SEDIMENTATION SURVEY OF FENA RESERVOIR, GUAM, MARIANA ISLANDS, 1979

by William F. Curtis

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4125

Prepared in cooperation with the

U.S. DEPARTMENT OF THE NAVY

PUBLIC WORKS CENTER

Guam

July 1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey, WRD
Room 6110, 300 Ala Moana Blvd.
Honolulu, Hawaii 96850

Copies of this report may be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
(Telephone: [303] 234-5888)

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION TABLE

The following table may be used to convert measurements in the inch-pound system to the International System of Units (SI).

Multiply inch-pound units	By	To obtain SI units
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meters (m^3)
pound	0.4535	kilogram (kg)
pound per cubic foot (lb/ft^3)	16.0	kilogram per cubic meter (kg/m^3)

SEDIMENTATION SURVEY OF FENA RESERVOIR, GUAM, MARIANA ISLANDS, 1979

By William F. Curtis

ABSTRACT

Fena Reservoir, in south-central Guam, was constructed in 1950-51 to provide a dependable water supply for the U.S. Navy.

At the request of the U.S. Navy, the U.S. Geological Survey conducted a sedimentation survey of Fena Reservoir during the months of November and December 1979.

The sedimentation survey showed that at the spillway elevation, the reservoir has a surface area of 195 acres and a volume of 7,863 acre-feet. Data from a network of 30 triangulation stations and 32 cross sections indicated a decrease of 440 acre-feet in reservoir capacity since 1949 due to the accumulation of sediment. Area capacity curves for 1949, 1973 and 1979 and a bathymetric map of the reservoir were constructed. The combination of denser water due to lower temperature and suspended sediment load appears to create a density current within the reservoir. Particle-size analyses and unit-weight computation are provided to define the physical characteristics of the accumulated sediment.

INTRODUCTION

In 1951, the U.S. Navy completed a dam that formed a major reservoir on the Fena River in south-central Guam. During the months of November and December 1979, at the request of the U.S. Navy, the U.S. Geological Survey conducted a sedimentation study of Fena Reservoir.

Purpose

The purpose of the sedimentation study was to conduct a topographic survey of Fena Reservoir in order to determine the change in storage capacity caused by sediment accumulation.

Physical Setting

Fena Reservoir, located in south-central Guam (fig. 1) was constructed as a water supply for U.S. Navy personnel and local residents.

The reservoir is contained in the flooded canyon. Three rivers, the Almagosa, Imong, and the Maulap, flow into the reservoir (fig. 1). The total drainage area at the dam (85 ft high and 1,050 ft long) is 5.81 mi^2. The watershed is within an ammunition storage area and is relatively undeveloped. Soils in the watershed are primarily of volcanic origin and are covered with dense tropical vegetation intermixed with grasses. Occasional bare areas occur throughout the watershed. At times, large areas of grassland are set on fire by poachers with attendant loss of ground cover. Erosion of the denuded ground contributes to the sediment load in the streams.

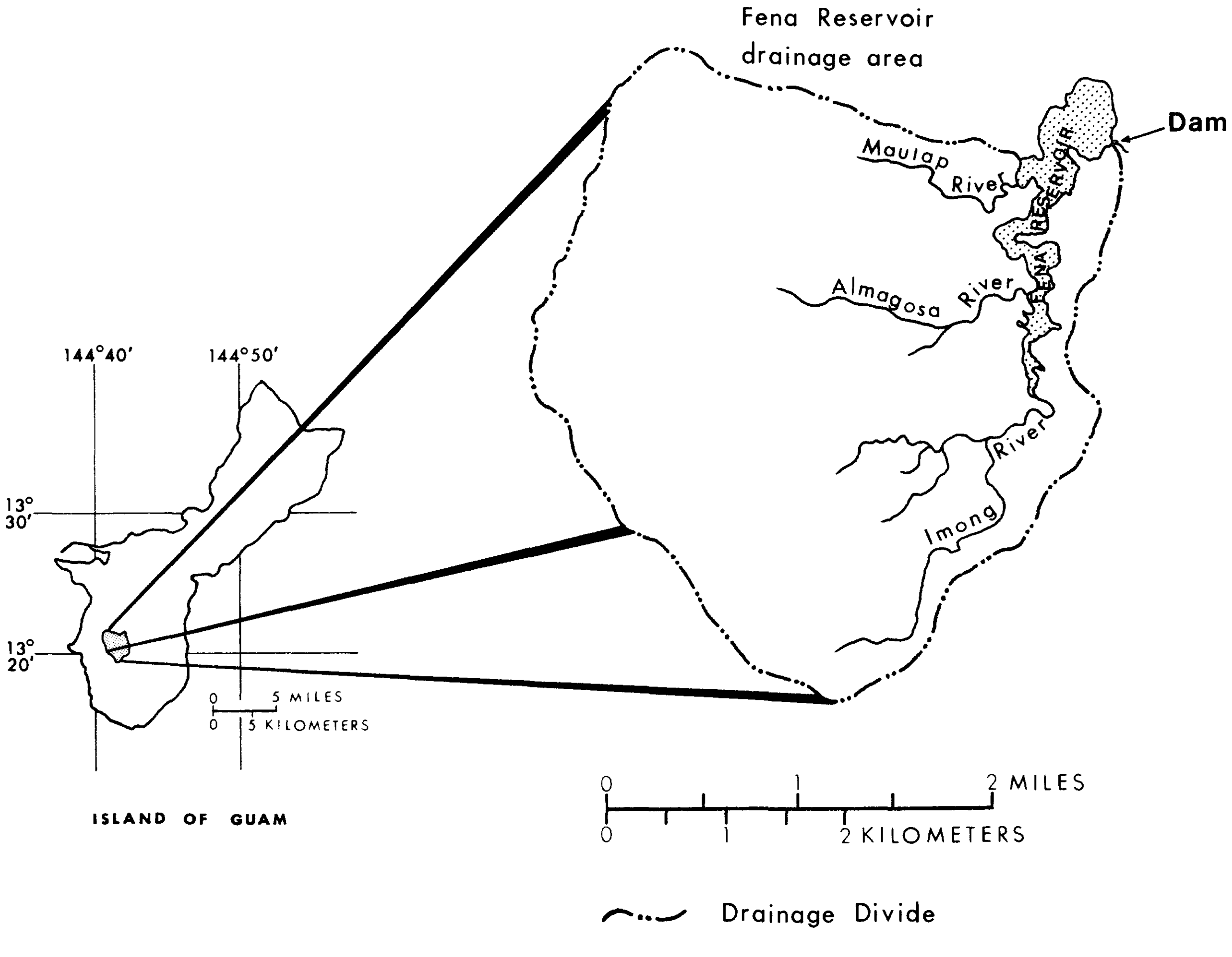


Figure 1. Location of Fena Reservoir and drainage area.

RESULTS AND DISCUSSION

Geometry of the Reservoir

At the spillway elevation of 111.3 feet above mean sea level, the Fena Reservoir has a surface area of 195 acres and a volume of 7,863 acre-ft. The original survey (1949) shows that the surface area of the reservoir was 197 acres and the volume was 8,300 acre-ft. The discrepancy in surface area, 2 acres, is attributed to surveying inaccuracy. The decrease in reservoir capacity, about 440 acre-ft, is due to the accumulation of sediment in the reservoir. Area-capacity curves for 1949, 1973, and 1979 are shown in figure 2.

To determine the change in capacity of the reservoir, a complete resurvey of the reservoir was made in 1979. Thirty permanent triangulation points were established around the perimeter of the reservoir and triangulated to determine their exact positions (fig. 3). Thirty-two cross sections of the reservoir were made using a sonic sounder. These cross sections were plotted, and a bathymetric map of the reservoir was constructed (fig. 3).

Five-foot contours were used in determining reservoir area. When comparing the new bathymetric map with the original (1949) survey, some discrepancies were noted. On the original map, the embayment immediately south of the Almagosa River was drawn on the east side of the reservoir instead of on the west. The embayment also contains a large-sized island that was not shown on the original survey. These two discrepancies could account for the different surface areas mentioned earlier.

By comparing the bottom contours of the 1949 and 1979 maps, it is possible to determine where sediment deposition has occurred. The southern, upstream part of the reservoir where the Imong River enters, shows considerable aggradation (between 1949 and 1979) (cross sections 25-26 and 27-30, fig. 4). Visual inspection of this sedimentary material revealed a composition of about 90 percent sand and gravel and 10 percent silt and clay, the usual pattern observed in most reservoirs. Most of the sand and gravel is transported in the tributary streams as bedload with the silt and clay as suspended load. When the water from the streams flows into the reservoir, the sand and gravel immediately deposits, aggrading the delta area. The finer material, silt and clay, is usually transported in suspension and is carried further into the reservoir before settling. The other area of major deposition in Fena Reservoir is in the northern part upstream from the dam (cross sections 1-4, 3-4, and 3-6, fig. 5 and 6).

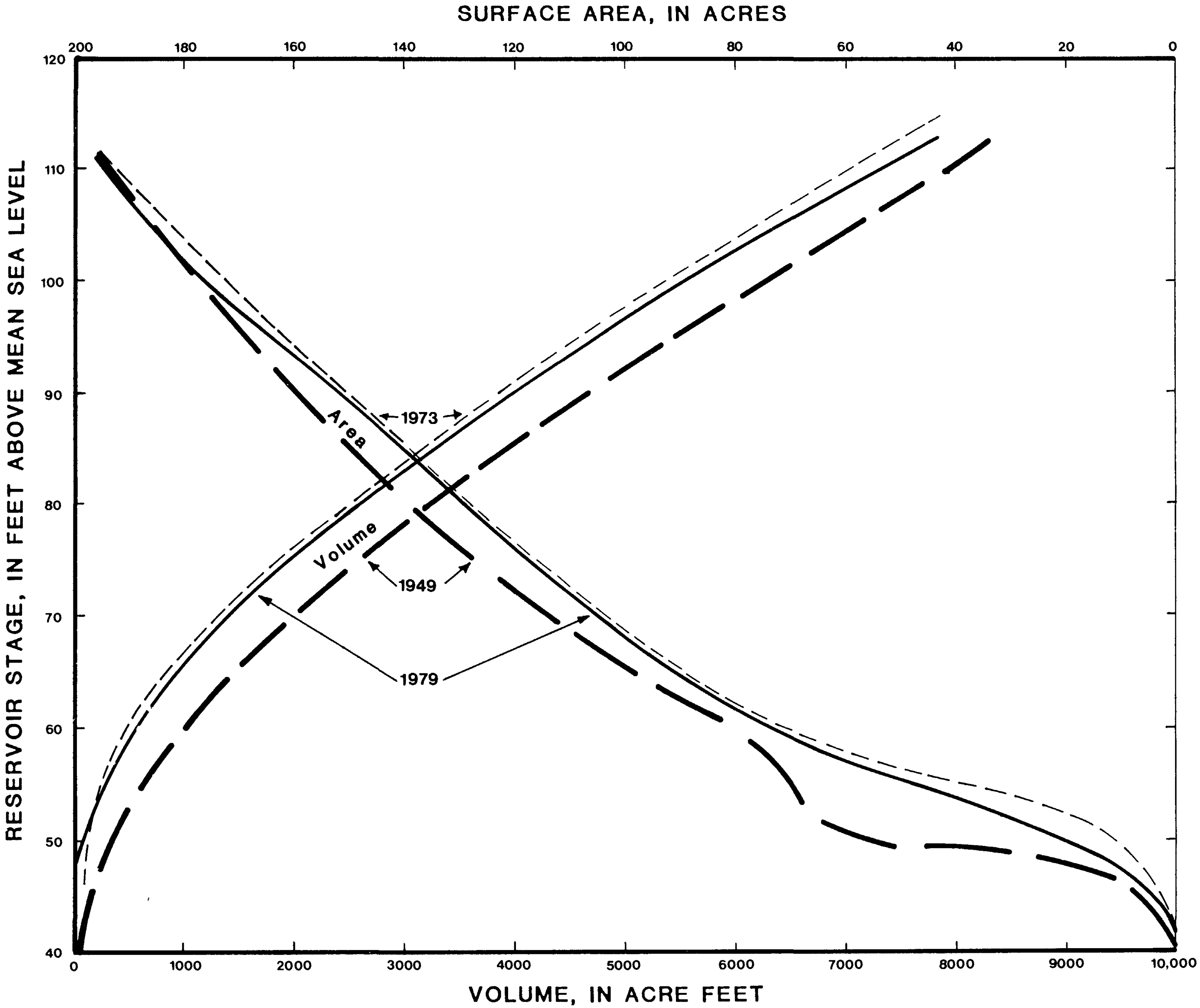


Figure 2. Area-capacity curves for Fena Reservoir.

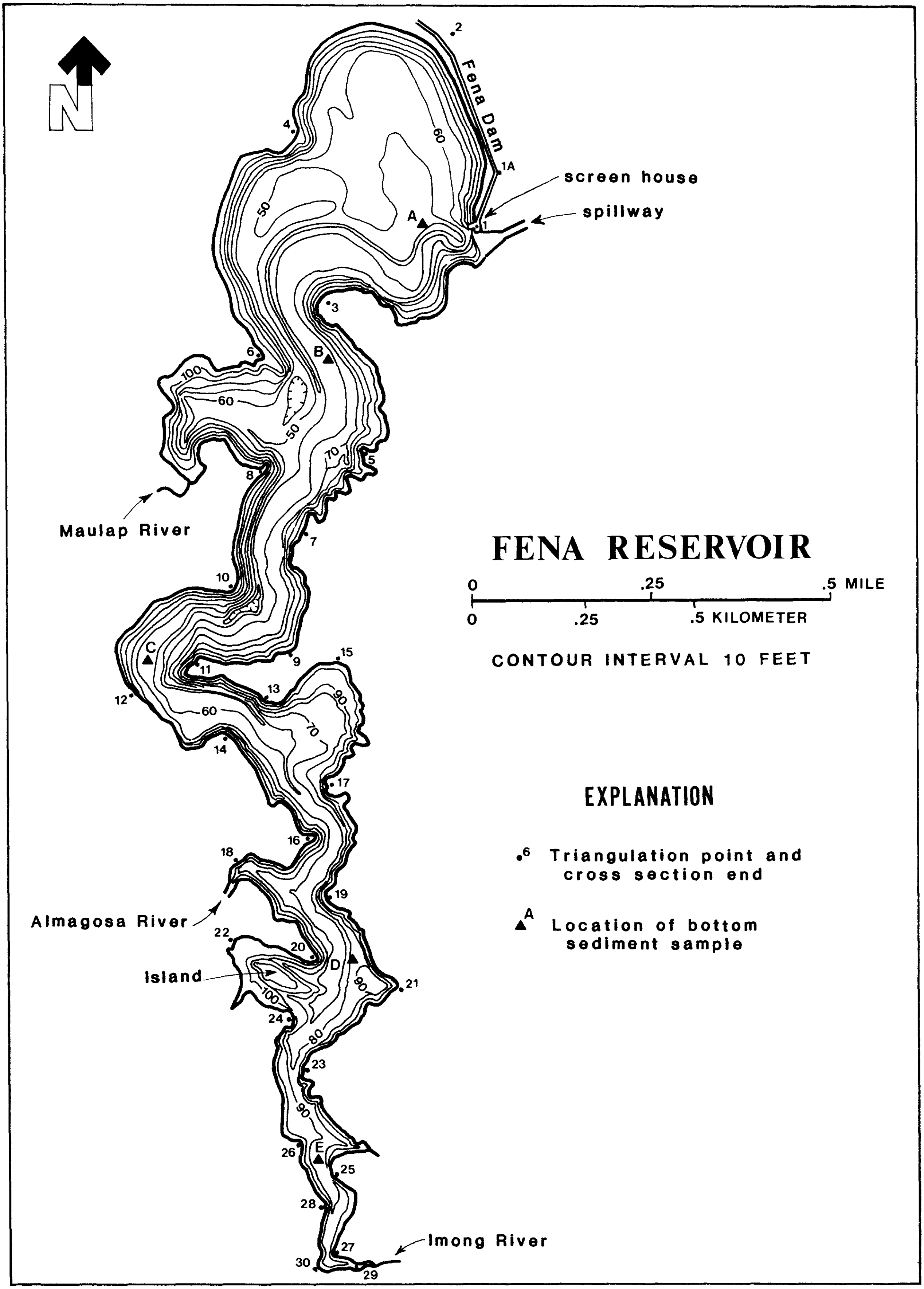
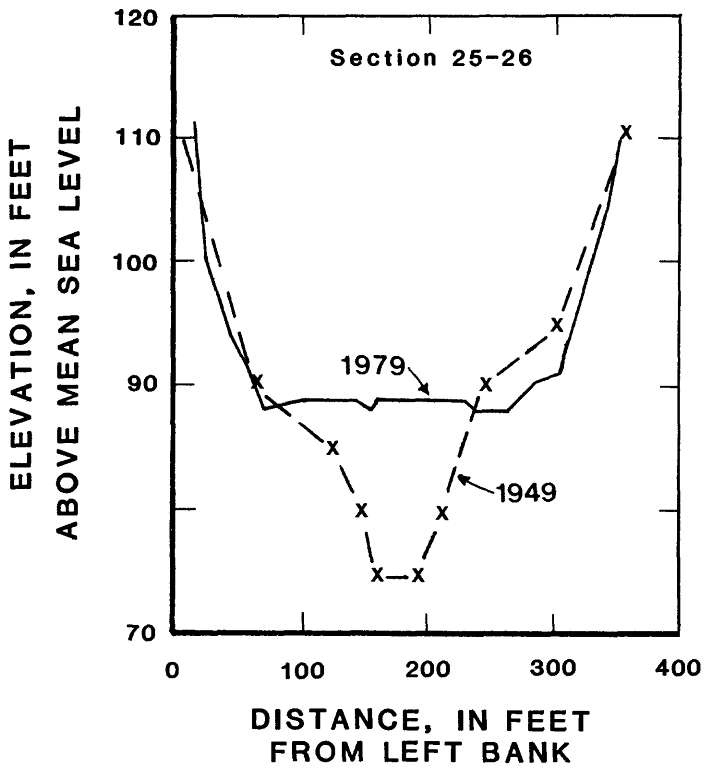


Figure 3. Bathymetric map of Fena Reservoir.



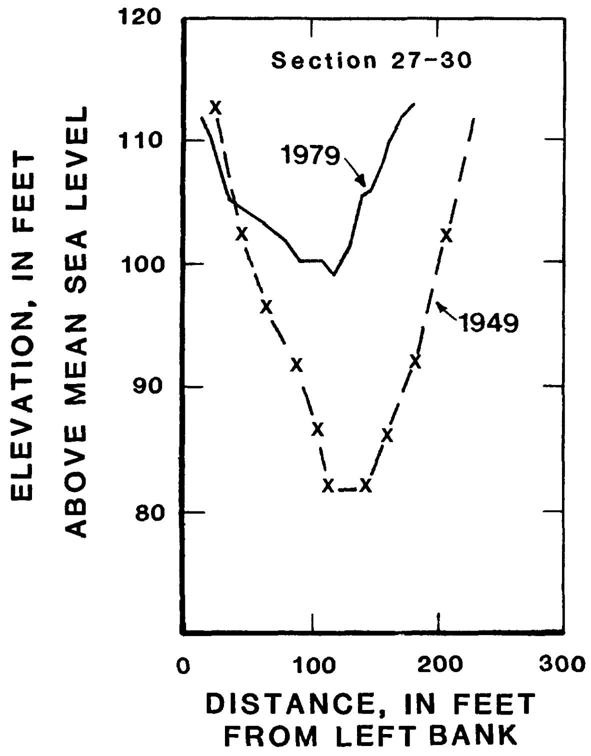


Figure 4. 1949 and 1979 cross sections of Imong River delta.

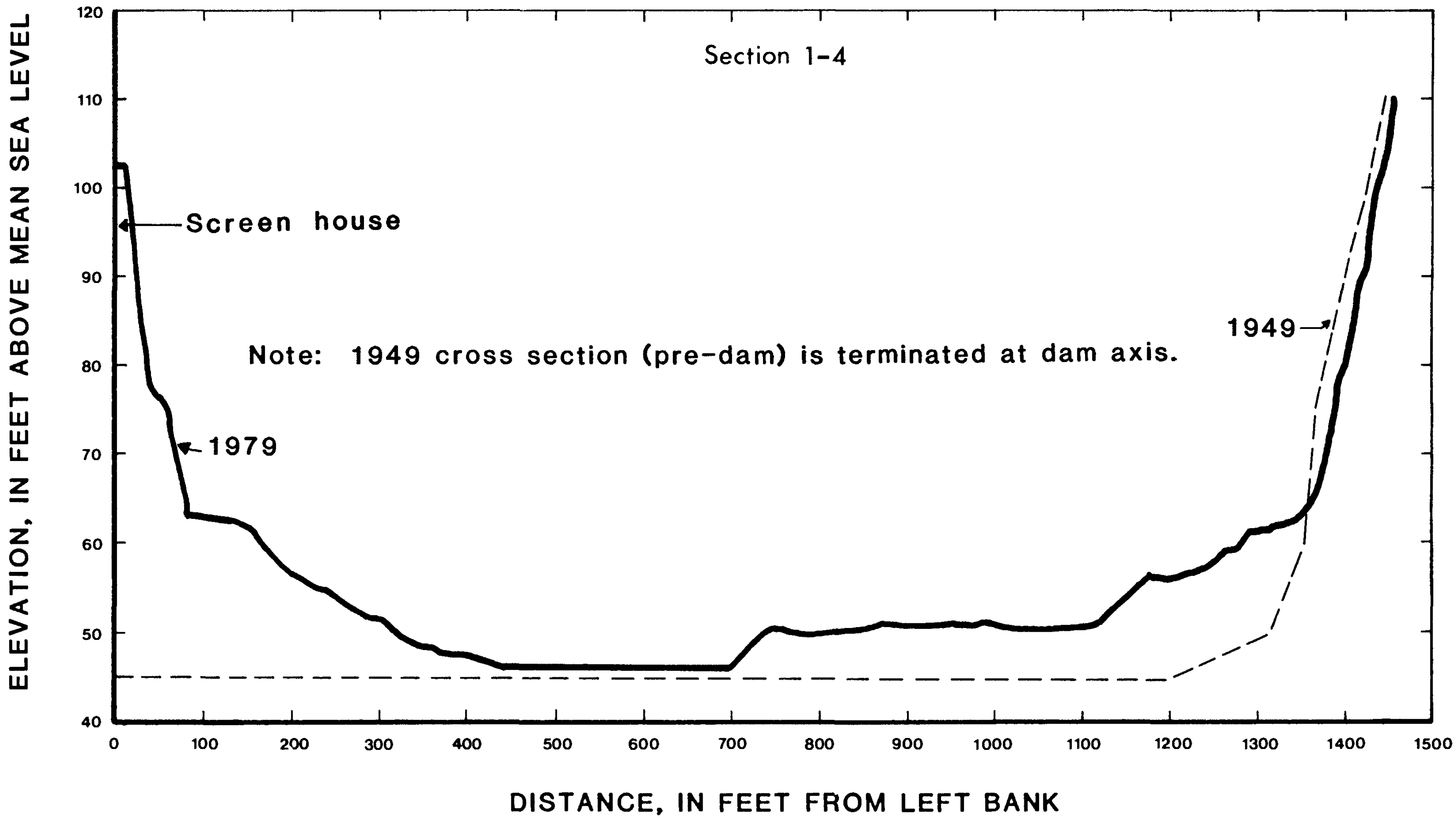
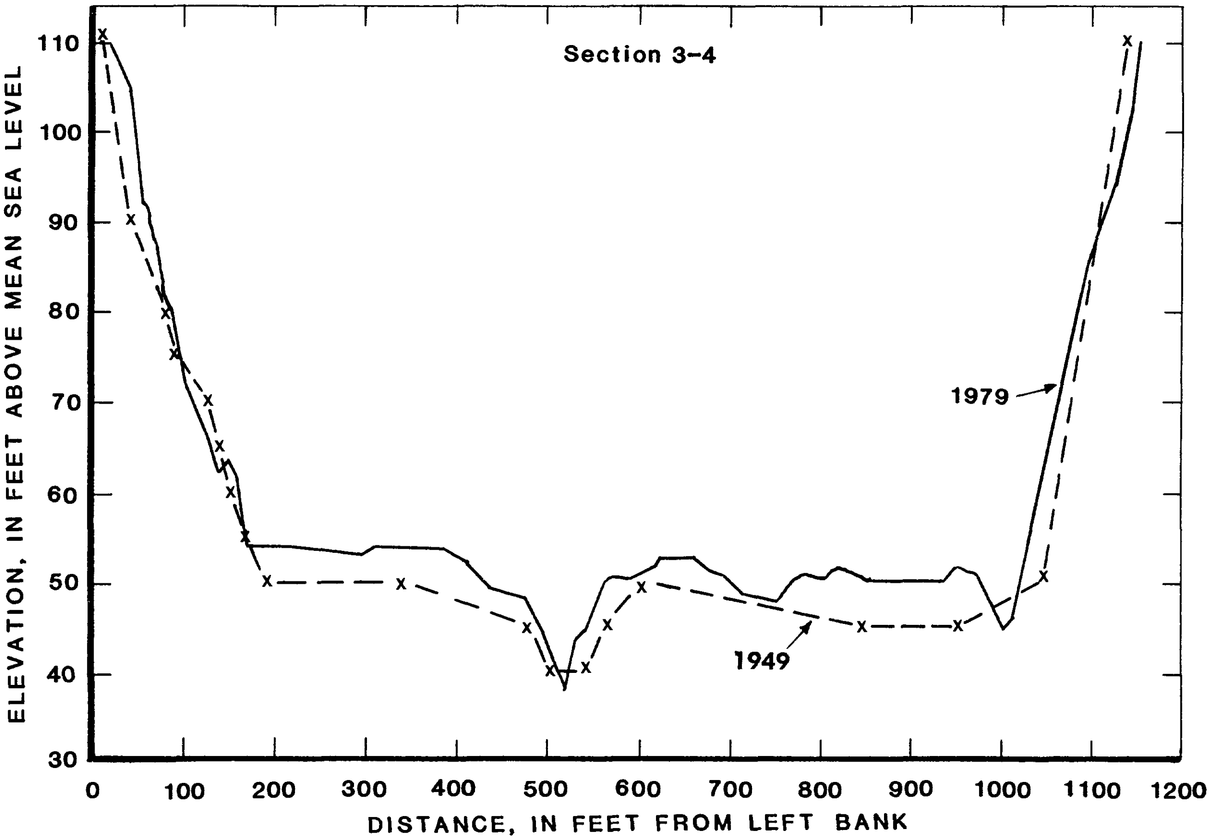


Figure 5. Cross section 1-4 near Fena Dam, 1949 and 1979.



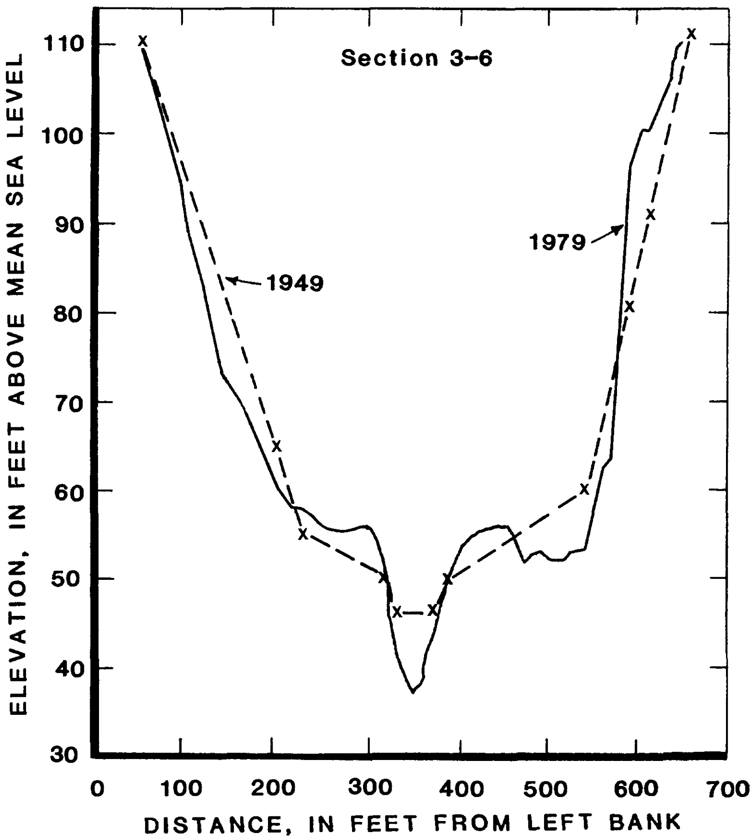


Figure 6. 1949 and 1979 cross sections near Fena Dam.

Particle-size Analyses of Sediment

Five samples of bottom material were collected at sites A, B, C, D, and E (fig. 3). Results of particle-size analyses of the samples are summarized in table 1. The data in the table and in figure 7 indicate that the very fine material, silt (0.016 mm) and clay (0.004 mm), is transported through the reservoir and deposited adjacent to the dam.

Table 1. Particle-size analyses of bottom material

Percent finer than size, in millimeters, indicated

Site	.250	.124	.062	.016	.004
A	--	--	100	97	96
B	--	--	100	93	81
C	--	--	100	95	79
D	--	100	99	84	45
E	100	99	89	27	13
Mouth Imong River (estimated)	--	--	10	--	--

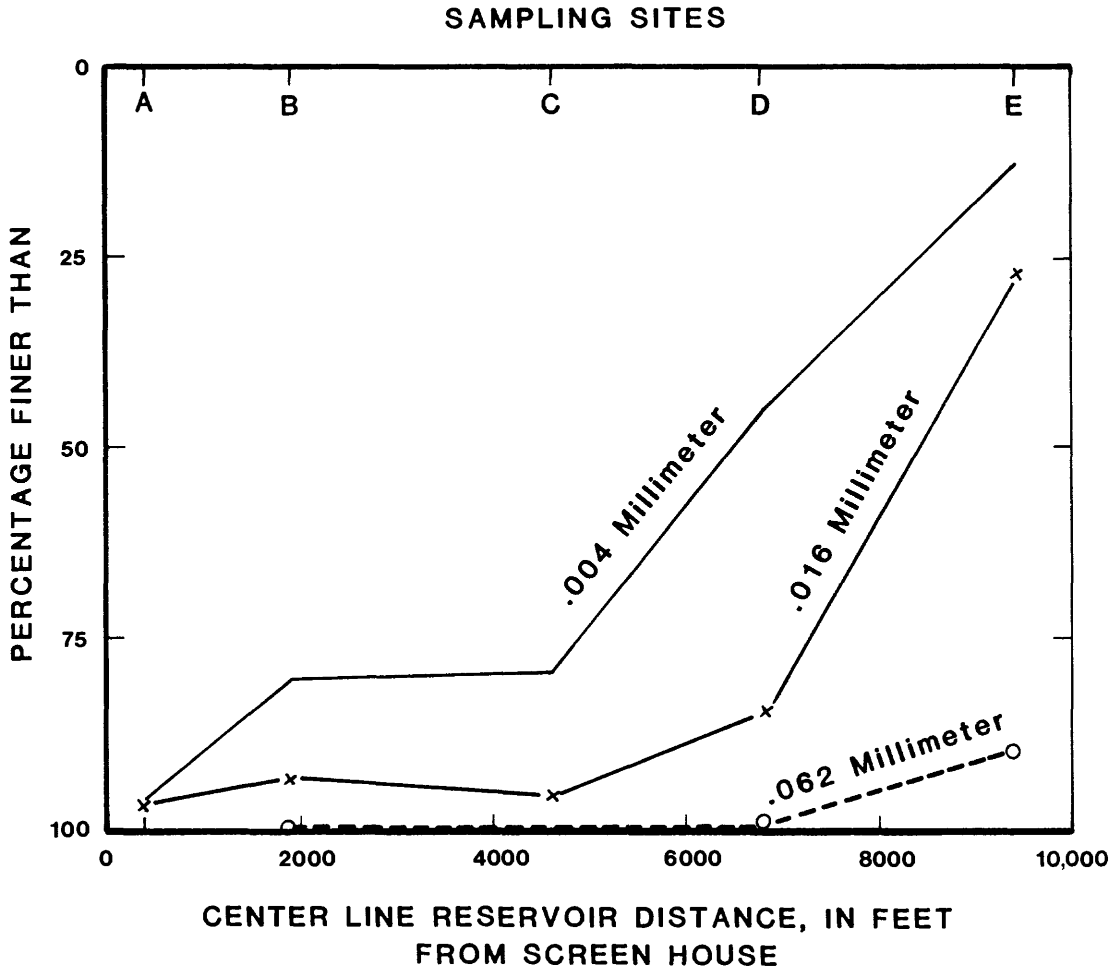
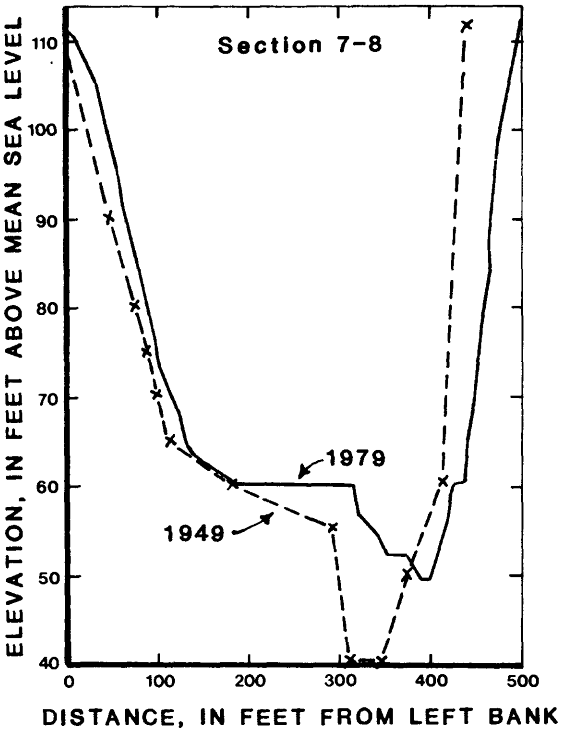


Figure 7. Percentage of bed material in size class versus distance from dam.

Mechanism for Transport and Deposition of Silt and Clay in the Reservoir

As little deposition seems to have occurred in the middle part of the reservoir (cross sections 7-8 and 9-10, fig. 8), there must be some mechanism by which the very fine material is transported toward the dam. The amount of water removed daily from the reservoir, about 30.7 acre-ft or 10 Mgal (million gallons), is small (0.4 percent) compared to the reservoir capacity, 7,863 acre-ft. Therefore, velocity currents within the reservoir may be ruled out. Mr. Gorman Dorsey, Director of Laboratory Services, U.S. Navy, Guam proposed that a density current flows down the thalweg (former channel) of the river to the dam, and the reservoir actually fills from the bottom. This appears to be correct based on the depositional pattern found in the reservoir. As indicated by cross sections 3-4 and 3-6 (fig. 6), there appears to be a natural levee accumulating along the Thalweg. This is taking place in the classical manner of surface water streams except that it is happening under water in a reservoir. During periods of high inflow in September and October, it is reasonable to assume that the sediment loads carried by the streams are also the highest. The temperature of the rainfall and, therefore, the streamflow at this time of year, is probably cooler than the water in the reservoir. The combination of denser water due to lower temperature and suspended sediment load, appears to create a density current in the reservoir.



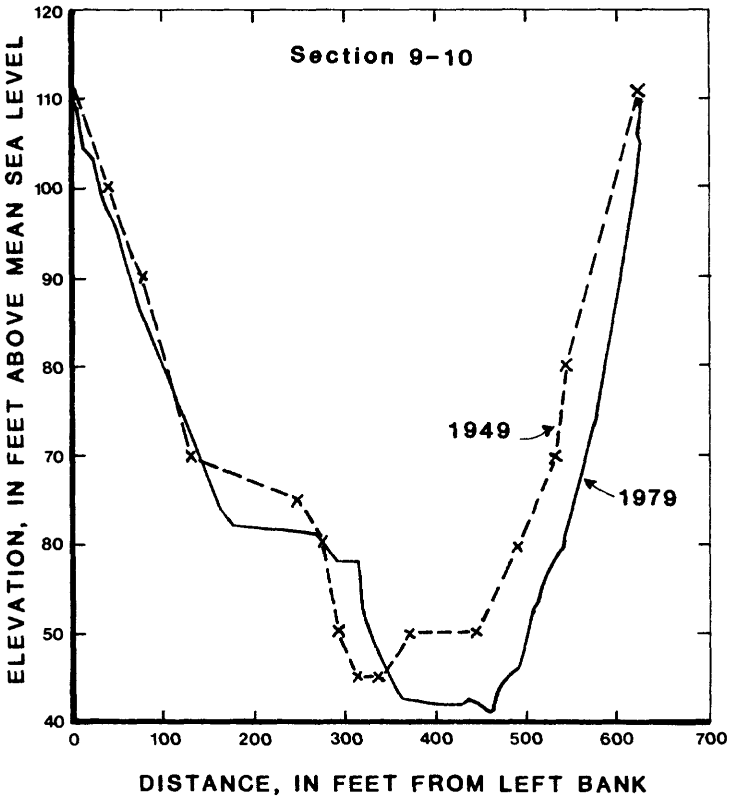


Figure 8. 1949 and 1979 cross sections near middle of Fena Reservoir.

In-Place Weight of Deposited Sediment

The in-place weight of the deposited sediment was computed by the Lara-Pemberton method (Lara and Pemberton, 1963) (initial unit weight of deposited sediments). Fena Reservoir would fit the type II reservoir conditions (normally moderate to considerable reservoir drawdown) as outlined in this method. The equation used to calculate the unit in-place weight is:

$$\delta = W_c p_c + W_m p_m + W_s p_s \qquad (1)$$

where:

δ = unit in-place weight, in pounds per cubic feet (lb/ft^3);

W = constant determined by regression analysis with dimensions of unit weight, applicable to each size class;

P = percentage of sample; and

c, m, s = subscripts denoting clay, silt, and sand.

From data given in the paper, the following weights (Lara and Pemberton, 1963) for type II reservoir conditions were used:

W_c = 35 lb, W_m = 71 lb, W_s = 97 lb; therefore, the following unit in-place weights were computed by use of equation (1). The percentages are derived from table 1.

Site A = 35(.96) + 71(.04) = 36.4 lb/ft^3,

Site B = 35(.81) + 71(.19) = 41.9 lb/ft^3,

Site C = 35(.79) + 71(.21) = 42.5 lb/ft^3,

Site D = 35(.45) + 71(.55) = 54.8 lb/ft^3,

Site E = 35(.13) + 71(.76) + 97(.11) = 69.3 lb/ft^3, and

Site Imong delta = 71(.1) + 97(.9) = 94.4 lb/ft^3.

The calculated unit weights of the samples indicate that the smallest size material with the lightest unit weight is deposited near the dam.

REFERENCES

American Society of Civil Engineers, 1975, Density current in sedimentation engineering: New York, p. 278-285.

Frederic R. Harris, Inc., 1947, Impounding reservoir, area and volume curves, Fena Dam project: San Francisco, architecture and engineering drawing 134-2.

Kennedy Engineers, Inc., 1973, Fena Reservoir study: San Francisco.

Lara, J. M., Pemberton, E. L., 1963, Initial unit weight of deposited sediments, U.S. Department of Agriculture, Proceedings of the Federal Inter-Agency Sedimentation Conference, Miscellaneous Publication No. 970, Agriculture Research Service, p. 818-845.

Ward, P. E., Hoffard, S. H., and Davis, D. A., 1965, Hydrology of Guam: U.S. Geological Survey Professional Paper 403-H, p. H1-H28.