WARM SPRINGS RESERVOIR
2000 RESERVOIR SURVEY

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed Warm Springs Reservoir in May 2000 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The underwater survey was conducted near reservoir elevation 3,401 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 aerial data collected near reservoir elevation 3,365. The new topographic map of Warm Springs Reservoir was developed from the combined 2000 aerial and underwater measured topography.

As of May 2000, at water surface elevation (feet) 3,406, the surface area was 4,194 acres with a total capacity of 169,714 acre-feet. Due to the lack of original reliable data no comparisons were made to estimate sediment accumulation since dam closure in 1919.

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Warm Springs Reservoir

2000 Reservoir Survey

by

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July 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. Kent Collins 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 the 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

Warm Springs Reservoir and dam are located in Malheur County on the middle fork of the Malheur River about 13 miles southwest of Juntura in southeastern Oregon (fig. 1). Warm Springs Reservoir is one of three storage features of the Vale Project with the other two being Beulah and Bully Creek Reservoirs. Warm Springs Dam construction was completed in 1919 by the Warm Springs Irrigation District. In 1926, the Bureau of Reclamation acquired one-half interest in the dam and reservoir for the Vale Project.

Warm Springs Dam is a constant radius, thin-arch, concrete structure whose dimensions are (fig. 2):

Hydraulic height[1]	92	feet[2]	Structural height	106	feet
Top width	8	feet	Crest length	469	feet
Crest elevation	3,409.0	feet			

The spillway is located in the central portion of the arch and is a 324-foot-long flat weir with a spillway crest elevation of 3,401.0. To provide additional water storage, stoplogs located at the spillway crest allow controlled reservoir storage to elevation 3,406.0. The spillway provides a maximum discharge of 9,799 cubic feet per second (cfs) at reservoir elevation 3,406.0.

The outlet works consist of two rectangular outlets near the right abutment that are controlled by two 3.25- by 6-foot cast-iron slide gates with each protected by an identical guard gate. Discharge capacity of the outlet works is 2,000 cfs at reservoir elevation 3,406.0.

The drainage area above Warm Springs Dam is 1,100 square miles that all is considered sediment contributing. The elevations range from 3,327.0, outlet sill elevation, to about 4,585 feet along the mountain peaks. Warm Springs Reservoir has an average width of 1.3 miles with a length of around 8.5 miles.

SUMMARY AND CONCLUSIONS

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

- develop reservoir topography
- compute present area-capacity relationships
- estimate storage depletion caused by sediment deposition since dam closure (this study did not locate reliable original area-capacity information to compute sediment deposition)

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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 in this report are based on the original project datum established by U.S. Bureau of Reclamation which is approximately 3.0 feet lower than North American Vertical Datum of 1988.

A static global positioning system (GPS) control survey was conducted to establish horizontal and vertical control points around the reservoir for the underwater and aerial surveys that were conducted in 2000. The horizontal control was established in Oregon south state plane coordinates in the North American Datum of 1983 (NAD83). The vertical control for the established points was in the North American Vertical Datum of 1988 (NAVD88). The survey found that for the established points the average elevations in NAVD88 were around 3.0 feet higher than the Reclamation project construction datum.

The aerial survey was flown in the fall of 2000 around reservoir water surface elevation 3,365 and the underwater survey was conducted in May of 2000 around reservoir water surface elevation 3,401. 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 Warm Springs Reservoir. The positioning system provided information to allow the boat operator to maintain a course along these grid lines. Water surface elevations recorded by 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 new Warm Springs Reservoir topographic maps are a combination of the aerial 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).

Table 1 contains a summary of the Warm Springs Reservoir watershed characteristics and the 2000 reservoir survey. The 2000 survey determined that the reservoir has a total storage capacity of 169,714 acre-feet and a surface area of 4,194 acres at reservoir elevation 3,406.0. No sediment calculations are given due to questions as to reliability of the original published area and capacity values for Warm Springs Reservoir.

RESERVOIR OPERATIONS

Warm Springs Dam operates in conjunction with several other reservoirs of the Vale Project to provide irrigation water for the Vale and Warm Springs Irrigation Districts. The May 2000 area-capacity tables show 169,714 acre-feet of total storage below elevation 3,406.0. The 2000 survey measured a minimum elevation of 3,321.8. The following values are from the May 2000 area-capacity tables:

- 86,901 acre-feet of joint use between elevation 3,381.55 and 3,406.0.
- 82,738 acre-feet of active conservation storage between elevation 3,327.0 and 3,381.55.
- 75 acre-feet of dead storage below elevation 3,327.0.

The Warm Springs Reservoir inflow and end-of-month stage records in table 1, operation period 1957 through May 2000, show the inflow and annual fluctuation since dam closure. The reservoir was formed in 1919, but the posted data was the only data readily available for this study. The estimated average inflow into the reservoir for the 1957 through May of 2000 operation period was 160,800 acre-feet per year. As reported by the USGS in the Water Resources publication for 1986, the extreme storage fluctuations of Warm Springs Reservoir ranged from an elevation of 3,327 in 1929, 1935, 1950 and 1977 to the maximum recorded elevation of 3,407.1 on May 13, 1958.

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 Warm Springs 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 Warm Springs 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 Warm Springs 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 compared to positional accuracies of $\pm$100 meters with a single receiver.

The Sedimentation and River Hydraulics Group started using Real-time Kinematic (RTK) GPS in the spring of 1999. The major benefits of RTK versus DGPS are that 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. This output was on the GPS datum of WGS-84 which the hydrographic collection software converted into Oregon's NAD83 state plane south zone coordinate system. The RTK GPS system employs two receivers that track the same satellites simultaneously just like with DGPS. The receivers track the L1 C/A code and full cycle L1 and L2 carrier phases. The additional data logged from the second frequency allows the on-the-fly centimeter accuracy measurements.

Survey Method and Equipment

The Warm Springs Reservoir hydrographic survey collection was conducted from May 21 through May 23, 2000 near water surface elevation 3,401 (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 perpendicular direction to the center line of the reservoir at 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.

Warm Springs Reservoir Datums

Prior to the aerial survey, a contract static global positioning system (GPS) control survey was conducted to establish horizontal and vertical control points around the reservoir. The horizontal control was established in Oregon state plane (south zone) coordinates in NAD83 in international feet. The vertical controls for the established points were in the NAVD88. The survey found that for the established points the average elevations in NAVD88 were around 3.0 feet higher than the Reclamation project datum. The Reclamation project datum elevation of the spillway overflow crest is 3,401.0 which all calculations and elevations in this report are based on. The contract survey utilized the following coordinates for the NGS point marked Warm Springs that is located on the right bank above Warm Springs Dam.

North 707,377.253
East 5,527,825.686
NAVD88 Elevation 3,547.64
Project Elevation 3,544.64

RESERVOIR AREA AND CAPACITY

Original Capacity

The original area-capacity curves and tables for Warm Springs Reservoir reported the total capacity as 192,400 acres-feet at reservoir elevation 3,406.0. The original plotted and published surface area at elevation 3,406.0 varied with all published values being between 4400 and 4600 acres. A plot of the original versus the measured 2000 survey areas, figure 6, indicated a problem that cannot be explained with the limited information available on the original values. The area comparison plot from elevation 3350 and above indicates a possible vertical datum shift between the two surveys, but shifting all the original data would create a question with the areas below elevation 3350. As part of the analysis the water surface area from the USGS quad sheets, elevation 3406, was digitized with the resulting surface area being 4,184 acres. This area compares well with the 2000 survey results for the same elevation indicating the problem is with the original values only.

Topography Development

Using ARC/INFO the topography of Warm Springs Reservoir was developed from the combined 2000 aerial and underwater data. ARC/INFO is a software package for development and analysis of geographic information system (GIS) layers and development of interactive GIS applications (ESRI, 1992). GIS technology provides a means of organizing and interpreting large data sets.

The 5-foot reservoir contours for elevation 3,365.0 through 3,425.0 were provided by the aerial contractor as a data exchange format (DXF) file. The underwater contours of the reservoir were developed by using the elevation 3400.0 contour as a boundary around the edge of the underwater data set. This polygon that enclosed the data set was assigned an elevation of 3,400.0 and was used to perform a clip such that interpolation was not allowed to occur outside of this boundary. This clip was performed using the hardclip option of the ARC/INFO CREATETIN command.

Contours for the reservoir below elevation 3,360.0 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 Warm Springs Reservoir TIN. In addition, the contours were generalized by eliminating certain 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 Warm Springs Reservoir since the areas were calculated from the developed TIN. The areas of the enclosed contour polygons developed from the aerial survey data were completed for 5-foot intervals from elevation 3,365.0 through 3,425.0.

The mapping features such as the dam, roads and the contours, from elevation 3365.0 and above, were imported from the aerial data. The contours from elevations 3360.0 and below were developed and imported from the underwater data. The contour topography at 5-foot intervals is presented on figures 3, 4, and 5 (drawing numbers 126-D-550 through 126-D-552).

Development of 2000 Contour Areas

The 2000 contour surface areas for Warm Springs Reservoir were computed at 5-foot increments, from elevation 3,325.0 to 3,425.0, using the 2000 survey data for Warm Springs Reservoir as discussed above. The 2000 survey measured the minimum reservoir elevation at 3,321.8 feet. These calculations were performed using the ARC/INFO commands to compute areas at user-specified elevations directly from the TIN (which takes into consideration all regions of equal elevation) and from the enclosed polygons from the aerial data developed contours.

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 3,325.0 to elevation 3,425.0 were used as the control parameters for computing the Warm Springs Reservoir capacity. The minium inputted elevation was 3,321.8. 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 Warm Springs 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 Warm Springs Reservoir area and capacity computations are listed in table1 and illustrated on figure 6. A separate set of 2000 area and capacity tables has been published for the 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. As of May 2000, at elevation 3,406.0, the surface area was 4,194 acres with a total capacity of 169,714 acre-feet.

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RESERVOIR SEDIMENT
DATA SUMMARY

Warm Springs Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

D	1. OWNER Bureau of Reclamation	2. STREAM Malheur River	3. STATE Oregon
A	4. SEC. 8 TWP. 23 S RANGE 37 E	5. NEAREST P.O.	6. COUNTY Malheur
M	7. LAT 43° 35' 07" LONG 118° 12' 30"	8. TOP OF DAM ELEVATION 3409.0	9. SPILLWAY CREST EL 3401.0[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					
	b. FLOOD CONTROL					1919
	c. POWER					
	d. JOINT USE	3406.0	4600	95,500	192,400	16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION	3381.55		95,500	96,900	
	f. INACTIVE					
	g. DEAD	3327.0		1,400	1,400	1919
	17. LENGTH OF RESERVOIR 8.5 MILES			AVG. WIDTH OF RESERVOIR 1.3 MILES		

BASIN		
	18. TOTAL DRAINAGE AREA 1,100 SQUARE MILES	22. MEAN ANNUAL PRECIPITATION 9.1[2] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 1,100 SQUARE MILES	23. MEAN ANNUAL RUNOFF 2.74[3] INCHES
	20. LENGTH MILES AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 160,800[4] ACRE-FEET
	21. MAX. ELEVATION MIN. ELEVATION	25. ANNUAL TEMP. MEAN 52°F RANGE -27°F to 106°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
1919					[5]	[5]	
5/00	81	81	Contour (D)	5-ft	4,194[6]	169,714[6]	1.06

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
5/00		160,800[7]	406,300	7,021,400	160,800	7,021,400

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.
5/00	[8]			[8]		

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.
5/00				[8]	[8]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION											
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
5/00												

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
1956				1957			202,000
1958			286,000	1959			58,000
1960			136,000	1961	3,372.9	3,327.2	71,000
1962	3,380.6	3,327.3	117,000	1963	3,389.2	3,331.5	144,500
1964	3,383.1	3,348.5	87,400	1965	3,406.6	3,347.6	296,600
1966	3,402.6	3,359.0	60,100	1967	3,394.1	3,358.6	137,200
1968	3,386.9	3,328.3	56,100	1969	3,397.7	3,331.1	172,500
1970	3,406.0	3,369.4	201,400	1971	3,405.8	3,382.8	236,700
1972	3,403.7	3,376.0	177,200	1973	3,391.5	3,332.1	71,100
1974	3,406.2	3,333.0	280,300	1975	3,406.2	3,384.4	200,300
1976	3,403.4	3,372.1	101,300	1977	3,379.0	3,330.9	25,600
1978	3,399.0	3,330.8	172,100	1979	3,400.2	3,369.2	132,200
1980	3,405.2	3,369.6	170,600	1981	3,405.6	3,373.7	100,800
1982	3,406.0	3,373.7	349,600	1983	3,406.1	3,390.3	406,300
1984	3,406.1	3,386.7	390,410	1985	3,403.9	3,363.5	134,950
1986	3,404.1	3,362.9	207,380	1987	3,387.5	3,327.7	68,120
1988	3,365.2	3,327.0	49,430	1989	3,405.1	3,327.4	203,450
1990	3,384.8	3,327.3	26,840	1991	3,358.7	3,327.0	48,570
1992	3,360.7	3,326.5	42,110	1993	3,405.9	3,327.8	273,140
1994	3,389.8	3,327.0	32,780	1995	3,400.6	3,327.4	171,560
1996	3,404.9	3,371.2	160,690	1997	3,405.4	3,375.9	201,740
1998	3,406.0	3,327.0	186,890	1999	3,406.0	3,327.0	221,290
2000	3,404.0	3,379.4	152,150				

46. ELEVATION - AREA - CAPACITY DATA FOR **2000 CAPACITY**[9]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
3321.8	0	0	3325	5.7	9	3330	142.6	379
3335	298.9	1,483	3340	642.1	3,836	3345	1,011.6	7,970
3350	1,323.3	13,807	3355	1,620.8	21,167	3360	1,885.3	29,933
3365	2,158.5	40,042	3370	2,421.2	51,491	3375	2,679.9	64,244
3380	2,917.8	78,238	3381.55	2,985	82,813	3385	3,135.3	93,371
3390	3,352.5	109,591	3395	3,591.3	126,950	3400	3,854.9	145,566
3405	4,137.9	165,548	3406	4,194	169,714	3410	4,420.2	186,943
3415	4,709.0	209,766	3420	4,975.5	233,977	3425	5,212.0	259,446

47. REMARKS AND REFERENCES

1 Top of 5-foot flashboards, elevation 3406.0.
2 Bureau of Reclamation Project Data Book, 1981.
3 Calculated using mean annual runoff value of 160,800 AF, item 24, 10/56-5/00.
4 Computed annual inflows from 10/56 through 5/00. Only readily available records.
5 Original surface area and capacity from a Reclamation reservoir allocation sheet are listed in section 13 and 14. These values were projected from original area and capacity curves and a capacity table. The 2000 study could not determined the validity of the original values.
6 Surface area & capacity at el. 3,406.0 computed by ACAP program.
7 Inflow values in acre-feet and maximum and minimum elevations in feet by water year from 10/56 through 5/00. Only readily available records.
8 There are questions as to validity of original area-capacity data so comparisons cannot be made to accurately compute loss due to sediment.
9 Capacities computed by Reclamation's ACAP computer program.

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

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

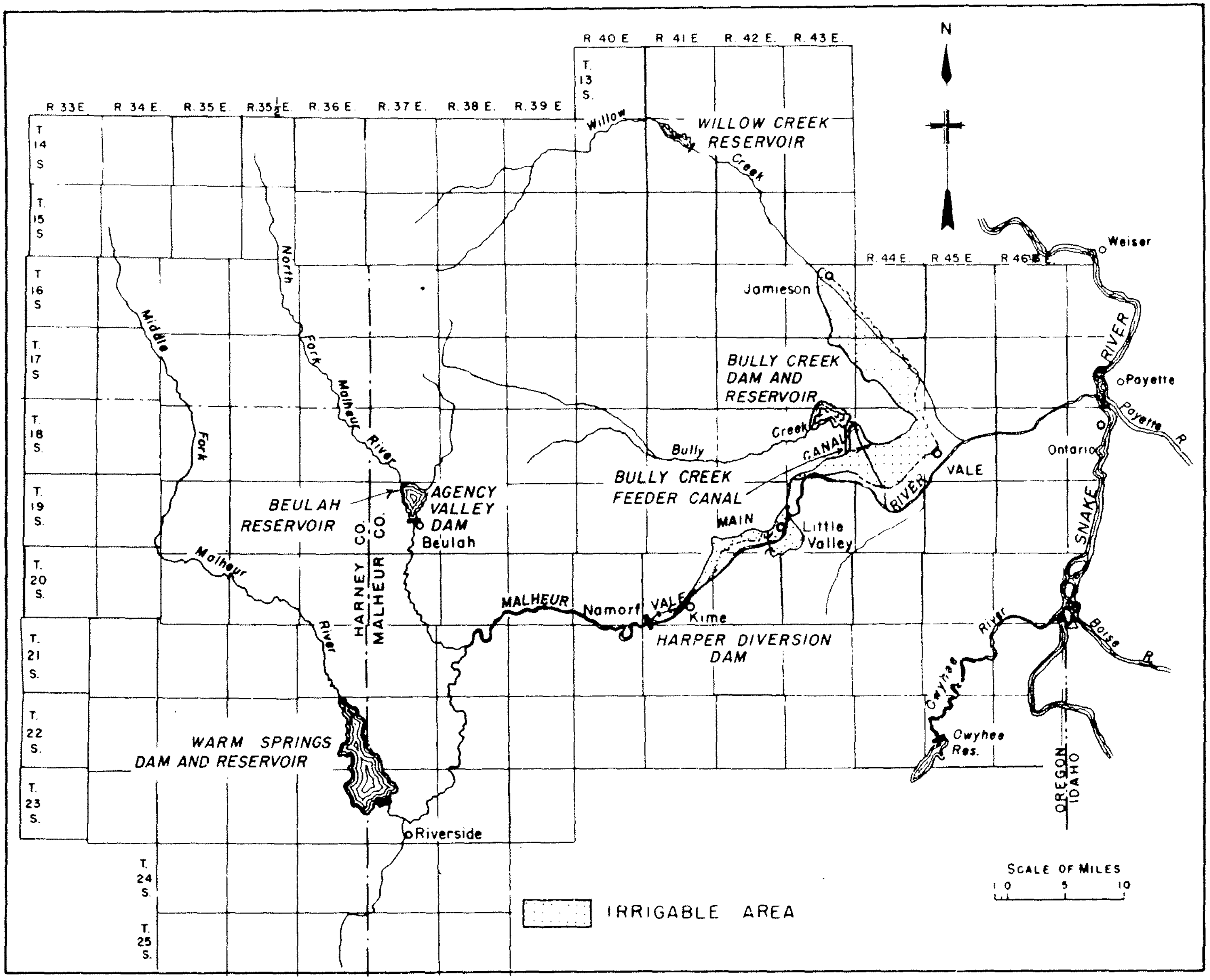

Figure 1. - Warm Springs Reservoir location map.

Space intentionally left blank due to security concerns

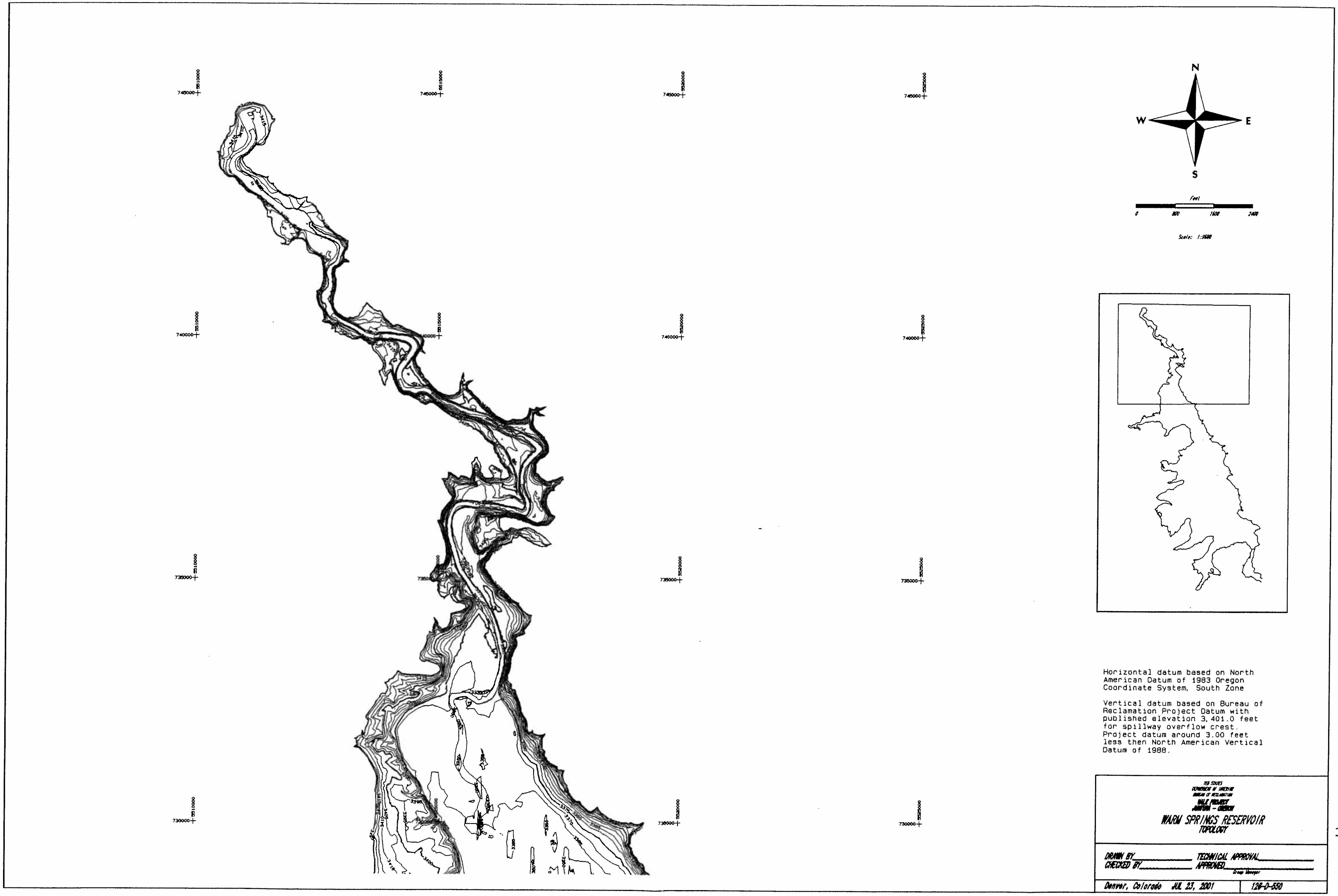

Figure 3. - Warm Springs Reservoir topographic map. No. 126-D-550

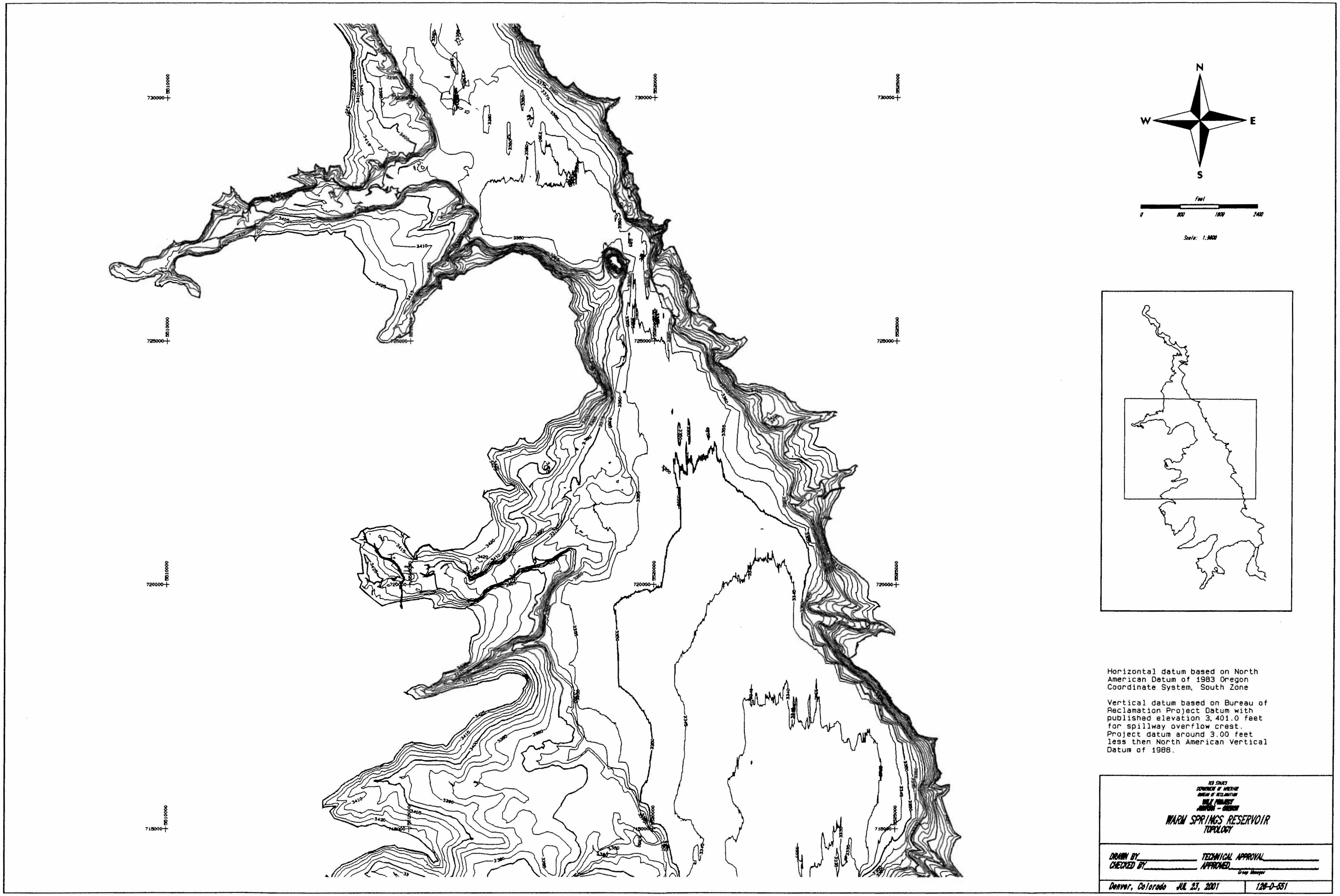

Figure 4. - Warm Springs Reservoir topographic map No. 126-D-551

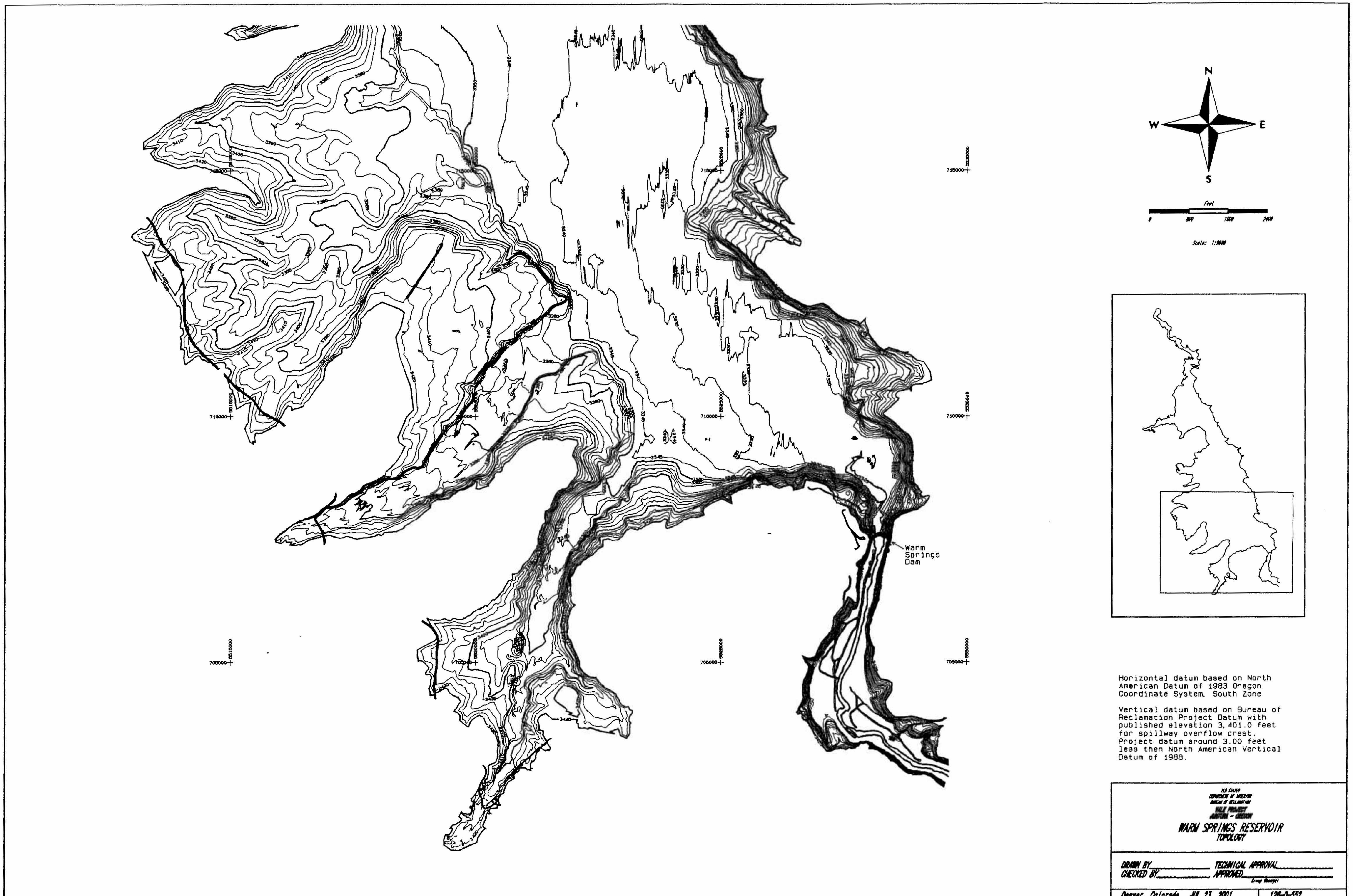

Figure 5.—Warm Springs Reservoir topographic map No. 126-D-552.

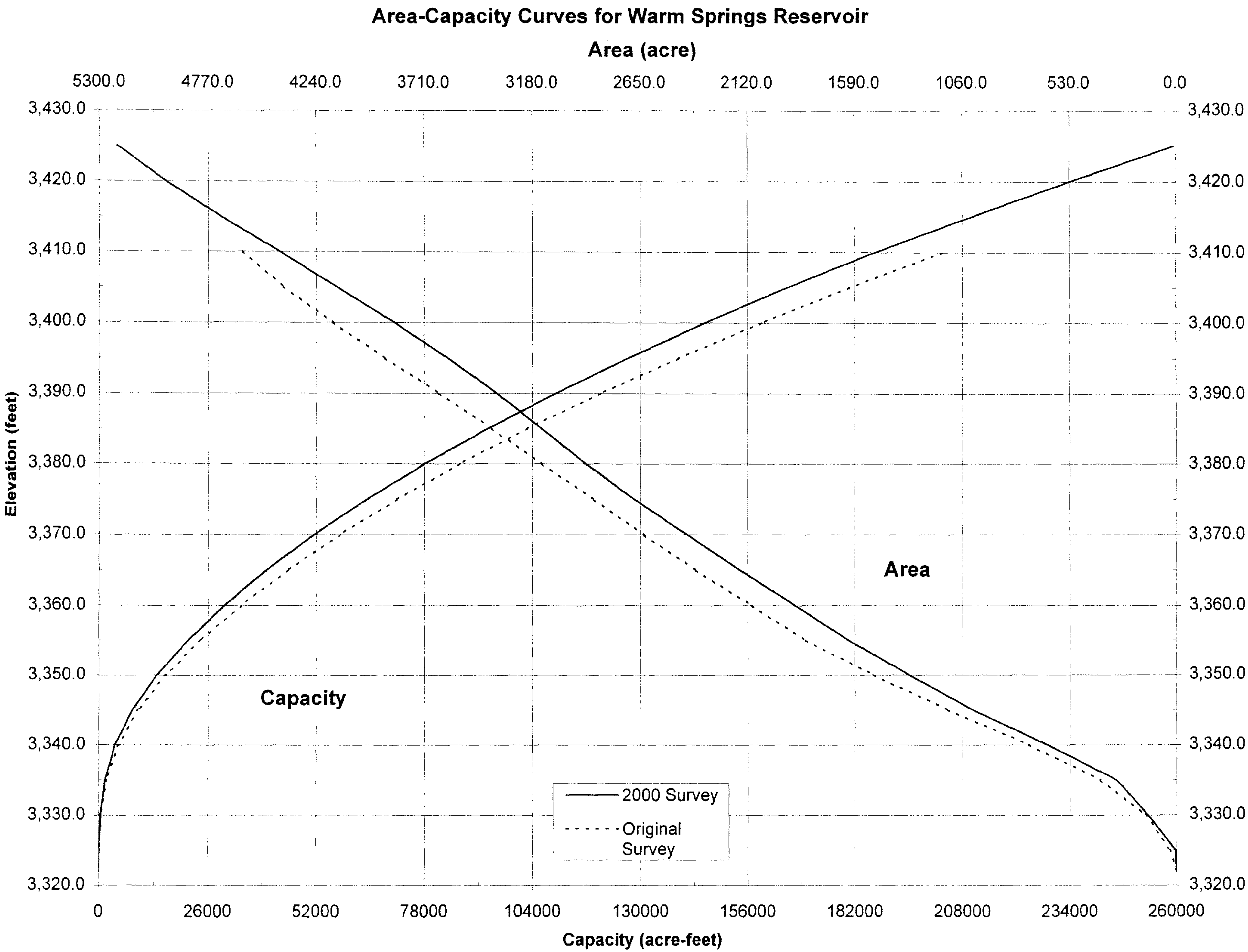

Figure 6. - Original versus 2000 area and capacity curves