A PRELIMINARY SURVEY OF
THE DAMARISCOTTA RIVER ESTUARY
LINCOLN COUNTY, MAINE

PART I - HYDROLOGY

PART II - SEDIMENTS

Prepared Under a Grant
From The
Maine Marine Stipend Program

Maine Department of Economic Development
Augusta, Maine

Division of Science, Technology & Mineral Resources
Robert G. Doyle, Director

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PRELIMINARY REPORT

An environmental survey of the Damariscotta River estuary, Lincoln County, Maine.

I. Hydrography.

Funding agency: State of Maine, Department of Economic Development, Office of Science and Technology.

Contractor: University of Maine

Principal investigator: Bernard J. McAlice, Ph.D., Ass't. Prof. of Zoology, Ira C. Darling Center, Univeristy of Maine, Walpole, Maine.

Research assistant: Wayne M. Petrie, B.S., Department of Botany and Plant Pathology, University of Maine, Orono, Maine.

Submitted: 30 June 1969

INTRODUCTION

Extensive studies of the physical and biological oceanography of the offshore waters in the Gulf of Maine have been carried out during the last half-century, beginning with the 1912-1916 cruises of the U.S. Bureau of Fisheries schooner *Grampus*. Colton (1964) gave a brief review of these investigations, which have established a consistent general picture of the physical and biological aspects of the Gulf's open waters.

The coast of Maine is dissected by numerous estuaries and embayments which have, with few exceptions, been little studied. The literature dealing with descriptive and taxonomic work on the inshore biota is voluminous, but ecologic studies have been largely confined to organisms of commercial importance. Exceptions are the ecologic survey of the Sheepscot River by Stickney (1959) and investigations conducted in the Passamaquoddy Bay region by personnel of the Canadian biological station at St. Andrews, New Brunswick. The hydrographic conditions in Maine's estuaries are even less well known than the biota. Passamaquoddy Bay and the Bay of Fundy have been extensively studied (e.g. Ketchum and Keen, 1953; Bailey, MacGregor, and Hachey, 1954). Haefner (1967) discussed the hydrography of Penobscot Bay, and Graham and Boyar (1965) gave some information on conditions near the mouths of the Damariscotta and Sheepscot Rivers.

Present and projected research in coastal oceanography conducted at the University of Maine's Ira C. Darling Center at Walpole on the Damariscotta River and the existence of an increasing source of domestic sewage pollution near the head of that estuary make a survey of environmental conditions therein desirable, if not imperative. The research described here was undertaken to determine present conditions in the Damariscotta River and to provide a basis for predicting and evaluating the effects of future insults resulting from man's activities.

The Damariscotta River is a narrow, north-south-trending embayment which extends from the Gulf of Maine to the head of Salt Bay, north of Damariscotta, Lincoln County, Maine (Figure 1). The distance from the southern end of Inner Heron Island to the head of Salt Bay is about 29 km. The only significant source of fresh water is the outflow from Damariscotta Lake into Salt Bay. Small quantities of domestic sewage and restaurant and laundry waste water are discharged into the upper end of the river, which is closed to the taking of shellfish north of Little Point. This report describes hydrographic studies in the Damariscotta River during the summer of 1968.

This research was supported by a grant from the Office of Science and Technology, Maine Department of Economic Development. The field work was performed by Mr. Wayne M. Petrie, Department of Botany and Plant Pathology, University of Maine. Mr. Michael Mazurkiewicz, Ira C. Darling Center, provided temperature and salinity data from Salt Bay, obtained under Office of Water Resources Research Grant R1090-13. Mr. Paul Johnson, Central Maine Power Company, supplied information on water flow through the penstock of the small hydroelectric station at the outfall of Damariscotta Lake.

METHODS

Eight mid-channel stations were established initially between Jack's Point and Fort Island (D1-D8, Figure 1). These stations were occupied on 11 occasions

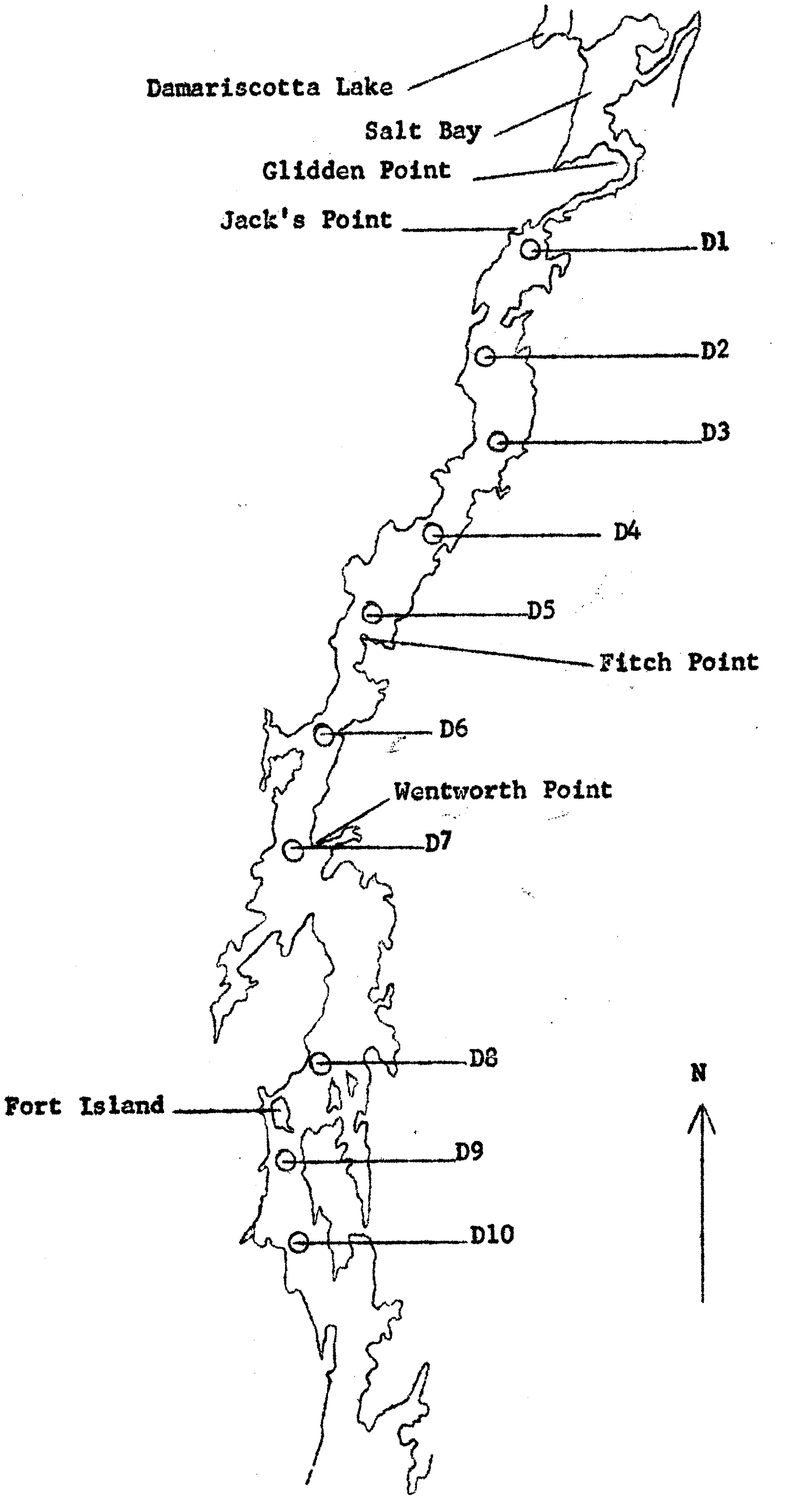


Figure 1. Damariscotta River showing location of sampling stations.

between 19 June and 29 July 1968. Two stations were added south of Fort Island (D9, D10, Figure 1) on 23 July and all ten were visited on that date and on eight more occasions through 29 August. On the last five sampling dates, a station near each bank of the river was occupied at each location D1-D10, as well as the mid-channel station.

At each station, temperature and salinity were measured at depths of ½, 3, 6, 9, 12, 18, and 24 m., or until bottom was reached. A Beckman RS5-B field salinometer-thermometer was used throughout. In all, 998 separate measurements of temperature and salinity were made. The sampling program is summarized in Table 1.

On seven sampling dates, Van Dorn water bottles were used to collect surface and bottom water at Stations D1 and D3. These were analyzed for PO_4-P and NO_3-N using the methods of Strickland and Parsons (1965) and Mullin and Riley (1955), respectively.

Morphometric data were obtained from U.S Coast and Geodetic Survey Chart 314 (Damariscotta, Sheepscot, and Kennebec Rivers) and U.S. Coast and Geodetic Survey Tide Tables, 1968, and areas and volumes determined according to the methods in Welch (1948).

RESULTS AND DISCUSSION

Morphometry

In the Damariscotta River, the estuarine region, defined as that in which sea water "is measurably diluted with fresh water" (Pritchard, 1967) does not extend seaward of Fort Island. Vertical and lateral constrictions exist

Table 1. Summary of hydrographic observations, Damariscotta River, 19 June - 29 August 1968.

Date	Tide	Stations	Number of T-S observations
19 June	Low	D1-D7	27
25 "	High	D1-D8	33
2 July	Low	"	45
5 "	Low	"	34
8 "	High	"	33
11 "	High	"	32
12 "	High	"	31
13 "	Low	"	30
15 "	Low	"	28
16 "	Low	"	30
23 "	High	D1-D10	47
29 "	Low	D1-D8	33
29 "	High	D1-D10	45
30 "	Low	"	44
3 August	Low	"	50
7 "	High	" *	102
15 "	Low	" *	90
20 "	High	" *	97
27 "	High	" *	98
29 "	Low	D4-D10*	69

*indicates dates on which three-position cross sections were made of each station.

at Fort Island, Fitch Point, and south of Glidden Point, partitioning the estuary into three more or less distinct basins. Morphometric data for the estuary north of Fort Island are given in Table 2.

The volume of the tidal prism, the difference between low tide and high tide volumes, is 88 x 10^6 m^3 for the estuary north of Fort Island. This quantity of water flows in and out through the Fort Island narrows during each tidal cycle. Currents in the narrows are very strong. The cross-sectional area available for tidal flow is about 1700 m^2, so the mean current speed over a 6 hour tidal period is 2.4 m sec^{-1} (4.6 kt.). Peak celerities are considerably higher. Of the total water volume entering the estuary on a flood tide, 46.4 x 10^6 m^3 remains in the lower basin. This is 53% of the total tidal prism, and represents a 55% increase in the low water volume of the basin.

The remainder of the tidal prism, 42 x 10^6 m^3, enters the middle basin through the constriction at Fitch Point, with an average speed of 0.48 m sec^{-1} (0.9 kt.). Of this water, 23.5 x 10^6 m^3, which is 48% of the total prism and 90% of the low water volume of the middle basin, stays in that basin. The last increment, 18 x 10^6 m^3, enters Salt Bay through the narrow channel under and north of the Damariscotta-Newcastle bridge. Mean current speed under the bridge is about 3.5 m sec^{-1} (6.9 kt.).

The tidal wave is impeded at each of the three major constrictions, so that the basins tend to fill in sequence, and high water at Newcastle occurs 16 min. later than at East Boothbay (Tide Tables, 1968). Flooding into Salt Bay continues after high stand at Newcastle. On the ebb, the processes described above are reversed, the estuary empties from the lower end, and low water at Newcastle lags that at East Boothbay by 28 min. (Tide Tables, 1968).

Table 2. Damariscotta River morphometric data.

Basin	Low Water			High Water		
	Area, km^2	Mean depth, m	Volume, $10^6 m^3$	Area, km^2	Mean depth, m	Volume, $10^6 m^3$
Fort Island to Fitch Point (lower basin)	9.4	9.0	84.5	11.2	11.7	130.9
Fitch Point to U.S. Route 1 bridge, Damariscotta-Newcastle (middle basin)	5.7	4.6	26.2	6.8	7.4	49.7
Salt Bay, north of Damariscotta-Newcastle bridge (upper basin)	0.5	4.0	1.9	3.0	6.7	20.3
Total, north of Fort Island	15.6	7.2	112.5	20.9	9.6	200.8

Temperature, salinity, and density

During spring and summer, longitudinal and vertical gradients of temperature, salinity, and density exist. Temperature decreases seaward and with depth, while salinity and density increase. Typical high water and low water mid-channel profiles of temperature and salinity are shown in Figures 2 and 3. Strong mixing occurs on the up-river sides of the Fort Island and Fitch Point constrictions on the flood, and conditions approaching vertical homogeneity are present in these areas at high water. During the flood, vertical inversions in the distributions of these conservative properties are regularly encountered in the areas of strong mixing.

Mixing is less effective on the ebb, and a region of marked vertical stratification extends south of Fitch Point as the relatively warm, fresh upstream water overrides the denser water downstream.

The cross-section sampling revealed no regular lateral gradients of temperature or salinity. Local surface lenses of low salinity water occur after rains and are attributed to localized fresh water runoff. High temperatures are of frequent occurrence in the vicinity of tidal flats, where solar heating is more effective. Neither of these factors is important to the overall dynamics of the system.

On 15 August, near the west bank of the river opposite Station D8, very high density water was found from 6 m depth to the bottom. The temperature range was 9.6-11.2°C; salinity, 34.9-35.3°/₀₀; and sigma-t, 26.75-27.32. The coldest and saltiest water elsewhere in the river was west of Station D9, at 12.8°C, 32.7°/₀₀, and sigma-t of 24.68. The densest water in the Gulf of Maine in the summer should be about 4°C, 33°/₀₀ (sigma-t 26.12) (Bigelow, 1927).

Figure 2. Distribution of temperature and salinity in the Damariscotta River at low water, 5 July 1968.

Vertical exaggeration 380:1
Solid lines, temperature, °C.
Broken lines, salinity, °/₀₀.

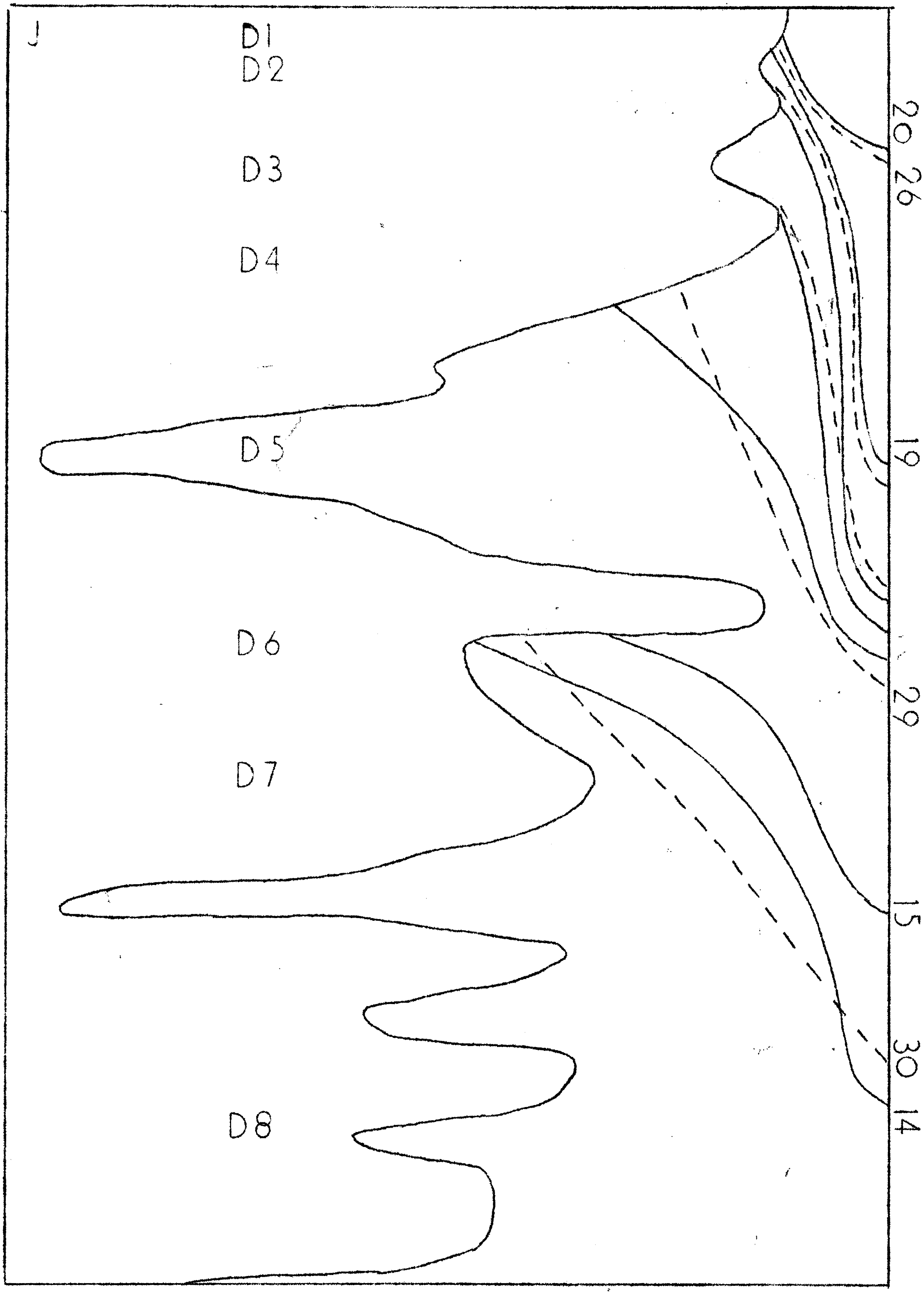
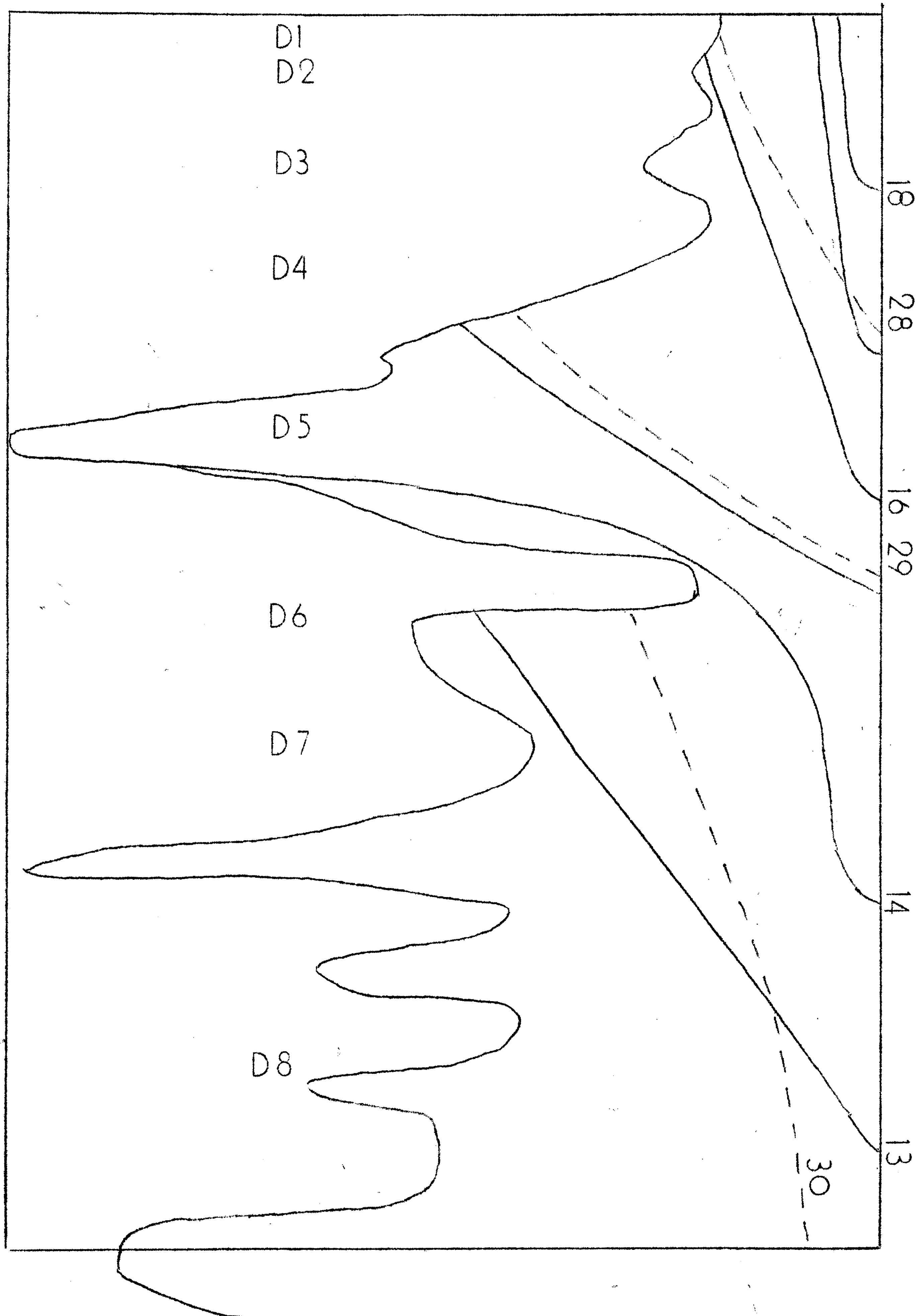

J
D1
D2
D3
D4
D5
D6
D7
D8
20
26
19
29
15
30
14

Figure 3. Distribution of temperature and salinity in the Damariscotta River at high water, 8 July 1968.

Vertical exaggeration 380:1
Solid lines, tmeperature, °C.
Broken lines, salinity, °/$_{oo}$.


D1
D2
D3
D4
D5
D6
D7
D8
18
28
16
29
14
13
30

Hachey (1961) stated that slope water at 6-8°C and 35°/₀₀ occasionally intrudes into the Gulf. This water would, however, be at the bottom because of its density, and bottom temperatures in the west central portion of the Gulf of Maine do not exceed 4-5°C (S. Appolonio, personal communication). There seems to be no local source for the high density water found at Station D8, and its origin remains unresolved.

Flushing rates

In estuarine pollution studies, prediction of the distribution and accumulation of a pollutant requires some knowledge of flushing or exchange rates in the estuary. These can be determined from morphometric data alone. Other commonly-used methods utilize fresh water as a tracer and are strictly valid only for pollutants introduced at the same point in the system as the fresh water.

Since tidal activity is the dominant mixing process in the Damariscotta River, flushing rates and exchange ratios can be calculated from the morphometric data. The simplest determination utilizes

$$t = \frac{V + P}{P} \tag{1}$$

where t is the flushing time in tidal periods, V is the low water volume of the estuary,,and P is the volume of the tidal prism. From Table 2,

$$t = \frac{(113 \times 10^6 \text{ m}^3) + (88 \times 10^6 \text{ m}^3)}{88 \times 10^6 \text{ m}^3} = 2.28 \text{ tidal periods,}$$

the flushing time of the entire estuary north of Fort Island. For the three basins, starting at Salt Bay (upper basin), the flushing times are 1.1, 2.1 and 2.8 tidal periods. Equation (1) assumes complete mixing in the estuary and thus sets only a lower limit to the flushing time, since the assumption is rarely justified (Bowden, 1967).

Ketchum (1951) presented a refinement of the tidal prism method. Here the estuary is divided into several segments, each having a length of one tidal excursion (the distance a particle of water travels on a single tide). Complete mixing within each segment is assumed, and an exchange ratio computed for each segment. If V_n is the low tide volume of the nth segment and P_n the corresponding tidal prism, then the exchange ratio r_n for the segment is

$$r_n = \frac{P_n}{P_n + V_n} \qquad (2)$$

Salt Bay is virtually emptied at each low tide, and the discussion below concerns only that portion of the river between Newcastle-Damariscotta and Fort Island. Tidal excursions determined from the longitudinal migration of isohalines over successive high and low tides showed that Stations D1-D8 gave an adequate segmentation of the estuary. Appropriate data for these segments, together with computed exchange ratios, are summarized in Table 3.

If the vertical distribution of salinity at a number of stations is known, together with the volume increments between stations, flushing rates can be calculated following Bowden (1967).

Let R = the rate of influx of fresh water, and
F = the total volume of fresh water accumulated in the estuary.
If S_o = the salinity of water outside the estuary which is available for mixing, and
S = the salinity at any point inside, then the fresh water content at that point is given by

$$f = \frac{S_o - S}{S_o} \quad . \qquad (3)$$

Table 3. Low water volumes, tidal prisms, and exchange ratios for Damariscotta River segments.

Segment		Low water volume V_n ($10^6 m^3$)	Tidal prism, P_n ($10^6 m^3$)	Exchange ratio, r_n
Salt Bay		1.86	18.41	0.908
Station	D1-D2	3.95	6.44	0.619
"	D2-D3	3.04	4.63	0.603
"	D3-D4	5.48	5.45	0.498
"	D4-D5	12.61	8.48	0.402
"	D5-D6	11.96	7.86	0.396
"	D6-D7	8.81	5.02	0.362
"	D7-D8	68.47	39.08	0.363

The accumulated fresh water volume is given by

$$F = \int f \, d(\text{volume}) \qquad (4)$$

integrated over the total volume. If a steady state is assumed, so that R is also the rate of removal of fresh water, then the flushing time is

$$t = \frac{F}{R} \, . \qquad (5)$$

Table 4 gives the volume increments for each station; each increment is the mean of the volumes of the two segments on either side of the station. In Table 5 the computed values of f and F for each sampling date are given, and in Table 6 the fresh water in each segment as a percentage of the segment's total volume.

Flushing time determination requires knowledge of the fresh water influx, R. This can be tenuously estimated for the Damariscotta River. The maximum penstock flow at the Damariscotta Mills hydroelectric station is 3.31 m^3 sec^{-1}. This effects a rapid draw-down of Damariscotta Lake, however, and the usual summer flow is only about 40% of the maximum (N. Hancock, Sr., personal communication). Assuming that half the outflow goes through the penstock, R is found to be 2.29×10^5 m^3 day^{-1}. Flushing times calculated from this flow value are included in Table 5. The average flushing time is 24.0 ± 7.4 days, the range 7.8 - 55.5 days. Some of this variation is due to the averaging process used in integration, some of it to the uncertainty in R, and some of it is undoubtedly real.

Independent evidence suggests that the flushing time of 24 days may be more realistic than the 2.6 tidal periods based on morphometry and the

Table 4. High and low water volume increments, ΔV, for Stations D1-D8. Units are $10^6 m^3$.

Station	ΔV, low water	ΔV, high water
D1	2.90	15.33
D2	3.50	9.03
D3	4.26	9.30
D4	9.04	16.01
D5	12.28	20.46
D6	10.38	16.82
D7	38.64	60.69
D8	43.48	66.60

Table 5. Computed values of f, F, and t for 15 sampling times, 1968. Units of f and F are $10^6 m^3$.

Tide & Date	f for station D1	D2	D3	D4	D5	D6	D7	D8	F	t, days
Low										
5-VII	0.710	0.448	0.443	0.587	0.650	0.415	1.159	0.391	4.803	20.8
13-VII	.939	.770	.502	.659	.699	.384	0.927	.608	5.488	23.8
16-VII	.797	.451	.408	.678	.822	.435	1.004	.869	5.464	23.7
29-VII	.240	.213	.166	.253	.257	.176	0.270	.217	1.792	7.8
30-VII	.246	.220	.195	.343	.343	.311	0.850	.565	3.073	13.3
3-VIII	-.168	.199	.183	.271	.331	.217	0.618	.391	2.042	8.9
15-VIII	.411	.441	.502	1.057	1.412	1.131	4.095	2.652	11.701	51.0
High										
8-VII	2.008	0.731	0.632	0.896	0.716	0.336	0.971	0.532	6.822	29.6
11-VII	2.253	.650	.613	.928	.797	.386	1.153	.666	7.446	32.4
12-VII	2.222	.668	.548	.784	.900	.319	0.485	.266	6.192	26.8
23-VII	1.747	.776	.660	1.088	1.370	.958	3.155	2.997	12.751	55.5
29-VII	0.873	.361	.390	0.528	0.757	.437	1.213	0.732	5.291	23.0
7-VIII	0.674	.216	.316	.512	.613	.437	1.760	.865	5.393	23.4
20-VIII	-	-	.158	.272	.286	.151	0.667	.399	1.933	8.4
27-VIII	0.582	.243	.241	.256	.020	.201	0.667	.466	2.676	11.6

Table 6. Accumulated fresh water, f, in each segment as a percentage of the total volume of the segment.

Tide &				Station					
Date	D1	D2	D3	D4	D5	D6	D7	D8	Total
Low									
5-VII	29.5	13.9	10.4	6.5	5.3	4.0	3.0	0.9	4.3
13-VII	32.4	22.0	11.8	7.3	5.7	3.7	2.4	1.4	4.9
16-VII	27.5	12.9	9.6	7.5	6.7	4.2	2.6	2.0	4.9
29-VII	8.3	6.1	3.9	2.8	2.1	1.7	0.7	0.5	1.6
30-VII	8.5	6.3	4.6	3.8	2.8	3.0	2.2	1.3	2.7
3-VIII	-5.9	5.7	4.3	3.0	2.7	2.1	1.6	0.9	1.8
15-VIII	14.2	12.6	11.8	11.7	11.5	10.9	10.6	6.1	10.4
High									
8-VII	13.1	8.1	6.8	5.6	3.5	2.0	1.6	0.8	3.4
11-VII	14.7	7.2	6.6	5.8	3.9	2.3	1.9	1.0	3.1
12-VII	14.5	7.4	5.9	4.9	4.4	1.9	0.8	0.4	3.7
23-VII	11.4	8.6	7.1	6.8	6.7	5.7	5.2	4.5	6.4
29-VII	5.7	4.0	4.2	3.3	3.7	2.6	2.0	1.1	2.6
7-VIII	4.4	2.4	3.4	3.2	3.0	2.6	2.9	1.3	2.7
20-VIII	-	-	1.7	1.7	1.4	0.9	1.1	0.6	1.0
27-VIII	3.8	2.7	2.6	1.6	0.1	1.2	1.1	0.7	1.3

assumption of complete mixing. Obvious differences have been found in the plankton populations in the three basins. The most noteworthy instance occurred in October, 1967, when a dense bloom of the diatom Asterionella japonica was present in the middle basin, in long healthy chains and at population densities approaching 10^7 cells per liter. The bloom persisted for about two weeks. At the same time in the lower basin the species was present only as individual, apparently chlorotic, cells and at densities of less than 10^5 cells per liter. This indicates that flushing was slow enough to permit the development and maintenance of a phytoplankton bloom within the confines of the southern half of the middle basin.

If the flushing time of the Damariscotta River is on the order of three weeks, local buildups of introduced pollutants can be expected, especially in water sheltered by land projections. Construction of a primary sewage treatment plant for the towns of Damariscotta and Newcastle would eliminate raw sewage from the upper estuary, but the introduction into and accumulation in the river of inorganic nutrient species entrained in the treated effluent could lead to eutrophication of the system, high BOD, and general deterioration of the environment.

Present and projected research

During the summer of 1969, hydrographic sampling will be continued on a less intensive basis. Studies of current patterns will be undertaken, as well as intensive sampling of NO_3-N, NH_3-N, PO_4-P, and O_2, especially in the middle basin. This should permit more reliable determinations of flushing rates and stronger inferences about possible effects of future environmental alterations. The limited data obtained during 1968 will not be further discussed here, but will be included with the data for 1969.

Bottom sampling will be started as well, preparatory to mapping the distribution of sediment types and the organic content of the sediments.

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PRELIMINARY REPORT

An environmental survey of the Damariscotta River
estuary, Lincoln County, Maine.

II. Sediments.

Funding Agency: State of Maine
Department of Economic Development
Office of Science and Technology

Contractor: University of Maine

Principal investigator: Bernard J. McAlice, Ph.D.
Assistant Professor of Zoology
Ira C. Darling Center, University of Maine
Walpole, Maine

Research assistant: Wayne M. Petrie, B.S.
Department of Botany and Plant Pathology
University of Maine, Orono, Maine

Submitted: 30 June 1970

INTRODUCTION

The rationale of the work described herein is detailed in the first report in this series (McAlice, 1969), which deals with hydrographic studies in the Damariscotta River. The present report is concerned chiefly with the nature and distribution of surficial sediments in the river.

This research was supported by a grant from the Office of Science and Technology, Maine Department of Economic Development. The field work and laboratory analyses were performed by Mr. Wayne M. Petrie, Department of Botany and Plant Pathology, University of Maine.

METHODS

Sediments. Surficial sediments were sampled with a Ponar grab sampler at 37 locations in the Damariscotta River. Hydrometer analysis of a 100g aliquot, dispersed with Calgon (sodium metaphosphate) detergent, was used to determine the size distribution of the < 63μ fraction. The same aliquot was then wet sieved through a set of 1ϕ interval screens (2000, 1000, 500, 250, 125, and 63μ) to obtain the size distribution of the > 63μ fraction. The procedure was that of ASTM Standard D422-51. The organic contents of the various fractions were obtained from weight loss after ashing at 600°C for 24 hours.

Size was plotted against cumulative weight percent on semi-logarithmic paper, and the following statistical parameters (Folk and Ward, 1957) calculated wherever possible:

Graphic mean, $M_z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$,

Inclusive graphic standard deviation, $\sigma_I = \frac{\phi_{84}-\phi_{16}}{4} + \frac{\phi_{95}-\phi_5}{6.6}$, and

Inclusive graphic skewness, $Sk_I = \frac{\phi_{16} + \phi_{84}-2\phi_{50}}{2(\phi_{84}-\phi_{16})} + \frac{\phi_5 + \phi_{95}-2\phi_{50}}{2(\phi_{95}-\phi_5)}$,

where ϕ_{16} is the phi diameter for the 16% point of the cumulative distribution, etc. Phi is related to the particle diameter in millimeters by

$\phi = \log_2$(diameter in mm).

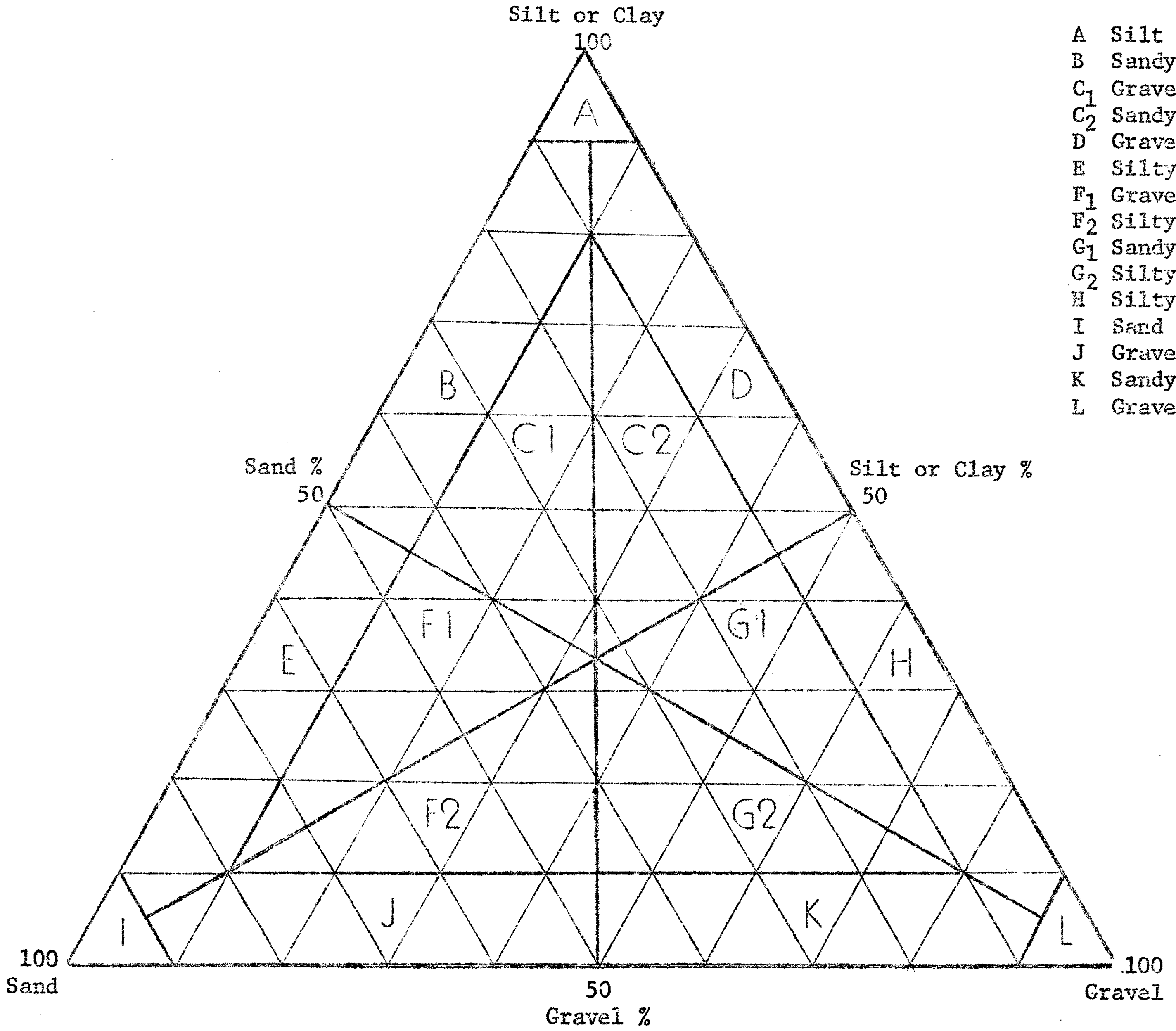
M_z is a measure of average particle size, σ_I of sorting, and Sk_I of the symmetry of the size distribution. The advantages of the phi scale are discussed by Tanner (1969). The relationships between the phi scale and other commonly-used size scales are shown in Table 1.

Sediments were classified according to the trilinear system of Figure 1 on the basis of their total percentages of gravel, sand, silt, and clay. No attempt was made to grade the > 2 mm fraction. Those stations yielding no sievable sediments - that is, where the samples consisted only of pebble-to-boulder-sized rocks - were classified as "rocky", and those from which no material was recovered as "hard bottom".

Hydrography and water chemistry. Hydrographic station locations are shown in Figure 2. Field methods and computational procedures are detailed in McAlice (1969). Temperature and salinity profiles were made on nine additional dates during the summer of 1969.

Table 1. Relationships between the phi scale and other common sediment size scales.

Size			Grade Scale			
Phi	mm	μ	Wentworth		U.S. Bureau of Soils	
-8	256		Boulder			
-7	128		Cobble		100 mm	
-6	64					
-5	32				Large	
-4	16		Pebble			Gravel
-3	8				10 mm	
-2	4				Medium	
-1	2		Granule			
0	1	1000	Very coarse		Fine	
1	1/2	500	Coarse	Sand	Coarse	
2	1/4	250	Medium		Medium	Sand
3	1/8	125	Fine		Fine	
4	1/16	62.5	Very fine		1/20 mm Very fine	
5	1/32	31.3	Coarse			
6	1/64	15.6	Medium	Silt	Silt	
7	1/128	7.8	Fine			
8	1/256	3.9	Very fine		1/200 mm	
9	1/512	1.95	Coarse			
10	1/1024	0.98	Medium	Clay	Clay	
11	1/2048	0.49	Fine			
12	1/4096	0.24	Very fine			



A	Silt or Clay
B	Sandy Silt or Clay
C_1	Gravelly Sandy Silt or Clay
C_2	Sandy Gravelly Silt or Clay
D	Gravelly Silt or Clay
E	Silty or Clayey Sand
F_1	Gravelly Silty or Clayey Sand
F_2	Silty or Clayey Gravelly Sand
G_1	Sandy Silty or Clayey Gravel
G_2	Silty or Clayey Sandy Gravel
H	Silty or Clayey Gravel
I	Sand
J	Gravelly Sand
K	Sandy Gravel
L	Gravel

Figure 1. Trilinear classification of sediments used herein.

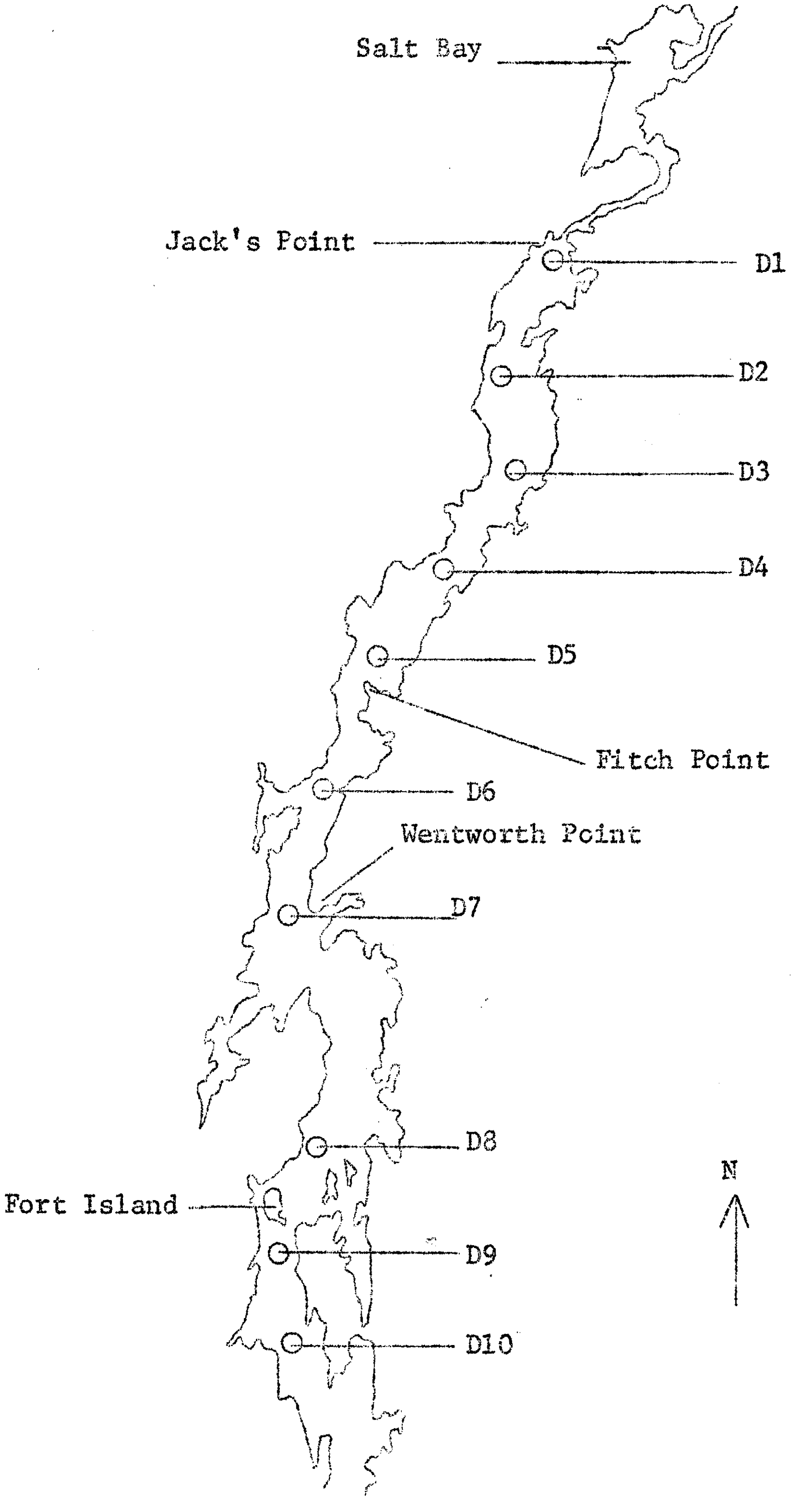


Figure 2. Damariscotta River showing location of hydrographic sampling stations.

Water samples for chemical analysis were collected in 2.5 liter Van Dorn water bottles. Dissolved oxygen was determined by the standard Winkler method, reactive phosphorous and reactive silicate by the methods of Strickland and Parsons (1965),and nitrate by that of Mullin and Riley (1955).

RESULTS

Sediments. Particle size distribution and cumulative frequency curves of Damariscotta River sediments are shown in Figures 3 to 7. The stations are presented in sequence from north to south, omitting those stations where only hard bottom or rocks were found. Table 2 summarizes pertinent data from the textural analyses.

The sediments are predominantly poorly- to moderately-sorted silts or sandy silts. The most poorly-sorted sediments are those in the upper reaches of the river, between Hall Point and Dodge Point. The best sorting is found in the lower river. Textural parameters do not reveal the sources of Damariscotta River sediments, which may come from its own drainage area, from the Gulf of Maine, or from both these sources.

The low energy portions of the river are characterized by the presence of fine sediments, while sediment cover is virtually non-existent in such dynamic regions as the vicinities of Glidden Ledge and the Fort Island Narrows. Hjulstrom (1939) indicates that bottom current speeds on the order of 100 cm/sec are required to erode fine sand and silt but that once particles of this size are in suspension they will not be deposited until the current speed falls below 0.5 cm/sec.

Figure 8 is a sediment distribution map of the Damariscotta River north of Farnum Point. Sediment classifications are known only for the

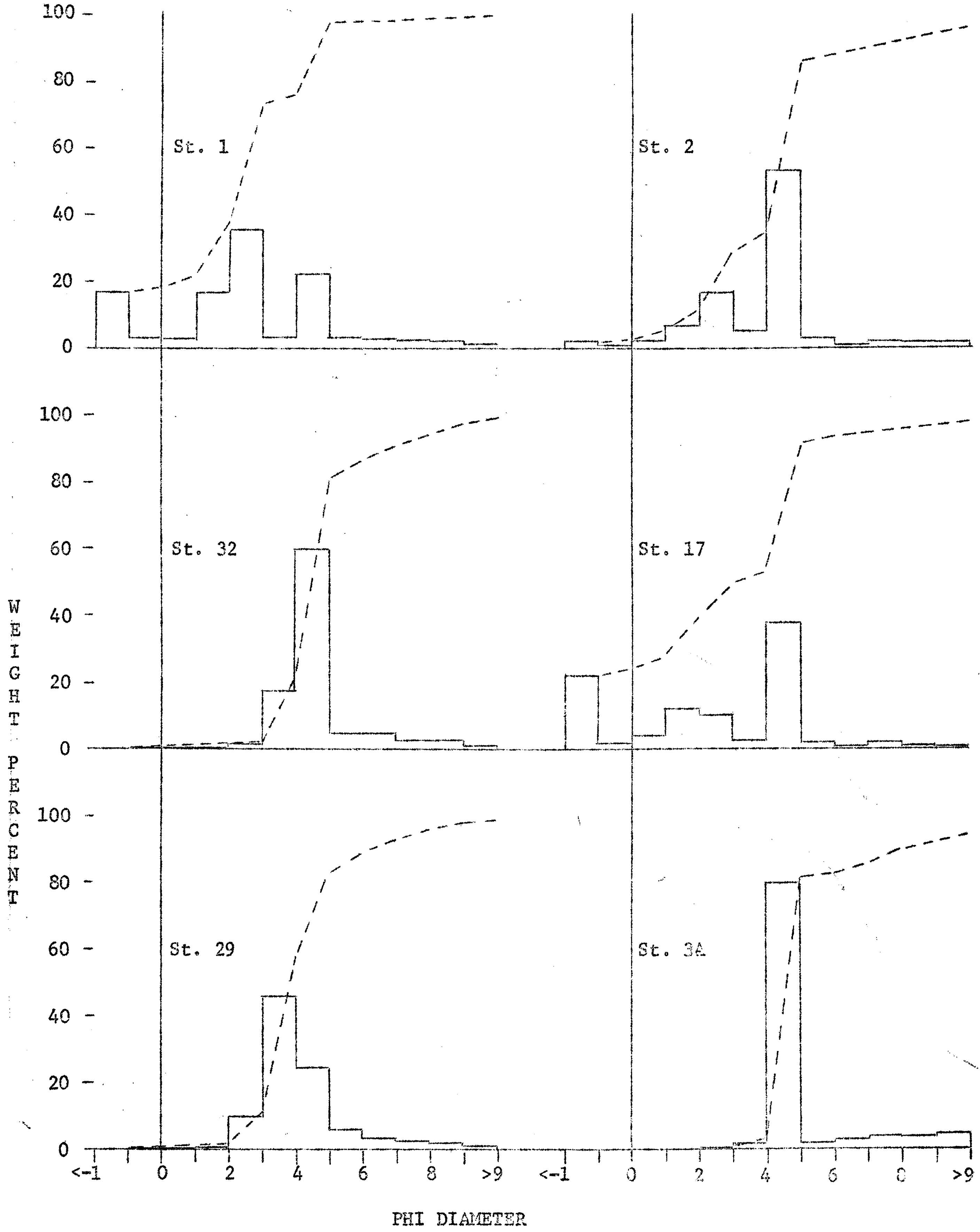


Figure 3. Size frequency distribution histograms and cumulative size frequency curves of Damariscotta River sediments.

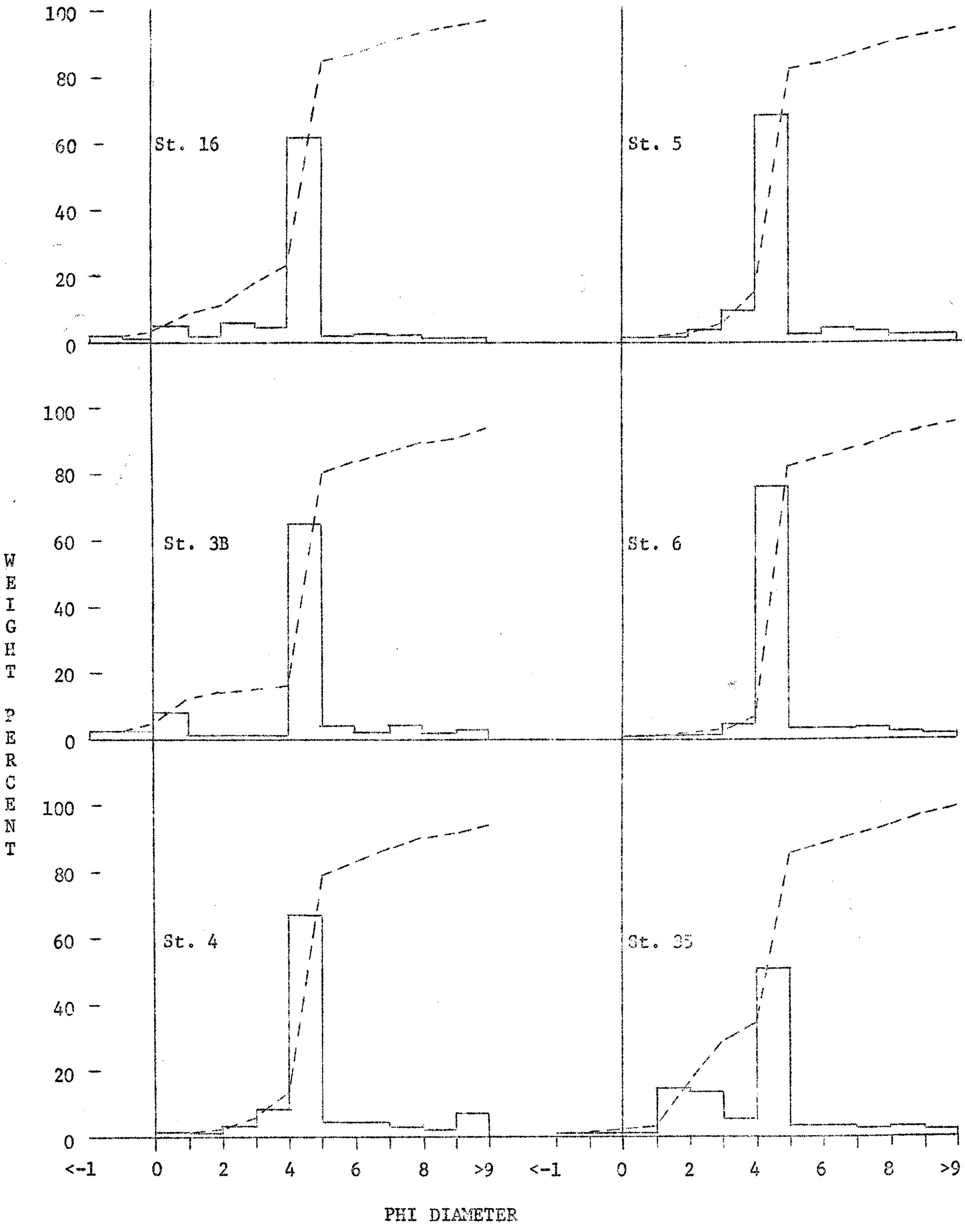


Figure 4. Size frequency distribution histograms and cumulative size frequency curves of Damariscotta River sediments.

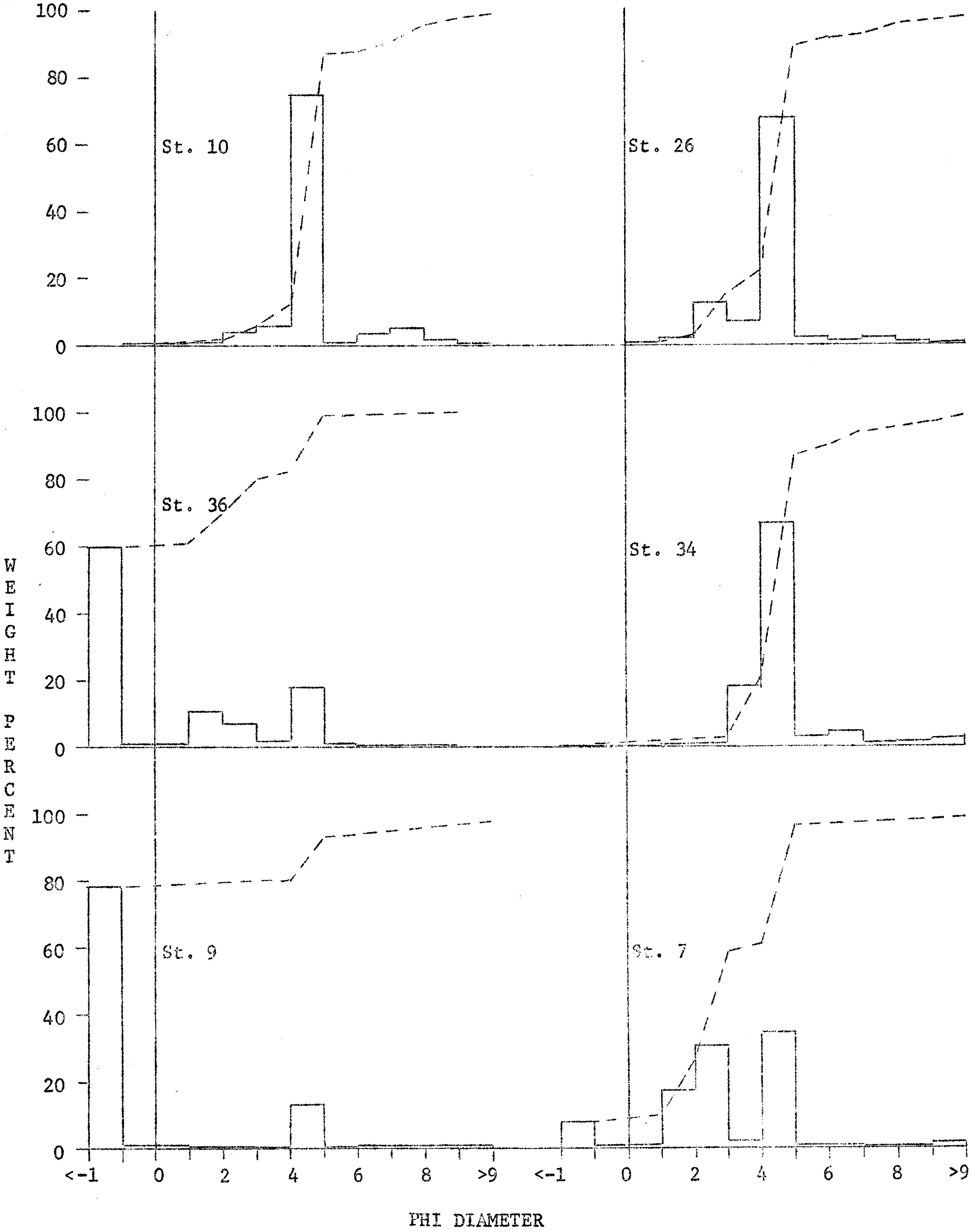


Figure 5. Size frequency distribution histograms and cumulative size frequency curves of Damariscotta River sediments.

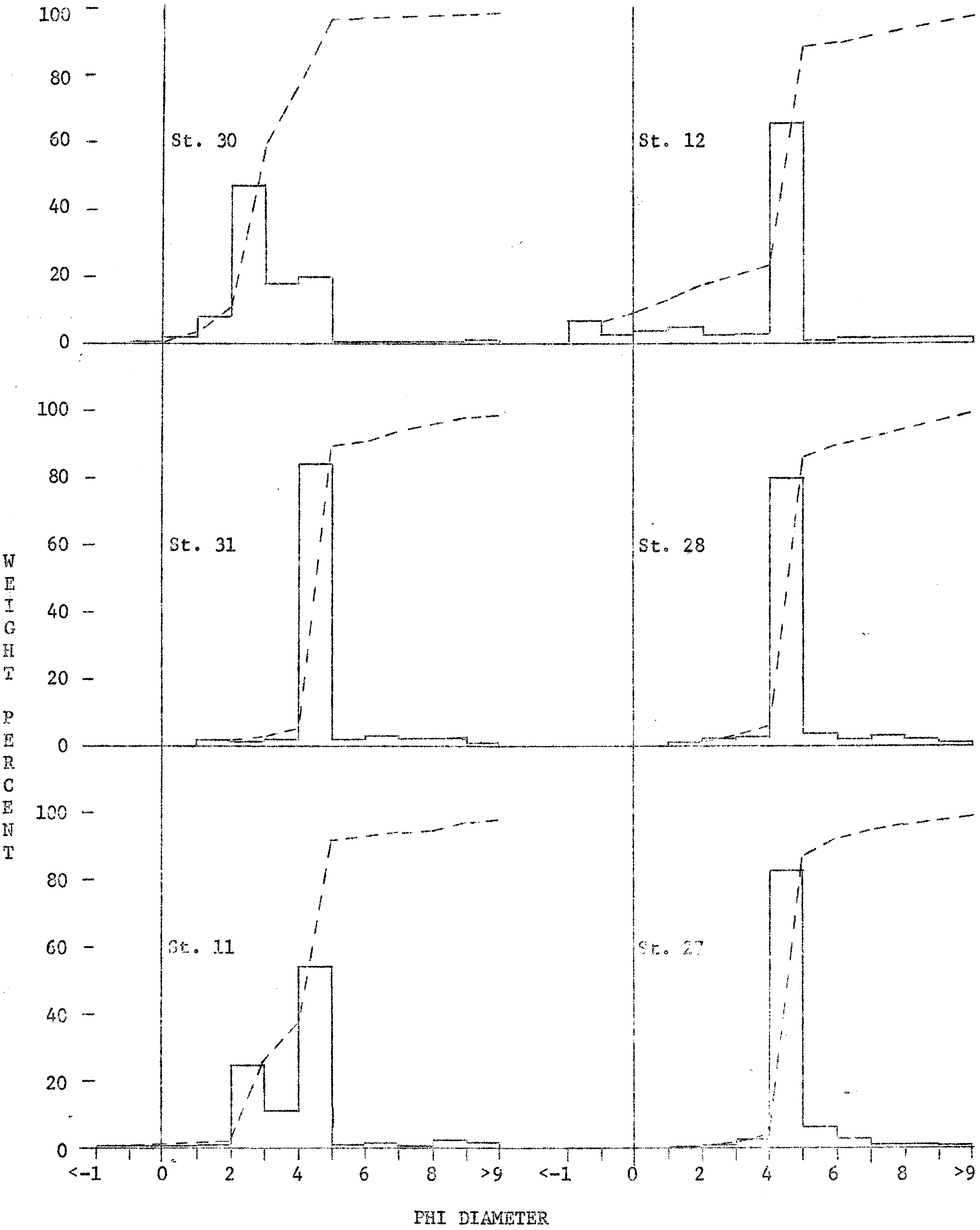


Figure 6. Size frequency distribution histograms and cumulative size frequency curves of Damariscotta River sediments.

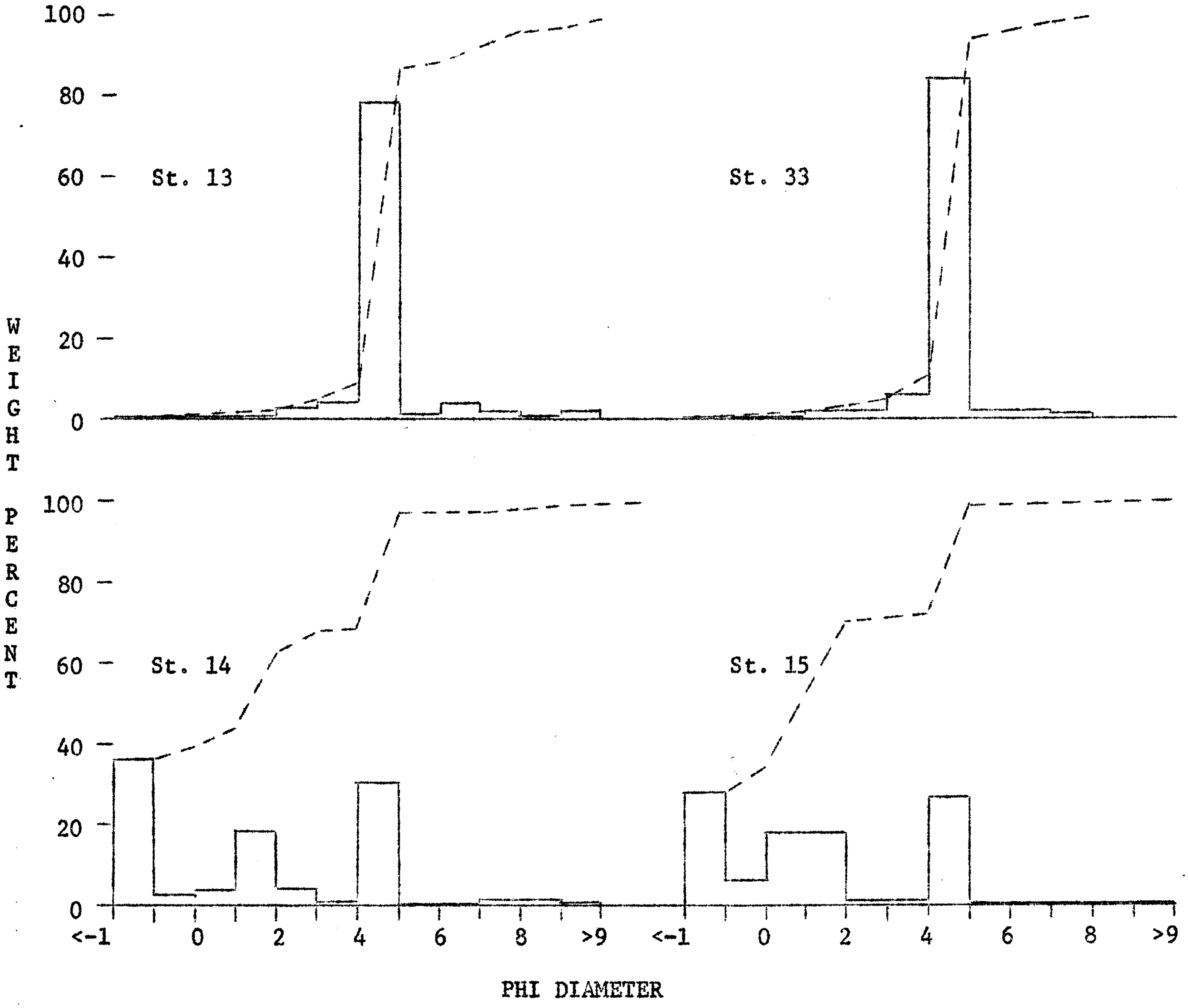


Figure 7. Size frequency distribution histograms and cumulative size frequency curves of Damariscotta River sediments.

Table 2. Summary of textural characteristics of Damariscotta River sediments. Station locations are shown in Figure 8.

Station	M_z	σ_I	Sk_I	%Gravel	%Sand	%Silt	%Clay	Classification	Sorting [a]
1	-	-	-	17	59	22	2	Gravelly Silty Sand	-
2	3.77	1.95	0.25	2	30	60	8	Sandy Silt	P
3A	4.97	1.48	-0.80	0	3	87	10	Silt	P
3B	4.87	2.11	-0.39	2	13	74	11	Sandy Silt	VP
4	4.92	1.78	-0.66	0	12	78	10	Sandy Silt	P
5	4.87	1.67	-0.68	0	14	76	10	Sandy Silt	P
6	4.80	1.38	-0.74	0	6	85	9	Silt	M
7	2.87	-	-	8	53	37	2	Silty Sand	-
8	-	-	-	-	-	-	-	Rocky	-
9	-	-	-	78	2	15	5	Silty Gravel	-
10	4.35	0.94	-0.18	0	12	84	4	Sandy Silt	M
11	3.75	1.43	0.08	0	38	57	5	Sandy Silt	P
12	3.55	-	-	7	16	71	6	Sandy Silt	-
13	4.41	0.92	-0.40	0	9	85	6	Silt	M
14	-	-	-	37	30	31	2	Sandy Silty Gravel	-
15	-	-	-	28	44	27	1	Gravelly Silty Sand	-
16	3.95	1.79	0.28	2	21	71	6	Sandy Silt	P
17	-	-	-	22	32	42	4	Gravelly Sandy Silt	-

a) W - well sorted
MW - moderately well sorted
M - moderately sorted
P - poorly sorted
VP - very poorly sorted

Table 2, Continued.

Station	M_z	σ_I	Sk_I	%Gravel	%Sand	%Silt	%Clay	Classification	Sorting [a]
18	-	-	-	-	-	-	-	Rocky	-
19	-	-	-	-	-	-	-	Rocky	-
20	-	-	-	-	-	-	-	Rocky	-
21	-	-	-	-	-	-	-	Rocky	-
22	-	-	-	-	-	-	-	Rocky	-
23	-	-	-	-	-	-	-	Hard Bottom	-
24	-	-	-	-	-	-	-	Rocky	-
25	-	-	-	-	-	-	-	Rocky	-
26	3.91	1.16	0.19	0	22	74	4	Sandy Silt	M
27	4.37	0.58	-0.47	0	4	93	3	Silt	MW
28	4.38	0.80	-0.42	0	6	89	5	Silt	M
29	4.08	1.30	-0.42	0	58	37	5	Silty Sand	M
30	3.10	0.95	-0.14	0	77	21	2	Silty Sand	M
31	4.32	0.63	-0.42	0	5	91	4	Silt	MW
32	4.57	1.24	-0.50	0	21	73	6	Sandy Silt	M
33	4.27	0.47	-0.16	0	11	88	1	Sandy Silt	W
34	4.23	0.82	-0.63	0	21	75	4	Sandy Silt	M
35	3.65	1.70	0.26	0	34	60	6	Sandy Silt	P
36	-	-	-	59	22	19	0	Silty Sandy Gravel	-

a) W - well sorted
MW - moderately well sorted
M - moderately sorted
P - poorly sorted
VP - very poorly sorted

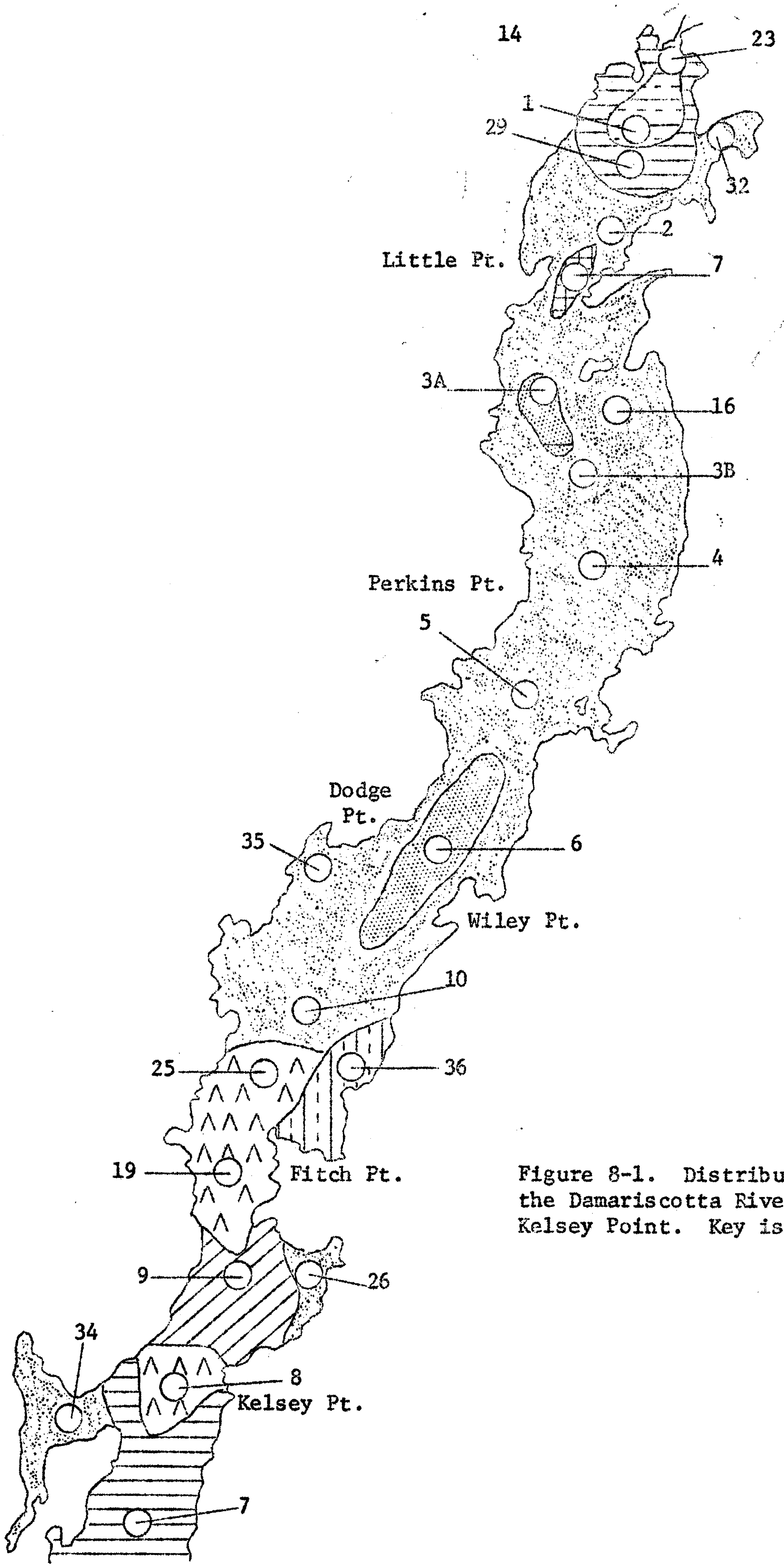


Figure 8-1. Distribution of sediments in the Damariscotta River, Damariscotta to Kelsey Point. Key is on next page.

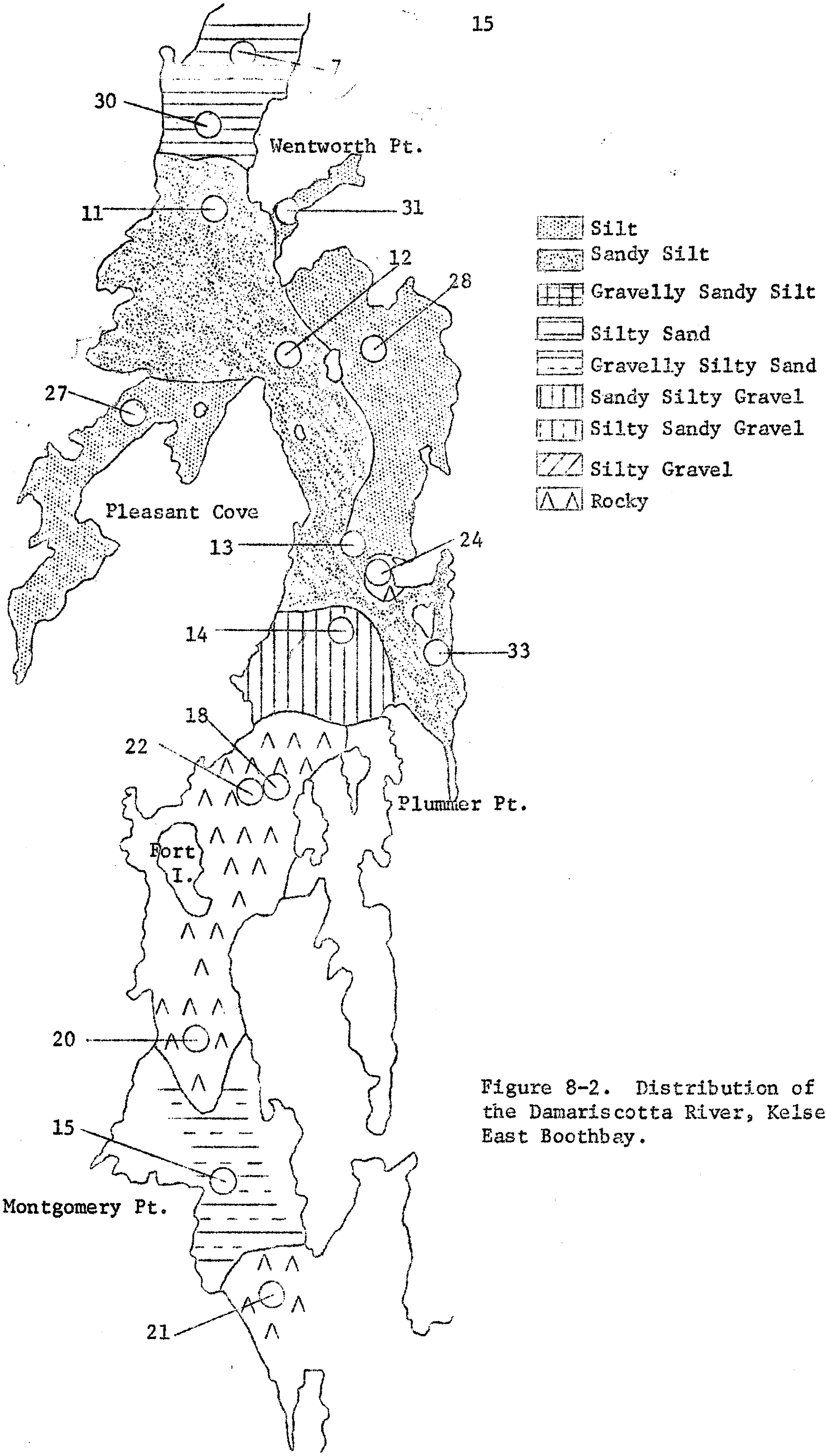


Figure 8-2. Distribution of sediments in the Damariscotta River, Kelsey Point to East Boothbay.

37 station locations shown; the contours are based on considerations of bathymetry and current speeds as well.

The organic contents of the < 63μ, > 63μ and total sediment fractions are shown in Table 3. Lacunae in this table are the result of unreliable ash weights or of mental lapses. No significant correlations were found between the organic content of any of the fractions and median grain size. The map of total sediment organic content (Figure 9) is based on the contours of Figure 8. There is no apparent accumulation of organic matter in the sediments which can be ascribed to domestic pollution from Damariscotta-Newcastle. The nature of the organic fraction has not been determined.

Hydrography. No marked differences in temperature or salinity distributions from those of 1968 (McAlice, 1969) were noted. The median flushing rate calculated for the nine temperature-salinity profiles made during the summer of 1969 was 41.6 days; that for 1968 was 31.6 days.

Water chemistry. Results of dissolved oxygen analyses are summarized in Table 4 and those for inorganic nutrients in Table 5. Oxygen values are close to saturation even in the bottom water. The system is apparently not being subjected to rigorous ecologic pressure by the present domestic and commercial effluent loads. There is a tendency for nitrate and phosphate values to be higher in the upper reaches of the estuary. The trend is more marked for phosphate and may reflect either the natural distribution of this moiety or its introduction in detergent wastes. It is expected that intensive sampling of nutrients during the summer of 1970 will resolve this question.

Table 3. Organic contents of the < 63μ, > 63μ and total sediment fractions of Damariscotta River sediments.

Sample	Md	< 63μ	> 63μ	Total
1	-	-	1.2	-
32	4.57	-	5.9	6.1
29	4.08	-	-	1.6
2	3.77	-	2.3	-
17	-	-	1.9	1.6
3A	4.97	-	2.1	-
16	3.95	-	26.0	1.9
3B	4.87	5.7	2.7	4.0
4	4.92	5.5	3.2	4.2
5	4.87	4.6	2.6	3.5
6	4.80	8.5	16.1	11.4
35	3.65	-	-	5.8
10	4.35	2.0	8.4	5.6
36	-	-	-	1.6
9	-	2.4	1.6	1.7
26	3.91	-	-	1.4
34	4.23	-	3.2	6.8
7	2.87	5.9	2.8	3.4
30	3.10	-	3.0	2.1
31	4.32	-	46.2	8.2
11	3.75	0.4	1.9	1.6
12	3.55	6.9	11.2	9.9
28	4.38	-	-	2.1
27	4.37	-	-	1.7
13	4.41	6.9	5.7	6.2
14	-	3.5	0.9	1.4
33	4.27	-	15.6	9.8
15	-	-	1.0	0.5

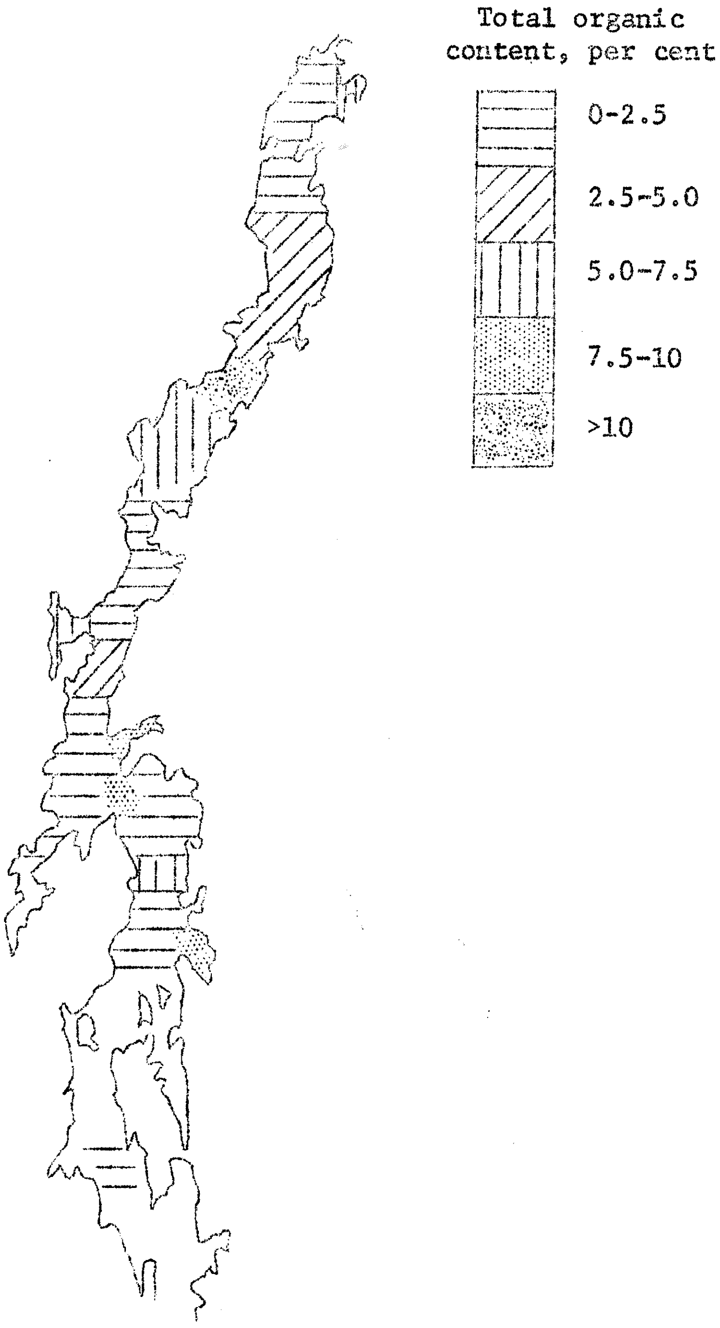


Figure 9. Total organic content of Damariscotta River sediments.

Table 4. Dissolved oxygen in the Damariscotta River, June-September, 1969. Station locations are shown in Figure 1.

Date	Station	Tide	Depth Meters	D.O. Ml/1	D.O. % Sat'n.
17-VI	1	High	1	4.62	81
	3		1	5.39	95
	5		1	5.35	95
	5		10	5.46	95
	6		1	5.74	99
	7		1	6.26	105
	7		7	6.02	100
27-VI	1	High	0.5	5.39	94
	3		0.5	5.39	93
	5		0.5	5.46	94
	5		5	5.32	89
	5		9	5.60	94
	6		0.5	5.67	96
	7		0.5	5.56	95
	7		5	5.67	92
	7		15	5.74	94
10-VII	1	High	0.3	5.39	101
	3		0.3	5.70	104
	5		0.3	6.16	111
	5		5	5.74	100
	5		18	5.81	101
	6		0.3	6.30	108
	7		0.3	6.16	104
	7		5	6.30	105
	7		15	6.23	101
25-VII	1	Low	0.3	5.60	106
	3		0.3	5.88	107
	5		0.3	5.95	107
	5		6	5.67	102
	5		13	5.53	98
	6		0.3	5.63	100
	7		0.3	5.74	102
	7		6	5.77	101
	7		13	5.74	99
	10		0.3	6.09	102

Table 4, Continued.

Date	Station	Tide	Depth Meters	D.O. Ml/1	D.O. % Sat'n.
6-VIII	1	Low	0.3	4.06	79
	3		0.3	4.27	81
	5		0.3	4.97	91
	5		6	4.65	84
	5		18	4.69	84
	6		0.3	4.69	84
	7		0.3	4.79	85
	7		6	4.76	83
	7		10	5.00	87
	8		0.3	5.00	89
20-VIII	1	Low	0.3	4.34	84
	3		0.3	5.11	98
	5		0.3	5.39	100
	5		6	5.32	97
	5		14	5.32	94
	6		0.3	5.39	96
	7		0.3	5.42	99
	7		6	5.46	97
	7		14	5.53	95
3-IX	1	Low	0.3	4.34	77
	3		0.3	5.25	98
	5		0.3	5.49	100
	5		6	5.39	97
	5		14	5.25	94
	6		0.3	5.39	95
	7		0.3	5.32	91
	7		6	5.32	90
	7		12	5.32	88

Table 5. Nitrate-nitrogen, phosphate-phosphorous and reactive silicate in the Damariscotta River, July-September, 1968 and June-August, 1969. Values are μg a/l.

Date	Station	Tide	Depth Meters	NO_3-N	PO_4-P	SiO_2
12-VII-68	1	Flood	0	-	0.44	-
	1		4	-	0.76	-
	3		0	-	0.33	-
	3		5	-	-	-
15-VII-68	1	Low	0	0.7	-	-
	1		3	0	-	-
	3		0	1.0	-	-
	3		4	1.0	-	-
26-VII-68	1	Flood	0	-	1.38	-
	1		4	-	1.24	-
	3		0	-	0.51	-
	3		5	-	0.55	-
6-VIII-68	1	High	0	0	0	-
	1		5.5	0.3	1.00	-
	3		0	1.0	0.69	-
	3		6.5	1.5	0.73	-
13-VIII-68	1	Low	0	0	0.91	-
	1		3	0.7	0.84	-
	3		0	0.5	0.64	-
	3		4	-	0.67	-
21-VIII-68	1	High	0	0.3	1.02	-
	1		5.5	1.0	1.13	-
	3		0	0	0.95	-
	3		6.5	1.7	0.76	-
5-IX-68	1	High	0	0.2	1.09	-
	1		5.5	0.2	0.84	-
	3		0	0.5	0.73	-
	3		6.5	1.0	0.69	-

Table 5, Continued

Date	Station	Tide	Depth Meters	NO_3-N	PO_4-P	SiO_2
23-VI-69	1	Low	1	-	0.84	13.2
	7		1	-	0.53	7.1
22-VII-69	1	Low	0	1.25	1.58	17.2
	1		2.5	0.59	1.68	17.1
	2		0	0.62	1.30	-
	2		3	0.62	0.49	-
	3		0	0.61	1.10	-
	3		3	0	0.79	-
	7		0	0.31	0.68	13.4
	7		10	0.32	0.79	10.1
5-VIII-69	1	High	0	2.01	-	-
	2		0	2.04	-	-
	3		0	1.61	-	-
11-VIII-69	1	High	0	-	1.46	-
	1		4	-	0.88	-
	2		0	-	0.71	-
	2		4	-	0.71	-
	3		0	-	0.71	-
	3		4	-	0.66	-
	7		0	-	0.75	-
	7		8	-	0.84	-
29-VIII-69	1	Flood	0	0.12	1.15	4.9
	1		2.5	0.12	1.10	4.9
	2		0	0	0.89	-
	2		3.5	0.30	0.81	-
	3		0	0.02	0.81	2.2
	3		4.5	0	0.76	3.0
	5		0	0.57	0.89	6.8
	5		10	1.31	0.94	7.1
	7		0	2.00	0.79	4.2
	7		12	1.92	0.94	5.9

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