BEULAH RESERVOIR
2000 RESERVOIR SURVEY

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed Beulah Reservoir in 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 December of 1935. The underwater survey was conducted in May of 2000 near reservoir elevation 3338 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 in the fall of 2000 near reservoir elevation 3,305. The new topographic map of Beulah Reservoir was developed from the combined aerial and underwater measured topography.

As of May 2000, at top of spillway crest gate water surface elevation (feet) 3,340, the surface area was 1,913.1 acres with a total capacity of 59,212 acre-feet. Since initial filling in December of 1935, about 713 acre-feet of sediment have accumulated in Beulah Reservoir below elevation 3,340.0, resulting in a 1.19 percent loss in reservoir volume. Since 1935, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 11.05 acre-feet.

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2000 RESERVOIR SURVEY

by

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Denver, Colorado

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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

Beulah Reservoir and dam (Agency Valley Dam) are located in Malheur County on the north fork of the Malheur River about 15 miles north of Juntura in southeastern Oregon (fig. 1). Beulah Reservoir is one of three storage features of the Vale Project with the other two being Bully Creek and Warm Springs Reservoirs. The dam and reservoirs are operated and maintained by the Vale Irrigation District.

Agency Valley Dam was completed in 1935 and is a rolled, zoned earth and rockfill embankment structure whose dimensions are (fig. 2):

Hydraulic height[1]	89	feet[2]	Structural height	110	feet
Top width	35	feet	Crest length	1,867	feet
Crest elevation	3,348.0	feet			

The spillway is located in the right abutment of the dam and consists of an inlet channel, three 18- by 17-foot radial gates, a chute, a stilling basin, and a discharge channel. The spillway crest is at elevation 3,323.0. The top of the spillway gate is at elevation 3,340.0. The spillway provides a discharge of 10,300 cubic feet per second (cfs) at reservoir elevation 3,343.3.

The outlet works is located through the right abutment of the dam and discharges into the spillway stilling basin. The discharge capacity of the outlet works is 600 cfs at reservoir elevation 3,340.0.

All of the 440 square mile drainage area upstream from Agency Valley Dam is considered to contribute sediment to the reservoir. Beulah Reservoir has an average width of 1.2 miles with a length of around 2.5 miles.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2000 results of the survey of Beulah 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

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

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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 11.1 feet lower than North American Vertical Datum of 1988.

in 2000. The horizontal control was established in Oregon's south state plane coordinates in the North American Datum of 1983 (NAD83) and International Feet. The vertical control for the established points was in the North American Vertical Datum of 1988 (NAVD88) and the Reclamation project construction datum. The survey found that for the established points the average elevations in NAVD88 were around 11.1 feet higher than the Reclamation project construction datum. All elevations in this report are reference to the Reclamation project datum.

The underwater survey was conducted in May of 2000 around reservoir water surface elevation 3,338 and the aerial survey was flown in the fall of 2000 around reservoir water surface elevation 3,305. 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 Beulah 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 developed aerial contours are also tied to the Reclamation vertical datum.

The new Beulah Reservoir topographic maps are a combination of the aerial and underwater survey data with the developed aerial contours being used for elevation 3305 and above. 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 Beulah Reservoir sedimentation and watershed characteristics for the 2000 survey. The 2000 survey determined that the reservoir has a total storage capacity of 59,212 acre-feet and a surface area of 1,913.1 acres at reservoir elevation 3,340.0. Since closure in December of 1935, the reservoir had an estimated volume change of 713 acre-feet below reservoir elevation 3,340.0. This volume represents a 1.19 percent loss in total capacity and an average annual loss of 11.05 acre-feet per year.

RESERVOIR OPERATIONS

Agency Valley Dam operates in conjunction with several other reservoirs of the Vale Project to provide flood control and irrigation water for the Vale and Beulah Irrigation Districts. The May 2000 area-capacity tables show 65,665 acre-feet of total storage below the maximum water surface elevation 3,343.3. The 2000 survey measured a minimum elevation of 3,266.2. The following values are from the May 2000 area-capacity tables:

- 6,453 acre-feet of joint use between elevation 3,340.0 and 3,343.3.
- 59,212 acre-feet of active conservation storage between elevation 3,266.2 and 3,340.0.
- 0 acre-feet of dead storage below elevation 3,266.2.

The Beulah Reservoir inflow and end-of-month stage records in table 1, operation period 1935 through May 2000, show the inflow and annual fluctuation since dam closure. The estimated average inflow into the reservoir for this operation period was 105,892 acre-feet per year. Since 1961 (period of data readily available), the extreme storage fluctuations of Beulah Reservoir ranged from an elevation of 3,263 in 1990 to the maximum recorded elevation of 3,340.8 in 1978.

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 Beulah 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 Beulah 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 collect is to resolve or cancel the inherent errors of GPS is called differential GPS (DGPS). DGPS are 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 Beulah 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 are 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 in 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 Oregon's NAD83 state plane south zone coordinate system. The system employs two receivers, like with DGPS, that collects additional satellite data that allows on-the-fly centimeter accuracy measurements.

Survey Method and Equipment

The Beulah Reservoir hydrographic survey collection was conducted on May 19 and May 20 of 2000 near water surface elevation 3,338.2 (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 300-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.

Beulah 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 11.1 feet higher than the Reclamation project datum. The project datum elevation of the spillway overflow crest is 3,323.0. All calculations and elevations in this report are based on the Reclamation project datum. The contract survey determined the following coordinates for the NGS point marked WC 568 that is located on the left abutment alignment of Agency Valley Dam.

North 826,151.000
East 5,540,339.767
NAVD88 Elevation 3,401.74
Project Elevation 3,390.63

RESERVOIR AREA AND CAPACITY

Topography Development

Using ARC/INFO the topography of Beulah 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 3,305.0 through 3,365.0 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 3,330.0 contour as a boundary around the edge of the underwater data set. This polygon that enclosed the data set was assigned an elevation of 3,330.0 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 3,330.0 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 Beulah Reservoir TIN. In addition, the contours were generalized by weeding 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 Beulah 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 elevations 3,305.0 through elevation 3,365.0.

The mapping features such as the dam, roads and the contours, from elevation 3305.0 and above, were imported from the aerial data. The contours from elevations 3300.0 and below were developed and imported from the underwater data. The contour topography at 5-foot intervals is presented on figures 3 and 4 (drawing numbers 126-D-546 and 126-D-547).

Development of 2000 Contour Areas

The 2000 contour surface areas for Beulah Reservoir were computed at 5-foot increments from elevation 3,270.0 to 3,365.0. The underwater TIN areas, as discussed above, were used for elevation 3,270.0 through 3,300.0. The 2000 underwater survey measured the minimum reservoir elevation at 3,266.2. These calculations were performed using the area option of 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. The aerial survey data mapped the surface areas for the 5-foot reservoir contour increments of elevation 3,305.0 through 3,365.0. These coverages were imported into ARC/INFO for the purpose of computing the closed contour areas and for final map development.

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 minimum reservoir elevation 3,266.2 to elevation 3,365.0 were used as the control parameters for computing the Beulah Reservoir capacity. 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 Beulah 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 Beulah 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 May 2000, at elevation 3,340.0, the surface area was 1,913.1 acres with a total capacity of 59,212 acre-feet.

RESERVOIR SEDIMENT ANALYSES

Figure 5 is a plot of Beulah Reservoir's original area data versus the 2000 measured areas. This illustrates the difference between the original and the 2000 measured surface areas. Since Agency Dam closure in December 1935, the measured total volume change at reservoir elevation 3,340 was estimated to be 713 acre-feet. The estimated average annual rate of capacity lost for this time period (64.5 years) was 11.05 acre-feet per year. The storage loss in terms of percent of original storage capacity was 1.19 percent. Tables 1 and 2 contain the Beulah Reservoir sediment accumulation and water storage data based on the 2000 resurvey.

The original 100 year sediment inflow estimate used during the design of Beulah Reservoir was 4,380 acre-feet, or a 7.3 percent decrease in original capacity. This computes to an average annual rate of capacity loss of 43.8 acre-feet compared to the 2000 survey results of 11.05 acre-feet. The 2000 survey computed a very low sediment inflow, but it is computed by comparing the 2000 measured results with the original survey results. A portion of this difference can be attributed to the different methods of measurements. A resurvey of Beulah 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

Beulah Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation	2. STREAM Malheur River	3. STATE Oregon
	4. SEC. 15 TWP. 19 S RANGE 37 E	5. NEAREST P.O. Juntura	6. COUNTY Malheur
	7. LAT 43° 54' 41" LONG 118° 09' 25"	8. TOP OF DAM ELEVATION 3348.0	9. SPILLWAY CREST EL 3223.0[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	3343.3		6,100	66,000	
	b. FLOOD CONTROL					
	c. POWER					12/35
	d. JOINT USE	3340.0	1,912	59,900	59,900	16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION					
	f. INACTIVE					
	g. DEAD	3263.21		0	0	12/35
	17. LENGTH OF RESERVOIR 2.46 MILES			AVG. WIDTH OF RESERVOIR 1.2 MILES		

BASIN	18. TOTAL DRAINAGE AREA 440 SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 9.1[2] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 440 SQUARE MILES		23. MEAN ANNUAL RUNOFF 4.5[3] INCHES
	20. LENGTH MILES	AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 105,892[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
	12/35			Contour (D)	5-ft	1912[5]	59,925[5]	.57
	5/00	64.5	64.5	Contour (D)	5-ft	1913.1[6]	59,212[6]	.56

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET			WATER INFLOW TO DATE, AF	
		a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	a. MEAN ANN.	b. TOTAL
5/00		105,892[7]	231,010	6,830,030	105,892	6,830,030

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
	a. TOTAL	b. AV. ANN.	c. /MI.²-YR.	a. TOTAL	b. AV. ANNUAL	c. /MI.²-YR.
5/00	713[8]	11.05	0.025	713	11.05	0.025

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT³)	40. SED. DEP. TONS/MI.²-YR.		41. STORAGE LOSS, PCT.		42. SEDIMENT	
		a. PERIOD	b. TOTAL TO	a. AV.	b. TOTAL TO	a.	b.
5/00				.0184[9]	1.19[9]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION										
	3260-3285	3285-3290	3290-3300	3300-3305	3305-3310	3310-3315	3315-3320	3320-3325	3325-3330	3330-3335	3335-3340
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
5/00	19.2	22.9	25.6	-13.6	-5.6	10.1	14.2	12.6	3.4	6.9	4.3

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
1936			49,300	1937			53,700
1938			138,830	1939			53,500
1940			90,570	1941			138,330
1942			105,600	1943			164,800
1944			55,090	1945			85,890
1946			109,590	1947			65,630
1948			87,330	1949			90,600
1950			91,580	1951			88,870
1952			159,850	1953			133,420
1954			79,760	1955			55,490
1956			124,330	1957			115,420
1958			180,860	1959			64,270
1960			85,200	1961	3,329.4	3,263.2	58,490
1962	3,331.5	3,263.2	78,130	1963	3,339.0	3,283.5	94,480
1964	3,333.0	3,300.3	73,800	1965	3,340.2	3,299.2	174,920
1966	3,331.4	3,289.4	61,400	1967	3,338.6	3,330.0	99,990
1968	3,332.3	3,263.2	66,290	1969	3,338.8	3,263.2	121,020
1970	3,340.2	3,292.1	138,930	1971	3,340.1	3,300.2	169,790
1972	3,339.0	3,307.7	114,210	1973	3,331.0	3,272.9	62,510
1974	3,340.0	3,311.8	189,450	1975	3,340.1	3,300.4	145,500
1976	3,333.0	3,298.1	82,650	1977	3,322.7	3,275.1	39,210
1978	3,340.8	3,285.0	106,680	1979	3,338.1	3,286.6	86,050
1980	3,340.0	3,289.1	115,460	1981	3,340.0	3,293.1	76,790
1982	3,340.3	3,309.6	220,670	1983	3,340.3	3,311.2	231,010
1984	3,340.2	3,311.1	200,180	1985	3,340.0	3,311.4	105,010
1986	3,340.1	3,311.0	130,190	1987	3,334.6	3,273.6	56,960
1988	3,319.5	3,263.2	53,570	1989	3,340.0	3,273.0	108,520
1990	3,326.6	3,263.0	45,840	1991	3,318.3	3,272.9	52,960
1992	3,319.1	3,272.8	43,470	1993	3,340.4	3,272.8	157,820
1994	3,331.3	3,273.1	40,550	1995	3,340.4	3,273.1	118,240
1996	3,340.3	3,313.0	122,990	1997	3,340.2	3,312.5	147,930
1998	3,340.0	3,315.5	134,300	1999	3,340.6	3,309.0	143,740
2000	3,339.9	3,314.2	92,520				

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

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
3266.2	0	0	3270	23.3	47	3275	74.0	290
3280	156.8	867	3285	249.6	1,883	3290	377.2	3,450
3295	501.9	5,648	3300	635.9	8,492	3305	821.9	12,137
3310	965.2	16,604	3315	1,113.8	21,802	3320	1,260.0	27,736
3325	1,414.0	34,421	3330	1,578.2	41,902	3335	1,716.3	50,138
3340	1,913.1	59,212	3343.3	1,998	65,665			

47. REMARKS AND REFERENCES

[1] Top of radial gates, elevation 3340.0.
[2] Bureau of Reclamation Project Data Book, 1981.

[3] Calculated using mean annual runoff value of 231,010 AF, item 24, 12/36-5/00.
[4] Computed annual inflows from 12/36 through 5/00.
[5] Original surface area and capacity at el. 3,340.0. For sediment computation purposes the original capacity was recomputed by the Reclamation ACAP program using the original surface areas.
[6] Surface area & capacity at el. 3,340.0 computed by ACAP program.

[7] Inflow values in acre-feet and maximum and minimum elevations in feet by water year from 12/36 through 5/00. Some months of missing records. Elevation data for 1961 through 1970 from USGS water records.
[8] Computed sediment volume at elevation 3340.0.

[9] Storage losses at elevation 3340.0.

[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
Elevations (feet)	Original Survey (acres)	Original Capacity (acre-feet)	2000 Survey (acres)	2000 Survey (acre-feet)	2000 Sediment Volume (acre-feet)	2000 Percent of Sediment	Percent of Reservoir Depth
3,343.3			1998	65665			
3,340.0	1912.0	59925	1913.1	59212	713	100.0	100.0
3,335.0	1730.0	50820	1716.3	50138	682	95.7	93.8
3,330.0	1584.0	42535	1578.2	41902	633	88.8	87.5
3,325.0	1418.0	35030	1414.0	34421	609	85.4	81.3
3,320.0	1292.0	28255	1260.0	27736	519	72.8	75.0
3,315.0	1122.0	22220	1113.8	21802	418	58.6	68.8
3,310.0	986.0	16950	965.2	16604	346	48.5	62.5
3,305.0	785.0	12523	821.9	12137	386	54.1	56.3
3,300.0	634.0	8975	635.9	8492	483	67.7	50.0
3,295.0	520.0	6090	501.9	5648	442	62.0	43.8
3,290.0	416.0	3750	377.2	3450	300	42.1	37.5
3,285.0	276.0	2020	249.6	1883	137	19.2	31.3
3,280.0	162.0	925	156.8	867	58	8.1	25.0
3,275.0	83.0	313	74.0	290	23	3.2	18.8
3,270.0	14.0	70	23.3	47	23	3.2	12.5
3,266.2	9.0	27	0.0	0	27	3.8	7.7
3,265.0	7.0	18			18	2.5	6.3
3,260.0	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.
5	Reservoir capacity computed using ACAP, from 2000 measured surface areas.
6	Measured sediment volume = column (3) - column (5).
7	Measured sediment expressed in percentage of total sediment 713 at elevation 3,340.0.
8	Depth of reservoir expressed in percentage of total depth of 80 feet.

Table 2. - Summary of 2000 survey results

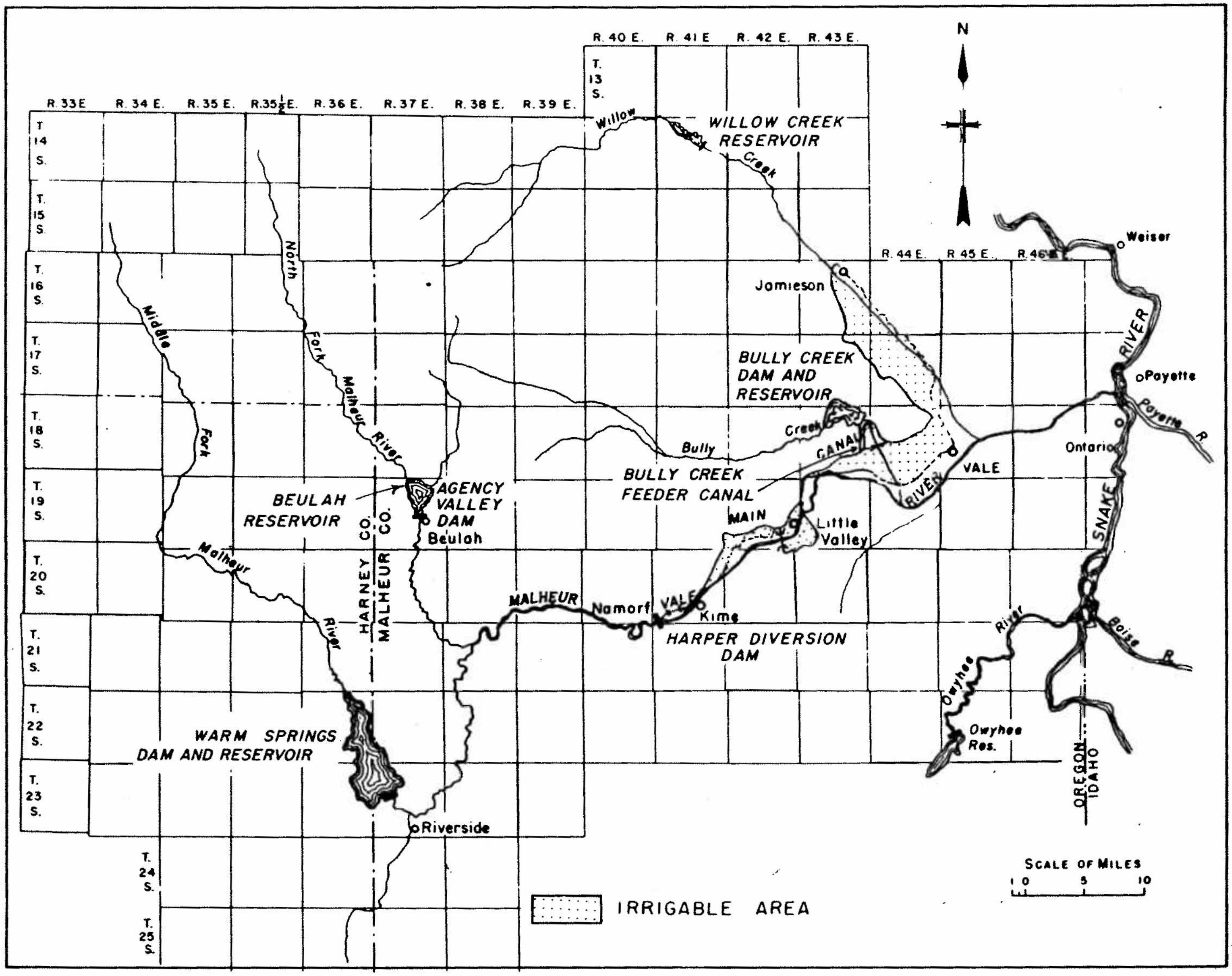

Figure 1. - Beulah Reservoir location map.

Space intentionally left blank due to security concerns

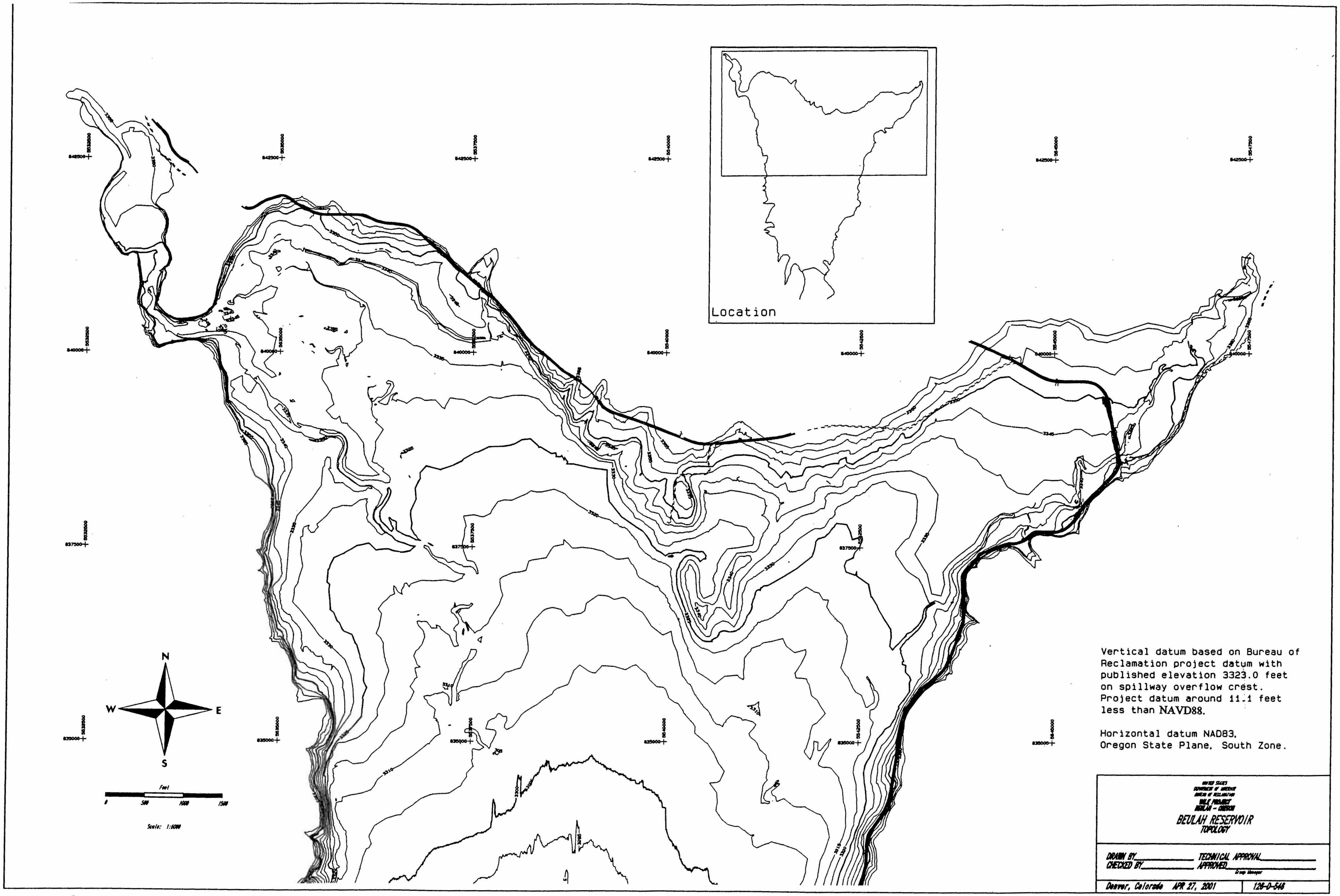

Figure 3. - Beulah Reservoir topographic map. No. 126-D-546

Figure 4 - Beulah Reservoir topographic map No. 126-D-547

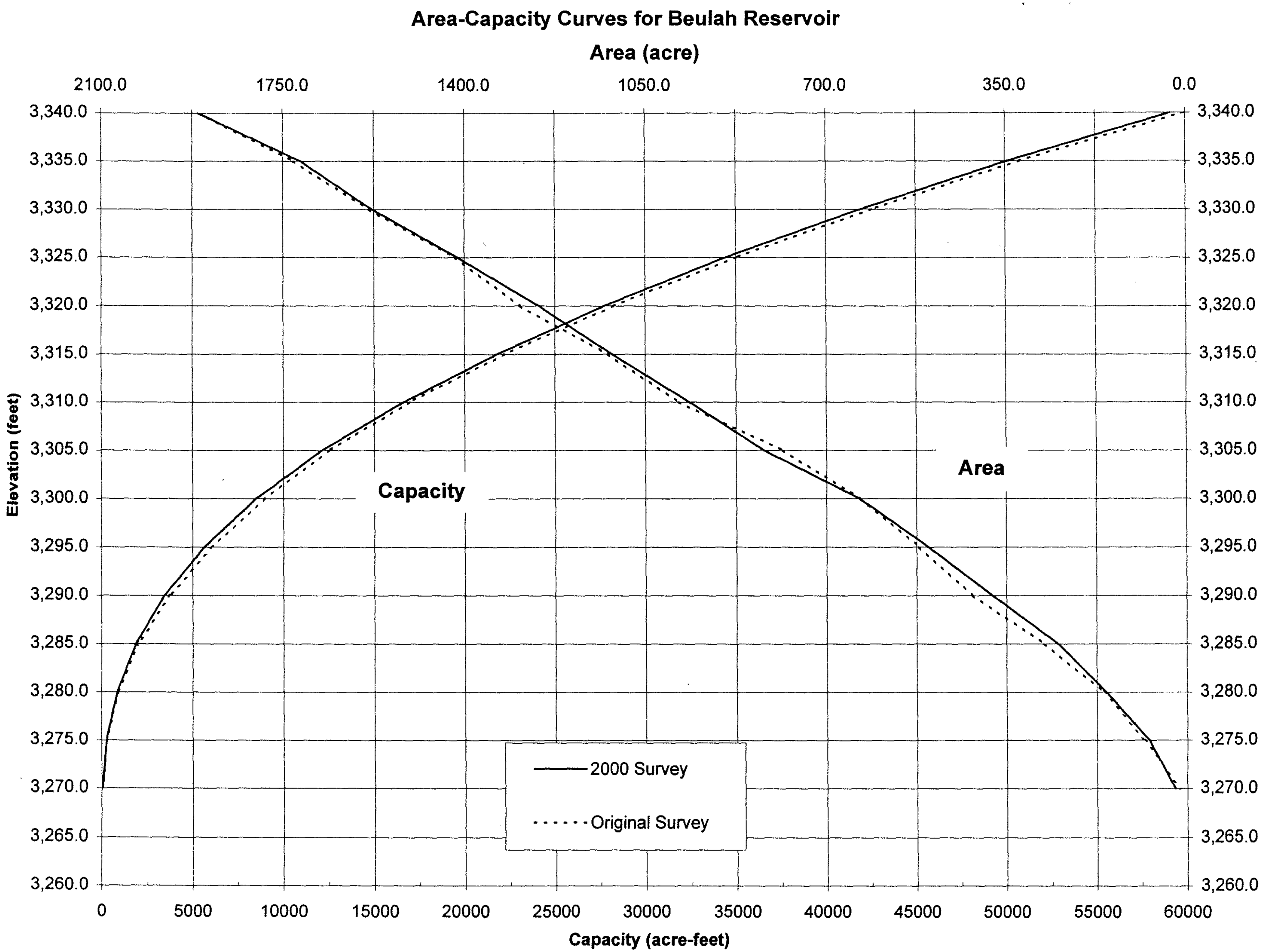

Figure 5. - 2000 area and capacity curves