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File 63 #471

NOTES on the MARINE BIOLOGY of the NISQUALLY--
the OUTER FLATS, DELTA FRONT, and REACH

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November 19, 1971

Introduction

In spite of the fact that the Nisqually Delta is one of the largest undeveloped estuarine areas in Puget Sound and a major component of the marine and terrestrial ecosystems of the southern Sound, no comprehensive oceanographic or biological surveys have been made in the area. Scattered data are available, and the purpose of this report is to draw them together in some preliminary fashion. Major sources include: data from cruises conducted by the University of Washington Department of Oceanography, U.S. Coast and Geodetic Surveys, masters' and doctoral dissertations mainly from Oceanogrpahy, U. of Washington, Washington State Department of Fisheries studies and reports, miscellaneous papers--including a position paper submitted by members of the professional community to the Thurston County Commissioners, undergraduate reports by students at the University of Puget Sound. Recently an excellent study, The Nisqually Delta, was produced by graduate students in the Environmental Geology Seminar and published by the Department of Geological Sciences, U. of Washington.

During the spring semester of 1971, students in a marine biology course under my direction used parts of the Delta area as an outdoor laboratory for their series of individual projects (listing follows the bibliography). Access to the vast areas of the delta plain is difficult, and field time was extremely limited. A one day cruise was made on May 2 aboard the chartered 75' vessel Twanoh out of Seattle. This trip provided some data on salinity, temperature, oxygen, and bottom fauna from four stations in the Nisqually Reach. Several additional forays were made by power skiff to points along the delta flats and slope. Most student effort, however, was concentrated on the west side of McAllister Creek because of ready access via Luhr Beach.

The Nisqually, similar to others of its type, is the result of long term geological processes where stream-carried sediments[1] are deposited at the mouth of a river where it meets the Sound. A constant struggle occurs between processes of deposition which build up the delta and those forces--waves and currents--which tend to carry away the sediments. Those geologists who have studied the Nisqually are generally agreed that the present delta is in a state of dynamic equilibrium between the varying opposing forces, i.e., at this time its size and major features remain relatively constant. Changes, however, which affect the degree of erosion

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[1] Brundage (1960) estimates the least average sedimentation rate of the Nisqually River as 100,000 cubic meters per year.

and land deposition will alter the balance and undoubtedly affect the distribution and composition of marine communities, these presumably also now in a relative state of equilibrium.

Another important term, "estuary", may be applied to the Nisqually. Broadly defined, an estuary is the wide mouth of a river or arm of the sea where the tide meets the river currents or flows and ebbs. The estuary is a buffer zone between fresh water and the saline water. The particular values of estuaries was stated succinctly in the introduction of the <u>National Estuary Study</u>, "Estuaries have unique biological and physical characteristics that make them an especially valuable part of the natural environment." Some of these features, based on a variety of sources, are:

1. Shallow basins with buildup of sediments into broad tidal flats.
2. Variable salinity due to tidal marine inflow and runoff of fresh water from the land.
3. Warmer summer temperatures may prevail, aiding total productivity.
4. Nutrient content high, nourished both by land and sea. Interaction of waters may provide "nutrient traps".
5. Often strong currents except in shallow fringe areas and marshes.
6. Strictly aquatic organisms are mainly of marine origin; semiaquatic forms tend to be derived from land or fresh water.
7. Numbers of organisms generally high, but variety may be limited due to special physical conditions high adaptive requirments of species.
8. Conditions afford nursery grounds for development of deeper water forms.
9. Lightly polluted systems tend to support a fairly wide diversity of poorly adapted species; heavily stressed sytem supports fewer species and these may be abundant but not usually of direct economic benefit to man.

Description of Area

For purposes of the notes to follow, the area under consideration is divided into three zones: (1) Nisqually Flats, the seaward intertidal delta plain, (2) the delta slope, particularly the initial part thereof, from about 2-20 fathoms depth, and (3) the deeper Nisqually Reach (figures 1 and 2). Lowther's short geological description helps to sharpen the terms used here. Broadly, the subaerial (above sea level) part of the entire Nisqually Delta plain occupies nearly all of the former Nisqually estuary, whereas the submerged part extends well out northward into the tidal channel as well as building up eastward and westward of the valley itself. At the high tide level, diking of the delta plain for agricultural and other purposes, has had the effect of sharpening the boundary between the general plain and the Nisqually Flats, the latter an area of approximately one thousand acres. Medium and fine sand

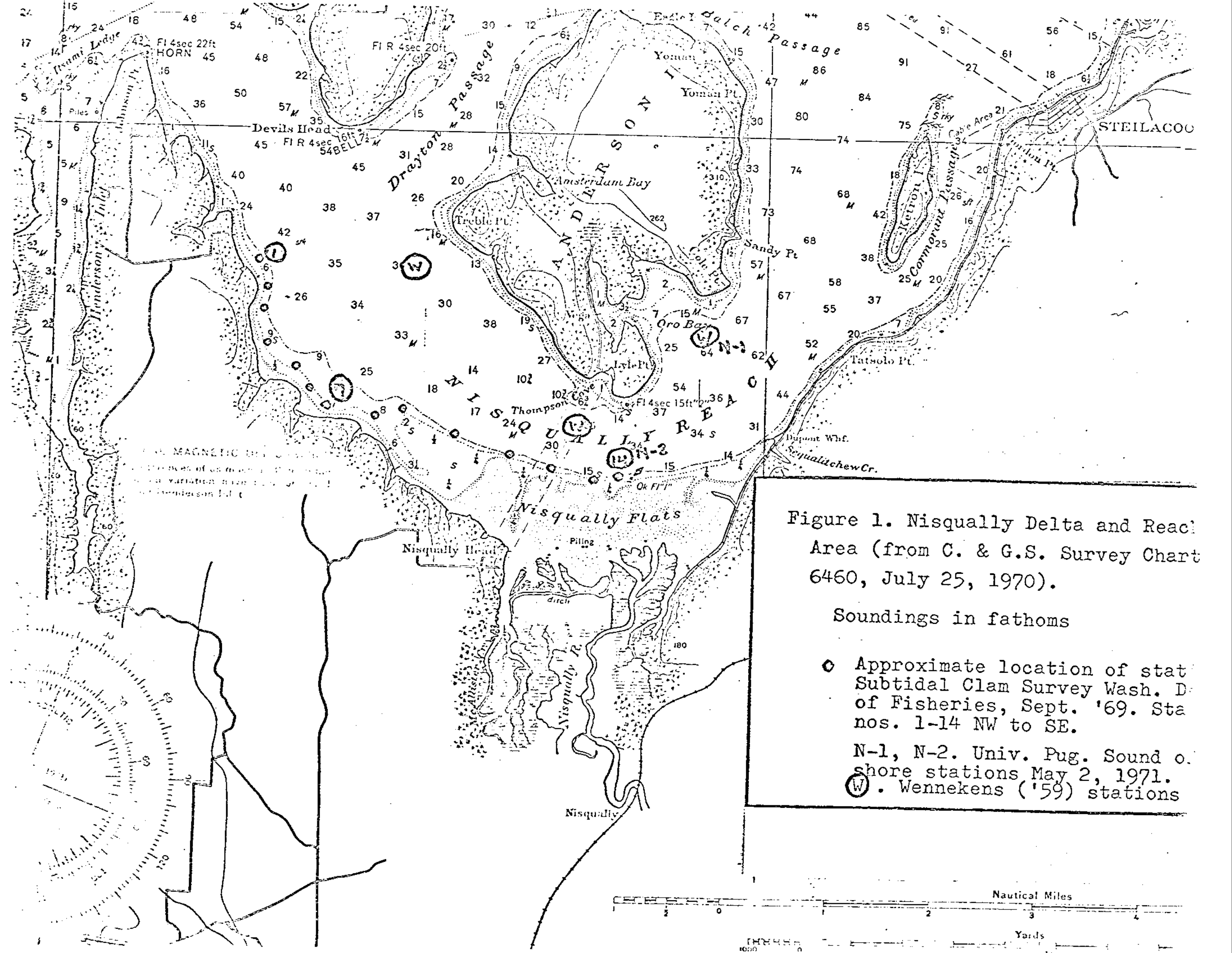


Figure 1. Nisqually Delta and Reac
Area (from C. & G.S. Survey Chart
6460, July 25, 1970).

Soundings in fathoms

- ○ Approximate location of stat
Subtidal Clam Survey Wash. D
of Fisheries, Sept. '69. Sta
nos. 1-14 NW to SE.

N-1, N-2. Univ. Pug. Sound o.
shore stations May 2, 1971.

Ⓦ. Wennekens ('59) stations

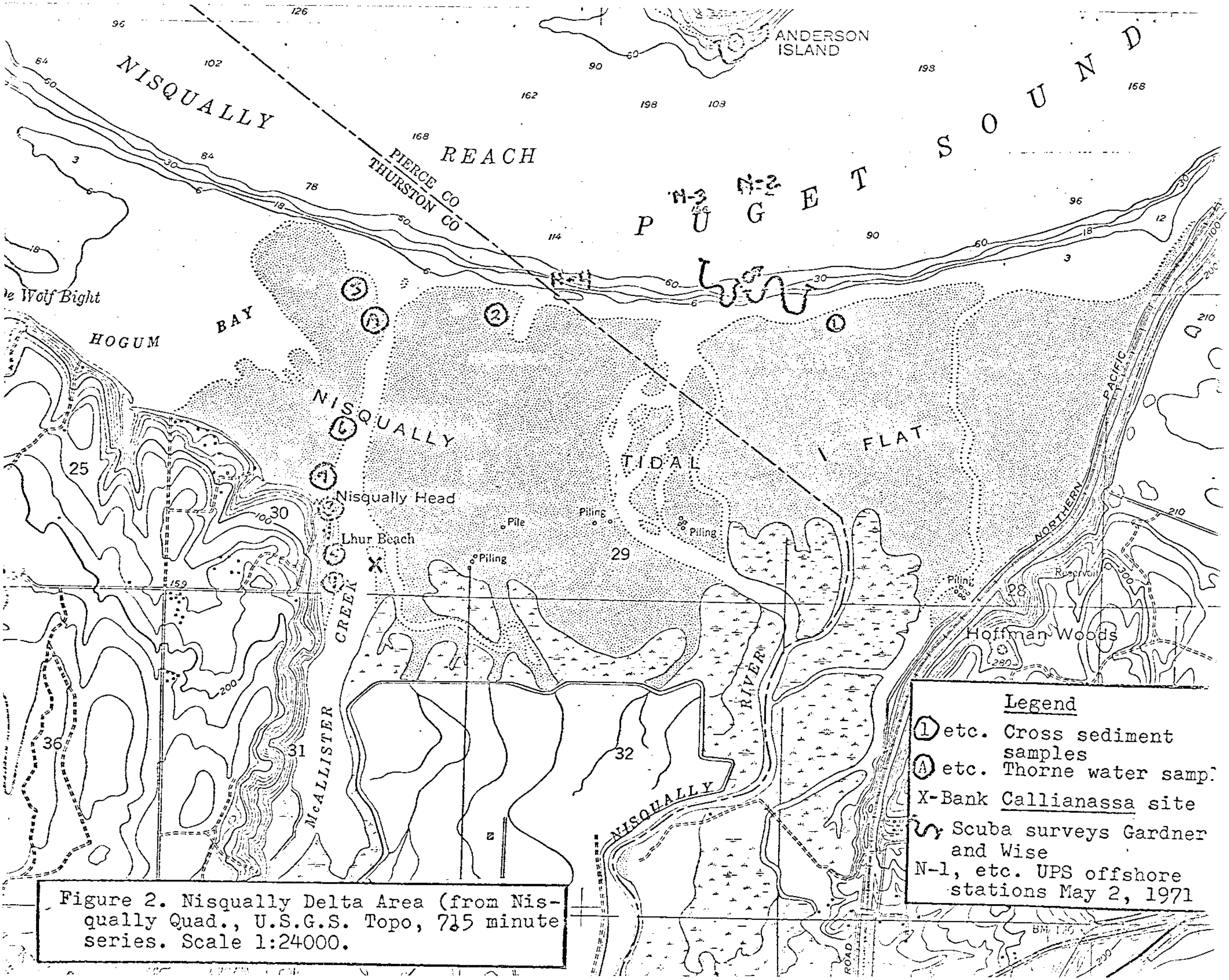


Figure 2. Nisqually Delta Area (from Nisqually Quad., U.S.G.S. Topo, 7½ minute series. Scale 1:24000.

dominate the surface sediments of the Flats, and its general description on marine charts as "mud" is misleading. It is true, particularly along the meandering stream channels, that outwash silt has mixed in with sand and water to form soft areas in which one's boots sink several inches with ease. Clay-sized sediments, however, are scarce throughout the entire delta area, according to Brundage (1960).

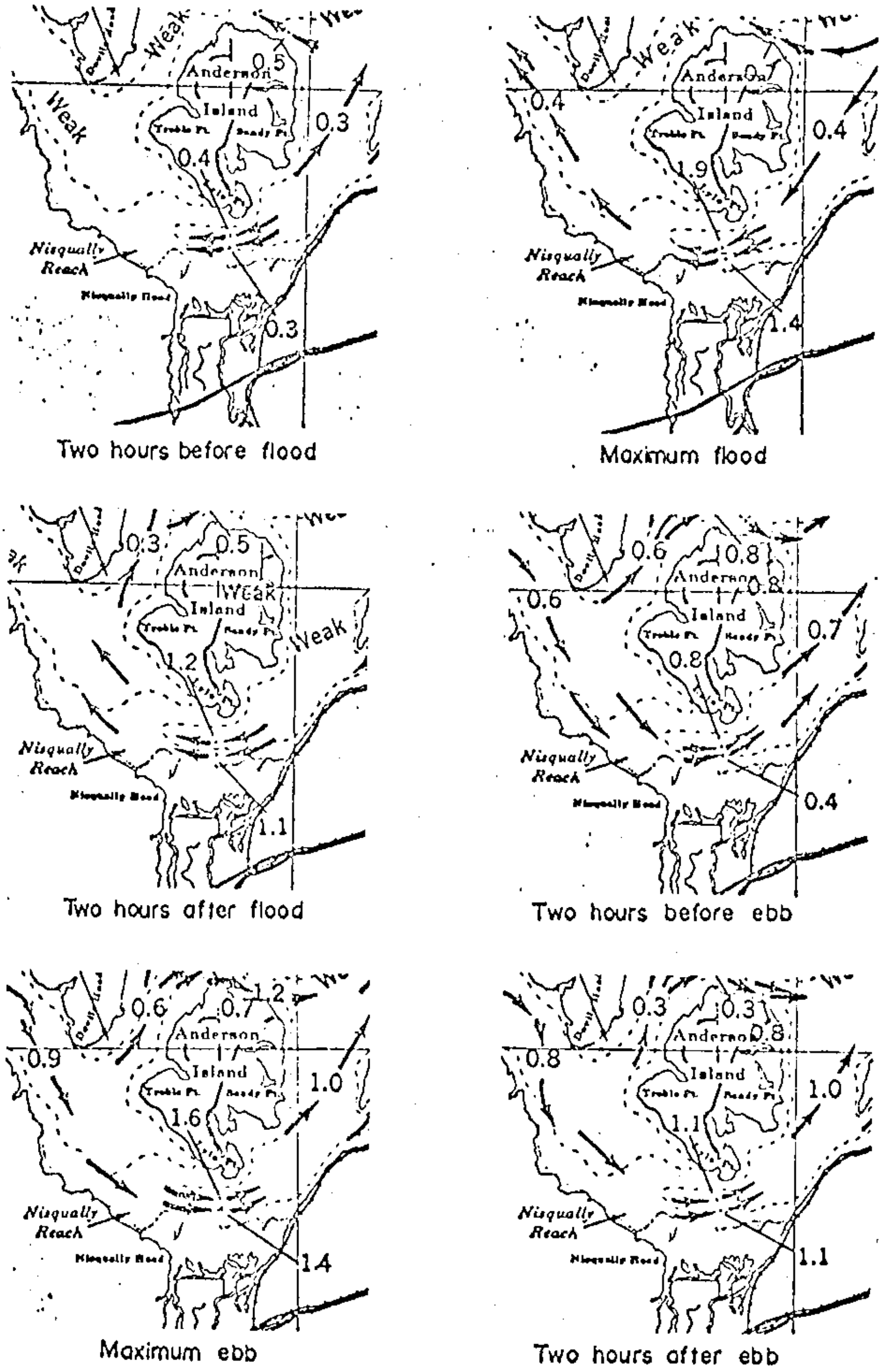
The delta front slopes off abruptly (see figures 2 and 10), commencing at approximately the minus 2 fathom (-12 feet) level below mean datum sea level and extending to the average depth of approximately 180 feet in the Nisqually Reach. The degree of slope approaches 20-30 or more degrees in places and the steep front of the delta is the area where both erosion and deposition are active processes. Slumping of the delta front has occurred repeatedly as suggested by the irregular platforms (figure 9). The sandy sediments here tend to be coarser than those on the flats, the finer materials having been washed away by the action of currents.

The deeper channel, the Nisqually Reach, varies in depth from about 20 to 70 fathoms but it tends to be irregular (figure 10). The bottom is blanketed by a remarkably uniform well-sorted medium sand which is indistinguishable from the channel deposits found in the lower stretches of the Nisqually River.

Tides and Currents

Tidal data from Sequalitchew Creek at the east edge of the Nisqually Reach show a mean range (mean of high tides plus mean of lows) of 13.4 feet. In 1971 the maximum exchange projected from published tidal tables was from -3.2' to +14.3' and occurred on May 25. It is probable that the total tidal range for that date, 17.5 feet, may exceed the calculated figure due to what is commonly referred to as the "basin effect". This southern tip of the Sound acts as the end of a tipped vessel of water, greater fluctuation of water level occurring at the extreme ends of the basin than in the center of the water mass. Olcay (1959) estimates the highest and lowest tides as +17.0' and -4.5' for the Sequalitchew Station.

Tidal inflow moves southward through the Tacoma Narrows at great velocity (maximum flood flow 4-5 knots) and continues southward to sweep around the curve formed by the channel between Anderson Island and Nisqually Delta, although a part of the water mass angles westward between the north side of Anderson and McNeil Island (figure 3). The flood tide in the reach has a



Two hours before flood

Maximum flood

Two hours after flood

Two hours before ebb

Maximum ebb

Two hours after ebb

Fig. 3. TIDAL CURRENTS NEAR THE NISQUALLY DELTA

Arrows show current direction. Time is from the Tacoma Narrows. Velocity is in knots.

(from U. of W. Dept. Geological Sci. Report) maximum velocity of 1.74 knots and an average velocity of 1.1 knots. Ebb tide velocities are even greater in the Reach, maximum 1.94 and average again 1.1. Wang, in 1955, noted that the transporting power of currents in the southern Sound was greater during the ebb than the flood (in Geological Sciences Report, U. of W., 1970). This may be partly explained by the fact that current velocities on the surface at ebb are greater than at 50 meters depth, whereas during flood more water moves at about two third of the bottom depth for much of this region (Paquetter and Barnes, 1951).

The usual assumption is made by the layman that strong tides, current, and waves will quickly, even daily, flush out a basin such as the Nisqually Reach. Even if 100% efficiency is assumed for the mixing of tidal and basin waters, calculations in the University of Washington Geological Sciences report show that the flushing rate for the Reach is still 4-5 days (Hood Canal some 11 days, on same basis). Mixing is never complete due to irregularities of the bottom, for one thing, and another estimate, based on techniques of measuring salt balance, give a flushing rate for the Nisqually of 48 days, assuming a flushing efficiency of 10 percent.

Shallow bays are often sites of intense wave buildup and turbulence dependent on exposure to winds of fairly long duration and distance or fetch. The fact that the Nisqually Delta faces northward provides some protection from the strong prevailing southerly and southwesterly storm winds. Even so, one author (Bretschneider, 1952) calculated the maximum wave height in the Reach as between three and six feet when generated over the 12.5 mile fetch southward down the Tacoma Narrows. In general, winds greater than 15 knots seldom last long enough to create greater than four feet waves. The significance of wave action is in terms of the amount of shoreline erosion. Studies have shown that 75% of total solid material entering the Sound derive from erosion, 25 percent from streams. Of this solid burden, only one-fourth passes out to the ocean, the rest is deposited in the Sound. (Bretschneider, ? supra cit.)

Salinity and Temperature

Estuaries commonly show a compensatory inflow at depth of salt water due to surface runoff of fresh water. This may create a double wedge effect at the mouth of a river system. The Nisqually probably shows this effect in local situations and under quiet water conditions, but general salinity measurements in the Reach indicate considerable mixing of the waters and a relative constancy of conditions. Monthly measurements were taken at a hydrographic station located directly off the Delta during 1953-4 by the University of Washington Department of Oceanography personnel. I have extracted selected months for 1954 (figure 4). In terms of temperatures, it is clear that variation between the surface waters in January and August exceeded five degrees C., but at no time were waters at 40-60 meters more than about a degree and a half colder than surface waters and usually less than one degree. Some reduction in oxygen occurs with depth on all the sampling days; surface waters, however, generally exceed 0.5 mg-at/L.

Olcay (1959) and others have shown that discharge from the Nisqually and other major river systems have a direct fresh water influence upon the upper 5 to 10 meters of the water column in this part of the Sound. The most pertinent data comes from Olcay's correlation of precipitation (Olympia station) and salinity off Johnson Point, approximately five nautical miles northwest of the Flats (see figure 5).

Notes on Biota

The following observations are based mainly on my own field work and those of students in my 1971 spring semester class, Biology 356--Natural History of Marine Invertebrates. The students' independent study reports (listed in bibliography) represent rather specific and limited approaches. Certainly there is no attempt to come up with a comprehensive survey in terms of area covered or total species. Wennekan's benthic study (1959), Dr. Paul Ilg's field notes for a 1954 dredge in the Nisqually Reach, and Washington Department of Fisheries records are additional sources.

Mouth of McAllister Creek. McAllister Creek, a small stream-fed by springs located south of Interstate 5, forms approximately the west boundary of the Nisqually Flats (see figure 2). Bundage (1960) claims the creek is tidal for its entire length. At its terminus the creek forms a broad estuarine slough, roughly a hundred yards in width and nearly a fourth of a mile in length. The slough is bordered on the east by raised mud-clay banks and by the gently sloping mixed gravel, sand and mud of Luhr Beach. Its waters generally are highly turbid and depths shallow, only 3-4 feet in mid-channel at zero tide near the mouth.

11 Jan 54 122° 42.6' W WIND NxW 10
2320 (+8) DEPTH 35 fm
Nisqually Reach

Depth (m)	Temp (°C)	Sal (°/oo)	O_2 (mg-at/L)	PO_4 (ug-at/L)
0	8.64	27.41	0.535	2.66
5	8.47	27.28	0.534	2.77
10	8.89	27.87	0.532	2.74
20	9.20	28.36	0.510	2.37
30	9.39	28.77	0.480	2.34
32	9.37	28.83	0.483	2.67
49	9.46	28.89	0.485	2.73

STA A-242 47° 07.1' N WEATHER c.
23 June 54 122° 45.5' W WIND NE 3
1959 (+8) DEPTH 35 fm
Nisqually Reach

Depth (m)	Temp (°C)	Sal (°/oo)	O_2 (mg-at/L)	PO_4 (ug-at/L)
0	11.47	27.90	0.539	1.78
5	10.34	28.77	0.515	2.05
15	10.36	28.97	0.502	2.05
35	10.08	29.10	0.491	2.07
55	10.09	29.07	0.490	2.13

STA 73-20 47° 07.2' N WEATHER c.
16 Nov 54 122° 42.8' W WIND SSW 8
0648 (+8) DEPTH 34 fm 50°/49°F
Nisqually Reach

Depth (m)	Temp (°C)	Sal (°/oo)	O_2 (mg-at/L)	PO_4 (ug-at/L)
0	10.75	29.72	0.406	2.55
5	10.75	29.72	0.406	2.61
10	10.72	29.73	0.398	2.57
20	10.67	29.79	0.394	2.61
39	10.68	29.88	0.388	2.62
59	10.65	29.90	0.382	2.57

STA 55-51 [illegible] N WEATHER o.
22 Apr 54 122° 42.5' W WIND S 6
2320 (+8) DEPTH 35 fm 45°/43°F
Nisqually Reach

Depth (m)	Temp (°C)	Sal (°/oo)	O_4 (mg-at/L)	PO_4 (ug-at/L)
0	8.78	27.99	0.572	2.09
5	8.76	27.99	0.573	2.18
10	8.64	28.11	0.566	2.20
20	8.60	28.17	0.560	2.26
30	8.26	28.39	0.543	2.38
40	8.30	28.46	0.552	2.33
60	8.34	28.48	0.534	2.17

STA A-275 47° 07.2' N WEATHER o.
12 Aug 54 122° 42.3' W WIND W 2
1041 (+8) DEPTH 36 fm 57°F
Nisqually Reach

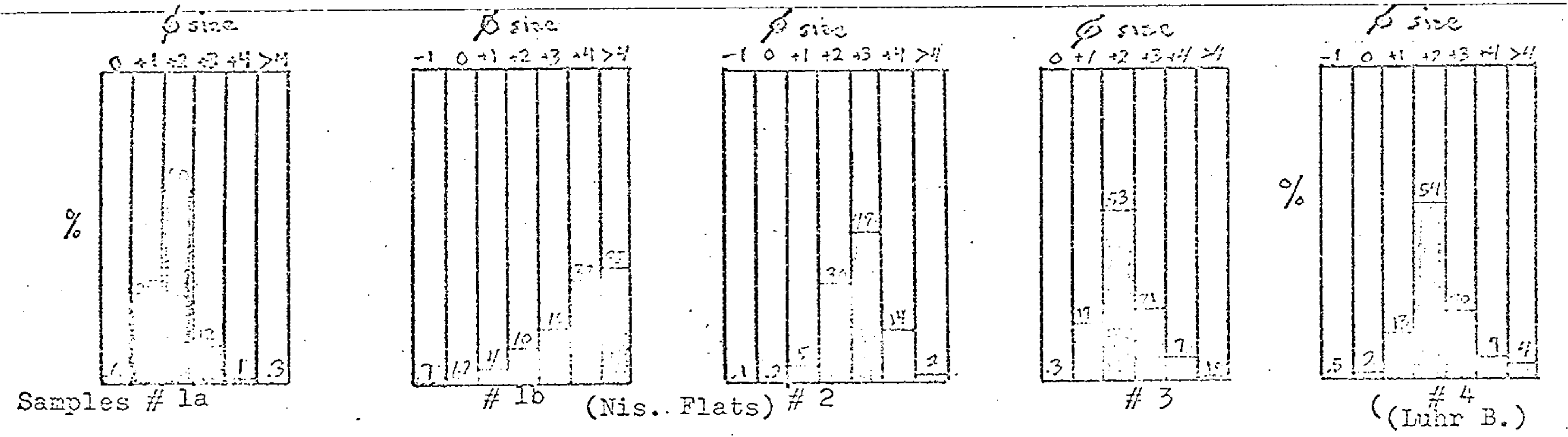
Depth (m)	Temp (°C)	Sal (°/oo)	O_2 (mg-at/L)	PO_4 (ug-at/L)
0	13.70	28.51	0.589	----
5	13.03	28.97	0.543	----
10	12.59	29.01	0.512	----
20	12.17	29.06	0.474	----
40	12.14	29.09	0.478	----
60	12.10	29.09	0.471	----

Figure 4.

SELECTED OCEANOGRAPHIC DATA

NISQUALLY REACH 1954

(from Barnes & Collias,
Technical Report No. 46,
U.of W. Department of
Oceanography)



Ø Unit	Wentworth Grade Scale		Ø Unit	(> 4--course silt on)	
-1	Very fine pebbles	to 2 mm.	+2	Medium sand	to ¼ mm.
0	Very course sand	" 1 mm.	+3	Fine sand	" 1/8 mm.
+1	Course sand	" ½ mm.	+4	Very fine sand	" 1/16 mm.

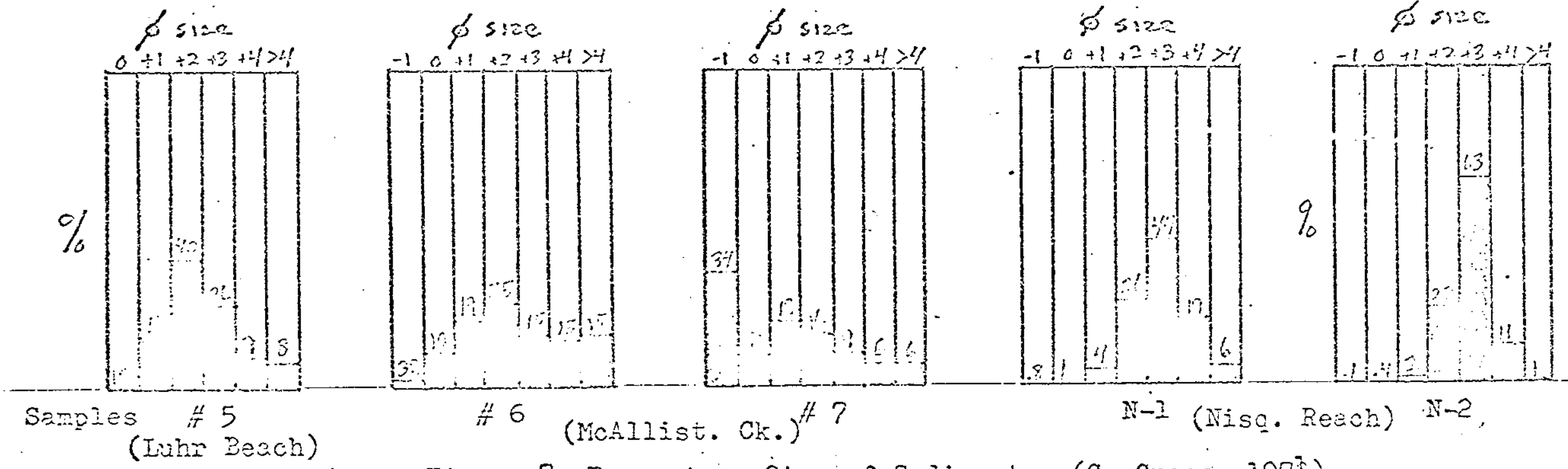


Figure 7. Percentage Size of Sediments (C. Cross, 1974)

Figure 5. Salinity & Precipitation in the Nisqually Region (After Olcay, 1959)

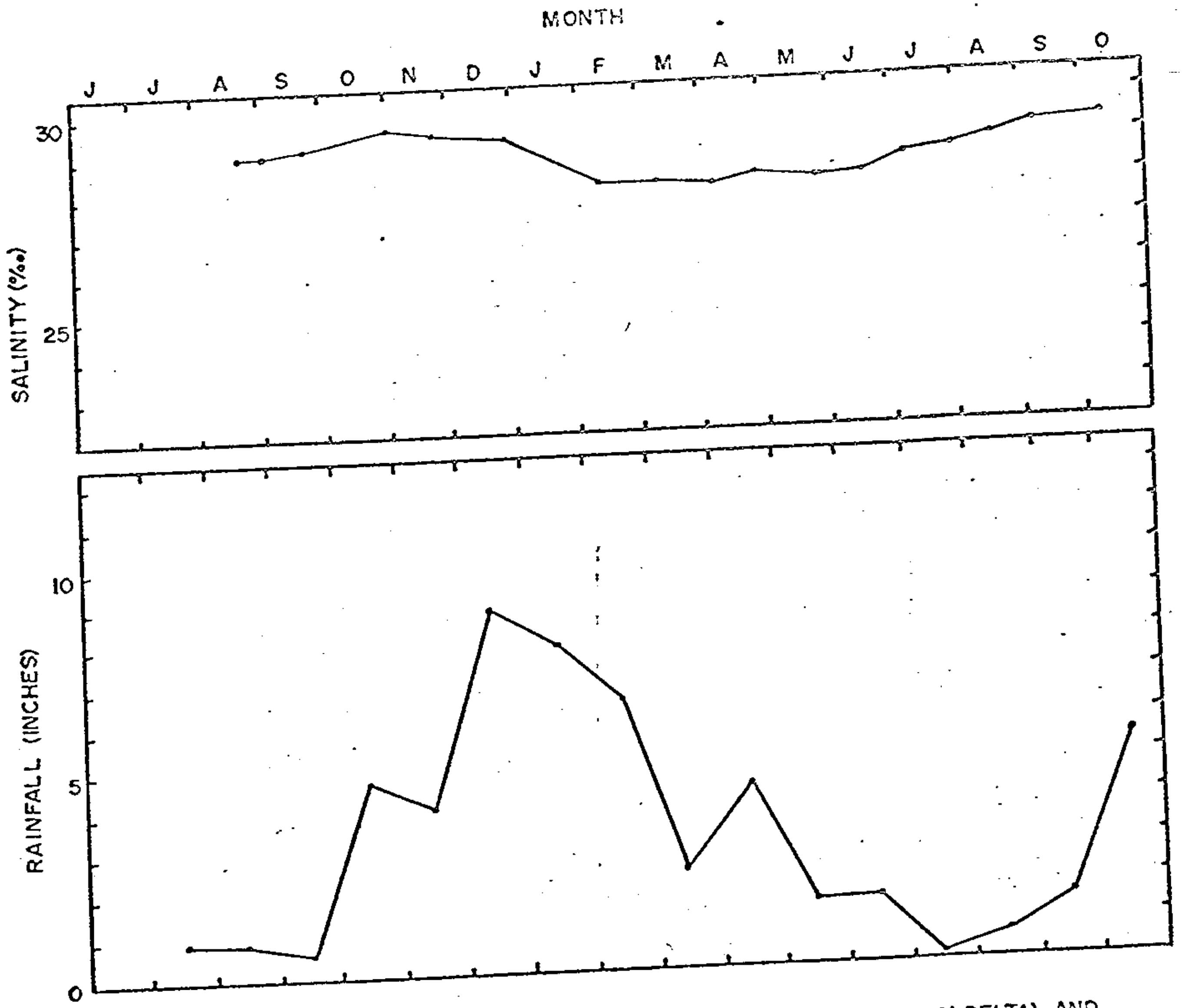


Fig. 5. SALINITY OF WATERS OFF JOHNSON PT. (5 MI. WEST OF NISQUALLY DELTA) AND PRECIPITATION AT OLYMPIA, JULY 1957-OCTOBER 1958. (FROM OLCAY, 1959) Reproduced from U. of Wash. Geological Sciences Report)

Luhr Beach presents extensive sand-mud flats during low water. Feldhaus gives a general description of substrate types and the macroscopic algae, basing her zones roughly on the traditional intertidal scheme of Ricketts and Calvin (1968). High on the beach is a strip of cobble and gravel extending from the splash zone or bulkhead to high intertidal zone 2. Macroscopic algae attached to the larger stones were abundant *Enteromorpha intesinalis* and small *Fucus* sp. *Ulva linza* also lies loosely on the stone and on the sand-mud substrate. Zone 3 shows patches and/or bands of unattached *Enteromorpha* (fig. 6), but the visible greens tend to drop out as lower zone 3 and zone 4 are reached, the habitat for large populations of *Callianassa californiensis*, the ghost shrimp.

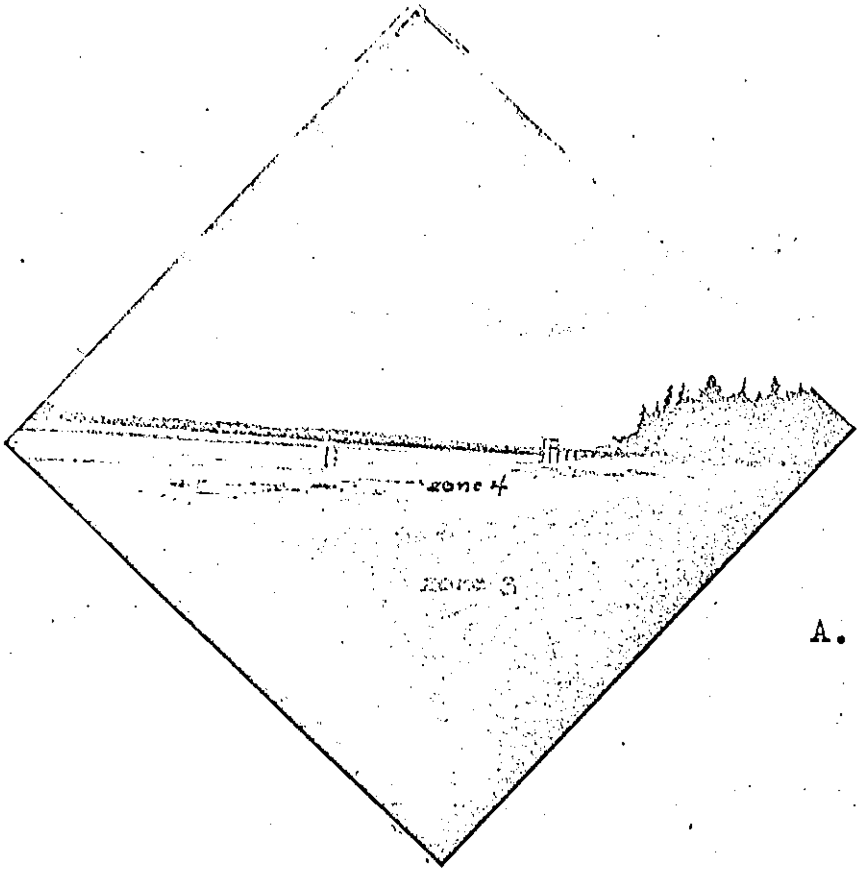
Callianassa observations

At Luhr Beach, particularly the flats several hundred yards south of the pier, the concentration of *Callianassa* is remarkable. Gross made counts of animals and burrows. In three substrate samples, cubic digs approximately 18 inches to a side, he came up with counts of 67 surface openings to 44 shrimp, 44/26, and 40/17 respectively. The totals are 151 surface holes to 87 shrimp for the 1-1/2 cubic yards.

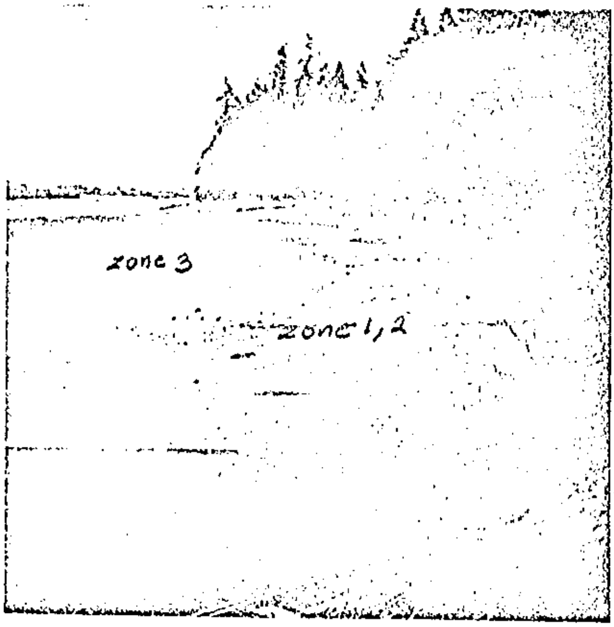
The substrate at the midtide *Callianassa* site is made up of 65% particles of size +1 to +3 (1/2 to 1/8 mm.), mainly fine to coarse sand, according to data taken by Chris Cross (see fig. 7), but the range of materials runs from silt to some fine pebbles.

It may be noted that *Callianassa* and the mud shrimp, *Upogebia pugettensis*, are of considerable economic import because of their reduction of oyster-producing areas. These shrimp-like anomurans affect the beds by altering soil compaction with subsequent smothering of the oysters. John Chambers of Washington Department of Fisheries reports ghost shrimp (both species) as high as 1/2 to 3 million per acre, and Cedric Lindsay, WDF, estimated in 1961 that more than 15,000 acres of beach valuable for oyster production in Washington are infested. Control attemps utilizing the powdered pesticide Sevin have been made (Wash. Dept. Fish., Technical Report 1, 1970). It should be noted here that National Fish and Oyster Company, owned and operated by Sam and George Bulldis, farms extensive beds of Pacific oysters north and west of Nisqually Head at the western edge of the Nisqually Delta.

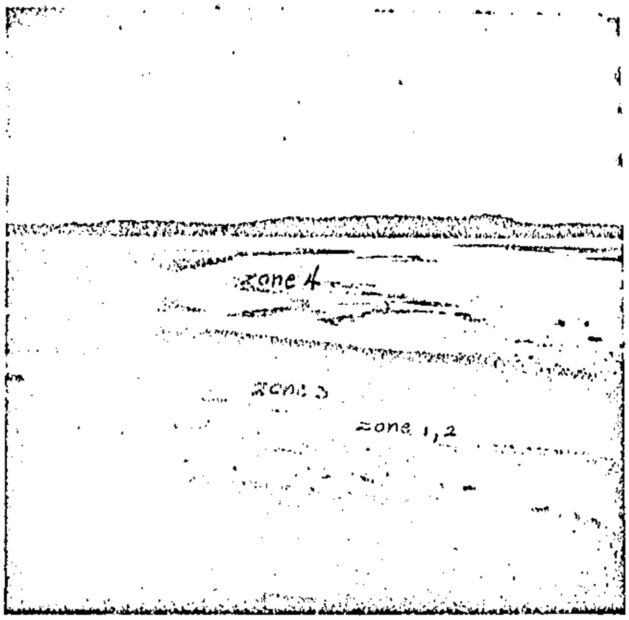
Figure 6. Photo's taken at Luhr Beach by Feldhaus.



A. Facing southward along west edge of McAllister Ck. Tidal level about -1.2ft. Note openings _Callianassa_ burrows in foreground. April 24, 1971.



B. Luhr Beach, again facing S up McAllister Ck. Zone e and lower highest populations of ghost shrimp. Tide -2.0 ft. May 13, 1971.



C. View NE from Luhr Beach across flats to Anderson I. in background. Eelgrass beds in area marked "zone 4". Mouth of McAllister Ck. Tide - 1.2 ft. April 24, 1971.

Callianassa also inhabits the mud-clay banks bordering the east side of McAllister Creek across from Luhr Beach. Here the marsh grass covered delta flats have been heavily eroded, leaving near vertical banks which drop down 5-8 feet to the more gently sloping edge of the slough. Larson found counts of shrimp burrow openings here as high as 79 per square meter.

This particular bank habitat presents an excellent opportunity to study competition between closely related crab species. Occupying the burrows in numbers are both forms of the common shore crabs, Hemigrapsus nudus and H. oregonensis. Many older references tend to emphasize the ecological separation of these species on typical beaches with mixed substrate conditions--nudus tending toward rock and gravel substrate (less silt) and oregonsenis favoring hard-packed sand and mud which often occurs lower on the beach. In the homogenous habitat here, the two species occur in near equal numbers.

Micro-Algae

The apparent barren surface of any mudflat misleads the uninformed. As pointed out by L. R. Pomeroy (1959) in his study of the Georgia salt marshes, the rich algae living in or on the mud, usually only a cell layer thick or seldom more than five cells thick, are sites of intense photosynthesis. Lacky (1967) stated that benthic diatoms far surpass planktonic forms in number at estuaries and are especially important in oxygen production and at the base of food chains. A partial survey of the epibenthic forms at Luhr Beach was undertaken by Feldhaus. Most were scraped from the surface of whole macroscopic algae, from eelgrass, or the surface of the mud. Her partial list added up to 26 species. Of the predominantly fresh water diatoms, Pleurosigma salinarum, Navicula iridus and N. crucicula were abundant. Most abundant and widespread in her seven sampling stations was Gyrosigma fasciola. Only one truly attached form, Synedra superba, was found. Most of the diatoms move in a slow, steady gliding motion. Seven species were recorded from the skinned film on Zostera, forms of Navicula most abundant.

Eel-grass flats

Zostera beds tend to occur in patches at the mouth of McAllister Creek or in somewhat narrow strips along both martins of the outer slough. A near zero tide is required for their exposure. Rather cursory investigation of one bed at the west side of Luhr Beach revealed a rather typical assemblage of marine forms: molluscs--Crossostrea gigas, Mytilus edulis, Protothaca staminea, Mya arenaria, Macoma nasuta, Clinocardium nuttallii, Nassarius mendicus, Polinices lewissi; crustacea--Callianassa californiensis, Balanus (several specie), amphipods and isopods; polychaetous annelids--Nereis vexillosa and Glycera americana. This list is anything but complete. Eel-grass habitat is particularly important for life in the estuary. Shorebirds and waterfowl, migratory or resident, make extensive use of the crustacea and molluscs which attach to the blades or the bases of these plants, and the plants provide food and protection for the development of numerous fish species. The ghost shrimp did not occur among the eel-grass in anywhere near the numbers found higher up the beach or farther upstream in the slough. Sediments here are coarser, 34% classes as very fine pebble, 28% as coarse to very coarse sand, and the rest through silt (sample #7, fig. 7).

Nereis vexillosa, the sand or piling worm, is widespread in the middle to low tide zones in the Luhr Beach area and particularly common in the substrate or burrows of the ghost shrimp. A number of investigators have pointed out that aeration of the burrows by the shrimps aids in maintaining favorable habitat for a number of species (crabs, gobies, scale worms) as well as nereids and other forms.

Various forms of Nereis are euryhaline and reported as surviving in water ranging from ocean salinity of 35 o/oo down to 8 o/oo. Omori ran salinity tests relating to Nereis vexillosa in and near the eel-grass beds. Samples of ebbing waters in May 1971 tested out 2.5-3.0 o/oo, whereas the substrate water in Nereis collection holes measured 15 o/oo. Experiments showed that adult vexillosa maintained at 15 o/oo increased in weight when placed in dilute solutions ranging down to 8 o/oo where constant weight was maintained. The worms showed considerable stress movements when shifted at two hour intervals to solutions of 5 and 3 o/oo, and death occurred within five hours for animals kept at the lower salinity. Our survey shows vexillosa well up into McAllister slough where ambient waters alone would be limiting. What is needed is critical study of the salinities within the habitable substrate as well as running waters under a variety of tidal situations.

Plankton

Thorne attempted the correlation of plankton density and salinity at two areas--off Luhr Beach and out in deeper waters of the Reach. Time available limited the survey to several stations, one offshore between Oro Bay (Anderson Is.) and the DuPont Wharf (see N-1, figure 2) at high tide May 2, the second off Luhr Beach, afternoon low tide on May 13. A Nansen 3-liter bottle was used for the offshore sample, whereas a #12 net (125 lines/inch) plankton tow was used at the beach site. No flow meter was available, so calculations of water volume are rough at the beach site. Miss Thorne ended up counting both diatoms and filamentous algae, the summary data shown in table next page. Recognizing the limitation of samples and methods, some interesting differences were suggested. Sample B from station 2 had fewer diatoms and filamentous algae than the more saline waters of the Reach. The Luhr Beach water has fewer marine varieties, as expected, and greater numbers of fresh and/or brackish water forms, including what appeared to be a brackish water mysid, *Acanthomysis awatchensis*, plus ostracods, cyclops, and a *Spirogyra*. The typically marine forms were not absent, however; the usually marine *Coscinodiscus* was present.

Data from station 1 suggests vertical distribution of various forms with a greater concentration of diatoms at 46 and 90 meters than in surface waters but the reverse situation for filamentous (mostly greens) algae where about four times the population occurred near the surface than samples from greater depths. Golden diatoms, especially *Cymbella cistula*, which lacks appendages or a general form to retard sinking, appeared most often in the deeper waters.

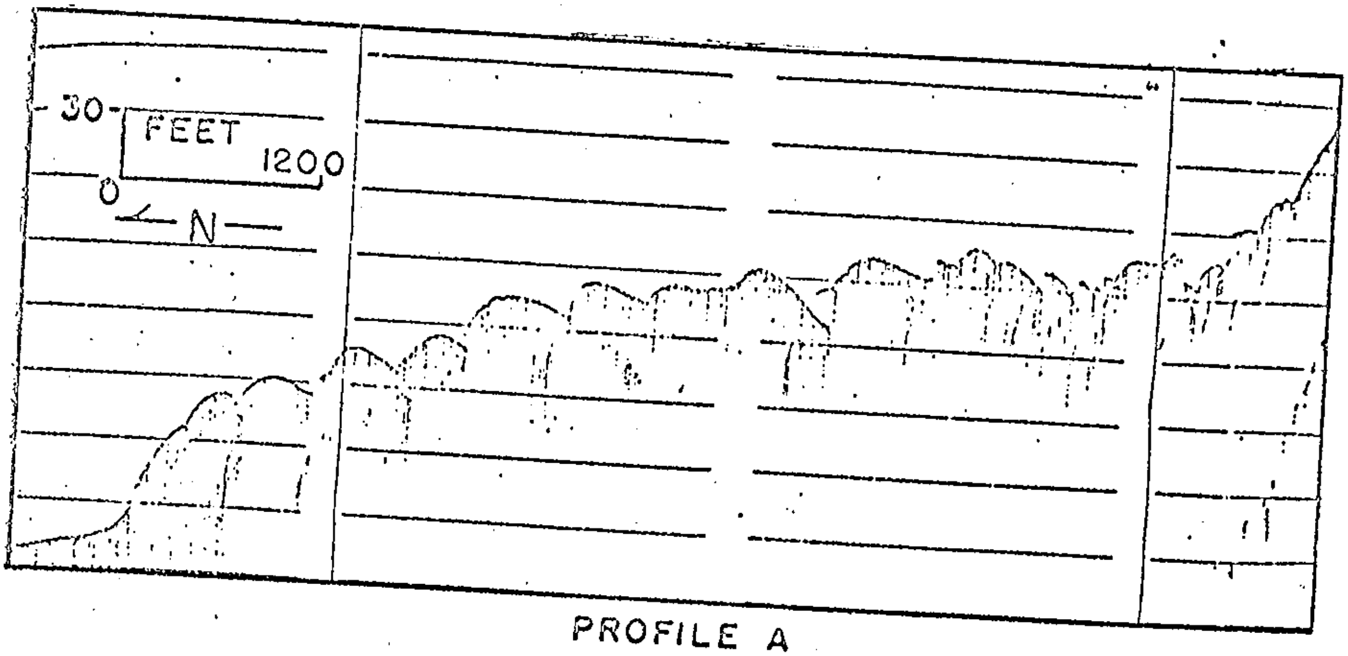
Delta front. Several scuba sorties were made off the delta front in April and May by Gardner and Wise, two dives near the black buoy located due north of the central flats and one dive, for comparative purposes, near the Lyle Point Beacon on Anderson Island (fig. 2). Visibility in the Reach varies considerably with tidal stages and general action of the river and marine currents. At Lyle Point April 18, 1100 hours, the visibility was only 5-6 feet at a depth of about 30 feet. The tide at the time of the dive was about two hours into ebb. Off the riber mouth May 2 during a period of high slack (9.8 feet at 1112 hours), visibility was 10-12 feet. The sun, however, was hazy but bright at the latter date, in contrast to full cloud cover April 18. A standard secchi disc reading

Figure 8. Plankton Data (Thorne)

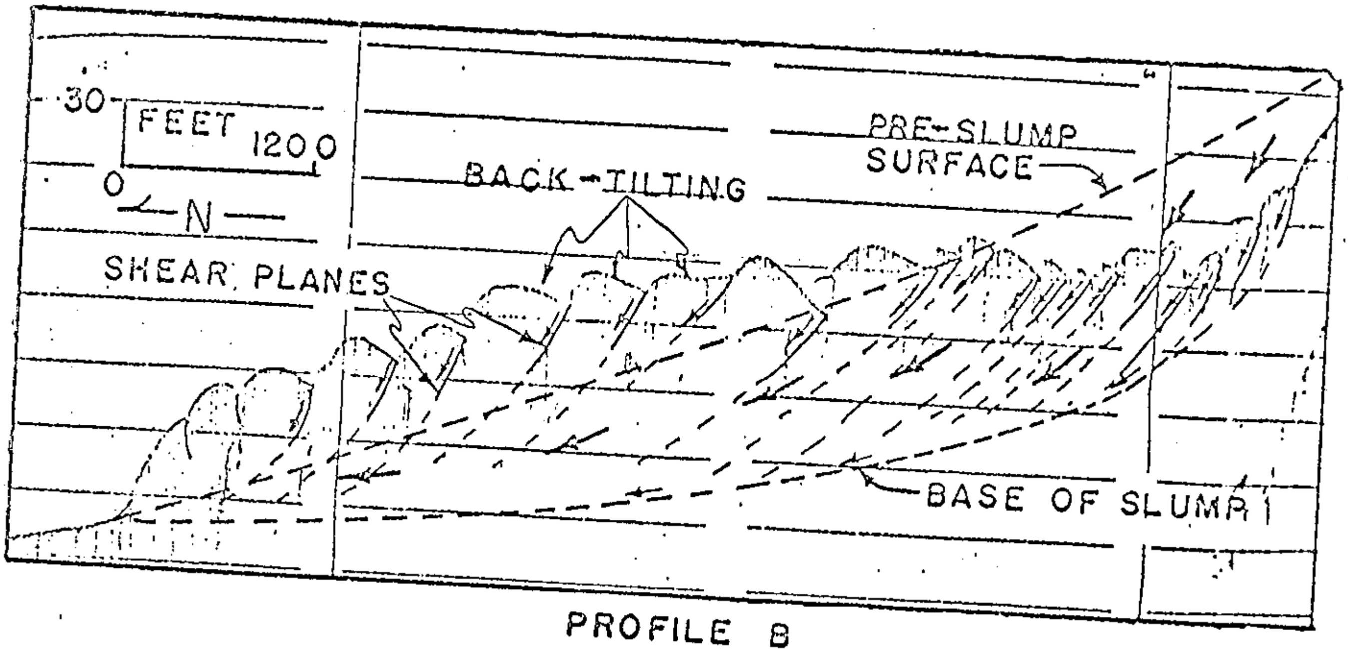
	Sample	#Diatoms/0.5ml.	Average # Diatoms/liter	#Filam. Algae/0.5ml.	Average # Filam. Algae/liter	Ave. of total #'s/liter (Corrected)	Depth	Sal. ‰	Temp.	pH	O₂ ppm
Station #1 (N-1)	A	① 118 ② 158 ③ 146	562.8	① 59 ② 52 ③ 40	50.3	764	90 meters	25 ‰	44.5°F	8.7	10ppm
	B	① 94 ② 73 ③ 110	369.2	① 70 ② 66 ③ 65	67	637.32	46 meters	26.38	44.5	8.8	9.3
	C	① 43 ② 55 ③ 61	212	① 200 ② 250 ③ 172	207.3	1041.32	Surface 0.5 m.	19.5	46.5	8.9	11.0
		# Diatoms/0.5ml (High Concent.)	(High Conc)	(High Conc)	(High Conc.)	(Corrected Average)					
Station #2 (Luthr Brch)	A (live Mysids)	① – ② – ③ –	—	– – –	–	–	0.5 meters	2.6	–	–	–
	B	① 417.2 ② 286.6 ③ 252.8	318.9	① 369.2 ② 126.6	248.9	567.8	0.5 meters	2.6	–	–	–

Figure 8. Plankton Data (R. Thorne, 1971)

Figure 9. Seismic Profile Delta Front (From U. of W. Geological Sciences Report)



PROFILE A



PROFILE B

Fig. 9. LARGE IRREGULARITES IN THE DELTA FRONT (PROFILE A).
SLUMP ORGIN INTERPRETATION OF THE IRREGULAR DELTA FRONT (PROFILE B).
(From Univ. of Wash. Dept. Geological Sciences Report)

In contrast to the relatively sparse and specialized fauna of the delta slope, the divers found the bottom off Lyle Point intensely rich in numbers and diversity. Here the substrate at 30 feet depth was mainly of cobble with some interspersed patches of sand. The single short dive resulted in some 27 species (compared with 8-9 from the delta slope) and included all from the slope with the exception of Stylatula. Included were octopus, the common Parastichopus,and a variety of rockfishes (Sebastodes) plus other fishes. These observations only confirm the summary statement made by Wennekans (1959: 234): "the fauna of the delta front is usually sparse. The instability of the sediments probably accounts for the animals lack of ability to thrive, unless they are able to cope with the shifting sediments." Regarding a sample taken in the Reach, again off Lyle Point, Wennekans suggests a more varied fauna in an area of generally stable sediments.

Data from Fisheries appears to be pertinent to the question of species abundance in relation to substrate in the Nisqually region. Mr. Lynn Goodwin, Fisheries Biologist with WDF and a Project Leader in the Subtidal Hard-Shell Clam Investigations, has kindly provided me with data (to be published later) on Panope generosa surveys made in the fall of 1969 at fourteen stations from southeast of Johnson Point to a point midway off the Nisqually Flats (fig. 1). Pairs of scuba-equipped divers surveyed transect plots of 900 square feet (6 x 150') at each station. The dives were made near mid-day, and depths given in table have not been corrected to a fixed datum level.

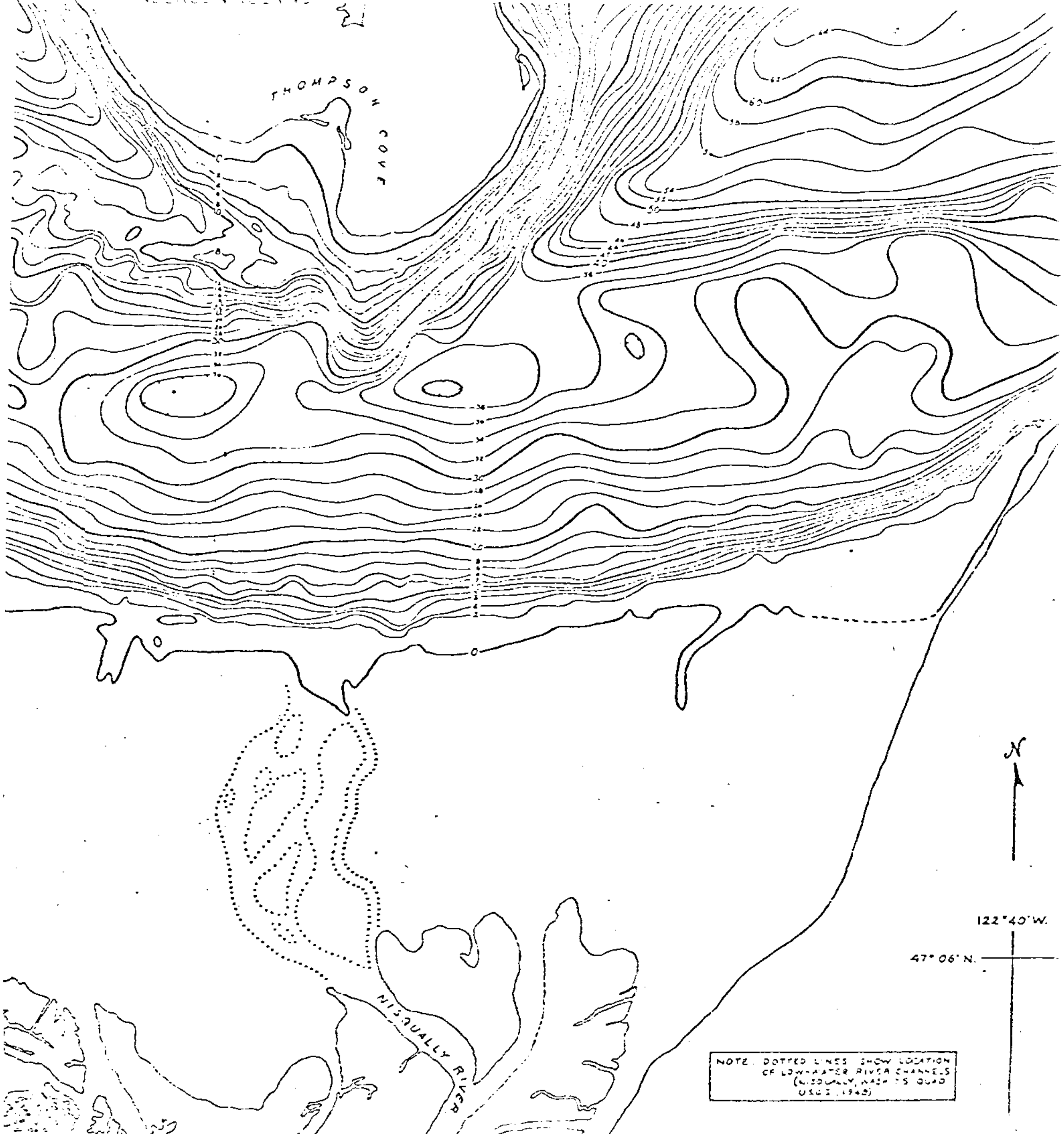
Fisheries Geoduck Survey Sept. 1969

Stat.	Date 1960	Approx. Depth(ft.)	No. Geoducks	Substrate Notes
1	9/12	10-20	2	Comp. sand & mud, sea-pens
2	"	22-29	143	Comp. sand, sea lettuce, pens
3	"	24-27	101	Same
4	"	27-34	38	Comp. muc-sand, sea-pens
5	"	42-46	439	Same
6	"	32-38	316	Same
7	"	40-55	158	Same
8	9/15	35-45	2	Soft sand, kelp, sea-pens
9	"	30-40	0	Soft sand-mud
10	"	30-60	5	Soft sand, old shell, sea-pens
11	"	20-38	1	Soft sand
12	"	20-60	0	Same
13	"	20-50	0	Same
14	"	30-45	0	Same

The dramatic decline in clams from Station 7 on appears to come with a shift from compact to soft surface substrate, the latter presumably under influence of currents sweeping sediments west of the Delta. But certainly one would need more exact information on substrate conditions to substantiate this conclusion, and it is recognized that other factors may come into play. Mr. Goodwin mentioned the general observation that there tends to be fairly close correlation between sea-pens and the likelihood of encountering Panope.

Deeper areas of Nisqually Reach.

Brundage (1970) points out that the foreset slope of the delta describes a remarkably uniform arc of about three miles, the gradient varying from a maximum of 15-20° to an average minimum of approximately 7° at the center (fig. 10). Except at the western side of the Reach, the Anderson Island southfacing slopes tend to be steeper. At profiles A-B and D-E (see fig.11) the maximum depth reaches 35 fathoms (210 feet), but the bottom slopes off to considerable depth toward the northeast section of profile F-G) where it sounds out at approximately 68 fathoms (408 feet).



NOTE: DOTTED LINES SHOW LOCATION OF LOW-WATER RIVER CHANNELS (NISQUALLY, WASH 7.5' QUAD USGS 1949)

Some Reflections

A review of the literature along with observations reported in this paper leads to the following general conclusions regarding the Nisqually Flats, the slope, and deeper Reach:

1. Probable high nutrient sources in surface and flowing silts and wide influence due to current action.

2. Rich flora of microscopic algae on surface sediments and covering plants. Bloom of larger algae minimum in April and May, comes later in summer.

3. Fairly high level of planktonic producers but again data taken prior to expected summer bloom.

4. Food organisms (small crustacea, small clams, polychaete worms, etc.) abundant in Flats and particularly so around eelgrass beds along McAllister Creek. Ghost shrimps and nereid worms dominant forms Luhr Beach area.

5. Relatively unstable delta front supports a more limited variety of infauna and epibenthic species, although many forms may move in and out of this zone for feeding.

6. Varied and rich benthic fauna occupies more stable deeper parts of the Nisqually Reach.

The real value of the Delta area proper lies not in its present commercially harvestable reserves but in its capacity for generation of nutrients and plankton to support not only local food chains, but through current action to influence the productivity of much of the ecosystem of at least the southern parts of Puget Sound. In terms of biological influence, no distinct boundaries can be drawn around the Nisqually Delta. Its present high water quality must be maintained and even hopefully improved if the system is to maintain its present values.

The history of industrial development in or near the bays and estuaries of Puget Sound has clearly shown patterns of deterioration in the productivity of these ecologically valuable resources. The Nisqually in 1971 is a particular treasure because of its relatively natural status. Any form of shoreline industrial development with its attendant disturbance of sediments and other forms of water pollution should certainly not occur either at the Delta proper or adjacent parts of the Nisqually Reach. The current proposal for an industrial park and docking facility at the Hawks Prairie Site in Thurston County, just west of the Delta, poses serious questions as to the future productivity of the marine ecosystem in this region.

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