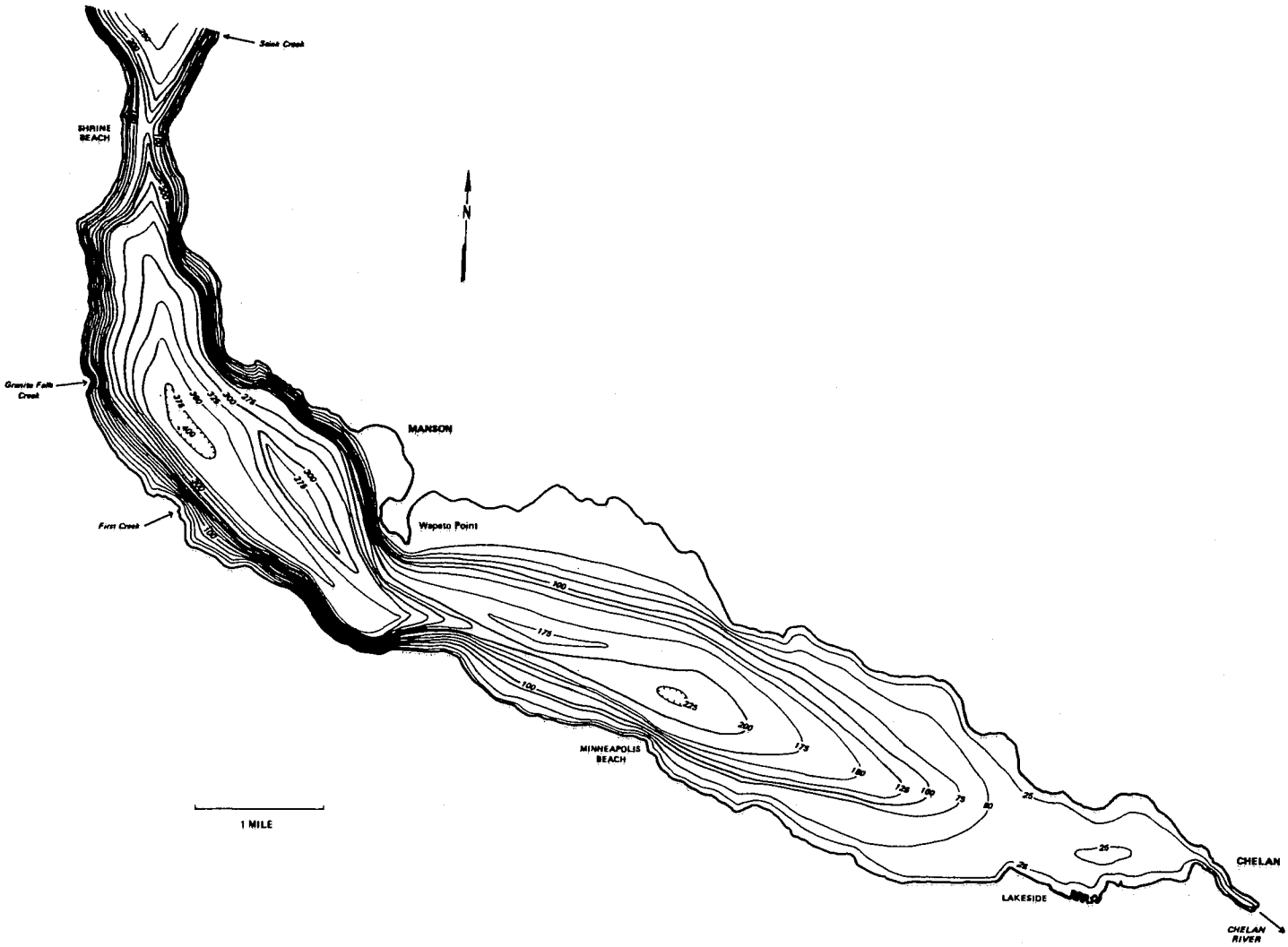
MORPHOMETRY OF LAKE CHELAN



WASHINGTON STATE DEPARTMENT OF ECOLOGY

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MORPHOMETRY OF LAKE CHELAN

by

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ABSTRACT

A morphometric survey of Lake Chelan, Washington, was conducted in July 1986. Forty echosounding profiles of subsurface topography were used to prepare three bathymetric maps of varying detail. Lake Chelan is the largest natural lake in Washington and the third deepest lake in the United States. Maximum and mean lake depths are 1,486 feet (453 meters) and 474 feet (144 meters), respectively. Lake volume is approximately 25 billion cubic yards (19 billion cubic meters) and hydraulic retention time is 10.6 years. Much of the lake is U-shaped in cross-section, a feature characteristic of glaciated valleys. The hydrographic attributes of Lake Chelan are strongly influenced by the morphometry and bathymetry of Lucerne Basin, which accounts for 74 percent of the lake's surface area and 92 percent of its volume.

INTRODUCTION

Lake Chelan is the largest natural lake in Washington State and one of the deepest lakes in the world. Located in Chelan County, the lake bears the elongate, subrectangular shape characteristic of glacially carved fjords. From its downstream terminus at the city of Chelan, the lake extends northwesterly more than 50 miles (80 kilometers) to the mouth of the Stehekin River, which headwaters in the Cascade Range and is the principal inlet to the lake. Other major tributaries to Lake Chelan include Railroad, Fish, Prince, and Twenty-five Mile Creeks.

The elevation of Lake Chelan is controlled by a concrete dam at the outlet of the lake. Constructed in 1927, the dam raised the level of the lake 21 feet (6 meters) to its present full-pool height of 1,100 feet (335 meters). Nearly all of the outflow from Lake Chelan is diverted through a penstock for power production by Chelan County Public Utility District (PUD) No. 1. Discharge from the Chelan Falls Power Plant flows immediately into the Columbia River. The elevation of Lake Chelan is maintained at full-pool during the peak recreational season (July through September).

The Chelan watershed drains an area encompassing 924 square miles (2,393 square kilometers). Most (92 percent) of the basin is forested or undeveloped (Dion, et al., 1976). Agricultural and residential uses comprise less than 3 percent of the acreage, while the lake itself accounts for most of the remainder. In addition to hydroelectric production, beneficial uses of Lake Chelan include recreation and water supply (domestic and agricultural).

As part of an ongoing water quality assessment of Lake Chelan, the Water Quality Investigations Section of Ecology initiated a morphometric study of the lake. Morphometry is the branch of limnology that concerns the measurement of the size and shape of a lake basin. Morphometric data are required to evaluate nutrient loading and sedimentation rates, chemical mass, water and energy budgets, thermal stability, biological productivity, and other structural and functional components of a lake ecosystem (Wetzel and Likens, 1979).

Objectives of the morphometric survey were two-fold: (1) to develop a bathymetric map of Lake Chelan, and (2) to quantify the hydrographic features of Lake Chelan in the form of standard morphometric parameters. The work reported here represents the first comprehensive analysis of the morphometry and bathymetry of Lake Chelan.

METHODS

The subsurface topography of Lake Chelan was surveyed July 15 and 22-24, 1986, using bathymetric techniques common to limnological investigations (Hakanson, 1981). Continuous echosounding profiles of the lake bottom were recorded by a fathometer mounted on a 20-foot motorboat. The boat was operated at constant speed and direction along 40 predetermined sounding track lines (Figure 1; Appendix A). Thirty-five of the sounding tracks were oriented approximately normal to the long axis of the lake. To verify accuracy, four tracks were positioned to cross several of the 35 lines. In general, headings for the track lines were visible from opposite shores and discernible on USGS maps. Occasionally, positions and course headings were fixed with a compass.

The fathometer was a Ross 800-Series Portable Survey Recorder. Powered by 24 volts DC, the fathometer had a range of 2,400 feet (732 meters). A 50-kilohertz, 22-degree transducer was suspended off the side of the boat by a rigid outrigger. Soundings were later adjusted to correct for the one-foot operating depth of the transducer. The stylus motor drive of the chart recorder was preset to function at a fixed sound velocity of 4,800 feet per second (1,463 meters per second). The fathometer was periodically calibrated with a graduated dacron sounding line. The elevation of Lake Chelan remained constant at 1,100 feet (335 meters) for the duration of the echosounding survey (B. Dearing, Chelan PUD, personal communication).

Bathymetric maps were drawn and morphometric parameters were subsequently calculated using the methods of Welch (1948), Hutchinson (1957), Lind (1979), and Wetzel and Likens (1979). Briefly, depth measurements along the sounding tracks were plotted to scale on outline maps of Lake Chelan. Contour lines were then drawn by freehand, using mathematical interpolation where necessary. The area of the plane circumscribed by each 100-foot contour was integrated on a computer-based digitizing system operated by the Washington State Department of Natural Resources. The volume of strata (layers) between contours was calculated using one of the following formulations:

1. $V = h(a_1+a_2)/2$

2. $V = h(a_1+a_2+\sqrt{a_1a_2})/3$

3. $V = ha_1/3$

4. $V = ha_1/2$

where: V = volume of stratum
h = depth (thickness) of stratum
a_1 = area of upper surface of stratum
a_2 = area of lower surface of stratum

For strata with contours of similar surface area, the rectangular prism formula was used (Equation 1). Where the areas diverged

considerably, the truncated cone formulation was applied (Equation 2). The volume of bottom strata which terminated at a point of maximum depth was calculated as the volume of a cone (Equation 3), while the volume of bottom strata of gradual or no slope was taken as the volume of a wedge (Equation 4). Total lake volume was determined by summing the strata volumes.

Additional morphometric parameters were measured or calculated as described in Table 1. Shoreline length was measured with a cartometer. Maximum depth was determined by intensively sounding the deepest portions of the lake. Hydraulic residence time was calculated as lake volume divided by mean annual outflow.

Table 1. Definition and significance of several morphometric features of lakes.

Parameter	Definition	Significance
Maximum Length	Open-water distance between the two most remote extremities of a lake.	This value is commonly reported as "lake length."
Maximum Effective Length	Longest straight-line open-water distance between any two shoreline points.	Represents the maximum fetch (i.e., effective length for wind to act without interruption by land).
Maximum Width	Maximum distance between opposite shores, perpendicular to the maximum-length axis.	--
Mean Width	Lake surface area divided by maximum length.	This value is commonly reported as "lake width."
Mean Depth	Lake volume divided by surface area.	Important in models describing lake productivity and trophic status.
Shoreline Development	Ratio of shoreline length (SL) to the length of the circumference of a circle of area (A) equal to that of the lake ($SL/2\sqrt{A\pi}$).	As an index of shoreline irregularity, this ratio reflects the potential for development of littoral communities.

RESULTS AND DISCUSSION

Lake Chelan consists of two basins, Wapato and Lucerne (Figures 2 - 4). The lower basin, Wapato, is relatively broad and shallow, with a length of 12.0 miles (19.3 kilometers) and maximum depth of 400 feet (122 meters). Lucerne Basin is 38.4 miles (61.8 kilometers) long and attains a maximum depth of 1,486 feet (453 meters) in the vicinity of Big Goat Creek. Between Twentyfive Mile Creek and Canoe Creek, the walls of Lucerne Basin descend abruptly to depths exceeding 1,000 feet (305 meters). Lucerne Basin is U-shaped in cross-section, a feature characteristic of most glaciated valleys. The two basins are separated by a shallow (127 feet/39 meters) sill located at a constriction of the lake known as the "Narrows" (Figure 5; Appendix A).

Lake Chelan was formed through glacial erosion of its upper and middle portions and deposition at the outlet (Freeman, 1944; Whetten, 1967). During the last major glaciation, the Chelan Glacier advanced down the Chelan Valley to a point near the Narrows. Meanwhile, the Okanogan-Columbia Valley lobe of the Cordilleran Ice Sheet invaded the Chelan Valley at least up to Wapato Point, creating Glacial Lake Chelan between the two glaciers. Recession of the Okanogan-Columbia Valley lobe left the lower Chelan River blocked with glacial deposits, forming Lake Chelan. Contemporary sediment thickness in Wapato Basin is greater than in Lucerne Basin due to the large volume of glacial debris that accumulated in the lower valley between the two glaciers.

At 1,486 feet (453 meters), Lake Chelan is the third deepest freshwater lake in the United States, behind Crater Lake (1,932 feet/589 meters) and Lake Tahoe (1,645 feet/501 meters) (Bue, 1963). Earlier investigators have reported Lake Chelan to be between 1,503 feet (458 meters) and 1,605 feet (489 meters) deep (Freeman, 1944; Hutchinson, 1957; Bue, 1963). However, the methods used to sound the lake were not documented and therefore are suspect. More recently, Whetten (1967) echosounded much of the lake and found a maximum depth of 1,529 feet (466 meters). Seven of Whetten's sounding tracks were the same as those of the present survey. A plot of depth maxima observed along these tracks during the two surveys reveals an interesting trend (Figure 6). As depth increases, Whetten's results deviate from ours by increasingly larger margins.

Our maximum sounding of 1,486 feet was confirmed in late 1986 during sediment coring operations with a metered winch (C. Patmont, Harper-Owes, personal communication). Several factors may explain the error in Whetten's measurements. Fathometer accuracy in the present survey was periodically verified to a depth of 450 feet (137 meters) using bar checks. Whetten did not document calibration procedures, hence the accuracy of his fathometer is uncertain. Further, the differences in depth measurement may reflect 20 years of advancement in echosounding technology. In addition, Whetten's fathometer generated sonar pulses at a frequency of 1 kilohertz, which is optimal for sediment penetration (layering studies) but of questionable utility for measurement of bottom topography. Finally, the echosounding

discrepancies may be attributed to the variable velocity of sound in water.

The speed of sound in water is a function of temperature, salinity, and depth (Albers, 1965):

$$C = 4625 + 7.68(t-32) - 0.0376(t-32)^2 + 3.35s + 0.018d$$

where: C = velocity of sound in water (feet per second [fps])
t = temperature (^{o}F)
s = salinity (parts per thousand)
d = depth (feet)

At the surface of a 58°F (14°C) freshwater lake, the velocity of sound is about 4,800 fps (1,463 m/s). Some fathometers feature a control to adjust sound velocity, but these instruments do not alter the speed of sound in water. Instead, they alter the speed of the motor-driven stylus to compensate for changes in sound velocity caused by density and pressure gradients. In other words, the sound velocity control internally corrects fathometer readings to reflect the true speed of sound under actual study conditions.

Using temperature and depth data from July 1986, the velocity of sound in Lake Chelan was estimated to be 4,723 fps (1,440 m/s). Because our fathometer readings were based on an assumed (preset) sound velocity of 4,800 fps (1,463 m/s), maximum depth measurements may have been overestimated by up to 1.6 percent (24 feet/7 meters). Whetten reported an assumed sound velocity of 4,921 fps (1,500 m/s), thus his maximum depth measurement may have been overestimated by 4.0 percent (61 feet/19 meters), assuming temperature gradients for August 1966 and July 1986 were similar. If Whetten's data are corrected for this error, maximum soundings from the two bathymetric surveys more closely coincide.

The hydrographic characteristics of Lake Chelan are strongly influenced by the morphometry and bathymetry of Lucerne Basin (Table 2). The maximum fetch of Lake Chelan occurs along a 15.4-mile (24.8-kilometer) stretch of Lucerne Basin. The mean depth of Lucerne Basin is considerably greater than that of Wapato Basin, but not unlike the overall lake mean. The shoreline development index suggests that Lucerne Basin has a higher potential than Wapato Basin for the development of littoral communities, but the steep walls of Lucerne Basin negate this potential. In total Lucerne Basin accounts for 74 percent of Lake Chelan's surface area and more than 92 percent of its volume.

The volume of Lake Chelan was calculated in both vertical and horizontal increments (Appendices B and C) to allow greater flexibility in the manipulation and analysis of area/volume data. Lake volume was

Table 2. Morphometric parameters of Lake Chelan and its two basins (delimited by the Narrows Sill).

Parameter[a]	Wapato Basin	Lucerne Basin	Lake Chelan
Maximum Length (mi.)	12.0	38.4	50.4
Maximum Effective Length (mi.)	9.6	15.4	15.4
Maximum Width (mi.)	1.8	1.4	1.8
Mean Width (mi.)	1.1	1.0	1.0
Maximum Depth (ft.)	400	1,486	1,486
Mean Depth (ft.)	140	590	474
Shoreline Length (mi.)	27.6[b]	82.3[b]	109.2
Shoreline Development	2.1	3.7	4.3
Surface Area (sq. mi.)	13.5	38.6	52.1
Percent of Lake Surface Area	26.0	74.0	100.0
Volume (cu. yds. x 10^9)	1.95	23.5	25.5
Percent of Lake Volume	7.6	92.4	100.0

[a]Defined in Table 1.

[b]Distance across lake at the Narrows Sill is included in this value.

approximately 25 billion cubic yards (19 billion cubic meters); in layman's terms, this amount of water is enough to cover an area the size of Washington State to a depth of 4.4 inches. Based on a 79-year average outflow of 2.4 billion cubic yards (1.8 billion cubic meters) per year (USGS, 1985), the hydraulic retention time of Lake Chelan was calculated to be 10.6 years.

Hypsographic (depth-area) and depth-volume curves of Lake Chelan were drawn to show the relationship of lake area and volume to depth (Figure 7). Hypsographic curves permit determination of the absolute and/or relative area circumscribed by a lake basin at any depth level. Similarly, depth-volume curves allow determination of the absolute and/or relative volume of water located above any specific depth. For example the depth-volume curves can be used to estimate the volume of water in Lake Chelan's cryptodepression (that portion of the lake basin beneath sea level). The curves reveal that 1.3 billion cubic yards (1 billion cubic meters) or 5 percent of the lake's volume is located below mean sea level (i.e., a depth of 1,100 feet or 335 meters).

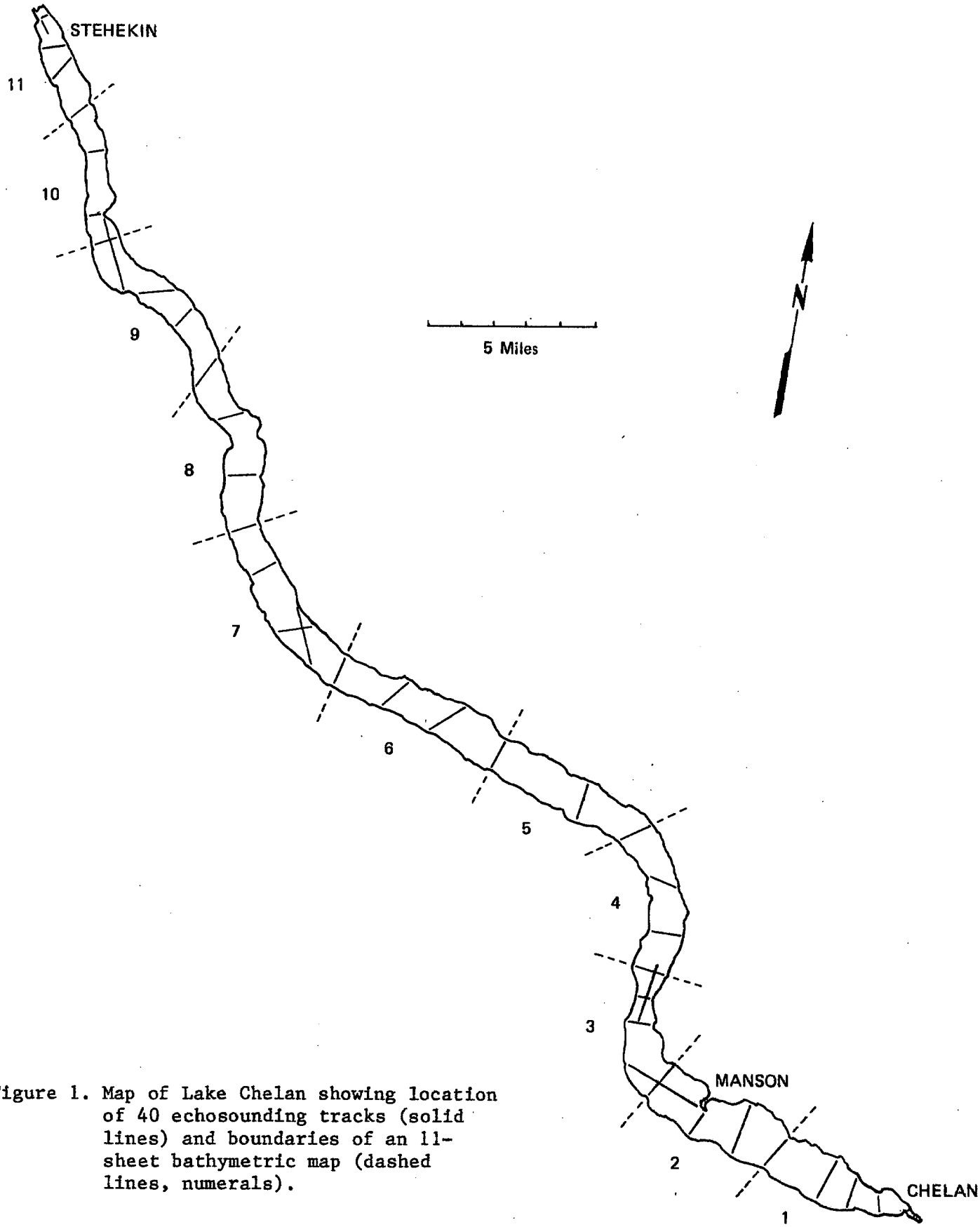


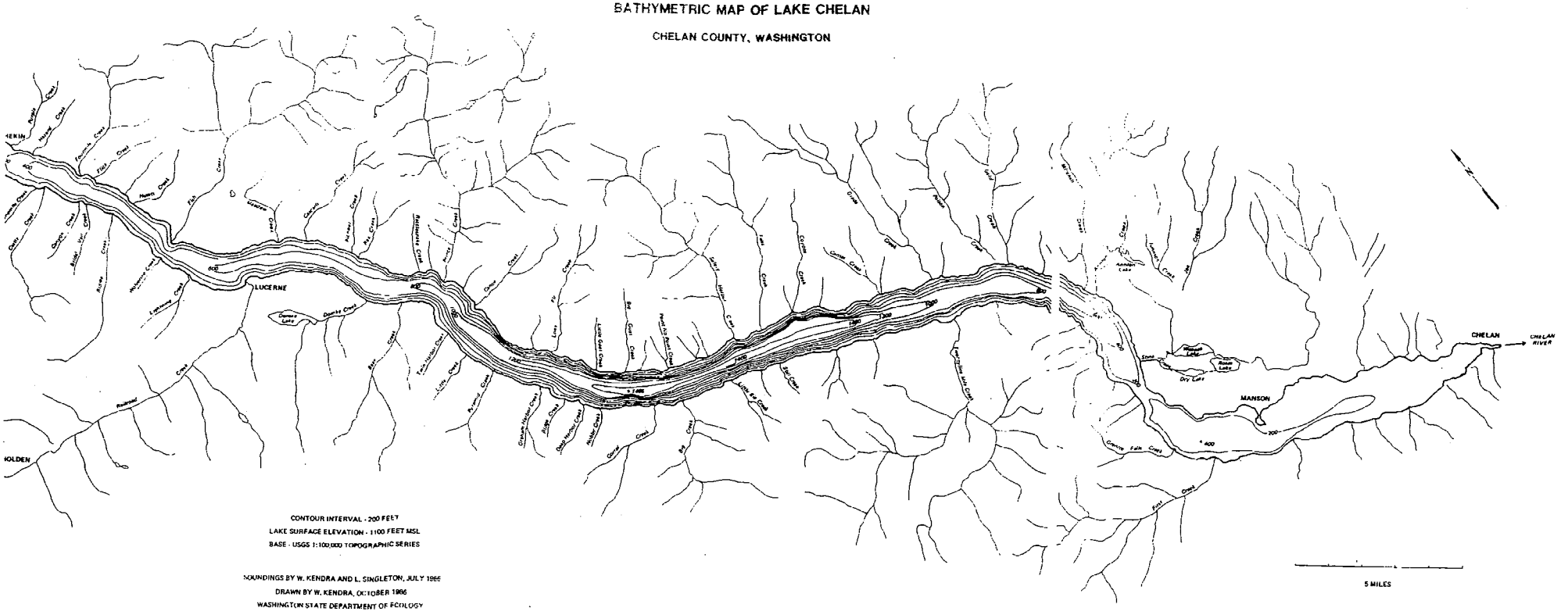
Figure 1. Map of Lake Chelan showing location of 40 echosounding tracks (solid lines) and boundaries of an 11-sheet bathymetric map (dashed lines, numerals).

Figure 2

Bathymetric Map of Lake Chelan with 200-foot Contour Intervals

BATHYMETRIC MAP OF LAKE CHELAN

CHELAN COUNTY, WASHINGTON



CONTOUR INTERVAL - 200 FEET

LAKE SURFACE ELEVATION - 1100 FEET MSL

BASE - USGS 1:100,000 TOPOGRAPHIC SERIES

SOUNDINGS BY W. KENDRA AND L. SINGLETON, JULY 1986

DRAWN BY W. KENDRA, OCTOBER 1986

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Figure 3

Bathymetric Map of Wapato Basin, Lake Chelan,
with 25-foot Contour Intervals

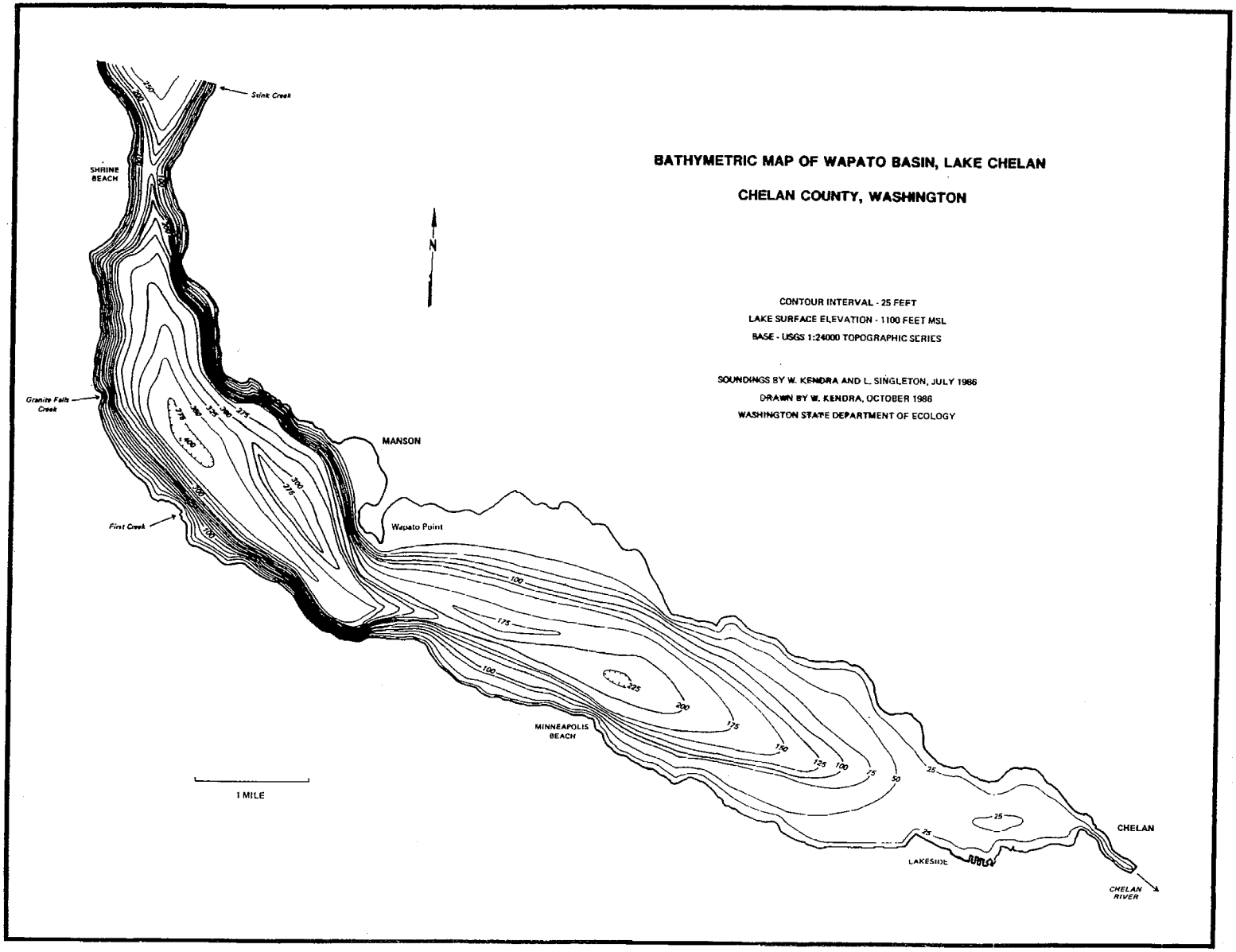

BATHYMETRIC MAP OF WAPATO BASIN, LAKE CHELAN
CHELAN COUNTY, WASHINGTON
CONTOUR INTERVAL - 25 FEET
LAKE SURFACE ELEVATION - 1100 FEET MSL
BASE - USGS 1:24000 TOPOGRAPHIC SERIES
SOUNDINGS BY W. KENDRA AND L. SINGLETON, JULY 1986
DRAWN BY W. KENDRA, OCTOBER 1986
WASHINGTON STATE DEPARTMENT OF ECOLOGY
N
Stink Creek
SHRINE BEACH
Granite Falls Creek
First Creek
MANSON
Wapato Point
MINNEAPOLIS BEACH
LAKESIDE
CHELAN
CHELAN RIVER
1 MILE

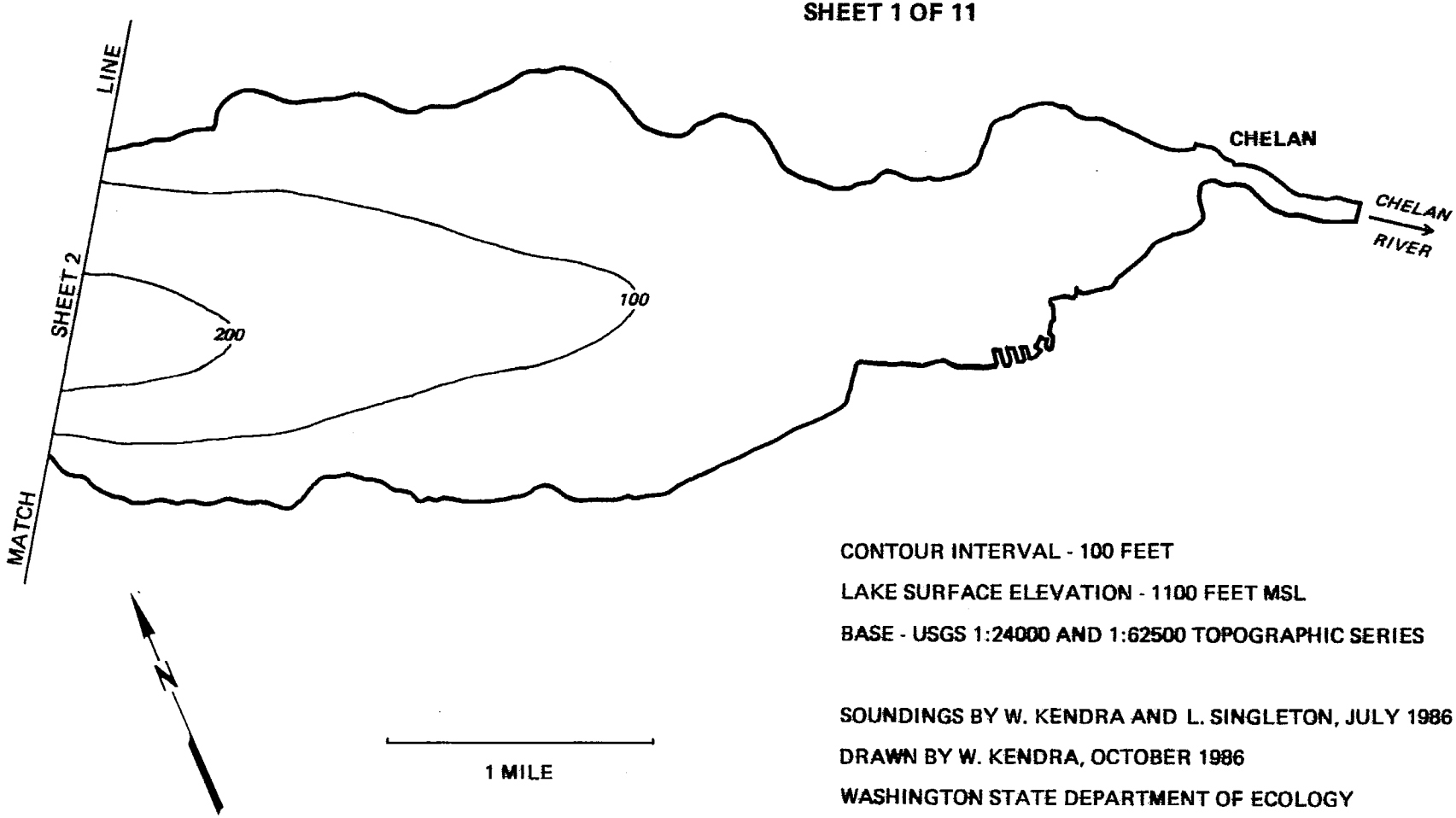
Figure 4

Bathymetric Map of Lake Chelan with 100-foot Contour Intervals
(map consists of 11 sheets; key to sheet locations
is provided in Figure 1)

BATHYMETRIC MAP OF LAKE CHELAN

CHELAN COUNTY, WASHINGTON

SHEET 1 OF 11



CONTOUR INTERVAL - 100 FEET

LAKE SURFACE ELEVATION - 1100 FEET MSL

BASE - USGS 1:24000 AND 1:62500 TOPOGRAPHIC SERIES

SOUNDINGS BY W. KENDRA AND L. SINGLETON, JULY 1986

DRAWN BY W. KENDRA, OCTOBER 1986

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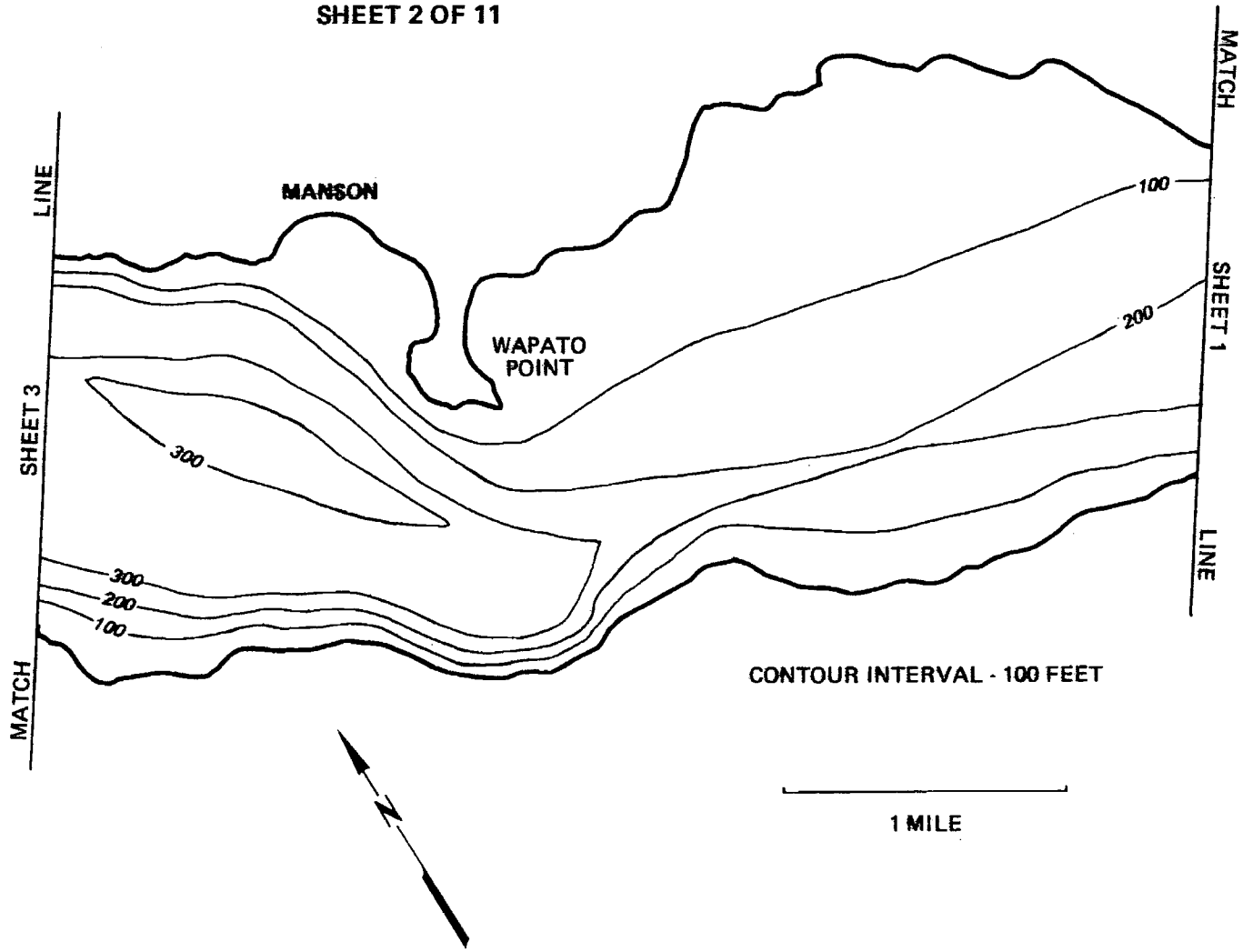
BATHYMETRIC MAP OF LAKE CHELAN

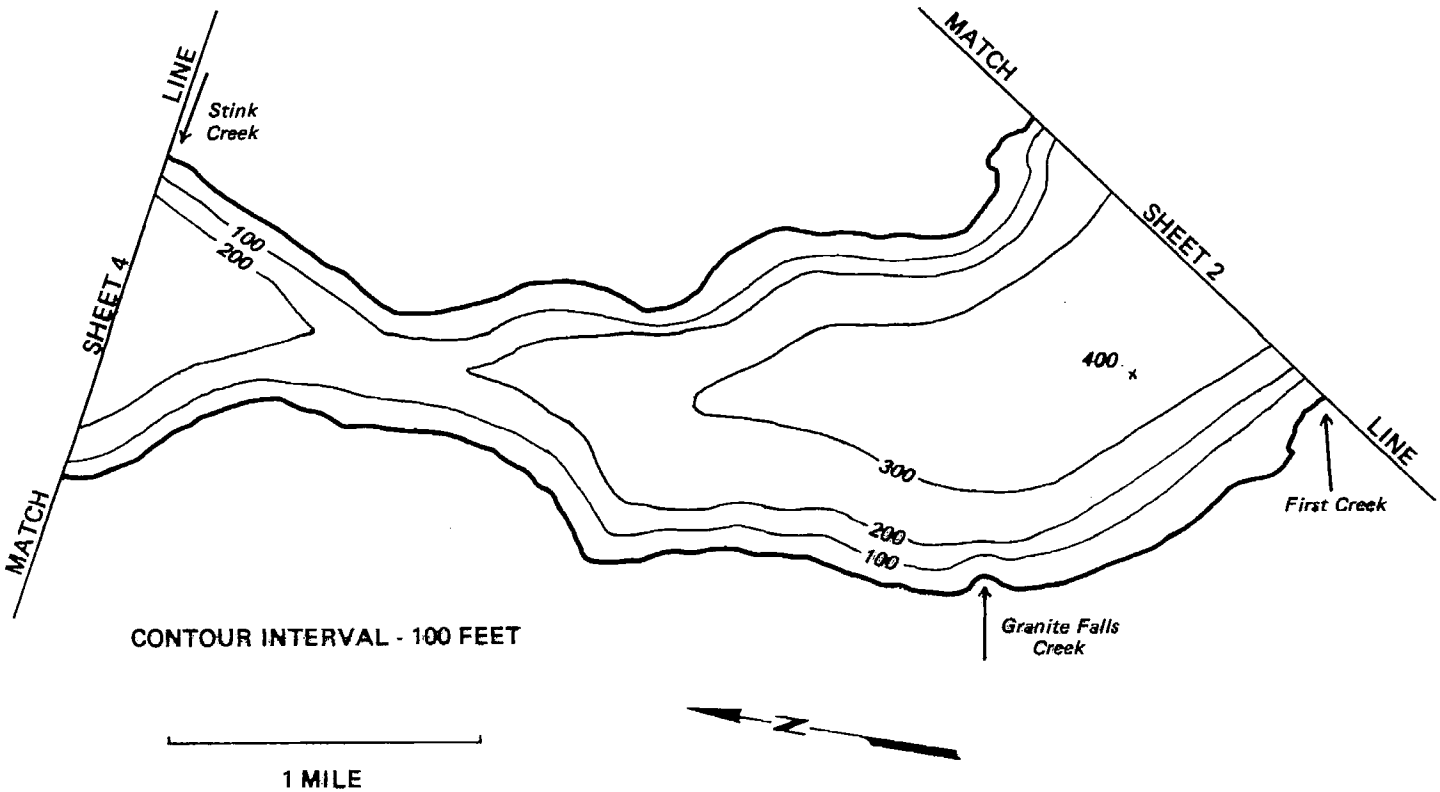
CHELAN COUNTY, WASHINGTON

SHEET 2 OF 11



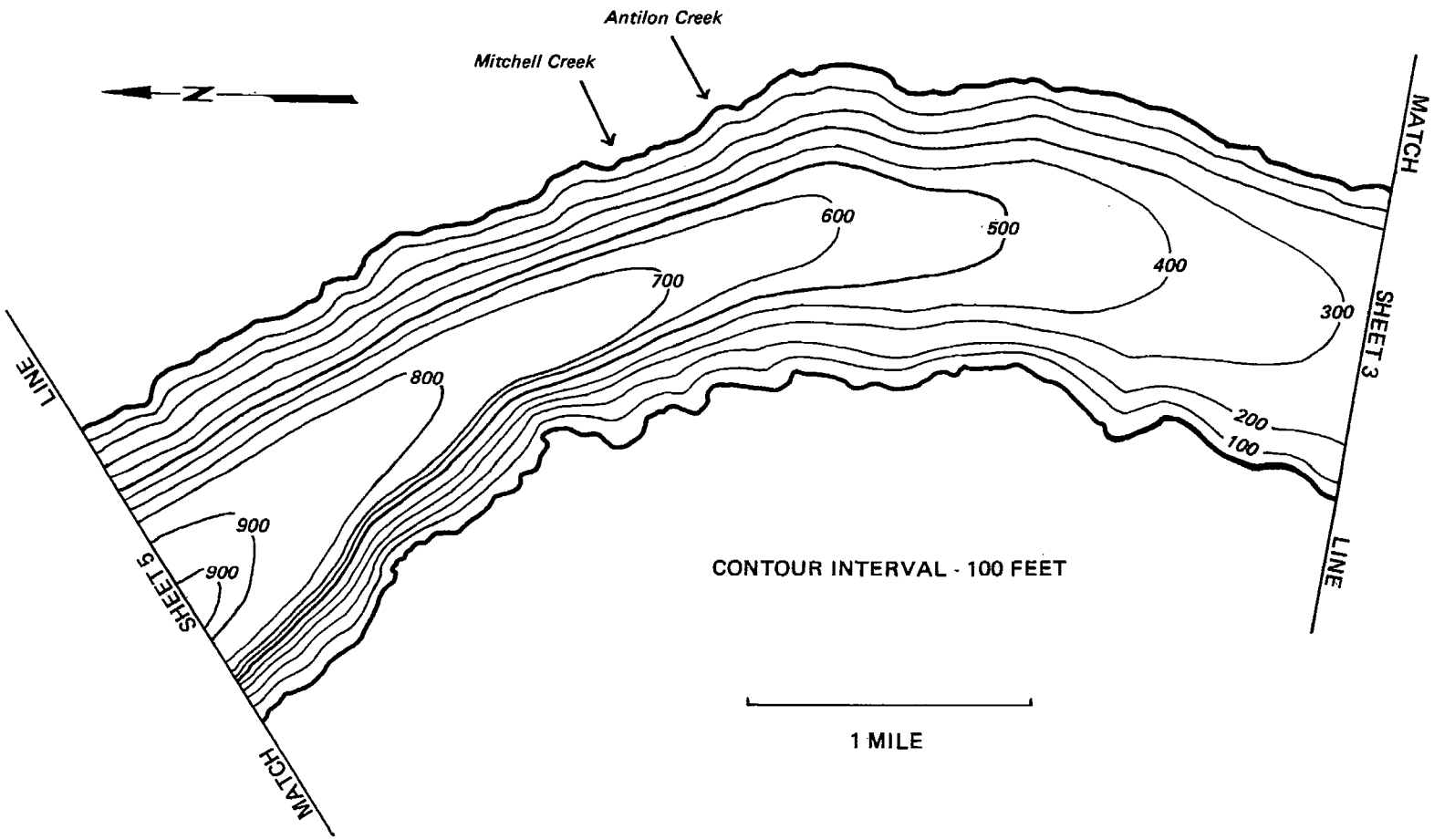
BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON

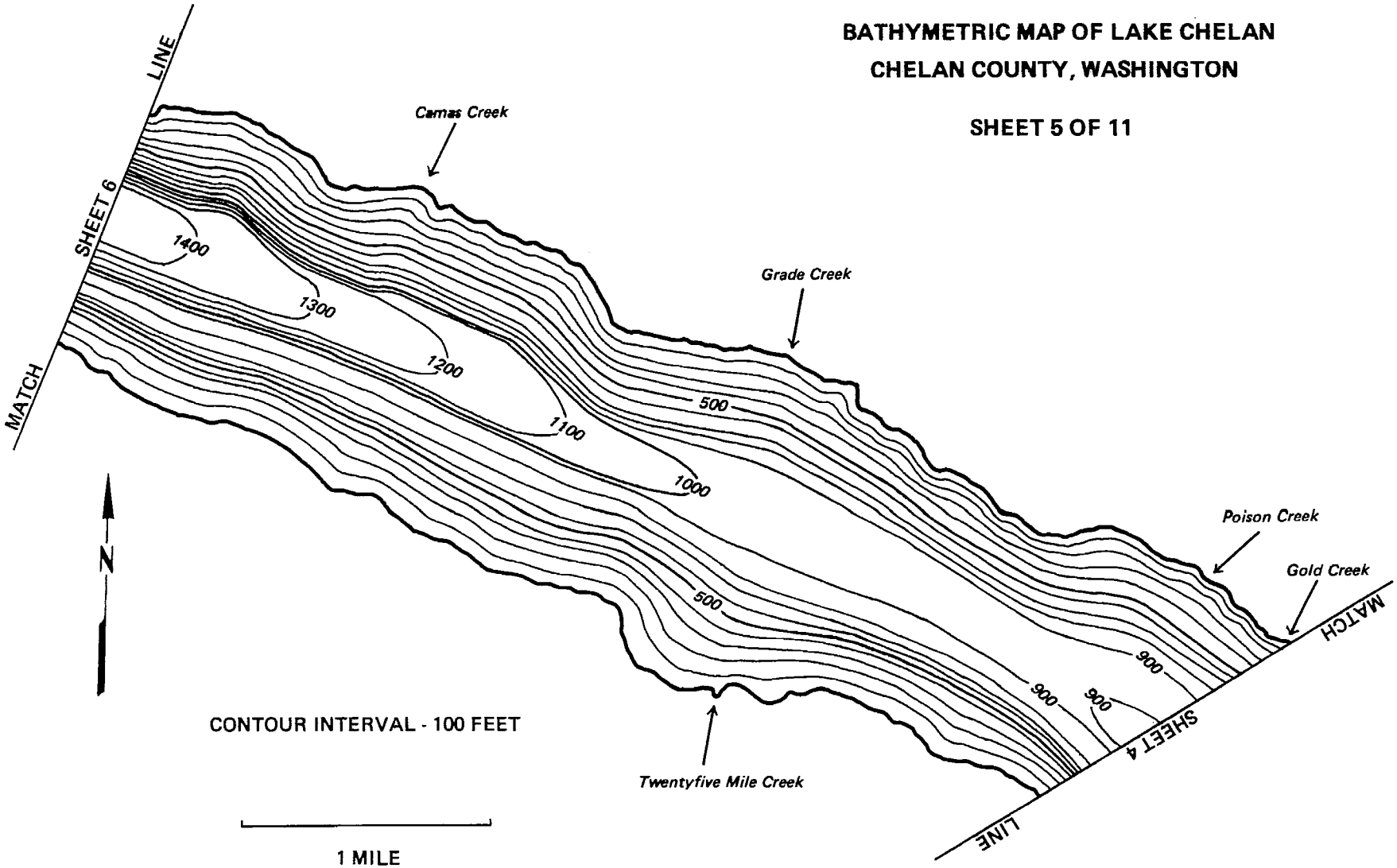
SHEET 3 OF 11



BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON

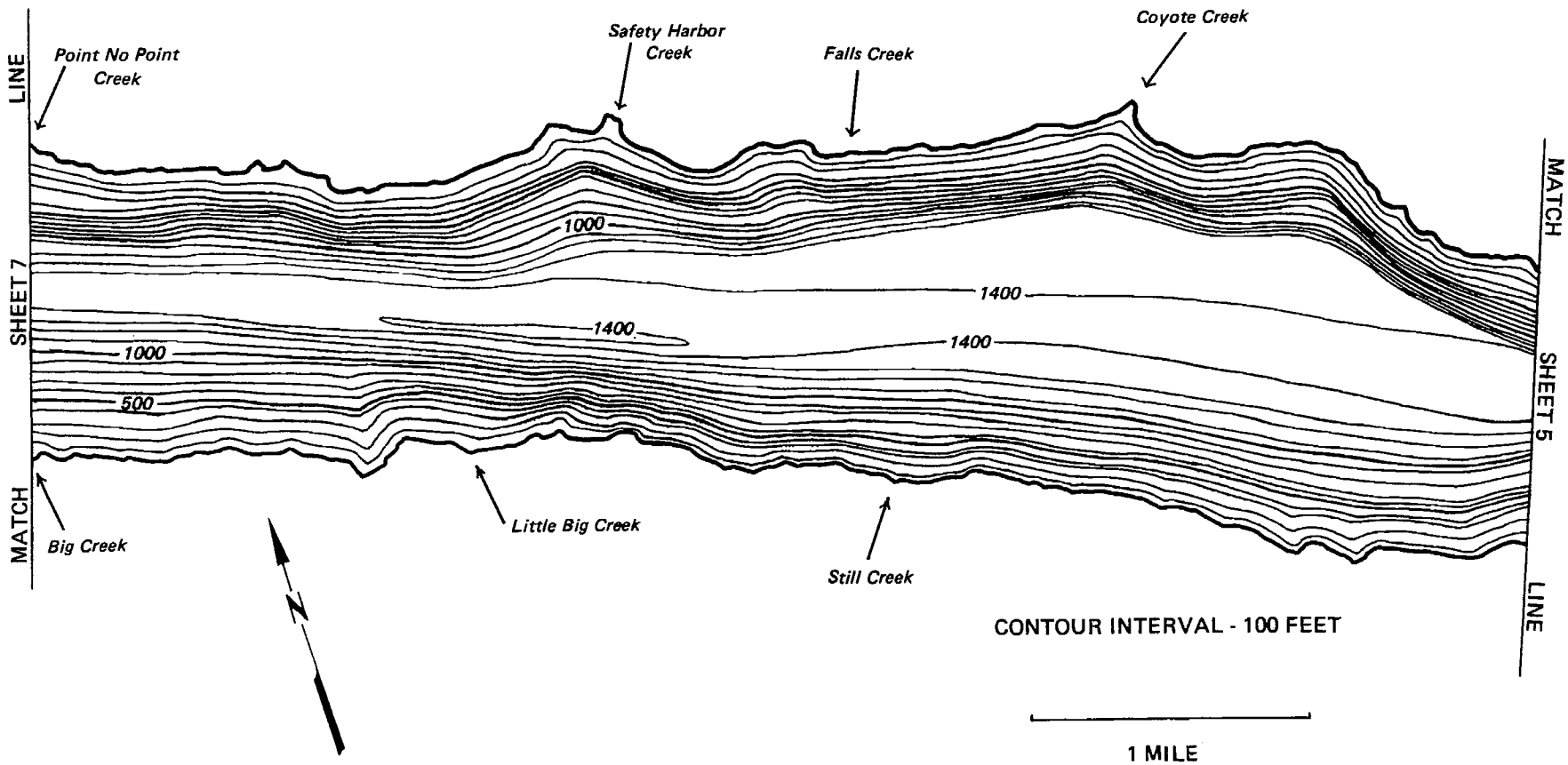
SHEET 4 OF 11

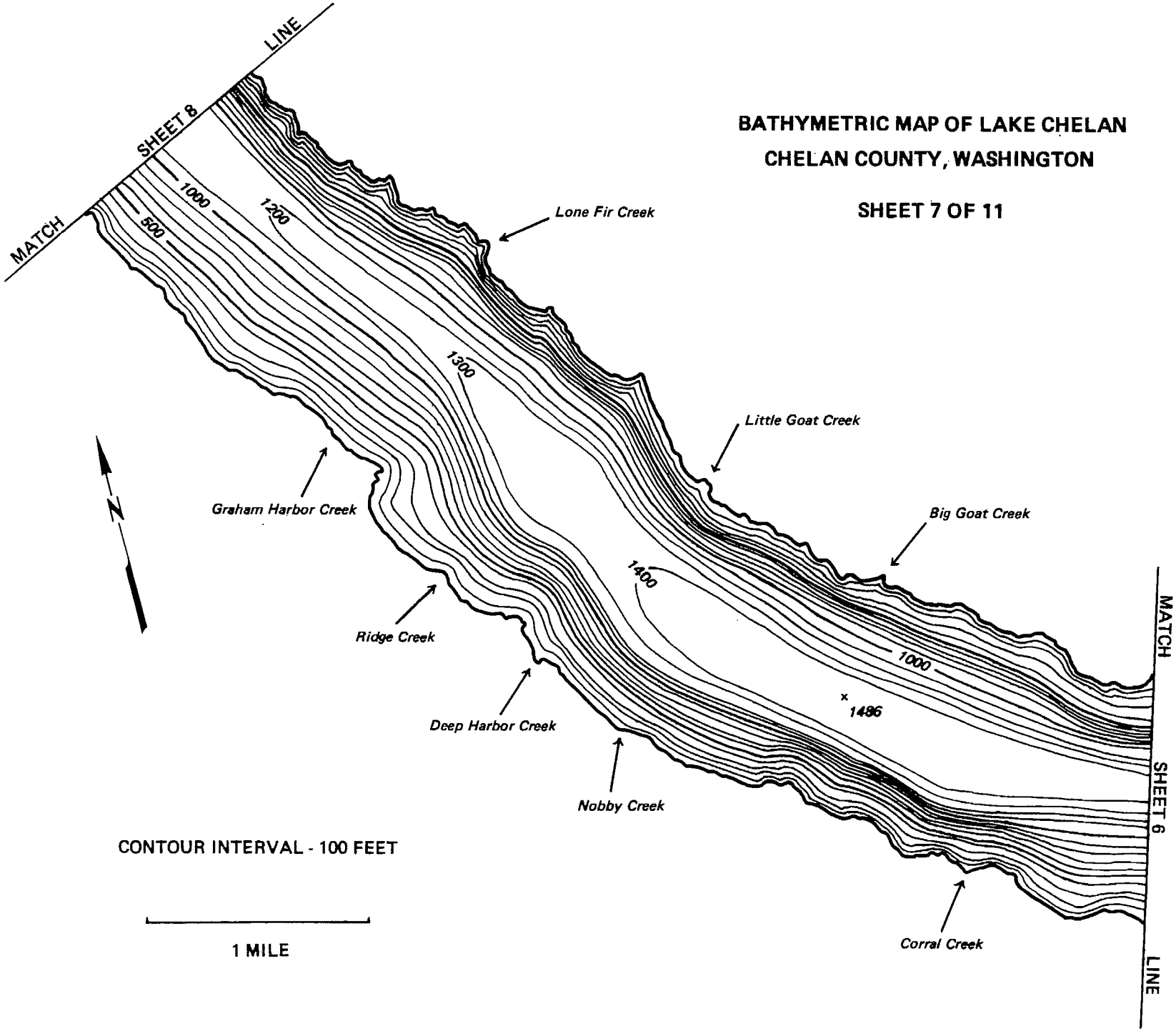



BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON
SHEET 5 OF 11
MATCH SHEET 6 LINE
Camas Creek
Grade Creek
Poison Creek
Gold Creek
Twentyfive Mile Creek
1400
1300
1200
1100
1000
500
900
N
CONTOUR INTERVAL - 100 FEET
1 MILE
MATCH SHEET 4 LINE

BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON

SHEET 6 OF 11

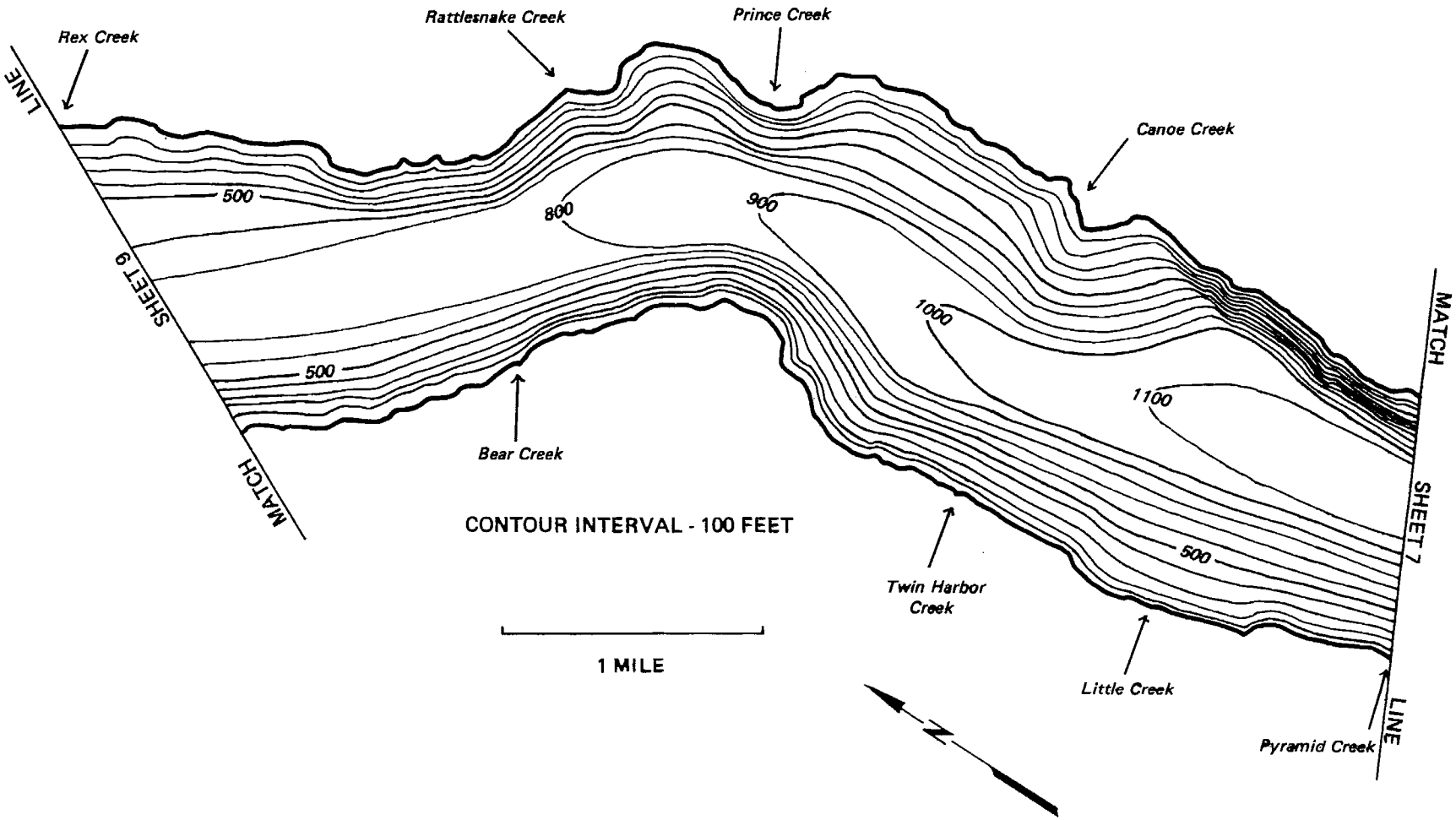



BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON
SHEET 7 OF 11
MATCH LINE
SHEET 8
MATCH
SHEET 6
LINE
500
1000
1200
1300
1400
1000
1486
Lone Fir Creek
Little Goat Creek
Big Goat Creek
Graham Harbor Creek
Ridge Creek
Deep Harbor Creek
Nobby Creek
Corral Creek
N
CONTOUR INTERVAL - 100 FEET
1 MILE

BATHYMETRIC MAP OF LAKE CHELAN

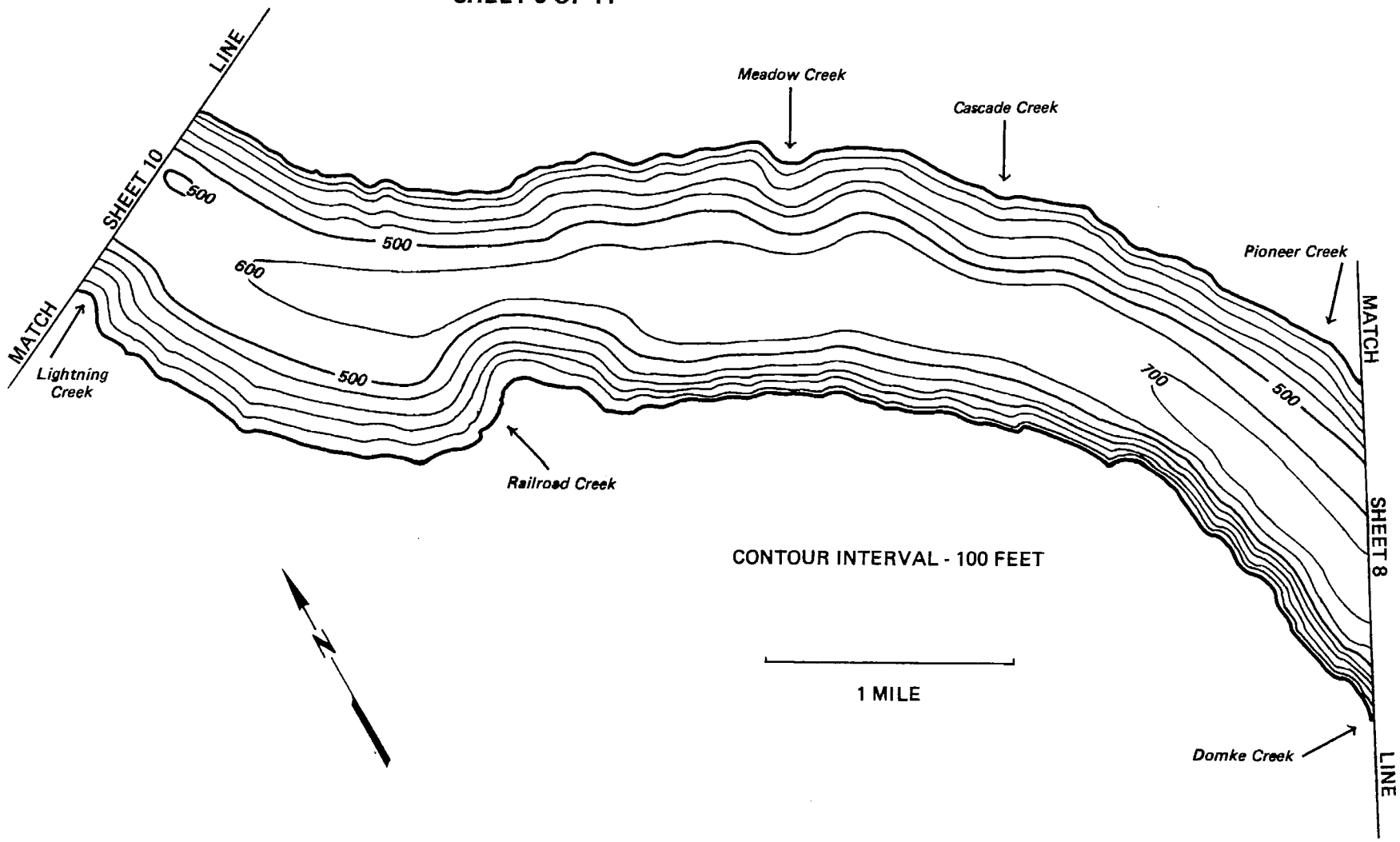
CHELAN COUNTY, WASHINGTON

SHEET 8 OF 11



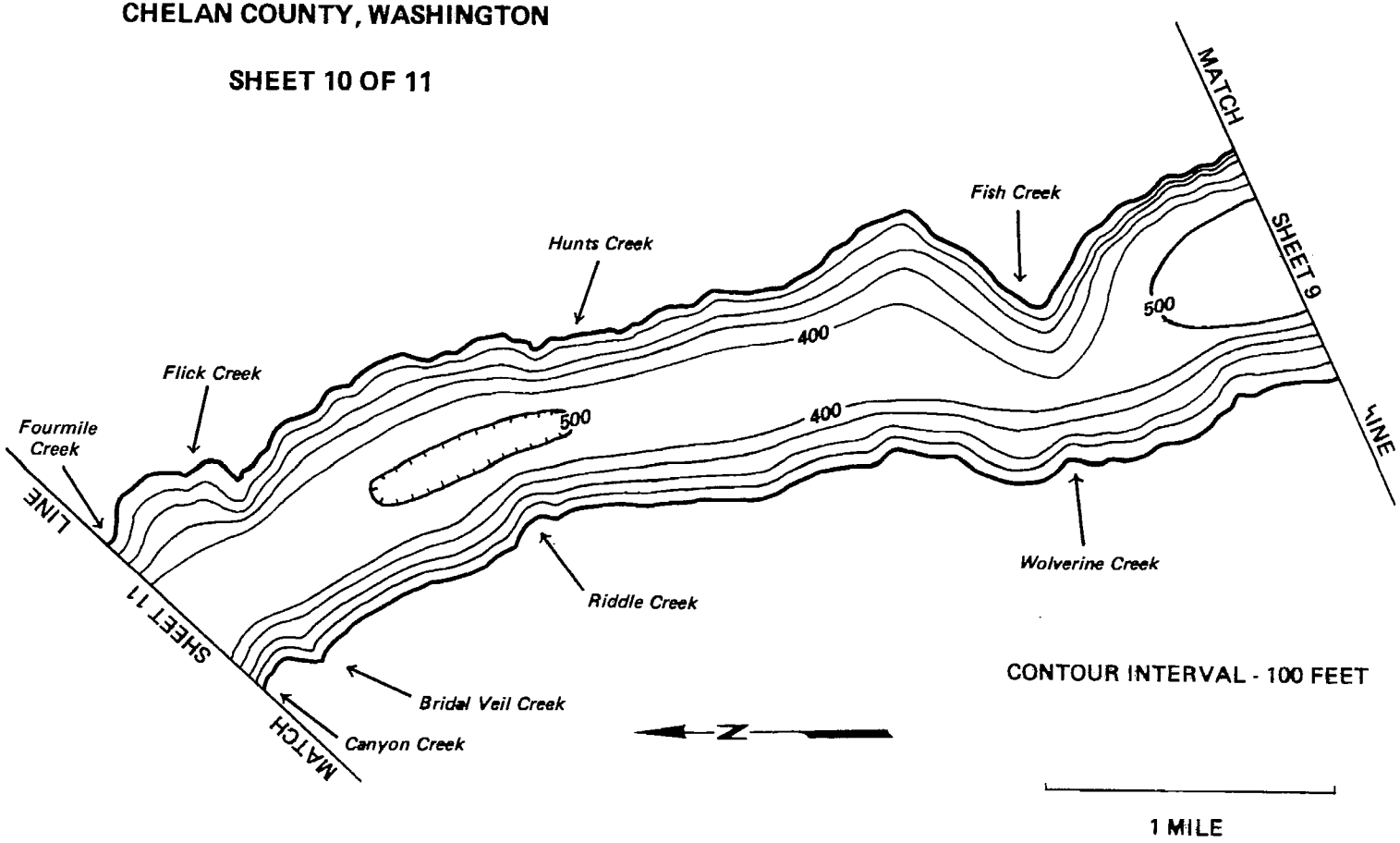
BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON

SHEET 9 OF 11



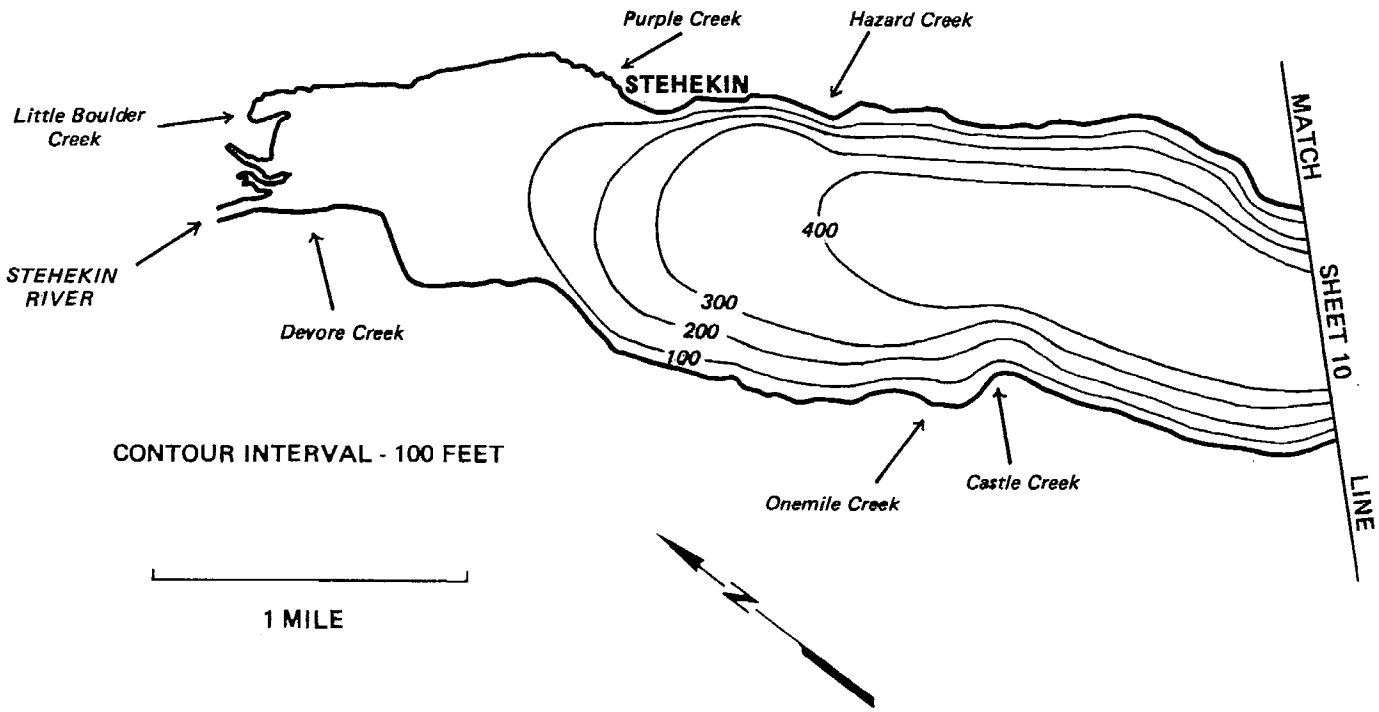
BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON

SHEET 10 OF 11



BATHYMETRIC MAP OF LAKE CHELAN
CHELAN COUNTY, WASHINGTON

SHEET 11 OF 11



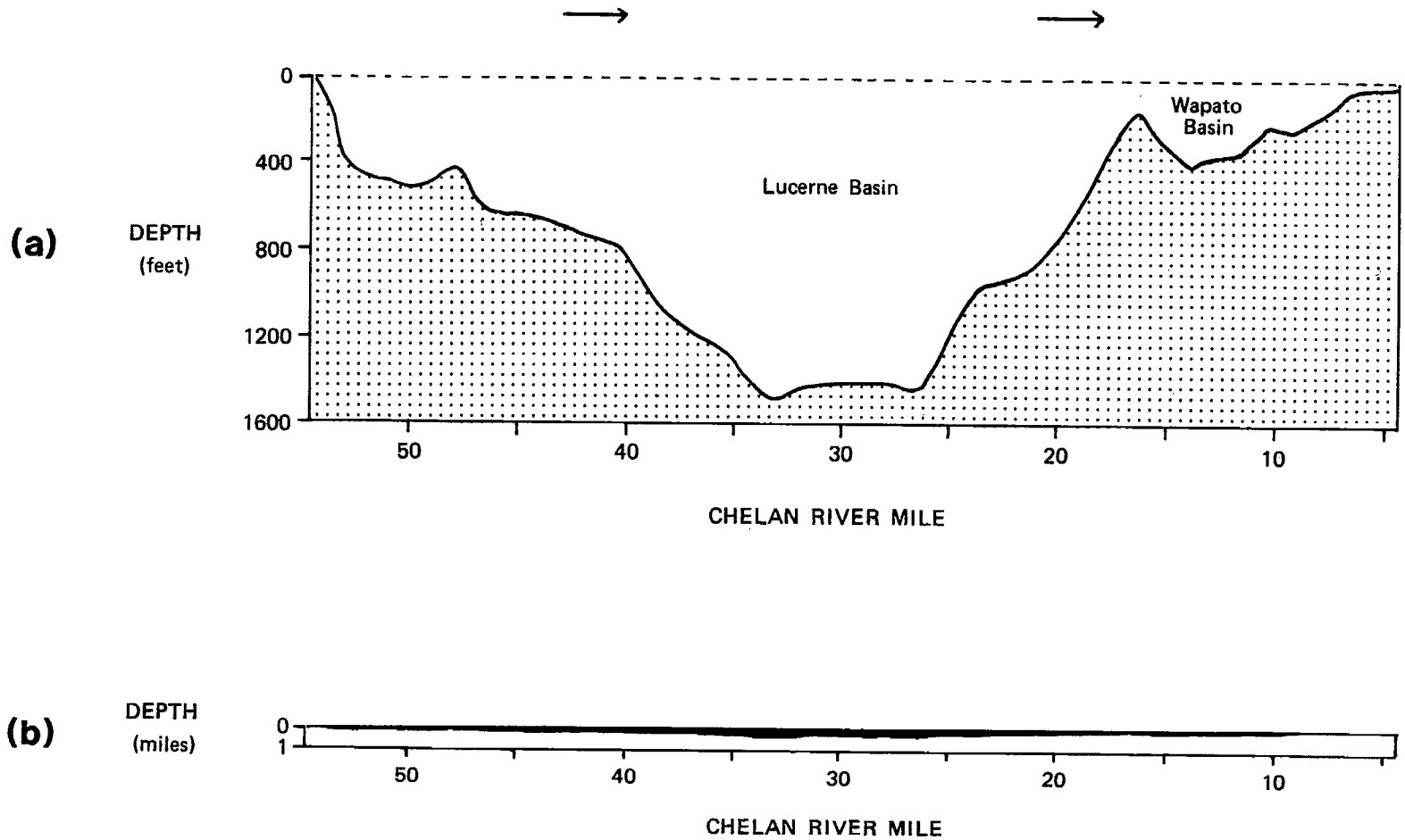


Figure 5. Longitudinal profile of the bottom topography of Lake Chelan, with (a) the vertical axis greatly exaggerated, and (b) both axes of same scale.

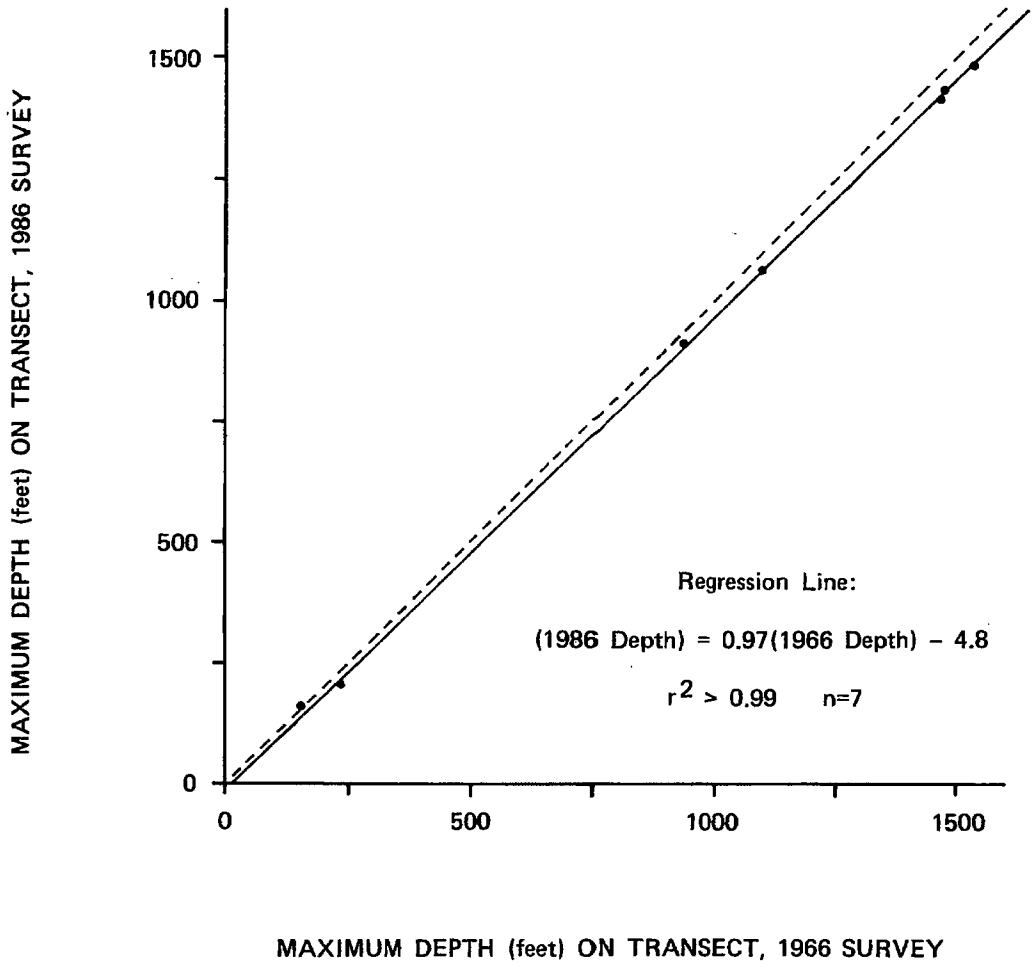


Figure 6. Relationship between depth maxima observed along echosounding transects common to both the 1966 (Whetten, 1967) and 1986 bathymetric surveys of Lake Chelan. The dashed reference line represents points of 1:1 correspondence.

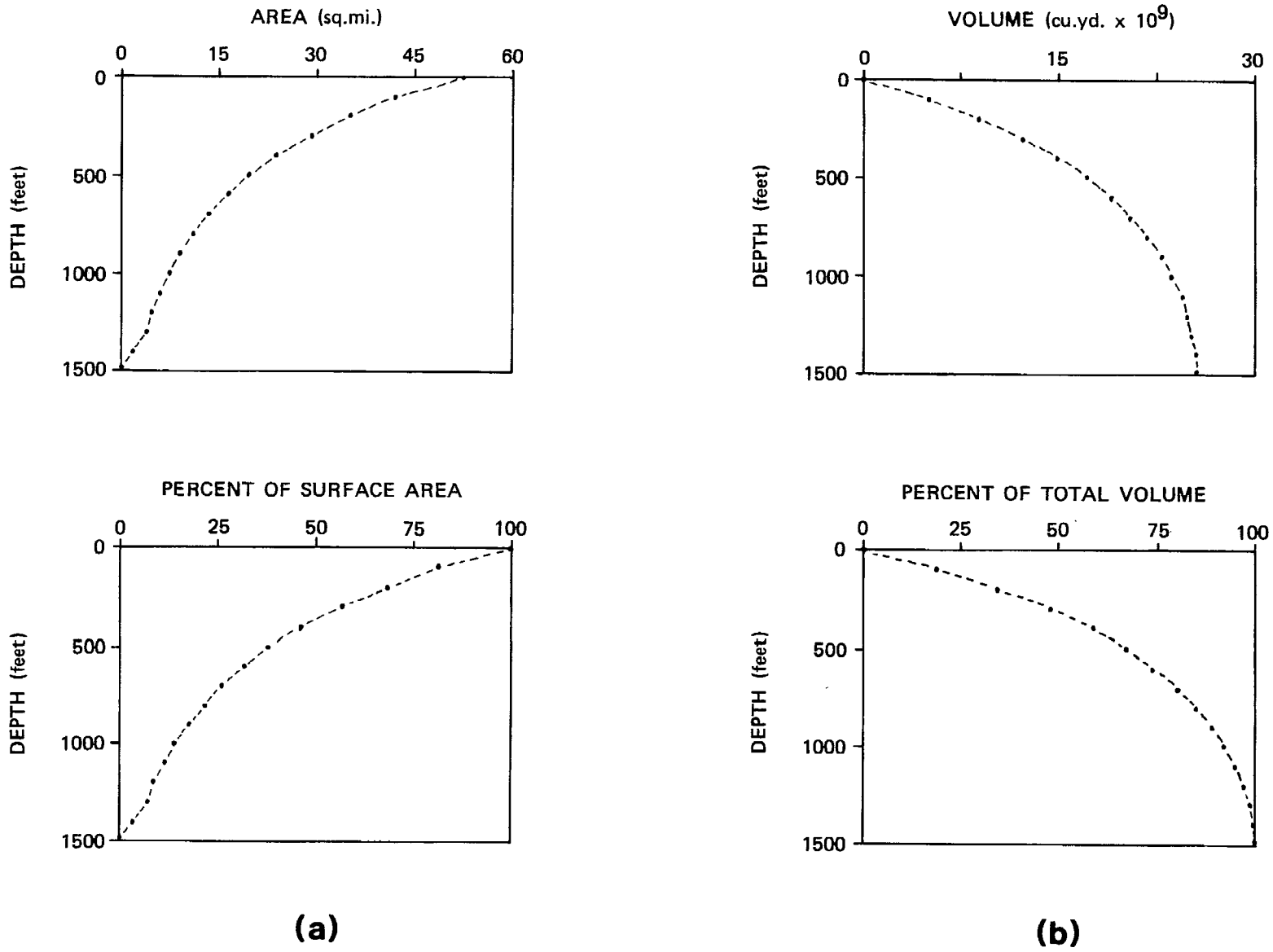


Figure 7. Hypsographic (a) and depth-volume (b) curves of Lake Chelan.

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APPENDICES

APPENDIX A. Location of 40 echosounding tracks on Lake Chelan and maximum depth recorded along each. Lake boundaries are river miles 4.3 and 54.7.

Approx. River Mile	Description of Sounding Track	Maximum Depth (ft)
4.5	SW to NE shore of neck, immediately uplake of new US-97 bridge	31
4.8	SW to NE shore of neck, immediately downlake from old US-97 bridge	27
5.7	Point SW of Spaders Bay to ferry landing opposite	29
6.6	Intermittent stream on N shore to USGS gage opposite	51
7.4	Point W of USGS gage to beachfront park opposite	138
9.2	Point at Minneapolis Beach to point opposite	229
10.4	Point SE of Sunnybank to water intake due W of Old Mill Park	206
11.7	Point below cliffs on S shore to S extent of Wapato Point	345
13.5	First Creek to Chelan Reclamation District agricultural drain #6	371
13.9[a]	Granite Falls Creek to S extent of Wapato Point	400
15.5	Point NW of Willow Point to Cove Marina opposite	277
16.3	Point opposite Shrine Beach to marina boat ramp	156
16.3[a]	Mid-lake, NW of Greens Landing, to mid-lake, E of Cove Marina	127[b]
17.2	Missouri Harbor to Stink Creek (Greens Landing)	275
18.4	Third point N of Missouri Harbor to swale/cliffs opposite	482
20.1	Fields Point to Mitchell Creek	757
21.8	Gold Creek to unnamed creek opposite	906
23.6	Twentyfive Mile Creek to Grade Creek	951
26.4	Unnamed creek E of Box Canyon to Deer Point opposite	1,441
28.4	Still Creek to Coyote Creek	1,412
30.1	Little Big Creek to Safety Harbor Creek	1,417
31.9	Big Creek to Point No Point Creek	1,431
33.4[a]	Little Goat Creek to Corral Creek	1,486
33.8	Big Goat Creek to Nobby Creek	1,471
35.8	Graham Harbor Creek to Lone Fir Creek	1,238
37.3	Point below cliffs to Pyramid Creek opposite	1,157
38.5	Twin Harbor Creek to Canoe Creek	1,059
40.5	Bear Creek to Rattlesnake Creek	793
41.8	Domke Creek to Rex Creek	745
43.8	Cliffs opposite Cascade Creek to swale 100 yds NW of Cascade Cr.	670
45.0	USFS residence at Lucerne to Meadow Creek	629
46.4[a]	Railroad Creek to Moore Point	620
47.2	Lightning Creek to opposite shore	566
48.0	Point at Wolverine Creek to Moore Point	421
49.9	Riddle Creek to unnamed creek opposite	509
51.2	Canyon Creek to Fourmile Creek	489
52.7	Onemile Creek to Adams Point	424
53.4	Gorge S of Painted Rocks to USGS gage	347
53.7	Weaver Point to mid-lake, W of Stehekin	133
54.3	Point NW of Stehekin to Weaver Point opposite	11

[a]Sounding track cross-checks main-scheme line(s); river mile shown corresponds to deepest point on track.

[b]Depth shown is a minimum along the track, which was sounded to locate the Narrows Sill.

APPENDIX B. Description and volume of discrete segments of Lake Chelan. Segment 1 begins at the lake outlet (river mile 4.3).

Segment	Upstream Boundary	Approx. River Mile	Volume (cu. yds. x 10^9)
1	Point W of USGS gage to beachfront park opposite	7.4	0.10
2	Point at Minneapolis Beach to point opposite	9.2	0.29
3	Point below cliffs on S shore to S extent of Wapato Point	11.7	0.45
4	First Cr to Chelan Reclamation Dist. agricultural drain #6	13.5	0.52
5	Narrows Sill: Shrine Beach to opposite shore	16.3	0.59
6	Antilon Creek to point opposite	19.4	0.83
7	Gold Creek to unnamed creek opposite	21.8	1.18
8	Grade Creek to point opposite (NW of Twentyfive Mile Cr)	23.9	1.41
9	Unnamed creek E of Box Canyon to Deer Point opposite	26.4	2.06
10	Falls Creek to Still Creek	28.8	2.98
11	Big Creek to Point No Point Creek	31.9	2.79
12	Little Goat Creek to Deep Harbor Creek	34.5	2.56
13	Point below cliffs to Pyramid Creek opposite	37.3	2.38
14	Prince Creek to point opposite	39.7	2.20
15	Domke Creek to Rex Creek	41.8	1.19
16	Meadow Creek to opposite shore	44.5	1.13
17	Lightning Creek to opposite shore	47.2	1.15
18	48° 15' north latitude	49.0	0.49
19	Canyon Creek to Fourmile Creek	51.2	0.47
20	Mouth of Stehekin River	54.7	0.68

APPENDIX C. Area of the plane circumscribed by each contour and volume of the horizontal strata delimited by the areas of sequential depth contours. Where applicable, areas of submerged lake mounts were subtracted from contour areas.

	Depth of Contour (ft.)	Area of Contour (sq. mi.)	Percent of Surface Area	Depth of Stratum (ft.)	Volume of Stratum (cu. yd. x 10^9)	Percent of Total Volume
Wapato Basin	0	13.52	100.0	0 - 100	1.043	53.6
	100	7.27	53.8	100 - 200	0.567	29.1
	200	3.86	28.5	200 - 300	0.275	14.1
	300	1.76	13.0	300 - 400	0.061	3.1
	Subtotal				1.946	100.0
Lucerne Basin	0	38.55	100.0	0 - 100	3.779	16.1
	100	34.64	89.9	100 - 200	3.406	14.5
	200	31.33	81.3	200 - 300	3.037	12.9
	300	27.52	71.4	300 - 400	2.650	11.3
	400	23.85	61.9	400 - 500	2.218	9.4
	500	19.56	50.7	500 - 600	1.842	7.8
	600	16.37	42.5	600 - 700	1.508	6.4
	700	13.35	34.6	700 - 800	1.250	5.3
	800	11.07	28.7	800 - 900	1.033	4.4
	900	9.07	23.5	900 - 1,000	0.836	3.6
	1,000	7.21	18.7	1,000 - 1,100	0.673	2.9
	1,100	5.86	15.2	1,100 - 1,200	0.532	2.3
	1,200	4.62	12.0	1,200 - 1,300	0.427	1.8
	1,300	3.67	9.5	1,300 - 1,400	0.273	1.2
	1,400	1.82	4.7	1,400 - 1,486	0.040	0.2
	Subtotal				23.504	100.0
Lake Chelan	0	52.07	100.0	0 - 100	4.822	18.9
	100	41.91	80.5	100 - 200	3.973	15.6
	200	35.19	67.6	200 - 300	3.312	13.0
	300	29.28	56.2	300 - 400	2.711	10.7
	400	23.85	45.8	400 - 500	2.218	8.7
	500	19.56	37.6	500 - 600	1.842	7.2
	600	16.37	31.4	600 - 700	1.508	5.9
	700	13.35	25.6	700 - 800	1.250	4.9
	800	11.07	21.3	800 - 900	1.033	4.1
	900	9.07	17.4	900 - 1,000	0.836	3.3
	1,000	7.21	13.9	1,000 - 1,100	0.673	2.6
	1,100	5.86	11.3	1,100 - 1,200	0.532	2.1
	1,200	4.62	8.9	1,200 - 1,300	0.427	1.7
	1,300	3.67	7.0	1,300 - 1,400	0.273	1.1
	1,400	1.82	3.5	1,400 - 1,486	0.040	0.2
	Grand Total				25.450	100.0