PRINEVILLE RESERVOIR

1998 SEDIMENTATION SURVEY

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed the underwater portion of Prineville Reservoir in May of 1998 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 1960. The underwater survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the reservoir. The above-water topography was measured from aerial photography obtained in October 1987 near reservoir elevation 3220 feet. The new topography map of Prineville Reservoir was developed by a computer graphics program using the combined 1987 and 1998 collected data.

As of May 1998, at top of spillway crest elevation (feet) 3234.8, the reservoir surface area was 3,028 acres with a total capacity of 150,216 acre-feet. Since initial filling in 1960, about 4,586 acre-feet of sediment have accumulated in Prineville Reservoir below elevation 3234.8, resulting in 2.96 percent loss in reservoir volume. Since 1960, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 122.3 acre-feet.

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PRINEVILLE RESERVOIR

1998 SEDIMENTATION SURVEY

by

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Water Resources Services
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Denver, Colorado

March 1999

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U.S. Department of the Interior
Mission Statement

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

Prineville Reservoir, formed by Arthur R. Bowman Dam, is the largest of the two water storage reservoirs of the Crooked River Project, the other storage feature being Ochoco Reservoir. The dam, located on the Crooked River in Crook County, is about 20 miles south of Prineville in central Oregon (fig. 1).

Arthur R. Bowman Dam closure and first reservoir storage occurred in December 1960. The dam was formerly known as Prineville Dam until the name changed in the 1970's. The multipurpose reservoir provides primarily irrigation storage with additional storage for flood control and recreation. The original reservoir survey measured a surface area of about 3,034 acres and a capacity of 154,802 acre-feet at the reservoir's full pool and top of spillway gate elevation 3234.8 (feet)[1]. At this elevation the reservoir is around 14 miles long and has an average width of around 0.3 miles. The drainage basin area behind Arthur R. Bowman Dam is about 2,700 square miles with an average elevation of 4,530 feet.

Arthur R. Bowman Dam is a zoned earth and rockfill structure (fig. 2) with:

- a structural height[2] of 245 feet
- a hydraulic height of 182 feet
- a crest elevation of 3264 feet
- a top crest width of 35 feet
- a crest length of 800 feet

The spillway, located on the right abutment of the dam, has a design capacity 8,120 cubic feet per second (ft^3/sec) at water surface elevation 3257.9. It consists of:

- an excavated inlet channel
- 20-foot-wide uncontrolled concrete ogee crest at elevation 3234.8
- a 377.8-foot-long concrete chute
- a 54-foot-wide by 100-foot-long jump-type stilling basin shared with the outlet works

The river outlet works is located on the right abutment, has a design capacity of 3,300 ft^3/sec at elevation 3234.8, and consists of:

- a trashrack drop inlet-type intake structure
- 11-foot-inside-diameter concrete-lined circular tunnel
- gate chamber with two hydraulically operated emergency gates
- two hydraulically operated high-pressure regulating gates
- a concrete-lined modified-horseshoe-shaped downstream tunnel

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[1]All elevations levels are shown in feet.

[2]The definitions of such terms as "structural height," and "hydraulic height" 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*.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 1998 results of the first extensive survey of Prineville Reservoir. The primary objectives of the survey were to gather data needed to:

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

Standard land surveying methods were used to establish the horizontal and vertical control points for the aerial survey that was flown in October of 1987 around reservoir water surface elevation 3220. The aerial analysis was conducted by a private contractor who produced 5-foot contours for the majority of the above water reservoir area. The final product was 56 reservoir topographic maps at a scale of 1 inch equals 100 feet. The horizontal control grid established in the 1987 aerial survey was used for the 1998 underwater survey.

The 1998 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 Prineville Reservoir. The positioning system provided information to allow the boat operator to maintain course along these grid lines. Water surface elevations recorded by a Reclamation gauge during the time of collection were used to convert the sonic depth measurements to true lake bottom elevations.

The new Prineville Reservoir topographic map is a combination of the 1987 aerial and 1998 underwater survey data. The 1998 reservoir surface areas at predetermined 5-foot contour intervals were generated by a computer graphics program using the collected data. The 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 Prineville Reservoir sedimentation and watershed characteristics for the 1998 survey. The 1998 survey determined that the reservoir has a total storage capacity of 150,216 acre-feet and a surface area of 3,028 acres at spillway crest elevation 3234.8. The difference between the recomputed original and the 1998 capacities, at reservoir elevation 3234.8, indicated a volume of 4,586 acre-feet of sediment has accumulated since dam closure in December 1960. This volume represents a 2.96 percent loss in total capacity and an average annual loss of 122.3 acre-feet per year.

RESERVOIR OPERATIONS

The reservoir is a multiuse facility having (the following elevation increments are from a May 5, 1973 Reservoir Capacity Allocations table, and capacity values are from May 1998 area-capacity tables):

- 80,193 acre-feet of surcharge storage between elevations 3234.8 and 3257.9.
- 60,021 acre-feet of joint use storage between elevations 3211.17 and 3234.8.
- 88,612 acre-feet of conservation storage between elevation 3114.0 and 3211.17.
- 284 acre-feet of inactive storage between elevations 3112.0 and 3114.0.
- 1,299 acre-feet of dead storage below elevation 3112.0.

The Prineville Reservoir inflow and end-of-month stage records are presented in table 1. The available records from December 1960 through May 1998 show that the average inflow into the reservoir was 257,656 acre-feet per year. This inflow computes to a mean annual runoff of 1.8 inches for the 2,700-square-mile basin. The end-of-month stage records show that Prineville Reservoir initially filled to spillway crest elevation 3234.8 in water year 1962 and since then the operation has ranged from elevation 3162.3 in 1993 to elevation 3241.3 in 1998.

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, helmsman display for navigation, a plotter, a computer, and hydrographic system software for collecting the underwater data. Power to the equipment was supplied by an on-board generator.

The shore equipment included a second GPS receiver with a built-in 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 units was provided by a 12-volt battery.

GPS Technology and Equipment

The positioning system that was used at Prineville 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 Department of Defense (DOD). The GPS receiver measures the distances between the satellites and itself and determines the receiver's position from the 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 precise orbits 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 that 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. For hydrographic surveying, the altitude or the Prineville Reservoir water surface elevation parameter was known, which realistically meant only three satellite observations were needed to track the survey vessel. During the Prineville Reservoir survey, a minimum of five satellites were used for position calculations while the majority of the time, the best six available satellites were used.

The GPS receiver's absolute position is not as accurate as it appears in theory because of the function of range measurement precision and geometric position of the satellites. Precision is affected by several factors—time, because of the clock differences, and atmospheric delays caused by the effect on the radio signal by the ionosphere. 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 during the Prineville 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, 1991).

An additional and larger error source of 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.

A method of collection to resolve or cancel the inherent errors of GPS (satellite position or S/A, clock differences, atmospheric delay, etc.) is called DGPS. DGPS was used during the Prineville 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 the 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 Prineville Reservoir Survey, position corrections were determined by the master receiver and transmitted via an ultra-high frequency (UHF) radio link every 3 seconds 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 resulted in positional accuracies of 1 to 2 meters for the moving vessel compared to positional accuracies of 100 meters with a single receiver.

The Technical Service Center (TSC) mobile and reference GPS units are identical in construction and consist of a six-channel L1 coarse/acquisition (C/A) code continuous parallel tracking receiver, an internal modem, and a UHF radio transceiver. The differential corrections from the reference station to the mobile station are transmitted using the industry standard Radio Technical Commission for Maritime Services message protocol via the UHF radio link. The programming to the mobile or reference GPS unit is accomplished by entering necessary information via a notebook computer. The TSC's GPS system has the capability of establishing or confirming the land base control points by using notebook computers for logging data and using postprocessing software. The GPS collection system has the capability of collecting data in 1927 or 1983 North American Datums (NAD) in the surveyed area's state plane coordinate system's zone. For the 1998 Prineville Reservoir survey, the state plane coordinate system used was 1927 NAD in Oregon's South Zone. The reference GPS unit was set over control points established for the 1987 aerial survey.

Original Survey

The original area and capacity tables for Prineville Reservoir appear to be generated from reservoir topography developed prior to dam construction. Drawing 113-119-181, dated September 1957, has a scale of 1 inch equals 1,000 feet with 10-foot contour intervals. The upper enclosed contour for this drawing was elevation 3250. An original area-capacity table for Prineville Reservoir, dated December 11, 1962, had area and capacity values from elevation 3077 to elevation 3260. It is assumed that the area value for elevation 3260 was projected from the area curve since no other information on surface area and contour development was located. For the purpose of computing sediment values for this study, the original surface area values (listed in column 2 of table 2) were used to recompute the original capacity of Prineville Reservoir (column 3 of table 2) using the area-capacity computer program ACAP (Bureau of Reclamation, 1985).

1987 Aerial Survey

In October of 1987 an aerial survey of Prineville Reservoir was conducted. Standard land surveying methods were used to establish the horizontal and vertical control points throughout the reservoir area. The aerial analysis was conducted by a private contractor and resulted in 5-foot contours for the majority of the reservoir area. The reservoir water surface at the time of collection was around elevation 3220. The uppermost complete contour was elevation 3285. The final product was fifty six Prineville Reservoir topographic maps at a scale of 1 inch equals 100 feet. The horizontal control grid for this aerial survey was Oregon's NAD 1927 south state plane coordinates. Several of these control points were located and used for the 1998 underwater survey.

During the planning of the 1998 underwater survey it was decided that the 1987 aerial data would be used for the upper contour development of Prineville Reservoir. It was decided that the expense of conducting a present aerial survey was not justified since the 1998 underwater survey was projected to be conducted near spillway crest reservoir elevation 3234.8 and the 1987 aerial data was of such detail from elevation 3220 and above. Digital computer file data were not available for the 1987 aerial topography, requiring the scanning of the 56 reservoir maps. This process was accomplished fairly cleanly by the Visual Presentation Group of the TSC since the maps were on mylar and did not have too much clutter. The original mylar maps were scanned at 600 dots per inch using a large format scanner. Using computer software, each map image was converted to vector elements, rubber sheeted to the proper scale, cleaned of excess scanner noise, and converted to true size and true space. Each map sheet was imported into a single base drawing where all map edges were matched within the final map that was an AutoCAD DXF file.

During the scanning process it was found that the aerial flight line did not cover the entire reservoir area. This affected the very upper area, where the Crooked River flows into the reservoir, and a large part of the Bear Creek arm of the reservoir. The aerial flight line ended in the upper reservoir area near state plane coordinate E196000 (start of map 113-D-591) and the upper end of Bear Creek near state plane coordinate N884000 (map 113-D588). To complete the upper reservoir contours required the digitizing of the available contours from the U.S. Geological Survey (USGS) quad maps and matching them with the aerial scan map contours. The available contours from the USGS quads included contour elevations 3235, 3240, and 3280. This had little effect on the underwater contour development and the sediment calculations since elevation 3235 was used as the clip for the underwater contour development. This is explained in the topography development section. Engineering judgement for interpolating the contours for these affected areas was required to compute surface areas for elevations 3245 through 3285. Contours were interpolated, for the affected areas, for elevations 3245, 3250, 3255, 3260, 3270 and 3285. The maximum water surface of

Prineville Reservoir is elevation 3257.9, but since the majority of the reservoir contour areas for elevations 3260 through elevation 3285 were available, these contours were also interpolated for future reference. This information was used to compute an area-capacity table for Prineville Reservoir up to elevation 3285.

1998 Underwater Survey

The Prineville Reservoir bathymetric survey was conducted May 14 through May 18, 1998 near reservoir water surface elevation 3235.5. The bathymetric surveys were run using sonic depth recording equipment interfaced with a DGPS capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved along closely spaced grid lines covering the reservoir area. Most of the transects (grid lines) were run perpendicularly to the original river alignment at a spacing of 300 feet. Data were also collected along the shore as the boat traversed to the next transect. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining course along these predetermined grid lines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing by TSC personnel. The underwater data set includes 46,485 data points. The water surface elevation recorded by a Reclamation gauge during the time of collection was used to convert the sonic depth measurements to true lake bottom elevations.

The 1998 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 water density, salinity, temperature, turbidity, and other conditions. The accuracy of an instantaneous reading from the depth finder is estimated to be $\pm$0.5 feet, which takes into consideration calibration error and data collection in a moving boat. The collected data were digitally transmitted to the computer collection system via an RS232 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 postprocessing, and when the analog charted depths indicated a difference from the recorded computer bottom depths, the computer data files were modified.

RESERVOIR AREA AND CAPACITY

Topography Development

Using ARC/INFO, the topography of Prineville Reservoir was developed from the combined 1987 aerial and 1998 underwater collected 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. As explained in the 1987 aerial survey section, the majority of the upper contours of the reservoir were developed from scanned 1987 aerial contour data supplemented by digitized USGS quad maps. ARC/INFO V7.0.2 GIS software was used to digitize the USGS quad map contours and features such as the roads. The USGS quad maps were developed from aerial photography dated 1984, with the last editing of the map dated

1990. The digitized information was transformed to Oregon's NAD 1927 south state plane coordinates using the ARC/INFO PROJECT command.

Using ARCEDIT, the underwater data points and the scanned 1987 aerial contours layers were plotted. Using the add and select commands, data points were added for the reservoir areas not covered by the 1998 underwater survey. This included areas along the reservoir shore line and the several islands within the reservoir area. This data set was used to compute the present reservoir capacity.

The elevation 3235.0 contour from the 1987 aerial and digitized USGS quad maps was used to perform a clip of the Prineville Reservoir triangular irregular network (TIN) such that interpolation was not allowed to occur outside the 3235.0 contour. The enclosed 1987 area for elevation 3235.0 was 3,036 acres which compares to the original area of 3,042 acres for the same elevation. This complete contour was selected since it was the elevation that most nearly enclosed the 1998 underwater data collected near reservoir elevation 3235.5.

A TIN is a set of adjacent, nonoverlapping 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 know as Delaunay's criteria for triangulation. Triangles are formed between all collected data points including all boundary points. This method preserves all collected survey points. The method requires that a circle drawn through the three nodes of a triangle will contain no other point. This requirement means that sample points are connected to their nearest neighbors to form triangles. Using the hardclip option of the ARC/INFO CREATETIN command, the clip or polygon boundary (elevation 3235) enclosed all the collected data, such that during TIN development, interpolation was not allowed to occur outside the boundary. The elevation contours are 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 Prineville Reservoir TIN for elevation 3235.0 and below. In addition, the contours were generalized by eliminating select 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 little bearing on the computation of surface areas and volumes for Prineville Reservoir because the surface areas were calculated from the developed TIN. The contour topography at 10-foot intervals is presented on figures 3 through 6 drawing numbers 113-D-588 through 113-D-591.

Development of 1998 Contour Areas

The 1998 contour surface areas for Prineville Reservoir were computed in 1-foot intervals from elevations 3087.2 to 3235.0.0 using the Prineville Reservoir TIN discussed above. 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.

1998 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Reclamation, 1985). The 1998 surface areas (minimum reservoir elevation 3087.0) at 5-foot contour intervals from elevations 3090.0 to 3230.0 and the 1987 aerial surface areas at 5-foot contour intervals from elevations 3235.0 to 3260.0 along with the 1987 aerial surface areas for elevation 3270.0, 3280.0, and 3285.0 were used as the control parameters for computing the Prineville Reservoir capacity. The program can compute an area and capacity at elevation increments of 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 Prineville 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 a 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:

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

where:

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

Results of the 1998 Prineville Reservoir area and capacity computations are listed in tables 1 and 2 and plotted on figure 7. A separate set of 1998 area and capacity tables was published for the 0.01-, 0.1-, and 1-foot elevation increments (Bureau of Reclamation, 1998). These tables include a description of the computations and coefficients output from the ACAP program. Computation results are listed in columns 4 and 5 of table 2. Column 2 gives original measured contour areas used in the original area and capacity computation, and column 3 gives original capacity recomputed using ACAP. Both the original and 1998 area and capacity curves are plotted on figure 7. As of May 1998, at spillway crest elevation 3234.8, the surface area was 3,028 acres with a total capacity of 150,216 acre-feet. This study computed 1998 reservoir area and capacity up to elevation 3285.0. As explained previously the surface areas in the upper reservoir elevations of the reservoir had to be interpolated using the USGS quad map contours as a guide. These interpolated surface areas compared well with the original surface areas for elevation 3250 and below. As shown on figure 7, the area curve above elevation 3250 plotted reasonably well, but the accuracy of these values is questionable. If a more accurate value is needed then the areas of the reservoir not covered by the 1987 aerial survey need to be remapped.

RESERVOIR SEDIMENT ANALYSES

Reservoir sediment survey data for Prineville Reservoir are shown in tables 1 and 2. The computed volume difference between the original (1960 survey) and 1998 measured reservoir capacities for Prineville Reservoir is 4,586 acre-feet below spillway crest elevation 3234.8. The average annual rate of lost capacity was 122.3 acre-feet per year, or 0.0453 acre-foot per square mile from the sediment-contributing drainage area of 2,700 square miles. The storage difference in terms of percent of original storage capacity was 2.96 percent.

The 1998 sediment calculations were based on the difference between the original and the 1998 measured reservoir capacities at elevation 3234.8. This method accounts for the sediment accumulation during the 37.5 years of reservoir operation, but the calculations are only as accurate as the two surveys. It is assumed that a portion of the 0.0453-acre-ft/mi^2 yield rate is attributable to the different survey collection methods, but all indications are the differences due to the collection methods are minor.

For future reservoir planning, a theoretical distribution of sediment in the reservoir was computed using the Empirical Area Reduction Method (Bureau of Reclamation, 1987b). A sediment volume of 122.3 acre-feet per year was assumed in the distribution calculations using the results from the May 1998 survey. An analysis of the original depth-capacity relationship determined that Prineville Reservoir should be classified as type II, which was used for the theoretical sediment distribution computations. The computed results are tabulated in columns 8, 9, and 10 of table 2. For the year 1998, the theoretical computations indicated that the sediment would reach an elevation of 3086.7 at the dam. This compares to the 1998 survey that measured a sediment elevation of 3087.2 at the dam. For the year 2060, the computation indicated that the sediment would reach an elevation of 3101.6 at the dam and would have a dead pool capacity of 219 acre-feet below elevation 3112.0. For the year 2098, the computation indicated that the sediment would reach an elevation of 3109.3 at the dam and would have a dead pool capacity of 18 acre-feet below elevation 3112.0.

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RESERVOIR SEDIMENT DATA SUMMARY

Prineville Reservoir
NAME OF RESERVOIR

DATA SHEET NO. 1

DAM	1. OWNER Bureau of Reclamation	2. STREAM Crooked River	3. STATE Oregon
	4. SEC. 11 TWP. 17 S RANGE 16 E	5. NEAREST P.O. Prineville	6. COUNTY Crook
	7. LAT 44° 06' 50" LONG 120° 46' 50"	8. TOP OF DAM ELEVATION 3264.0	9. SPILLWAY CREST EL 3234.8[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 / 16. DATE NORMAL OPERATION BEGAN
a. SURCHARGE	3257.9	3997	80300	234990	15. 12/60
b. FLOOD CONTROL					
c. POWER					
d. JOINT USE	3234.8	3034	60000	154690	
e. CONSERVATION	3211.17	2098	92800	94690	
f. INACTIVE	3114.0	138	260	1890	
g. DEAD	3112.0	124	1630	1630	16. 12/60

17. LENGTH OF RESERVOIR 14 MILES	AVG. WIDTH OF RESERVOIR 0.3 MILES

BASIN		
	18. TOTAL DRAINAGE AREA 2,700 SQUARE MILES	22. MEAN ANNUAL PRECIPITATION 9.9[2] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 2,700 SQUARE MILES	23. MEAN ANNUAL RUNOFF 1.8[3] INCHES
	20. LENGTH MILES / AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 257,656[4] ACRE-FEET
	21. MAX. ELEVATION / MIN. ELEVATION	25. ANNUAL TEMP. MEAN 47°F RANGE -34°F to 105°F[2]

SURVEY DATA

26. DATE OF SURVEY	27. PER.	28. ACCL.	29. TYPE OF SURVEY	30. NO. OF RANGES OR	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO AF/AF
12/60			Contour (D)	10-ft	3034[5]	154,802[5]	.60
5/98	37.5	37.5	Contour (D)	5-ft	3028[6]	150,216[6]	.58

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
5/98	9.9[2]	257,656[7]	636,560	9,662,110	257,656	9,662,110

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.
5/98	4,586[8]	122.3	.0453	4,586	122.3	.0453

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.
5/98				.079[9]	2.96[9]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION											
		3075-3100	3100-3140	3140-3160	3160-3180	3180-3200	3200-3234.8					
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
5/98		7.4	9.6	26.2	20.5	23.8	12.5					

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
1960				1961	3,219.9	3,211.4	122,330
1962	3,235.8	3,200.2	216,420	1963	3,235.1	3,210.0	233,170
1964	3,229.9	3,211.6	110,490	1965	3,239.0	3,208.1	434,450
1966	3,232.9	3,210.2	133,170	1967	3,236.1	3,209.6	227,540
1968	3,224.5	3,199.8	58,490	1969	3,236.1	3,199.8	248,420
1970	3,237.5	3,210.9	273,490	1971	3,236.0	3,204.5	314,130
1972	3,235.4	3,210.1	323,360	1973	3,234.5	3,210.6	99,620
1974	3,236.8	3,208.7	400,020	1975	3,235.0	3,211.3	237,820
1976	3,237.8	3,211.0	219,040	1977	3,217.0	3,178.0	49,160
1978	3,237.8	3,177.4	343,570	1979	3,238.7	3,210.9	374,620
1980	3,237.4	3,211.3	253,100	1981	3,237.4	3,211.3	179,980
1982	3,235.6	3,210.8	459,510	1983	3,236.4	3,210.6	546,400
1984	3,242.7	3,209.9	636,560	1985	3,236.3	3,201.6	367,700
1986	3,237.0	3,210.2	357,030	1987	3,236.9	3,208.6	212,140
1988	3,233.0	3,201.0	111,700	1989	3,237.2	3,202.4	336,790
1990	3,225.8	3,199.8	82,830	1991	3,206.0	3,173.7	67,750
1992	3,204.6	3,163.4	65,150	1993	3,242.4	3,162.3	454,110
1994	3,224.7	3,161.8	72,060	1995	3,237.6	3,188.8	204,420
1996	3,237.3	3,210.1	263,590	1997	3,236.7	3,207.5	314,290
1998	3,241.3	3,206.9	257,690				

46. ELEVATION - AREA - CAPACITY DATA FOR **1998 CAPACITY**[10]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
3087.2	0	0	3090	2.1	3	3095	19.6	57
3100	45.9	221	3105	79.9	536	3110	122.4	1,041
3115	155.1	1,735	3120	189.3	2,596	3125	234.9	3,657
3130	289.7	4,968	3135	338.8	6,539	3140	405.1	8,399
3145	487.7	10,631	3150	574.2	13,286	3155	671.0	16,399
3160	754.7	19,963	3165	844.9	23,962	3170	967.5	28,493
3175	1,123.4	33,720	3180	1,247.4	39,647	3185	1,356.3	46,157
3190	1,468.4	53,218	3195	1,589.2	60,862	3200	1,723.8	69,145
3205	1,867.5	78,123	3210	2,010.6	87,818	3211.2	2,054	90,257
3215	2,190.9	98,322	3220	2,411.4	109,828	3225	2,643.2	122,465
3230	2,831.7	136,152	3234.8	3,028	149,611	3235	3,036.3	150,822
3240	3,194	166,398	3245	3,402	182,888	3250	3,606	200,408
3255	3,843	219,030	3257.9	4,004	230,409			

47. REMARKS AND REFERENCES

1 Uncontrolled ogee crest at elevation 3,234.8.

2 Bureau of Reclamation Project Data Book, 1981. Reported value for all of Crooked River Project.

3 Calculated using mean annual runoff value of 257,656 AF, item 24, 12/60-5/98.

4 Computed annual inflows from 12/60 through 5/98.

5 Original surface area and capacity at el. 3,234.8. 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. 3,234.8 computed by ACAP program using 1988 aerial and 1998 underwater survey data. 1988 aerial data was 1 in. = 100 ft. With 5-ft contour interval. Flight line did not cover all of reservoir area and was completed using USGS 71/2 quad map contours. Mainly affected areas above el. 3235.

7 Inflow values in acre-feet and maximum and minimum elevations in feet by water year from 12/60 through 5/98. Inflow for 1995, 1996, 1997, and 1998 have missing monthly records. Elevation data for 1960 through 1976 from USGS water records.

8 Computed sediment volume at elevation 3234.8.

9 Storage losses at elevation 3234.8.

10 Capacities computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE September 1998

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

1 Elevations (feet)	2 Original Area (acres)	3 Original Capacity (acre-feet)	4 1998 Area (acres)	5 1998 Capacity (acre-feet)	6 Measured Sediment Volume (acre-feet)	7 Percent of Computed Sediment	8 Computed 1998 Capacity (acre-ft)	9 Computed 2060 Capacity (acre-ft)	10 Computed 2098 Capacity (acre-ft)
3234.8	3034	154802	3028	150216	4586	100.0	150216.0	142572.0	137925.0
3230	2830	140730	2832	136152	4578	99.8	136185.0	128611.0	124010.0
3225	2613	127123	2643	122465	4658	101.6	122675.0	115273.0	110783.0
3220	2400	114590	2411	109828	4762	103.8	110262.0	103070.0	98716.0
3215	2218	103045	2191	98322	4723	103.0	98853.0	91899.0	87697.0
3211.2	2098	94845	2054	90257	4588	100.0	90764.0	84005.0	79930.0
3210	2060	92350	2011	87818	4532	98.8	88306.0	81610.0	77576.0
3205	1918	82405	1867	78123	4282	93.4	78518.0	72098.0	68241.0
3200	1780	73160	1724	69145	4015	87.5	69438.0	63306.0	59636.0
3195	1643	64603	1589	60862	3741	81.6	61052.0	55220.0	51743.0
3190	1520	56695	1468	53218	3477	75.8	53319.0	47795.0	44517.0
3185	1415	49358	1356	46157	3201	69.8	46162.0	40952.0	37878.0
3180	1300	42570	1247	39647	2923	63.7	39556.0	34666.0	31797.0
3175	1142	36465	1123	33720	2745	59.9	33635.0	29068.0	26408.0
3170	1020	31060	968	28493	2567	56.0	28416.0	24173.0	21722.0
3165	908	26240	845	23962	2278	49.7	23781.0	19863.0	17623.0
3160	810	21945	755	19963	1982	43.2	19671.0	16078.0	14047.0
3155	734	18085	671	16399	1686	36.8	15995.0	12724.0	10901.0
3150	640	14650	574	13286	1364	29.7	12743.0	9791.0	8174.0
3145	544	11690	488	10631	1059	23.1	9962.0	7325.0	5912.0
3140	460	9180	405	8399	781	17.0	7629.0	5301.0	4087.0
3135	382	7075	339	6539	536	11.7	5697.0	3671.0	2653.0
3130	310	5345	290	4968	377	8.2	4135.0	2403.0	1575.0
3125	244	3960	235	3657	303	6.6	2912.0	1466.0	822.0
3121.5	201	3172	203	2890	282	6.1	2235.0	982.0	462.0
3120	190	2875	189	2596	279	6.1	1984.0	812.0	345.0
3114	138	1896	149	1583	313	6.8	1183.0	324.0	59.0
3112	124	1634	135	1299	335	7.3	1183.0	219.0	18.0
3110	110	1400	122	1041	359	7.8	800.0	138.0	1.0
3109.3									0.0
3105	83	918	80	536	382	8.3	451.0	22.0	
3101.6								0.0	
3100	60	560	46	221	339	7.4	215.0		
3095	40	310	20	57	253	5.5	76.0		
3090	25	148	2	3	145	3.2	12.0		
3087.2	18	87	0	0	87	1.9			
3086.7							0.0		
3085	13	53	0	0	53	1.2			
3080	4	10	0	0	10	0.2			
3075	0	0	0	0	0	0.0			

Table 2. - Summary of 1998 survey results.

1	2	3	4	5	6	7	8
Elevations (feet)	Original Area (acres)	Original Capacity (acre-feet)	1998 Area (acres)	1998 Capacity (acre-feet)	Computed Sediment Volume (acre-feet)	Percent of Computed Sediment	Percent of Reservoir Depth
3285			4939	352898			
3280			4834	328465			
3270			4475	281920			
3260	4100		4121	238940			
3257.9	3997	235053	4004	230409			100.0
3255	3855	223668	3843	219030			98.4
3250	3610	205005	3606	200408			95.7
3245	3393	187498	3402	182888			92.9
3240	3200	171015	3194	166398			90.2
3235	3042	155410	3036	150822			87.5
3234.8	3034	154802	3028	150216	4586	100.0	87.4
3230	2830	140730	2832	136152	4578	99.8	84.7
3225	2613	127123	2643	122465	4658	101.6	82.0
3220	2400	114590	2411	109828	4762	103.8	79.3
3215	2218	103045	2191	98322	4723	103.0	76.5
3211.2	2098	94845	2054	90257	4588	100.0	74.5
3210	2060	92350	2011	87818	4532	98.8	73.8
3205	1918	82405	1867	78123	4282	93.4	71.1
3200	1780	73160	1724	69145	4015	87.5	68.3
3195	1643	64603	1589	60862	3741	81.6	65.6
3190	1520	56695	1468	53218	3477	75.8	62.9
3185	1415	49358	1356	46157	3201	69.8	60.1
3180	1300	42570	1247	39647	2923	63.7	57.4
3175	1142	36465	1123	33720	2745	59.9	54.7
3170	1020	31060	968	28493	2567	56.0	51.9
3165	908	26240	845	23962	2278	49.7	49.2
3160	810	21945	755	19963	1982	43.2	46.5
3155	734	18085	671	16399	1686	36.8	43.7
3150	640	14650	574	13286	1364	29.7	41.0
3145	544	11690	488	10631	1059	23.1	38.3
3140	460	9180	405	8399	781	17.0	35.5
3135	382	7075	339	6539	536	11.7	32.8
3130	310	5345	290	4968	377	8.2	30.1
3125	244	3960	235	3657	303	6.6	27.3
3120	190	2875	189	2596	279	6.1	24.6
3115	145	2038	155	1735	303	6.6	21.9
3114	138	1896	149	1583	313	6.8	21.3
3112	124	1634	135	1299	335	7.3	20.2
3110	110	1400	122	1041	359	7.8	19.1
3105	83	918	80	536	382	8.3	16.4
3100	60	560	46	221	339	7.4	13.7
3095	40	310	20	57	253	5.5	10.9
3090	25	148	2	3	145	3.2	8.2
3087.2	18	87	0	0	87	1.9	6.7
3085	13	53	0	0	53	1.2	5.5
3080	4	10	0	0	10	0.2	2.7
3075	0	0	0	0	0	0.0	0.0

1 Elevation of reservoir water surface.
2 Original reservoir surface area.
3 Original calculated reservoir capacity computed using ACAP.
4 Reservoir surface from 1998 for elevations 3235 and below. Areas for elevation 3240 and greater from 1988 aerial survey.
5 1998 calculated reservoir capacity computed using ACAP from 1998 surface areas.
6 Measured sediment volume = column (3) - column (5).
7 Measured sediment expressed in percentage of total sediment 4586 acre-feet at elevation 3234.8.
8 Depth of reservoir expressed in percentage of total depth (182.9 feet).

Table 3. - Summary of 1998 survey and theoretical sediment distribution computations.

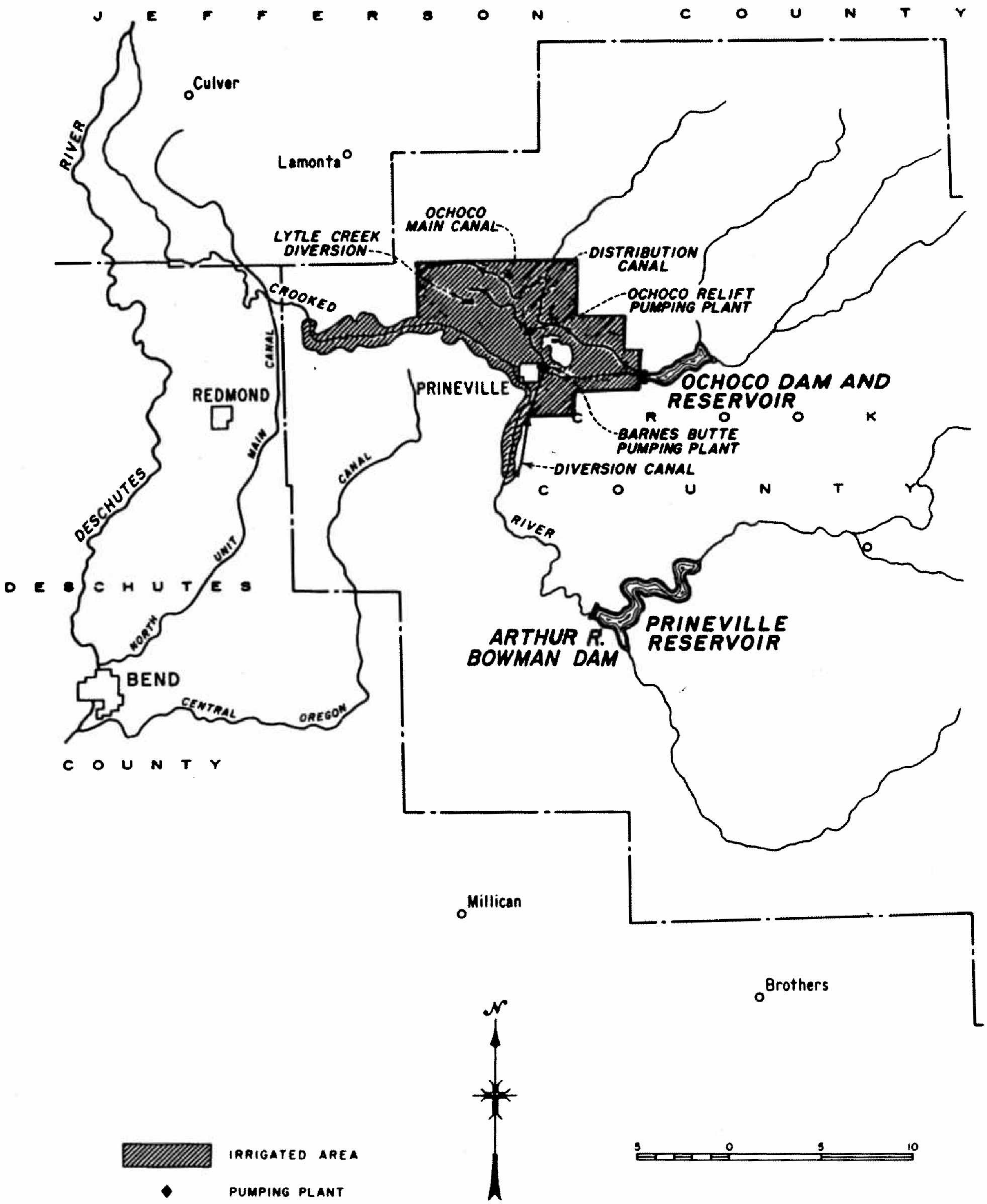
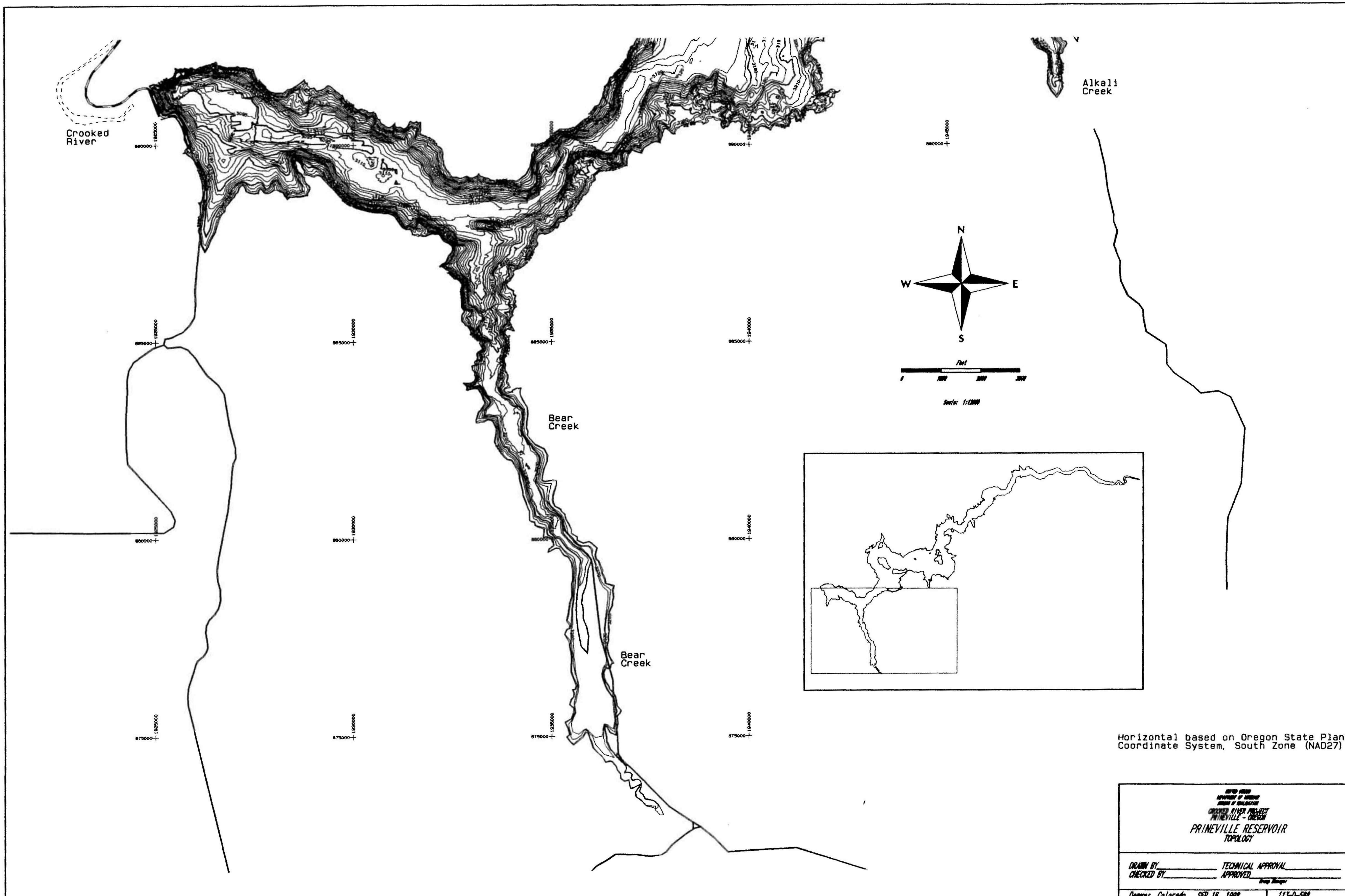


Figure 1. - Prineville Reservoir location map.

Space intentionally left blank due to security concerns


Crooked River
Alkali Creek
Bear Creek
Bear Creek
N
S
E
W
Feet
Horizontal based on Oregon State Plane Coordinate System, South Zone (NAD27).
CROOKED RIVER PROJECT
PRINEVILLE - OREGON
PRINEVILLE RESERVOIR
TOPOLOGY
DRAWN BY
CHECKED BY
TECHNICAL APPROVAL
APPROVED
Denver, Colorado SEP 16, 1998
113-D-588

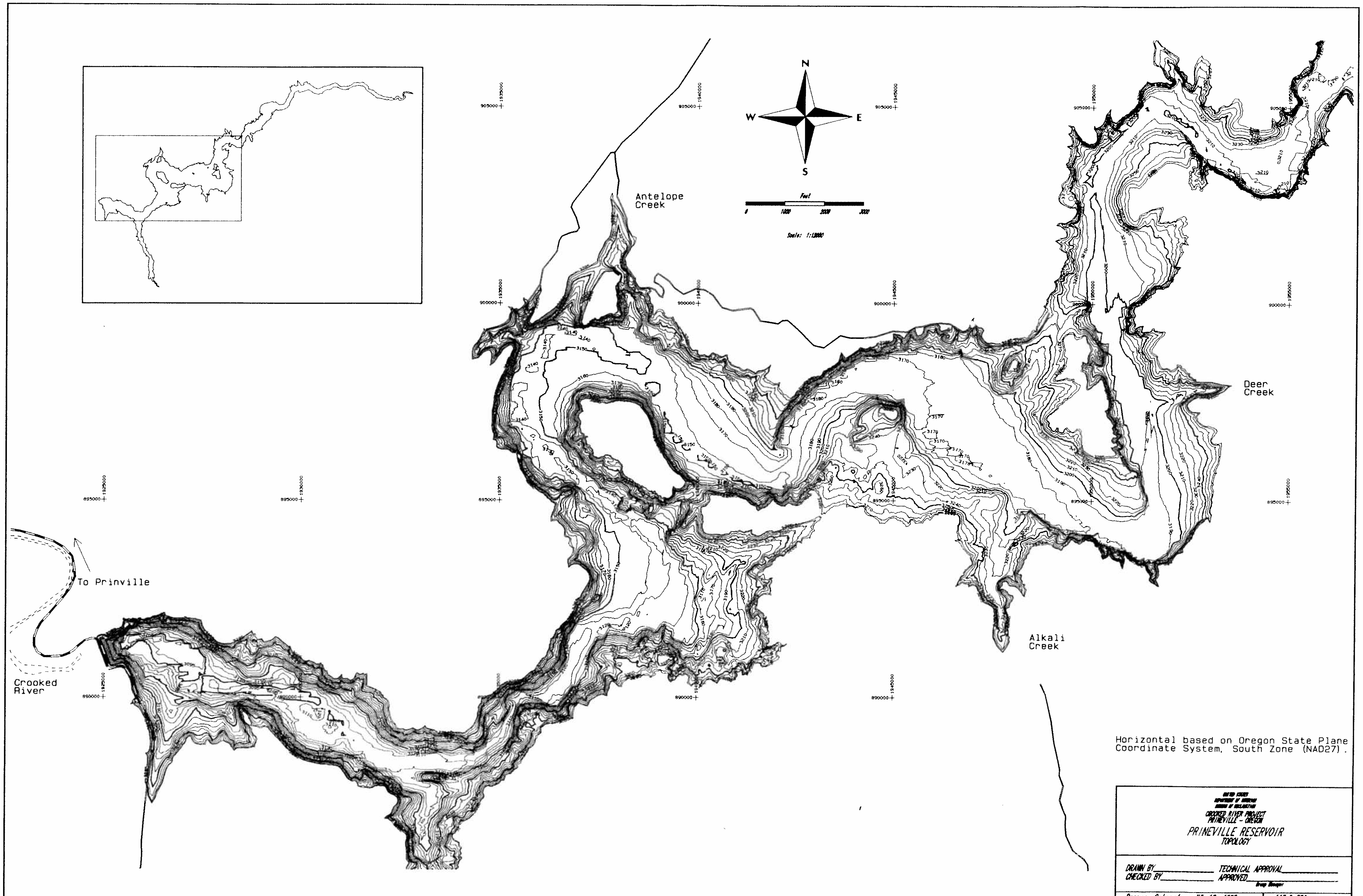


Figure 4. - Prineville Reservoir topology map, No. 113-D-589

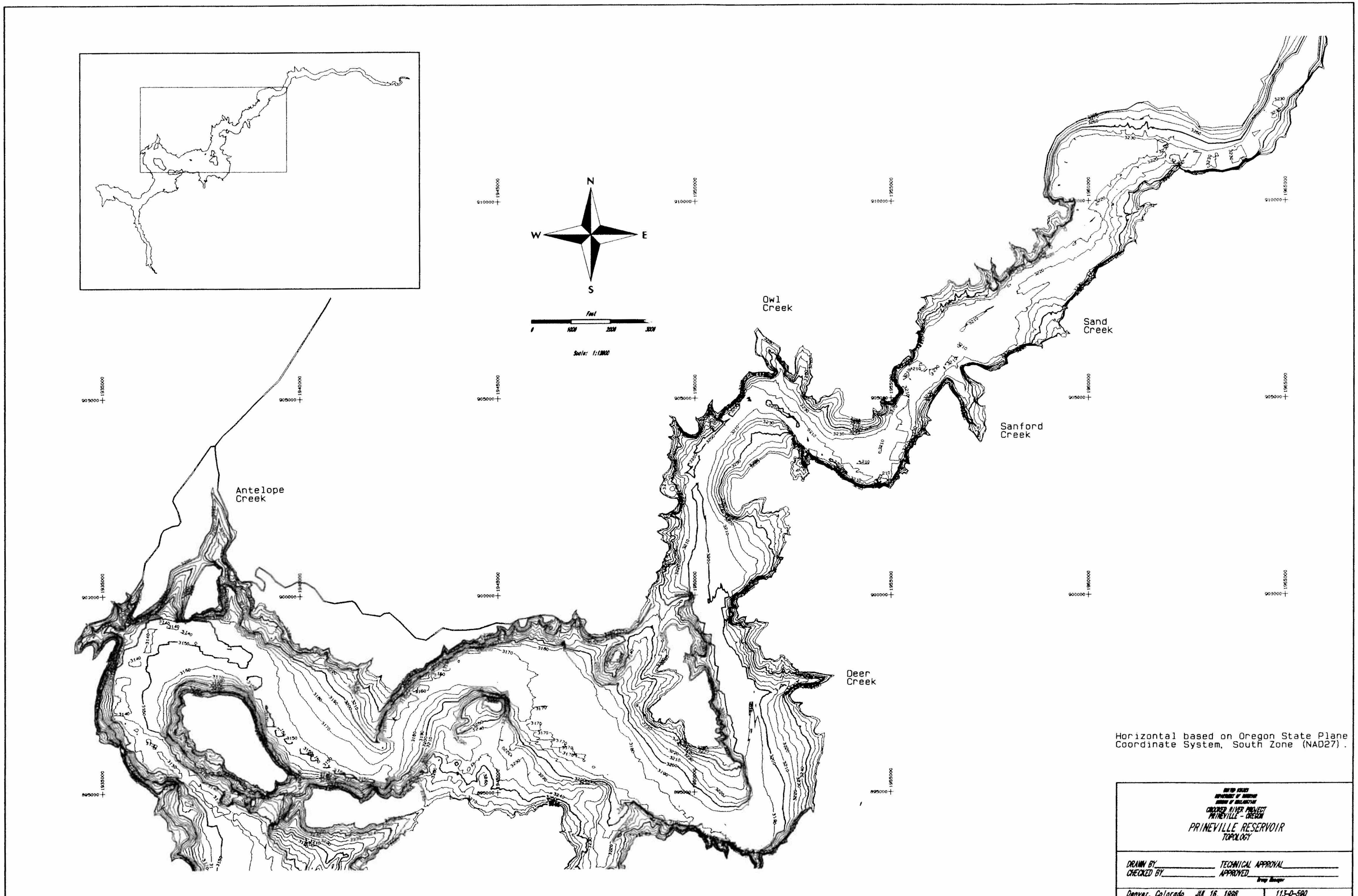
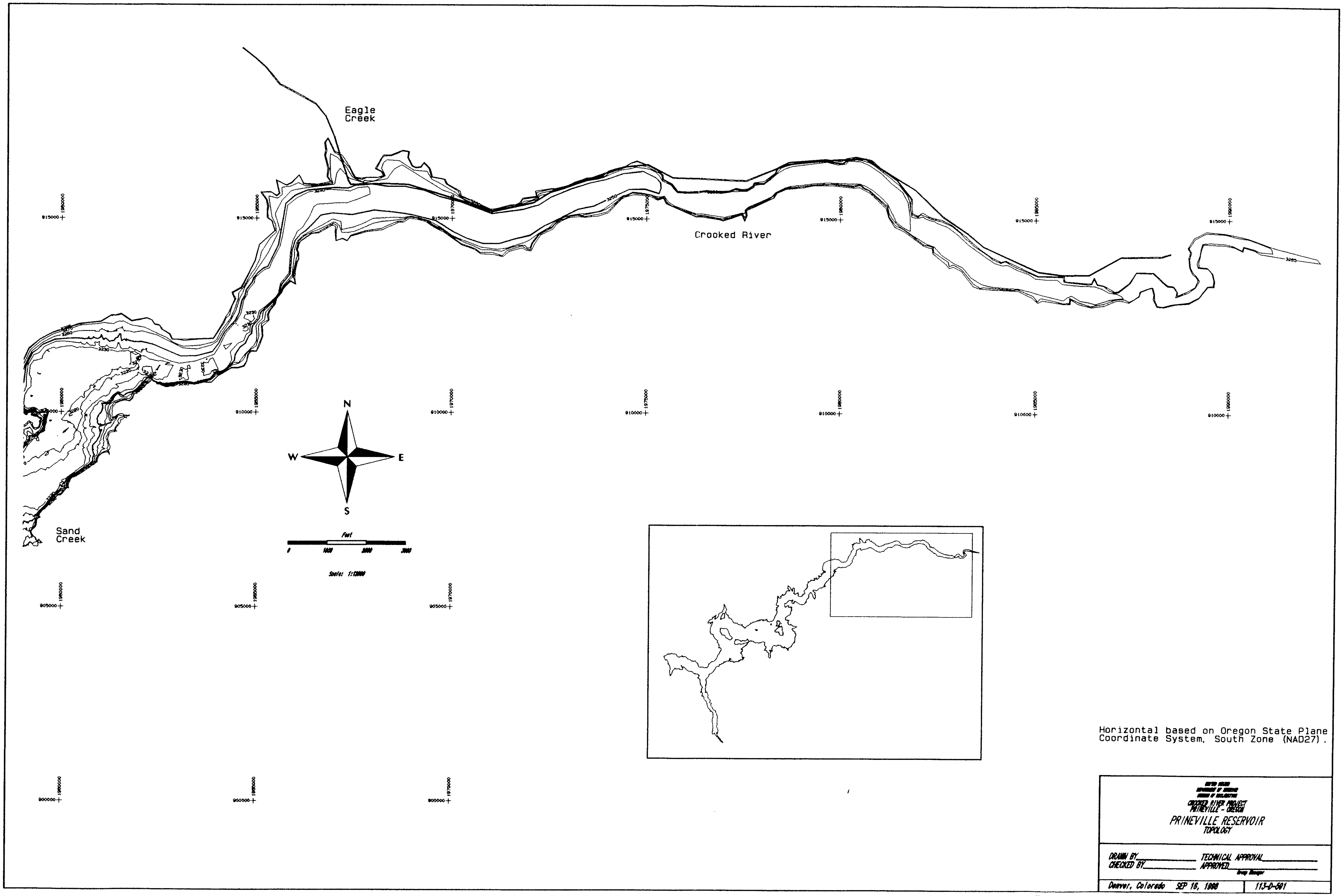


Figure 5 - Prineville Reservoir topology



Eagle Creek
Crooked River
Sand Creek
N
S
W
E
Feet
0
1000
2000
3000
Scale: 1:12000
Horizontal based on Oregon State Plane Coordinate System, South Zone (NAD27).
CROOKED RIVER PROJECT
PRINEVILLE - OREGON
PRINEVILLE RESERVOIR
TOPOLOGY
DRAWN BY
CHECKED BY
TECHNICAL APPROVAL
APPROVED
Denver, Colorado
113-D-501

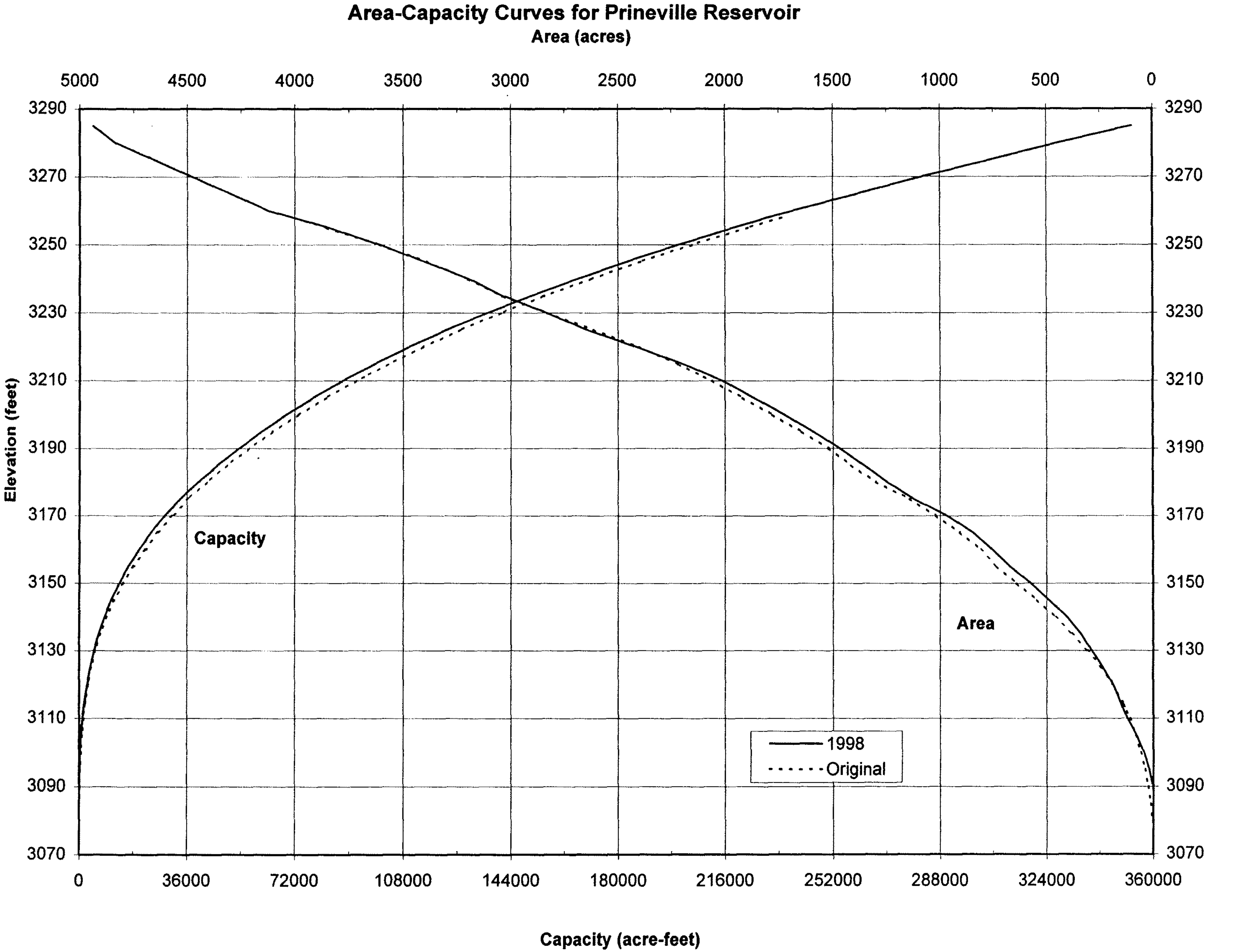


Figure 7. - 1998 area and capacity curves.

MISSION

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.