# KEENE CREEK RESERVOIR
1999 SURVEY

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed Keene Creek Reservoir in June 1999 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 1959. 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 measured in 1999 by standard land surveying methods. Digitized contour lines from the U.S. Geological Survey quadrangle (USGS quad) map of the reservoir area were used to assist in upper contour development. The new topographic map of Keene Creek Reservoir was developed from the combined 1999 measured topography and the digitized USGS contours.

As of July 1999, at reservoir water surface elevation (feet) 4,407.0, the surface area was 15 acres with a total capacity of 349 acre-feet. Since initial filling in 1959, about 43 acre-feet of sediment have accumulated in Keene Creek Reservoir below elevation 4,407.0, resulting in a 11.0 percent loss in reservoir volume.

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# KEENE CREEK RESERVOIR

## 1999 SURVEY

by

**Ronald L. Ferrari**

Sedimentation and River Hydraulics Group
Water Resources Services
Technical Service Center
Denver, Colorado

September 2000

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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. Ronald Ferrari and Tim Randle of the TSC conducted the hydrographic survey. Special thanks to Darren Knuteson of the Pacific Northwest Region for his assistance during the bathymetric survey which included locating necessary control and assembling of the collection system. Also special thanks to Sam Trachsler of the Columbia Basin Project Office of the Pacific Northwest Region for his assistance supporting the bathymetric survey, determining the vertical control, and mapping the above water area. Ronald Ferrari completed the data processing needed to generate the new map topology and area-capacity tables. Kent Collins performed the 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

Keene Creek Dam that forms Keene Creek Reservoir is one of several facilities constructed by Reclamation as part of the Rogue River Basin Project. The dam, located on Keene Creek in Jackson County, is about 17 miles southeast of Ashland in southwestern Oregon (fig. 1). Keene Creek Reservoir is in the Klamath River watershed, but essentially all water stored and regulated for power generation and irrigation is diverted through the Cascade Divide by facilities located in the Emigrant Creek basin which is within the Rogue River watershed. Keene Creek Dam is one of several water storage facilities located on the eastern side of the Cascade Divide to collect, store, and divert water from the eastern side of the divide to the western side of the divide. Keene Creek Reservoir reregulates releases from Howard Prairie and Hyatt Reservoirs by providing forebay storage for the Green Springs Powerplant. The Cascade Divide Tunnel and conduit carry water from Keene Creek Reservoir across the Cascade divide to the powerplant located on Emigrant Creek. Keene Creek Dam closure and first storage occurred in 1959. The reported original reservoir surface area was about 14.5 acres with a total capacity of 339 acre-feet at reservoir elevation 4,403.5 (feet)[1]. The natural drainage basin area behind Keene Creek Dam is about 14 square miles.

Keene Creek Dam is a zoned earth rockfill embankment structure (fig. 2) with:

- a structural height[2] of 78 feet
- a hydraulic height of 57.5 feet
- a crest elevation of 4,412.5 feet
- a top crest width of 30 feet
- a crest length of 558 feet

The spillway is located on the left abutment of the dam with a crest elevation of 4,403.5. The design capacity is 2,650 cubic feet per second (cfs) at water surface elevation 4407.0. It consists of:

- a side channel inlet structure
- an uncontrolled 110-foot-long overflow crest
- a 377-foot-long and 16-foot-wide chute
- a 16-foot-wide by 103-foot-long stilling basin

The only facility for releasing water stored in the reservoir below the top of active conservation at elevation 4403.5 is through the Cascade Divide Tunnel. The conduit intake is located around 540 feet upstream from the right abutment of the dam. Releases can be made from the tunnel through the wasteway and the Green Springs Powerplant. There is one generator at the powerplant with a discharge capacity of 130 cfs. The wasteway has a discharge capacity of 95 cfs at elevation 4403.5.

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[1]All elevations levels are shown in feet.

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

## SUMMARY AND CONCLUSIONS

This Reclamation report presents the 1999 results of the survey of Keene Creek 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

Prior to the underwater survey a global positioning system (GPS) control survey was conducted to establish horizontal and vertical control points on the dam. The horizontal control was established in Oregon's state plane south zone coordinates in the North American Datum of 1983 (NAD83). The vertical control for the established points was tied to Reclamation's project datum that was determined to be near the National Geodetic Vertical Datum of 1929 (NGVD29). Standard land surveying methods were used to measure the above water areas of the reservoir.

The bathymetric survey was run using sonic depth recording equipment interfaced with a differential global positioning system 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 Keene Creek Reservoir. Water surface elevations recorded by the hydrographic survey crew during the time of collection were used to convert the sonic depth measurements to true reservoir bottom elevations.

Tables 1 and 2 contain a summary of the 1999 Keene Creek Reservoir survey. The 1999 survey determined that the reservoir has a total storage capacity of 349 acre-feet and a surface area of 15 acres at reservoir elevation 4,407.0. Since closure in 1959, the reservoir has accumulated a volume of 43 acre-feet of sediment below elevation 4407.0. This volume represents a 11.0 percent loss in total capacity.

## HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted on an aluminum framed pontoon raft equipped with an outboard motor. 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 computer, and hydrographic system software for collecting underwater data. Power to the equipment was supplied by 12-volt batteries.

The shore equipment included a second GPS receiver with an external radio and an omnidirectional antenna. The GPS receiver was mounted on a survey tripod over a known datum point. The power for the shore unit was provided by a 12-volt battery.

**GPS Technology and Equipment**

The hydrographic positioning system used at Keene Creek 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. For hydrographic surveying, the altitude (Keene Creek's water surface elevation parameter) was known, which in theory meant only three satellite observations were needed to track the survey vessel. During the Keene Creek Reservoir survey, the best available satellites were used for position calculations which usually consisted of 5 or more.

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 Keene Creek 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 ±10 meters.

A method of collection to resolve or cancel the inherent errors of GPS is called differential GPS (DGPS). DGPS was 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 Keene Creek 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 ±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 in 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 Keene Creek Reservoir hydrographic survey collection was conducted on June 29, 1999. 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 close-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. Data was also collected along the shore as the boat traversed to the next 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 1999 underwater data were collected by a depth sounder that was calibrated by lowering a survey rod below the sounders transducer. The depth sounder was calibrated by adjusting the speed of sound, which can vary with water 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. During the survey the reservoir water surface elevation was changing due to releases to the powerplant. All elevations were adjusted to Reclamation's project datum. The reservoir's water surface elevations recorded by the hydrographic survey crew during the time of the survey were used to convert the sonic depth measurements to true lake-bottom elevations. The above water area was mapped a few days after the underwater survey using standard land surveying techniques and the same control network.

## Keene Creek Reservoir Datum

Prior to the underwater survey in June1999, a RTK GPS survey was conducted to establish horizontal and vertical control points on Keene Creek Dam. The National Geodetic Survey control point on nearby Hyatt Dam was used as the base station for the control survey. The radio link between Hyatt Dam and Keene Creek Dam was intermittent, but control information appears to be good. A point on Keene Creek Dam was established for the underwater survey. A measurement was obtained on the USGS brass cap marked 1988 V760 that is tied to the project datum. The published elevation for V760 is 4413.311 which appears to be near NGVD29. All 1999 elevations in this report were tied to this datum.

# RESERVOIR AREA AND CAPACITY

## Topography Development

Using ARC/INFO the topography of Keene Creek Reservoir was developed from the 1999 collected data and the USGS quad maps. The USGS contour labeled 4440 was used to assist in developing the reservoir contours. 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.

ARC/INFO V7.0.2 geographic information system software was used to digitize the USGS quad contours. The digitized contours were transformed into Oregon's NAD 1983 state plane coordinates using the ARC/INFO PROJECT command. Using the contour digitized from USGS quad map as a pattern, a clip or boundary around the edge of the 1999 data set was developed 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 elevations 4,412 and below were computed from the 1999 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 between all data points within a polygon or the boundary clip. This 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 preserving all collected survey points. Elevation contours are then interpolated along the triangle elements. The TIN method is discussed in great 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 Keene Creek 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 little bearing on the computation of surface areas and volumes for Keene Creek Reservoir since the areas were calculated from the developed TIN. The contour topography at 2-foot intervals is presented on figures 3, drawing number 415-D-904.

## Development of 1999 Contour Areas

The 1999 contour surface areas for Keene Creek Reservoir were computed at 1-foot increments, from elevation 4,353.0 to 4,408.0, using the Keene Creek 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.

**1999 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). The 1999 measured surface areas at 2-foot contour intervals from reservoir elevation 4,358.0 to elevation 4408.0 were used as the control parameters for computing the Keene Creek 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 Keene Creek 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:

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

where:

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

Results o the 1999 Keene Creek Reservoir area and capacity computations are listed in table 1 and columns (4) and (5) of table 2. Listed in columns (2) and (3) of table 2 are the original surface areas and capacity values. In the appendix is the 1999 area and capacity tables at 0.1-foot elevation increments. A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 1999 area-capacity curves are plotted on figure 4. As of June 1999, at elevation 4,407.0, the surface area was 15 acres with a total capacity of 349 acre-feet.

## Analysis of Results

The Keene Creek Reservoir original and 1999 area and capacity values are illustrated on the figure 4 plot and table 1 and 2 results. These presentations illustrate the large area and capacity changes that have occurred during the 40 years of reservoir operations. The accuracy of the original data is unknown and this must be noted when making sediment calculations. It must also be noted that the 1999 data is very limited in the upper reservoir area above elevation 4407 requiring the use of the USGS quad sheet contours to develop the upper contours. If this portion of the reservoir, above elevation 4407, is of importance then it is recommended that additional data be collected for a more accurate map of the upper reservoir area. The study found surface area change in the upper area of the reservoir that could be the result of some shoreline erosion.

The 1999 study found that since storage of Keene Creek Reservoir began in 1959, sediments have accumulated to a total volume of 43 acre-feet below elevation 4407.0. The average annual rate of sediment deposition since closure was 1.08 acre-feet from the sediment contributing drainage area that includes the 14 square miles above Keene Creek Dam, but should also include the drainage areas above Howard Prairie and Hyatt Reservoirs which divert water to Keene Creek Reservoir. The storage loss in terms of percent of original storage capacity was 11.0 percent.

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Corps of Engineers, October 1994. Engineer and Design - ***Hydrographic Surveying***, EM 1110-2-1003 (FR), Department of the Army, Washington DC (www.usace.army.mil/inet/usace.docs/eng-manuals/em.htm).

Environmental Systems Research Institute , Inc. (ESRI), 1992. ***ARC Command References***.

# RESERVOIR SEDIMENT DATA SUMMARY

**Keene Creek Reservoir**
NAME OF RESERVOIR

1
DATA SHEET NO.

| | | | |
|---|---|---|---|
| DAM | 1. OWNER Bureau of Reclamation | 2. STREAM Keene Creek | 3. STATE Oregon |
| | 4. SEC. 33 TWP. 39 S RANGE 3 E | 5. NEAREST P.O. Ashland | 6. COUNTY Jackson |
| | 7. LAT 42° 07' 45" LONG 122° 28' 43" | 8. TOP OF DAM ELEVATION 4412.5[1] | 9. SPILLWAY CREST EL 4403.5[2] |

| 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 | | | | | 1959 |
| | c. MULTIPLE USE | 4407.0 | 15.6 | 53 | 392 | |
| | d. WATER SUPPLY | | | | | 16. DATE NORMAL OPERATION BEGAN |
| | e. CONSERVATION | 4403.5 | 14.5 | 262 | 339 | |
| | f. INACTIVE | 4378.0 | 6.2 | 34 | 77 | |
| | g. DEAD | 4371.5 | | 43 | 43 | 1959 |
| | 17. LENGTH OF RESERVOIR 0.4 MILES | | | AVG. WIDTH OF RESERVOIR 0.06 MILES | | |

| BASIN | | |
|---|---|---|
| | 18. TOTAL DRAINAGE AREA 14 SQUARE MILES | 22. MEAN ANNUAL PRECIPITATION 19.7[3] INCHES |
| | 19. NET SEDIMENT CONTRIBUTING AREA 14 SQUARE MILES | 23. MEAN ANNUAL RUNOFF [4] INCHES |
| | 20. LENGTH MILES AV. WIDTH MILES | 24. MEAN ANNUAL RUNOFF [5] ACRE-FEET |
| | 21. MAX. ELEVATION MIN. ELEVATION | 25. ANNUAL TEMP. MEAN 54°F RANGE -6°F to 109°F[3] |

**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 |
|---|---|---|---|---|---|---|---|
| 1959 | | | Contour | 10-ft | 15.6[6] | 392[6] | |
| 6/99 | 40 | 40 | Contour (D) | 2-ft | 15[7] | 349[7] | |

| 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 |
| 6/99 | | | | [8] | | |

| 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. |
| 6/99 | 43 | 1.08 | | | | |

| 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. |
| 6/99 | | | | 0.276[9] | 11.0 | | |

| 26. DATE OF SURVEY | 43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION | | | | | | | | | | | |
| 5/99 | | | | | | | | | | | | |

| 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[10]

| YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AF | YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AF |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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46. ELEVATION - AREA - CAPACITY DATA FOR **1999 CAPACITY**[11]

| ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY |
|---|---|---|---|---|---|---|---|---|
| 4355.0 | 0 | 0 | 4360.0 | 1 | 1 | 4365.0 | 1 | 6 |
| 4370.0 | 3 | 17 | 4375.0 | 4 | 34 | 4378.0 | 5 | 48 |
| 4380.0 | 6 | 59 | 4385.0 | 8 | 95 | 4390.0 | 10 | 140 |
| 4395.0 | 11 | 193 | 4400.0 | 13 | 254 | 4403.5 | 14 | 300 |
| 4405.0 | 14 | 321 | 4407.0 | 15 | 349 | | | |

47. REMARKS AND REFERENCES

1 All elevations tied to Reclamation project datum which is tied to NGVD29.

2 Uncontrolled spillway crest.

3 Bureau of Reclamation Project Data Book, 1981.

4 Inflow from drainage area and diverted flows from Rogue River watershed.

5 Inflow from drainage area and diverted flows from Rogue River watershed.

6 Original surface area and capacity at elevation 4407.0.

7 Surface area and capacity at elevation 4407.0 computed by ACAP program using 1999 surface areas.

8 Inflow from drainage area and diverted flows from Rogue River watershed.

9 Capacity loss calculated by comparing original capacity and 1999 capacity at reservoir elevation 4407.0. Portion of capacity difference due to accuracy of surveys.

10 Maximum and minimum elevations may fluctuate on an hourly basis. Inflow from drainage area, but main inflow from diverted flows from Rogue River watershed.

11 Capacities computed by Bureau of Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE September 2000

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

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| | | | | | 1999 | 1999 | Percent of |
| Elevations | Original | Original | 1999 | 1999 | Sediment | Percent of | Reservoir |
| | Survey | Capacity | Survey | Survey | Volume | Sediment | Depth |
| (feet) | (acres) | (acre-feet) | (acres) | (acre-feet) | (acre-feet) | | |
| 4,407.0 | 15.6 | 392 | 14.6 | 349 | 43 | 100.0 | 100.0 |
| 4,405.0 | 15.0 | 361 | 14.0 | 321 | 40 | 93.0 | 96.5 |
| 4,403.5 | 14.5 | 339 | 13.7 | 300 | 39 | 90.7 | 93.9 |
| 4,400.0 | 13.3 | 290 | 12.7 | 254 | 36 | 83.7 | 87.7 |
| 4,395.0 | 11.7 | 228 | 11.3 | 193 | 35 | 81.4 | 78.9 |
| 4,390.0 | 10.0 | 174 | 10.0 | 140 | 34 | 79.1 | 70.2 |
| 4,385.0 | 8.4 | 128 | 8.0 | 95 | 33 | 76.7 | 61.4 |
| 4,380.0 | 6.8 | 90 | 6.1 | 59 | 31 | 72.1 | 52.6 |
| 4,378.0 | 6.2 | 77 | 5.2 | 48 | 29 | 67.4 | 49.1 |
| 4,375.0 | 5.1 | 60 | 4.2 | 34 | 26 | 60.5 | 43.9 |
| 4,370.0 | 4.0 | 36 | 2.8 | 17 | 19 | 44.2 | 35.1 |
| 4,365.0 | 2.8 | 19 | 1.4 | 6 | 13 | 30.2 | 26.3 |
| 4,360.0 | 1.6 | 8 | 0.5 | 1 | 7 | 16.3 | 17.5 |
| 4,355.0 | 0.8 | 2 | 0.0 | 0 | 2 | 4.7 | 8.8 |
| 4,350.0 | 0.0 | 0 | 0.0 | 0 | 0 | 0.0 | 0.0 |

| | |
|---|---|
| 1 | Elevation of reservoir water surface. |
| 2 | Original reservoir surface area. |
| 3 | Original reservoir capacity. |
| 4 | Reservoir surface area from 1999 survey. |
| 5 | Reservoir capacity computed using ACAP, from 1999 measured surface areas. |
| 6 | Measured sediment volume = column (3) - column (5). |
| 7 | Measured sediment expressed in percentage of total sediment 43 at elevation 4,407.0. |
| 8 | Depth of reservoir expressed in percentage of total depth of 57 feet. |

Table 2. - Summary of 1999 survey results

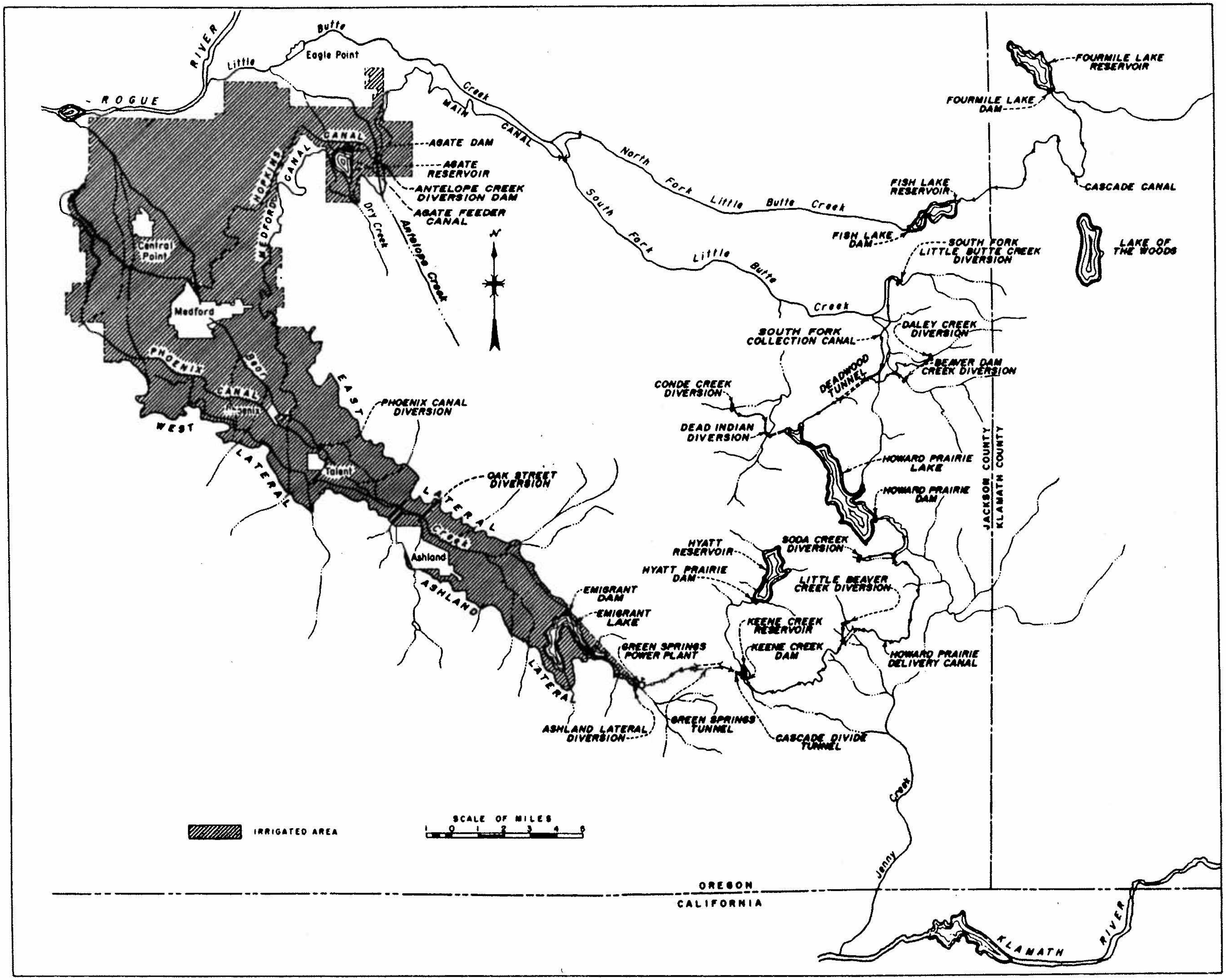


Figure 1. - Keene Creek Reservoir location map.

**Space intentionally left blank due to security concerns**

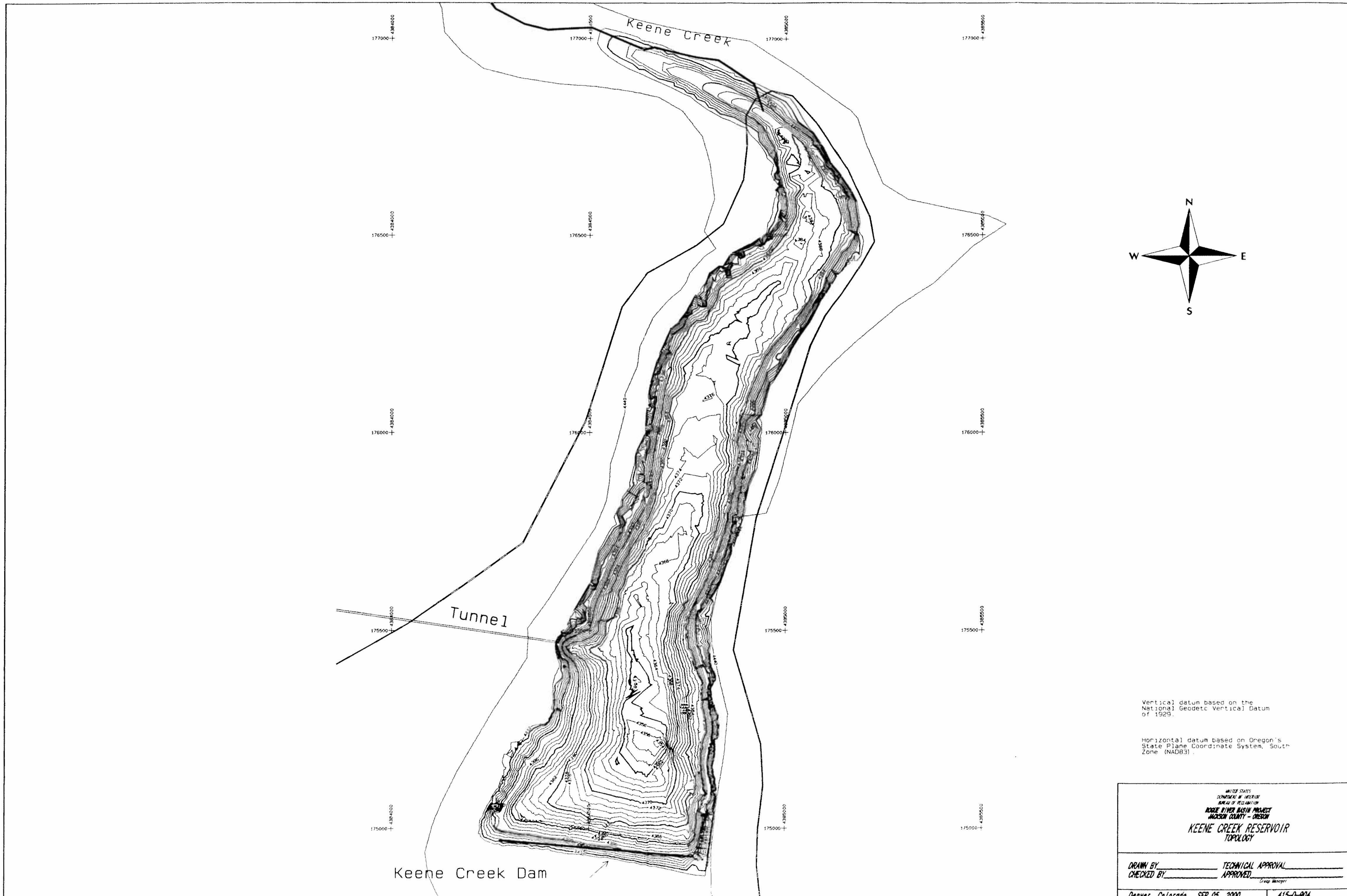


Figure 3. - Keene Creek Reservoir topographic map, No. 15-D-279

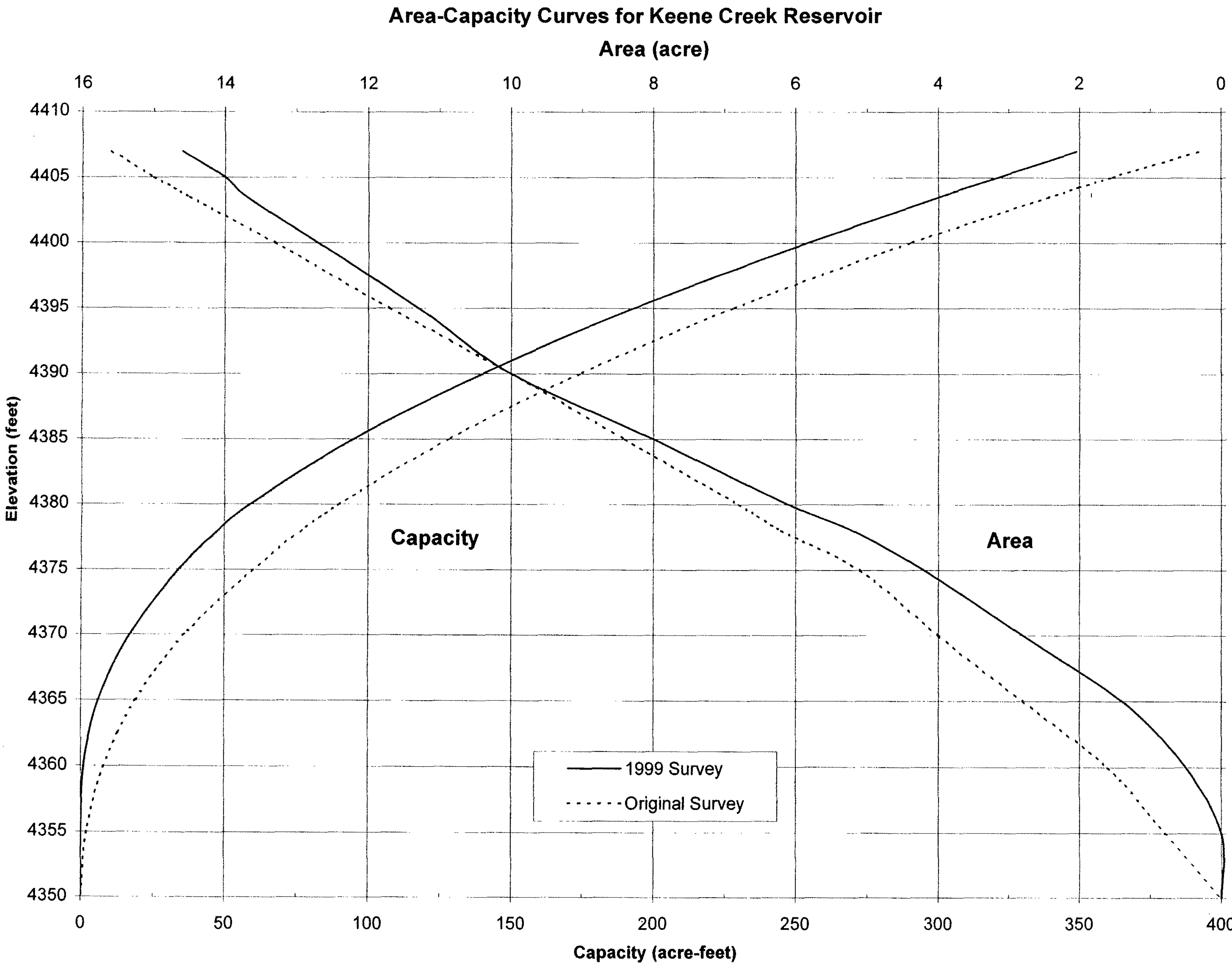


Figure 4. - 1999 area and capacity curves

# APPENDIX

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PACIFIC NORTHWEST REGION

**ROGUE RIVER BASIN PROJECT**

# KEENE CREEK RESERVOIR

**OREGON**

**AREA AND CAPACITY TABLES**

**JUNE 1999**

The tables for Keene Creek Reservoir were generated by means of the area-capacity program ACAP, using the least squares method of curve fitting developed by the Bureau of Reclamation Technical Service Center. This program computes area at 1.0-, 0.1-, and 0.01-foot increments by linear interpolation between basic data contours. The respective capacities and capacity equations are than obtained by integration of the area equations. The initial capacity equation is tested over successive intervals to check whether it fits within an allowable error term. At the next interval beyond, a new capacity equation (integrated from the basic area equation over that interval) begins testing the fit until it too exceeds the error term. The capacity curve thus becomes a series of curves, each fitting a certain region of data. The final area equations are obtained by differentiation of the capacity equations. Capacity equations are of the form $y = a_1 + a_2x + a_3x^2$ where y is capacity and x is the elevation above an elevation base. The capacity equation coefficients for the reservoir are shown below ($\varepsilon = 0.000001$).

KEENE CREEK RESERVOIR - ROGUE RIVER BASIN PROJECT, OREGON
1999 AREA-CAPACITY TABLES

| EQUATION NUMBER | ELEVATION BASE | CAPACITY BASE | COEFFICIENT A1(INTERCEPT) | COEFFICIENT A2(1ST TERM ) | COEFFICIENT A3(2ND TERM ) |
|---|---|---|---|---|---|
| 1 | 4353.00 | 0 | .0000 | .0000 | .0000 |
| 2 | 4355.00 | 0 | .0000 | .0000 | .0333 |
| 3 | 4358.00 | 0 | .3000 | .2000 | .0750 |
| 4 | 4362.00 | 2 | 2.3000 | .8000 | .1000 |
| 5 | 4364.00 | 4 | 4.3000 | 1.2000 | .1500 |
| 6 | 4368.00 | 11 | 11.5000 | 2.4000 | .1000 |
| 7 | 4370.00 | 16 | 16.7000 | 2.8000 | .1250 |
| 8 | 4374.00 | 29 | 29.9000 | 3.8000 | .1750 |
| 9 | 4378.00 | 47 | 47.9000 | 5.2000 | .2250 |
| 10 | 4380.00 | 59 | 59.2000 | 6.1000 | .2000 |
| 11 | 4382.00 | 72 | 72.2000 | 6.9000 | .1750 |
| 12 | 4384.00 | 86 | 86.7000 | 7.6000 | .2000 |
| 13 | 4390.00 | 139 | 139.5000 | 10.0000 | .1500 |
| 14 | 4392.00 | 160 | 160.1000 | 10.6000 | .1250 |
| 15 | 4396.00 | 204 | 204.5000 | 11.6000 | .1750 |
| 16 | 4398.00 | 228 | 228.4000 | 12.3000 | .1250 |
| 17 | 4406.00 | 334 | 334.8000 | 14.3000 | .1750 |
| 18 | 4408.00 | 364 | 364.1000 | 15.0000 | .1250 |

The Keene Creek Reservoir survey in June of 1999 used the contour method to obtain the basic data for these tables. Close interval profiles of the underwater portion of the reservoir were collected by standard surveying techniques using a global positioning system and echo sounder. The above-water portion was determined by standard land surveying methods. The computed surface areas from the 1999 survey provided measured surface areas at 2-foot increments from elevation 4352 to 4408. The minimum elevation was measured as elevation 4353. The underwater survey was run by personnel from the Technical Service Center. Reduction of the underwater field data was completed at the Technical Service Center in Denver, Colorado.

KEENE CREEK RESERVOIR - ROGUE RIVER BASIN PROJECT, OREGON

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1999 AREA-CAPACITY TABLES

THE AREA TABLE IS IN ACRES

THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

| ELEV. FEET | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4353 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4354 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4355 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4356 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4357 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4358 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4359 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4360 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 4361 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 4362 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 4363 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 4364 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 4365 | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 4366 | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 4367 | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 4368 | 2. | 2. | 2. | 2. | 2. | 2. | 3. | 3. | 3. | 3. |
| 4369 | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |
| 4370 | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |
| 4371 | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |
| 4372 | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 4. | 4. |
| 4373 | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4374 | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4375 | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4376 | 4. | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 5. |
| 4377 | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 5. |
| 4378 | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 6. | 6. | 6. |
| 4379 | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. |
| 4380 | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. |
| 4381 | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. |
| 4382 | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. |
| 4383 | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 8. | 8. |
| 4384 | 8. | 8. | 8. | 8. | 8. | 8. | 8. | 8. | 8. | 8. |
| 4385 | 8. | 8. | 8. | 8. | 8. | 8. | 8. | 8. | 8. | 8. |
| 4386 | 8. | 8. | 8. | 9. | 9. | 9. | 9. | 9. | 9. | 9. |
| 4387 | 9. | 9. | 9. | 9. | 9. | 9. | 9. | 9. | 9. | 9. |
| 4388 | 9. | 9. | 9. | 9. | 9. | 9. | 9. | 9. | 10. | 10. |
| 4389 | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 10. |

KEENE CREEK RESERVOIR - ROGUE RIVER BASIN PROJECT, OREGON (ACAP92) COMPUTED 8/ 5/2000

1999 AREA-CAPACITY TABLES 13:15:49

THE AREA TABLE IS IN ACRES THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

| ELEV. FEET | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4390 | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 10. |
| 4391 | 10. | 10. | 10. | 10. | 10. | 10. | 10. | 11. | 11. | 11. |
| 4392 | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. |
| 4393 | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. |
| 4394 | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 11. |
| 4395 | 11. | 11. | 11. | 11. | 11. | 11. | 11. | 12. | 12. | 12. |
| 4396 | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. |
| 4397 | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. |
| 4398 | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 12. | 13. | 13. |
| 4399 | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. |
| 4400 | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. |
| 4401 | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. |
| 4402 | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 13. | 14. | 14. |
| 4403 | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. |
| 4404 | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. |
| 4405 | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. | 14. |
| 4406 | 14. | 14. | 14. | 14. | 14. | 14. | 15. | 15. | 15. | 15. |
| 4407 | 15. | 15. | 15. | 15. | 15. | 15. | 15. | 15. | 15. | 15. |
| 4408 | 15. | | | | | | | | | |

KEENE CREEK RESERVOIR - ROGUE RIVER BASIN PROJECT, OREGON

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1999 AREA-CAPACITY TABLES

THE CAPACITY TABLE IS IN ACRE FEET

THE ELEVATION INCREMENT IS ONE TENTH FOOT

| ELEV. FEET | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4353 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4354 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4355 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4356 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4357 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4358 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. |
| 4359 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 4360 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 2. |
| 4361 | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 4362 | 2. | 2. | 2. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |
| 4363 | 3. | 3. | 3. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4364 | 4. | 4. | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 6. |
| 4365 | 6. | 6. | 6. | 6. | 6. | 6. | 7. | 7. | 7. | 7. |
| 4366 | 7. | 7. | 8. | 8. | 8. | 8. | 8. | 9. | 9. | 9. |
| 4367 | 9. | 9. | 10. | 10. | 10. | 10. | 11. | 11. | 11. | 11. |
| 4368 | 12. | 12. | 12. | 12. | 12. | 13. | 13. | 13. | 13. | 14. |
| 4369 | 14. | 14. | 15. | 15. | 15. | 15. | 16. | 16. | 16. | 16. |
| 4370 | 17. | 17. | 17. | 18. | 18. | 18. | 18. | 19. | 19. | 19. |
| 4371 | 20. | 20. | 20. | 21. | 21. | 21. | 22. | 22. | 22. | 22. |
| 4372 | 23. | 23. | 23. | 24. | 24. | 24. | 25. | 25. | 26. | 26. |
| 4373 | 26. | 27. | 27. | 27. | 28. | 28. | 28. | 29. | 29. | 30. |
| 4374 | 30. | 30. | 31. | 31. | 31. | 32. | 32. | 33. | 33. | 33. |
| 4375 | 34. | 34. | 35. | 35. | 36. | 36. | 36. | 37. | 37. | 38. |
| 4376 | 38. | 39. | 39. | 40. | 40. | 40. | 41. | 41. | 42. | 42. |
| 4377 | 43. | 43. | 44. | 44. | 45. | 45. | 46. | 46. | 47. | 47. |
| 4378 | 48. | 48. | 49. | 49. | 50. | 51. | 51. | 52. | 52. | 53. |
| 4379 | 53. | 54. | 54. | 55. | 56. | 56. | 57. | 57. | 58. | 59. |
| 4380 | 59. | 60. | 60. | 61. | 62. | 62. | 63. | 64. | 64. | 65. |
| 4381 | 66. | 66. | 67. | 67. | 68. | 69. | 69. | 70. | 71. | 72. |
| 4382 | 72. | 73. | 74. | 74. | 75. | 76. | 76. | 77. | 78. | 79. |
| 4383 | 79. | 80. | 81. | 81. | 82. | 83. | 84. | 84. | 85. | 86. |
| 4384 | 87. | 87. | 88. | 89. | 90. | 91. | 91. | 92. | 93. | 94. |
| 4385 | 95. | 95. | 96. | 97. | 98. | 99. | 99. | 100. | 101. | 102. |
| 4386 | 103. | 104. | 104. | 105. | 106. | 107. | 108. | 109. | 110. | 110. |
| 4387 | 111. | 112. | 113. | 114. | 115. | 116. | 117. | 118. | 118. | 119. |
| 4388 | 120. | 121. | 122. | 123. | 124. | 125. | 126. | 127. | 128. | 129. |
| 4389 | 130. | 131. | 132. | 133. | 134. | 135. | 136. | 137. | 138. | 139. |

KEENE CREEK RESERVOIR - ROGUE RIVER BASIN PROJECT, OREGON

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1999 AREA-CAPACITY TABLES

THE CAPACITY TABLE IS IN ACRE FEET

THE ELEVATION INCREMENT IS ONE TENTH FOOT

| ELEV. FEET | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4390 | 140. | 141. | 142. | 143. | 144. | 145. | 146. | 147. | 148. | 149. |
| 4391 | 150. | 151. | 152. | 153. | 154. | 155. | 156. | 157. | 158. | 159. |
| 4392 | 160. | 161. | 162. | 163. | 164. | 165. | 167. | 168. | 169. | 170. |
| 4393 | 171. | 172. | 173. | 174. | 175. | 176. | 177. | 178. | 180. | 181. |
| 4394 | 182. | 183. | 184. | 185. | 186. | 187. | 189. | 190. | 191. | 192. |
| 4395 | 193. | 194. | 195. | 196. | 198. | 199. | 200. | 201. | 202. | 203. |
| 4396 | 205. | 206. | 207. | 208. | 209. | 210. | 212. | 213. | 214. | 215. |
| 4397 | 216. | 217. | 219. | 220. | 221. | 222. | 224. | 225. | 226. | 227. |
| 4398 | 228. | 230. | 231. | 232. | 233. | 235. | 236. | 237. | 238. | 240. |
| 4399 | 241. | 242. | 243. | 245. | 246. | 247. | 248. | 250. | 251. | 252. |
| 4400 | 254. | 255. | 256. | 257. | 259. | 260. | 261. | 263. | 264. | 265. |
| 4401 | 266. | 268. | 269. | 270. | 272. | 273. | 274. | 276. | 277. | 278. |
| 4402 | 280. | 281. | 282. | 284. | 285. | 286. | 288. | 289. | 290. | 292. |
| 4403 | 293. | 294. | 296. | 297. | 298. | 300. | 301. | 303. | 304. | 305. |
| 4404 | 307. | 308. | 309. | 311. | 312. | 314. | 315. | 316. | 318. | 319. |
| 4405 | 321. | 322. | 323. | 325. | 326. | 328. | 329. | 331. | 332. | 333. |
| 4406 | 335. | 336. | 338. | 339. | 341. | 342. | 343. | 345. | 346. | 348. |
| 4407 | 349. | 351. | 352. | 354. | 355. | 357. | 358. | 360. | 361. | 363. |
| 4408 | 364. | | | | | | | | | |