performed using the ARC/INFO VOLUME command. This command computes areas at user-specified elevations directly from the TIN and takes into consideration all regions of equal elevation. As indicated above, the underwater data was collected near reservoir elevation 5,537 and no above water data was collected during the 2000 survey. For the purpose of this study the measured 2000 survey areas at 5-foot increments from elevation 5,450 through 5,530 were used to compute the new area and capacity tables. Due to the lack of above water data this study assumed no area change from elevation 5,540 and above. The areas between elevation 5,530 and 5,540 were computed by the area and capacity program which assumed a straight line interpolation.

2000 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP85 (Bureau of Reclamation, 1985). Surface areas at 5-foot contour intervals from reservoir elevation 5,450.0 to elevation 5,530.0 were used as the control parameters for computing the Clark Canyon Reservoir capacity. Since this study did not collect any above water data, the original areas from elevation 5,540 and above were used to complete the table. The program can compute an area and capacity at elevation increments 0.01- to 1.0-foot by linear interpolation between the given contour surface areas. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit. The error limit was set at 0.000001 for Clark Canyon Reservoir. The capacity equation is then used over the full range of intervals fitting within this allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from basic area curve over that interval) is utilized until it exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Final area equations are derived by differentiating the capacity equations, which are of second order polynomial form:

$$y = a_1 + a_2x + a_3x^2$$

where:

y = capacity
x = elevation above a reference base
a_1 = intercept
a_2 and a_3 = coefficients

Results of the 2000 Clark Canyon Reservoir area and capacity computations are listed in table 1 and columns 4 and 5 of table 2. On table 2, columns 2 and 3 list the original surface areas and recomputed capacities. A separate set of 2000 area and capacity tables has been published for the 0.01, 0.1 and 1-foot elevation increments (Bureau of Reclamation 2000). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 2000 area-capacity curves are plotted on figure 5. As of June 2000, at elevation 5,571.9, the surface area was 6,606.2 acres with a total capacity of 325,324 acre-feet.

RESERVOIR SEDIMENT ANALYSES

Figure 5 is a plot of Clark Canyon Reservoir's original area data versus the 2000 measured areas. This illustrates the difference between the original and the 2000 measured surface areas. Since Clark Canyon Dam closure in August 1964, the measured total volume change at reservoir elevation 5,546.1 was estimated to be 4,106 acre-feet. The estimated average annual rate of capacity lost for this time period (35.8 years) was 114.7 acre-feet per year. The storage loss in terms of percent of original storage capacity was 2.3 percent. Tables 1 and 2 contain the Clark Canyon Reservoir sediment accumulation and water storage data based on the 2000 resurvey.

The original 100 year sediment inflow estimate used during the design of Clark Canyon Reservoir was 10,000 acre-feet for an average annual rate of capacity loss of 100 acre-feet which is near the 2000 survey computed result of 114.7 acre-feet per year. It must be noted that the 2000 area and capacity table were generated using measured surface areas from elevation 5,530 and below. The original surface areas from elevation 5,540 and above were used to complete the new area and capacity table. This assumed no surface area change from elevation 5,540 and above which in all probability is not the case. The ACAP program computed a straight line interpolation to compute the surface areas between elevation 5,530 and 5,540. Overlaying the 2000 collected data with the digitized USGS quad contours appears to indicate there has been shoreline erosion since the original survey at elevation 5,542, but the only way to confirm this would be to conduct a shoreline survey. A resurvey of Clark Canyon Reservoir should be considered in the future if major sediment inflow events are observed, or if the average annual rate of sediment accumulation requires further clarification.

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RESERVOIR SEDIMENT
DATA SUMMARY

Clark Canyon Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation	2. STREAM Beaverhead River	3. STATE Montana
	4. SEC. 32 TWP. 9 S RANGE 10 W	5. NEAREST P.O. Grant	6. COUNTY Beaverhead
	7. LAT 45° 00' 06" LONG 112° 51' 27"	8. TOP OF DAM ELEVATION 5578.0	9. SPILLWAY CREST EL 5560.4[1]

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, AC	13. ORIGINAL CAPACITY, AF	14. GROSS STORAGE ACRE- FEET	15. DATE STORAGE BEGAN
	a. SURCHARGE	5571.9	6,600	71,827	328,979	
	b. FLOOD CONTROL	5560.4	5,903	79,090	257,152	8/64
	c. POWER					
	d. JOINT USE	5546.1	5,160	50,436	178,062	16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION	5535.7	4,496	126,117	127,626	
	f. INACTIVE	5470.6	367	1,448	1,509	
	g. DEAD	5455.0	23	61	61	8/64
	17. LENGTH OF RESERVOIR	4.5 MILES		AVG. WIDTH OF RESERVOIR	2.0 MILES	

BASIN	18. TOTAL DRAINAGE AREA 2,321 SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 11.5[2] INCHES	
	19. NET SEDIMENT CONTRIBUTING AREA 1,751 SQUARE MILES		23. MEAN ANNUAL RUNOFF 2.33[3] INCHES	
	20. LENGTH MILES	AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 288,963[4] ACRE-FEET	
	21. MAX. ELEVATION	MIN. ELEVATION	25. ANNUAL TEMP. MEAN 43°F	RANGE -40°F to 100°F[2]

SURVEY DATA	26. DATE OF SURVEY	27. PER. YRS.	28. ACCL. YRS.	29. TYPE OF SURVEY	30. NO. OF RANGES OR INTERVAL	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO AF/AF
	8/64			Contour (D)	10-ft	5,151[5]	178,473[5]	.62
	6/00		35.8	Contour (D)	5-ft	5,151[6]	174,367[6]	.60

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	WATER INFLOW TO DATE, AF a. MEAN ANN.	b. TOTAL
6/00		288,963[7]	718,116	10,344,871	288,963	10,344,871

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET a. TOTAL	b. AV. ANN.	c. /MI.²-YR.	38. TOTAL SEDIMENT DEPOSITS TO DATE, AF a. TOTAL	b. AV. ANNUAL	c. /MI.²-YR.
6/00	4106[8]	114.7	0.066	4106	114.7	0.066

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT³)	40. SED. DEP. TONS/MI.²-YR. a. PERIOD	b. TOTAL TO	41. STORAGE LOSS, PCT. a. AV.	b. TOTAL TO	42. SEDIMENT a.	b.
6/00				0.064[9]	2.3[9]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION											
	5460-5465	5460-5470.6	5470.6 5480	5480-5495	5495-5505	5505-5515	5515-5525	5525-5530	5530-5535.7	5535.7 5546.1		
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
6/00	4.0	9.2	12.9	12.8	7.3	5.4	15.8	15.5	13.9	3.2		

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR													
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-105	105-110	110-115	115-120	120-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														

Table 1. - Reservoir sediment data summary (page 1 of 2).

45. RANGE IN RESERVOIR OPERATION[7]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1964	5,493.3		19,671	1965	5,547.0	5,493.6	336,701
1966	5,542.4	5,521.2	199,264	1967	5,543.6	5,521.3	194,348
1968	5,543.2	5,536.1	252,984	1969	5,543.7	5,535.7	348,496
1970	5,545.6	5,535.7	314,767	1971	5,547.4	5,537.3	428,853
1972	5,542.8	5,535.7	393,999	1973	5,545.5	5,525.3	277,711
1974	5,543.4	5,517.9	266,131	1975	5,556.9	5,516.8	410,178
1976	5,554.5	5,540.5	408,233	1977	5,546.4	5,531.5	211,457
1978	5,547.5	5,533.1	263,965	1979	5,548.3	5,531.0	237,730
1980	5,548.2	5,532.2	250,648	1981	5,550.8	5,534.6	298,216
1982	5,549.6	5,534.6	333,406	1983	5,547.9	5,541.5	386,884
1984	5,564.7	5,542.2	718,116	1985	5,544.9	5,524.4	317,466
1986	5,545.8	5,536.8	250,958	1987	5,544.6	5,536.5	223,408
1988	5,546.6	5,522.1	140,224	1989	5,534.6	5,508.7	109,182
1990	5,531.9	5,511.0	131,346	1991	5,534.1	5,513.9	153,305
1992	5,537.7	5,509.8	133,115	1993	5,532.3	5,509.9	185,765
1994	5,546.7	5,523.1	175,003	1995	5,553.7	5,523.2	371,093
1996	5,544.0	5,532.0	346,664	1997	5,545.6	5,532.7	322,898
1998	5,551.1	5,539.7	402,243	1999	5,546.5	5,534.7	367,303
2000	5,532.2		163,150				

46. ELEVATION - AREA - CAPACITY DATA FOR **2000 CAPACITY**[10]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
5449.0	0	0	5455	1.2	4	5460	21.4	60
5465	82.9	321	5470	170.6	955	5470.6	184	1,061
5475	284.8	2,093	5480	454.9	3,942	5485	661.8	6,734
5490	929.2	10,712	5495	1,207.5	16,053	5500	1,503.5	22,831
5505	1,824.4	31,151	5510	2,151.3	41,090	5515	2,508.5	52,739
5520	2,966.4	66,427	5525	3,399.6	82,342	5530	3,880.1	100,541
5535	4,343	121,098	5535.7	4,407	124,160	5540	4,805.3	143,968
5546.1	5,151	174,367	5550.0	5,363.0	194,870	5560	5,880.1	251,086
5560.4	5,904	253,442	5570	6,481.0	312,891	5571.9	6,606.2	325,324

47. REMARKS AND REFERENCES

1 Top of uncontrolled concrete spillway crest.
2 Bureau of Reclamation Project Data Book, 1981.
3 Calculated using mean annual runoff value of 718,116 AF, item 24, 8/64-6/00.
4 Computed annual inflows from 8/64 through 6/00.
5 Original recomputed surface area and capacity at el. 5,546.1. For sediment computation purposes the original area and capacity was recomputed by the Reclamation ACAP program using the original 5-foot increment surface areas.
6 Surface area & capacity at el. 5,546.1 computed by ACAP program.
7 Inflow values in acre-feet and maximum and minimum elevations in feet by water year from 8/64 through 6/00.
8 Computed sediment volume at elevation 5,546.1.
9 Storage losses at elevation 5,546.1.
10 Capacities computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE March 2001

Table 1. - Reservoir sediment data summary (page 2 of 2).

1	2	3	4	5	6	7	8
					2000	2000	Percent of
Elevations	**Original**	**Original**	**2000**	**2000**	**Sediment**	**Percent of**	**Reservoir**
	Survey	**Capacity**	**Survey**	**Survey**	**Volume**	**Sediment**	**Depth**
(feet)	**(acres)**	**(acre-feet)**	**(acres)**	**(acre-feet)**	**(acre-feet)**		
5,571.9	6606.2	329430	6606.2	325324			100.0
5,570.0	6481.0	316997	6481.0	312891			98.5
5,565.0	6181.0	285343	6181.0	281237			94.5
5,560.4	5904.0	257548	5904.0	253442			90.8
5,560.0	5880.1	255191	5880.1	251086			90.5
5,555.0	5622.0	226437	5622.0	222332			86.5
5,550.0	5363.0	198976	5363.0	194870			82.5
5,546.1	5151.0	178473	5151.0	174367	4106	100.0	79.4
5,542.0	4929.0	157808	4929.0	153702	4106	100.0	76.2
5,540.0	4805.3	148074	4805.3	143968	4106	100.0	74.6
5,535.7	4468.0	128136	4407.0	124160	3976	96.8	71.1
5,535.0	4413.0	125028	4343.0	121098	3930	95.7	70.6
5,530.0	4020.6	103944	3880.1	100541	3403	82.9	66.6
5,525.0	3513.0	85110	3399.6	82342	2768	67.4	62.6
5,520.0	3005.2	68815	2966.4	66427	2388	58.2	58.6
5,515.0	2578.0	54857	2508.5	52739	2118	51.6	54.6
5,510.0	2150.6	43036	2151.3	41090	1946	47.4	50.6
5,505.0	1845.0	33048	1824.4	31151	1897	46.2	46.7
5,500.0	1538.6	24590	1503.5	22831	1759	42.8	42.7
5,495.0	1238.0	17649	1207.5	16053	1596	38.9	38.7
5,490.0	937.1	12212	929.2	10712	1500	36.5	34.7
5,485.0	720.0	8069	661.8	6734	1335	32.5	30.7
5,480.0	503.0	5013	454.9	3942	1071	26.1	26.7
5,475.0	354.0	2871	284.8	2093	778	18.9	22.7
5,470.6	223.0	1601	184.0	1061	540	13.2	19.2
5,470.0	205.2	1473	170.6	955	518	12.6	18.7
5,465.0	125.0	648	82.9	321	327	8.0	14.8
5,460.0	44.7	224	21.4	60	164	4.0	10.8
5,455.0	22.0	56	1.2	4	52	1.3	6.8
5,450.0	1.0	1	0.0	0	1	0.0	2.8
5,449.0	0.0	0	0.0	0	0	0.0	2.0
5,446.5	0.0	0	0.0	0	0	0.0	0.0
1	**Elevation of reservoir water surface.**						
2	**Original reservoir surface area.**						
3	**Original reservoir capacity recomputed using ACAP.**						
4	**Reservoir surface area from 2000 survey. Assume no change from elevation 5,540.0.**						
5	**Reservoir capacity computed using ACAP using surface areas from column 4.**						
6	**Measured sediment volume = column (3) - column (5).**						
7	**Measured sediment expressed in percentage of total sediment 4,106.**						
8	**Depth of reservoir expressed in percentage of total depth of 125.4 feet.**						

Table 2. - Summary of 2000 survey results

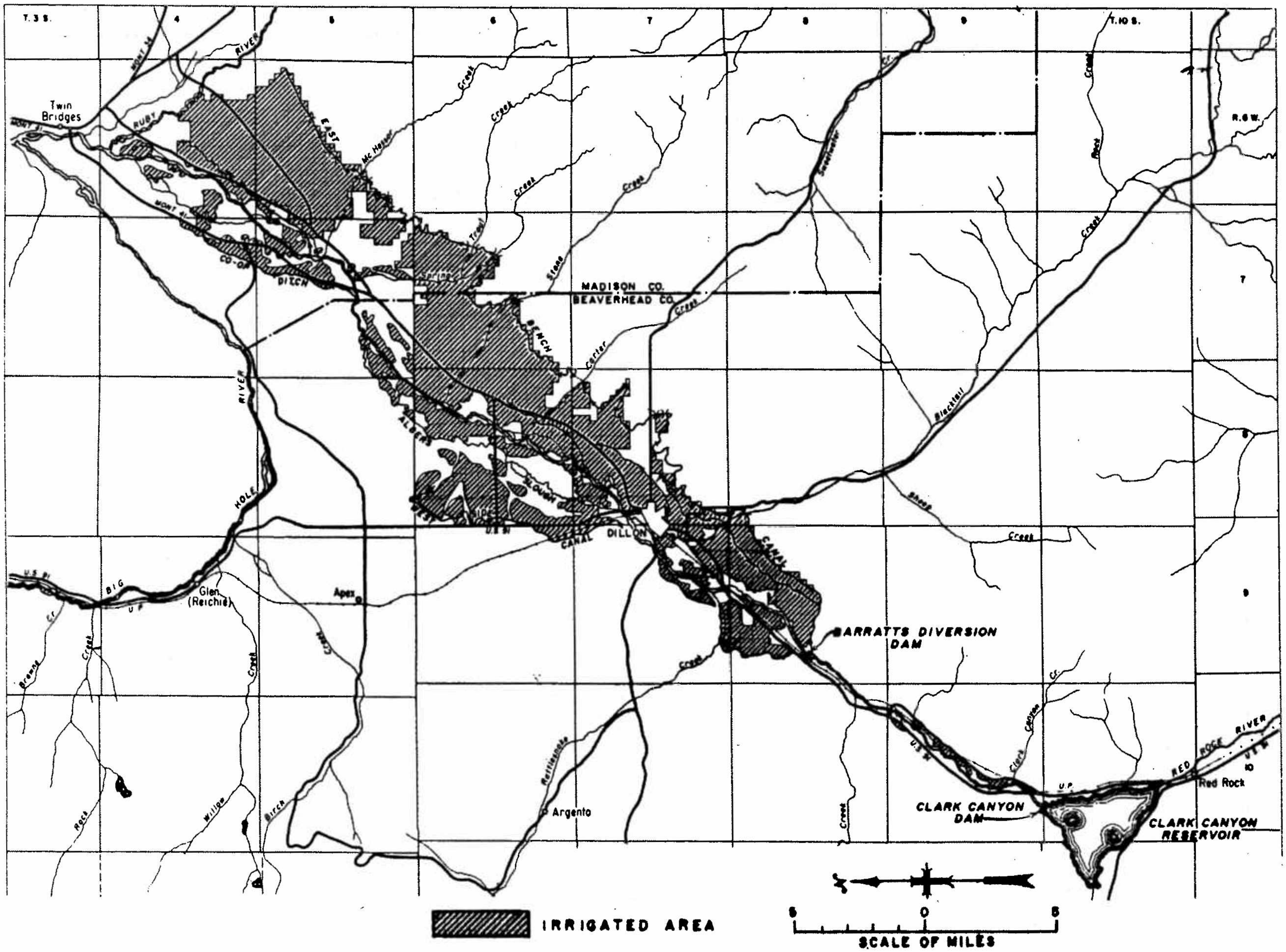
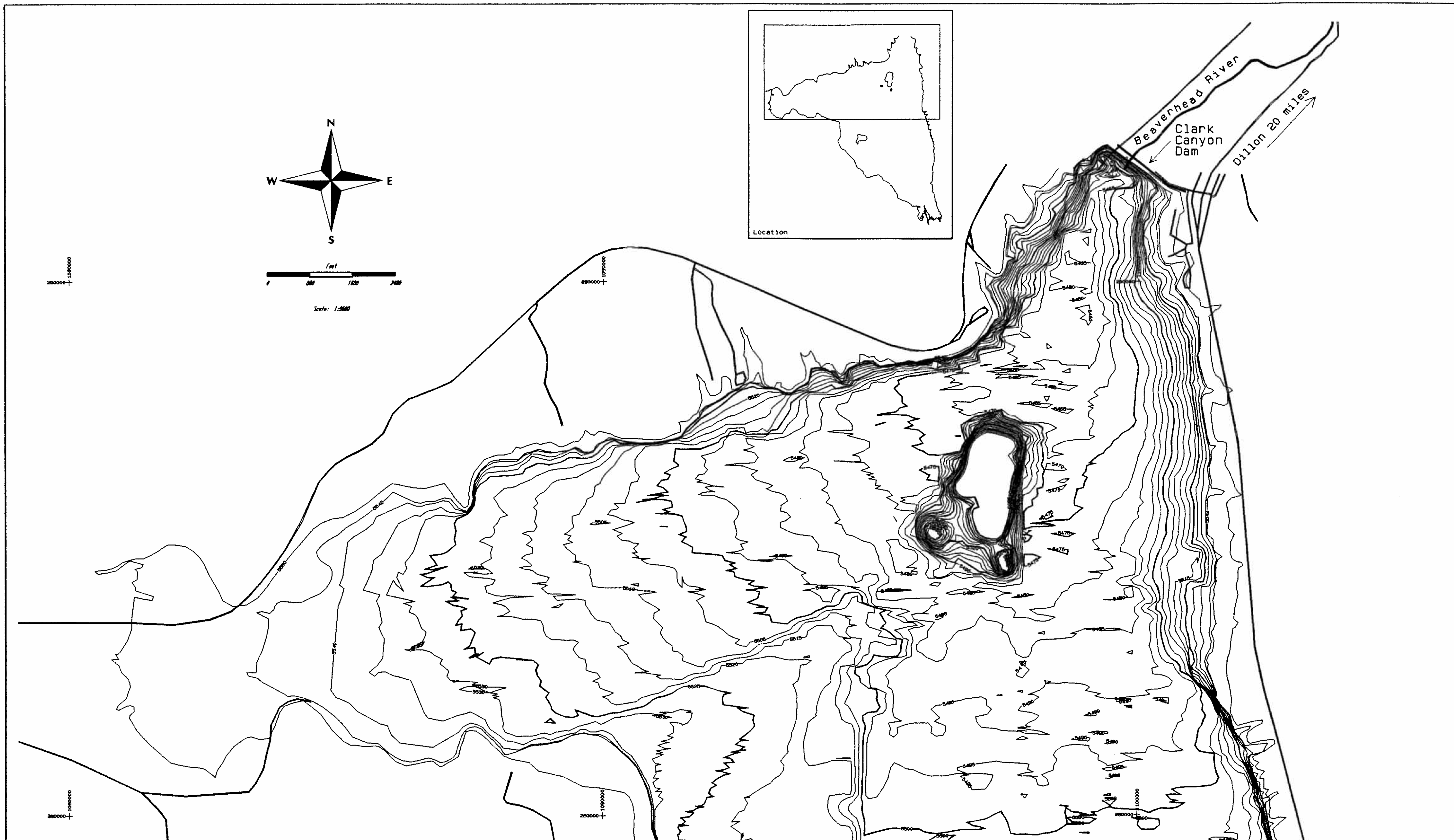


Figure 1. - Clark Canyon Reservoir location map.

Space intentionally left blank due to security concerns



Horizontal datum based on North American Datum of 1983, Montana's State Plane Coordinate System.

Vertical datum based on the Bureau of Reclamation Datum, North American Vertical Datum of 1929.

EAST BENCH UNIT
BEAVERHEAD COUNTY - MONTANA
CLARK CANYON RESERVOIR
TOPOLOGY

DRAWN BY______________ TECHNICAL APPROVAL______________
CHECKED BY______________ APPROVED______________

Denver, Colorado AUG 02, 2001 | 699-D-569

Figure 3. - Clark Canyon Reservoir topographic map, No. 699-D-569

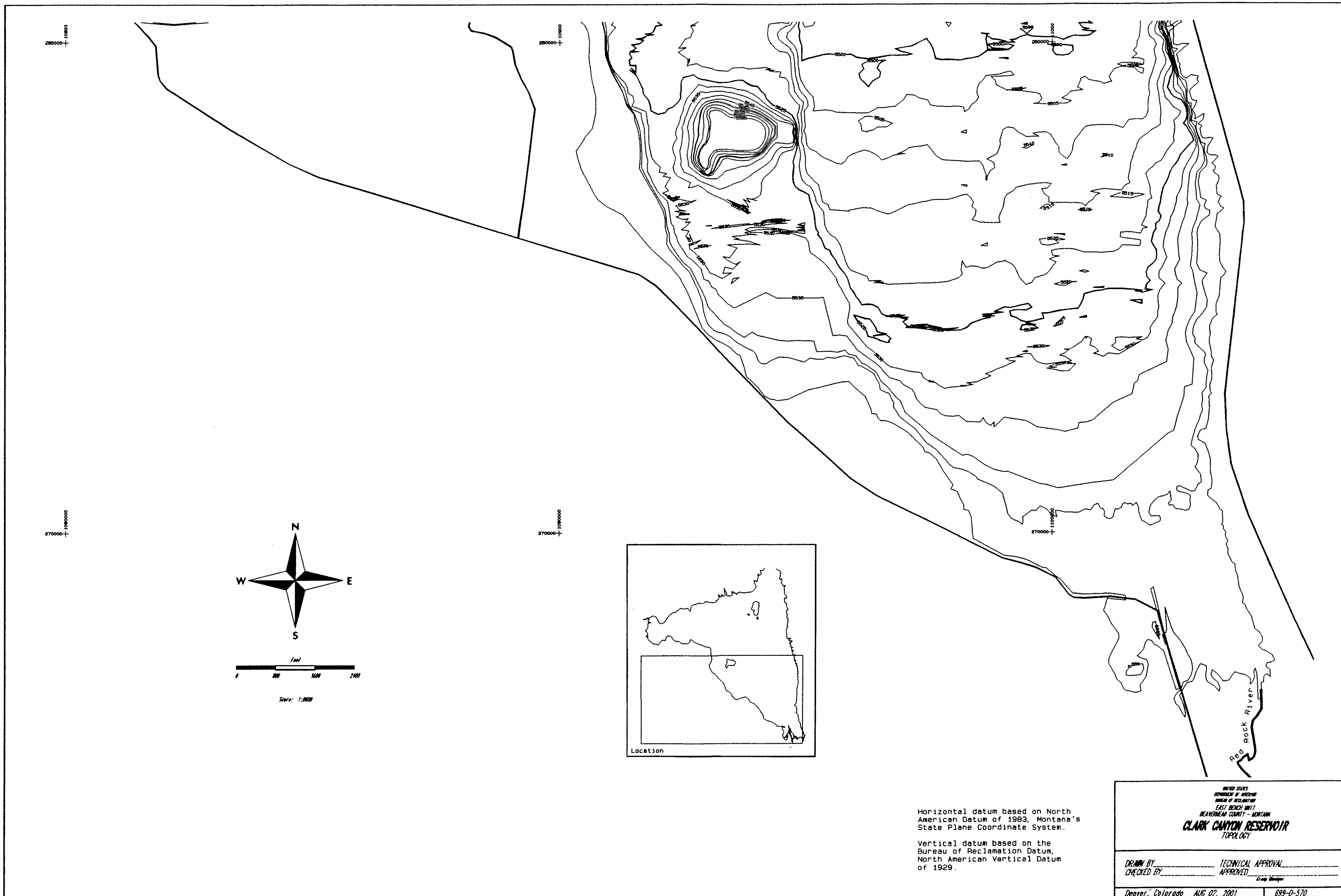


Figure 4. - Clark Canyon Reservoir topographic map, No. 699-D-570

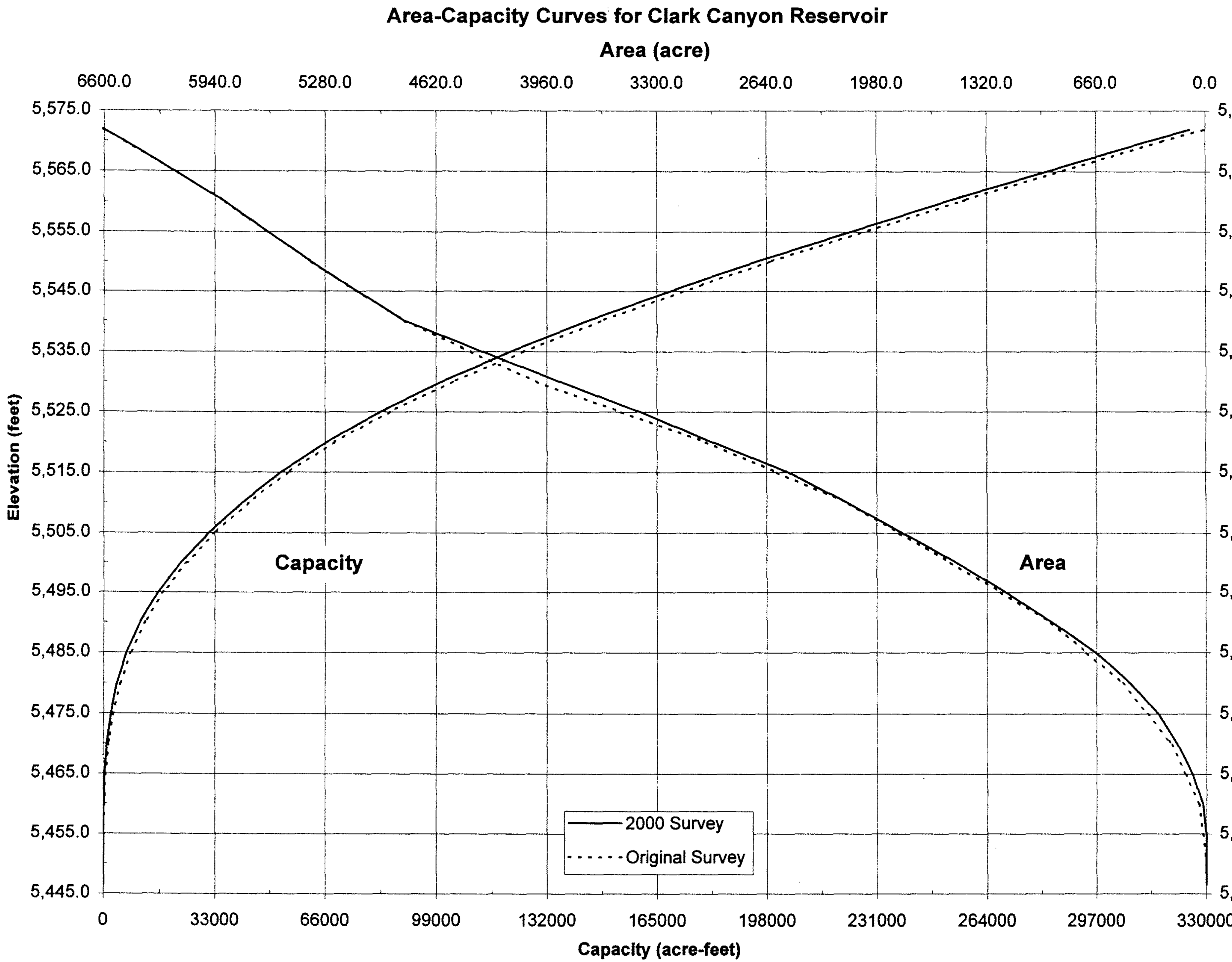


Figure 5. - 2000 area and capacity curves