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Patterns of beach erosion and accretion due to jetty construction are examined for the coast of Oregon. All jetty systems are included with the exception of those on the Columbia River, making a total of nine systems.

All evidence indicates that these areas of the Oregon coast are experiencing a seasonal reversal in the sand drift, but with a zero or near zero net drift over a several years time span. Thus, shoreline changes resulting from jetty construction are not the usual examples of jetties blocking a net drift as found in southern California and elsewhere.

In general, accretion of the shoreline took place adjacent to the jetties following their construction, both to the north and south. This accretion resulted mainly from the embayment formed between the jetty and the pre-jetty shoreline, the embayment becoming filled until

the shoreline is straight and again in equilibrium with the waves such that there is a zero net sand drift. In some cases, as at the entrance to Yaquina Bay, the jetties are oblique to the trend of the shoreline and so produced a protected zone from the waves where accretion could occur.

Sand for the accretion adjacent to the jetties was derived from beach erosion at greater distances from the jetties. The severity of the erosion depended on the total amount of sand required for the beach accretion to a new equilibrium, and the length of beach that was undergoing erosion. When only a short stretch of beach occurs to one side of the jetties, as at Bayocean Spit, then the resulting erosion was particularly severe, in that case leading to the breaching of the spit.

A computer model is developed to simulate the shoreline changes that occurred following construction of the jetties on the Siuslaw River mouth. The model demonstrates deposition next to the jetty to fill the embayment created by the jetty, and erosion at greater distances from the jetty. The shoreline advances of the model agreed closely with the actual shoreline changes found in surveys following jetty construction.

Shoreline Changes Due to Jetty Construction On The Oregon Coast

by

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To my parents

Román Lizarraga

Lydia Arciniega-de-Lizarraga

and wife

María Antonieta

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SHORELINE CHANGES DUE TO JETTY CONSTRUCTION ON THE OREGON COAST

CHAPTER I

INTRODUCTION

Jetties are built at the mouth of a river or tidal inlet to a bay, lagoon, or estuary, to stabilize the channel, to prevent shoaling by littoral drift, and to protect the channel entrance from storm waves. The jetties direct or confine the stream and tidal flow to aid in the channel's self-scouring ability, and help prevent immediate filling if dredging is relied upon to deepen the channel entrance. In order to prevent littoral drift from entering the channel, the jetties generally extend through the entire nearshore to beyond the breaker zone. However, in doing so, they also act in some instances as a dam to the longshore drift of sand in the nearshore. As the sand moves alongshore under the natural processes of waves breaking obliquely to the shoreline, the drift must stop when it reaches such an obstacle placed across the littoral zone. As a result the sand accumulates on the updrift side of the jetties and the shoreline advances. At the same time, on the downdrift side of the jetties the sand transport processes continue to operate and so cause sand to drift away from the jetties; erosion and shoreline retreat therefore occur on the downdrift side of the jetties.

Many examples are known of such cases where jetties block a net littoral drift and thereby produce significant shoreline changes. One that has been extensively studied is the breakwater at Santa Barbara, California (Figure 1). As originally constructed in 1927-28 the breakwater was detached, but in 1930 it was extended and connected to the shoreline to prevent harbor shoaling. The predominant waves are from a westerly direction, causing a large littoral transport to the northeast, computed to average about 215,000 cubic meters per year (Johnson, 1953). The breakwater interrupted this littoral drift and caused deposition on its updrift side (Figure 1), and erosion on the downdrift side. Sand accumulated on the west side of the breakwater until the entire area was filled, the sand then moved along the breakwater arm, swinging around its tip, and depositing in the quiet waters of the harbor as a tongue or spit of sand. Without dredging, the spit would have eventually grown across the entire harbor mouth, attaching to the opposite shoreline and closing off the harbor. A complete case history of the problems at Santa Barbara can be found in Wiegel (1959, 1964).

Jetties built in 1935 to stabilize the inlet south of Ocean City, Maryland, provide another example, one from the Atlantic coast. Again the jetties trapped a strong net littoral drift of sand, south at that location. The shoreline advanced considerably on the north side of the jetties, opposite Ocean City, and eroded to the south of the

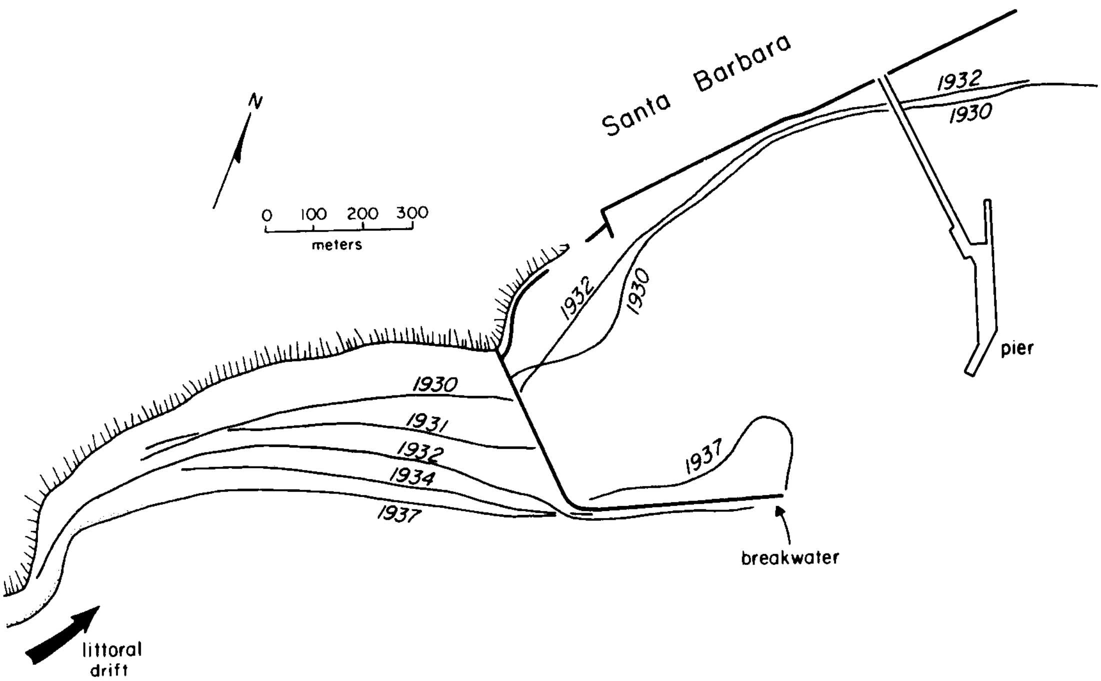


Figure 1. Shoreline accretion and erosion due to the construction of a breakwater at Santa Barbara, California, which blocked a net littoral drift of sand along the beach (Johnson, 1953).

jetties on the barrier Assateague Island. The eroded shoreline retreated about 450 meters in the twenty years following jetty construction (Shepard and Wanless, 1971).

It has thus been well established that significant erosion and deposition occurs when jetties or a breakwater block a net littoral drift of sand. Fewer studies have been undertaken of jetties that do not block a net sand transport. The obvious reason is that under these circumstances less profound shoreline changes occur. There is widespread belief in fact that erosion problems do not ensue from jetty construction on coasts that do not experience a net littoral drift. However, the study of Terich and Komar (1973, 1974) of the erosion of Bayocean Spit on the Oregon coast has provided an example where erosion did occur following jetty construction even though the area is one of zero or near-zero net sand drift.

The principal purpose of the present study is to further examine shoreline changes resulting from jetty construction in areas of zero net littoral sand drift. This study is centered on the Oregon coast where such conditions prevail. The following jetty systems are included: Nehalem River entrance, Tillamook Bay, Yaquina Bay, the Siuslaw River mouth, the Umpqua River, Coos Bay entrance, the Coquille River, Rogue River, and Chetco River mouth (Figure 2). This includes all the jetties on the Oregon coast with the exception of the jetties on the Columbia River. The principal sources of

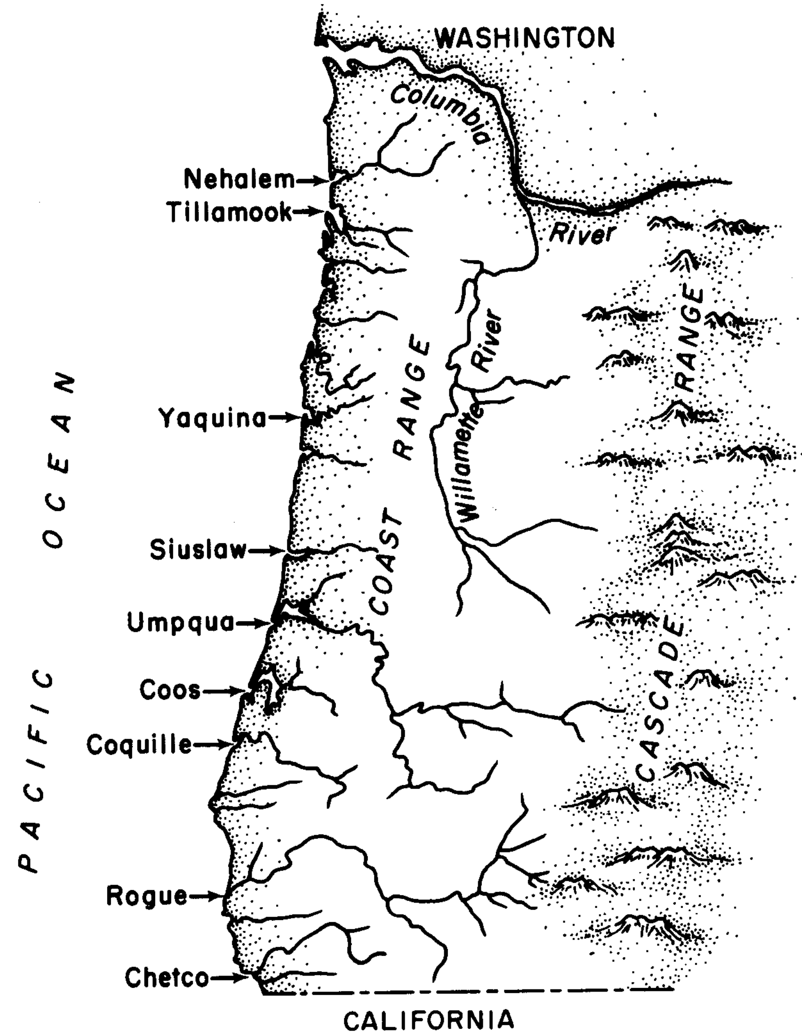


Figure 2. Locations of jetties on the Oregon coast.

information on the shoreline changes are surveys undertaken by the Corps of Engineers before and after jetty construction, aerial photographs from a variety of sources, field studies of old shorelines and other features that are still visible, and our own surveys in cases where jetties have been recently constructed or extended.

CHAPTER II

DESCRIPTION OF THE OREGON COAST

Physiography

The physiography of the Oregon coastline has been controlled by tectonism (Kulm and Fowler, 1974), and by changes in sea level produced by the development and recession of glaciers. Evidence for a rapid rise in sea level from 20,000 to 15,000 years before present (B. P.) and then a slowing down from 6,000 years B. P. to the present has been presented by many studies [for example, Shepard (1963), Curray (1969), and Milliman and Emery (1968)]. This process caused drowning of low areas such as river valleys to form the estuaries on the Oregon coast. Other areas have undergone erosion to form the sea cliffs typical of many stretches of the coast. Most of these cliffs are cutting into uplifted marine terraces, varying in height from about 30 to 500 meters (Byrne, 1963). These cliffs are composed mainly of marine sedimentary rocks associated with the Coast Range (North and Byrne, 1965) capped with a layer of marine sandstones associated with the formation of the terraces. These deposits erode much more readily than the basaltic outcrops on the coast which are present as headlands due to their resistance to wave attack. Because of these headlands, the Oregon beaches may be viewed as a series of large pocket beaches. The largest extends from Cape Arago on the south to Heceta Head north of the Siuslaw River, a beach length of nearly 100 km (Figure 2). These beaches have the typical arcuate form of a pocket beach, concave seaward.

The mineralogical studies of Scheidegger et al. (1971) indicate that when the sea level was lowered at the time of glacier advance, there was a net sand transport to the north along the beaches. At that time there were no headlands to interrupt the sand transport. It appears that under the present physiography of the Oregon coast the headlands prevent such a net longshore sand drift. This is shown by differences in sand texture and composition on opposite sides of headlands, and by the configuration of the shoreline. As indicated above, the beaches have the arcuate shape of a pocket beach where little or no bypassing is occurring around the headlands. No hook-shaped shorelines are present which indicate a net sand transport (Silvester, 1970; Silvester and Ho, 1973). There are no cases where sand accumulates on one side of a jetty or headland, and erodes on the other. Sand spits extend both to the north and south. For example, Bayocean Spit opposite Tillamook Bay extends to the north while Nehalem Spit to the immediate north extends to the south (Figure 3). The mouths of large and small rivers and streams that enter the ocean migrate north and south but do not indicate a preference for one direction over the other. Thus, all of the available

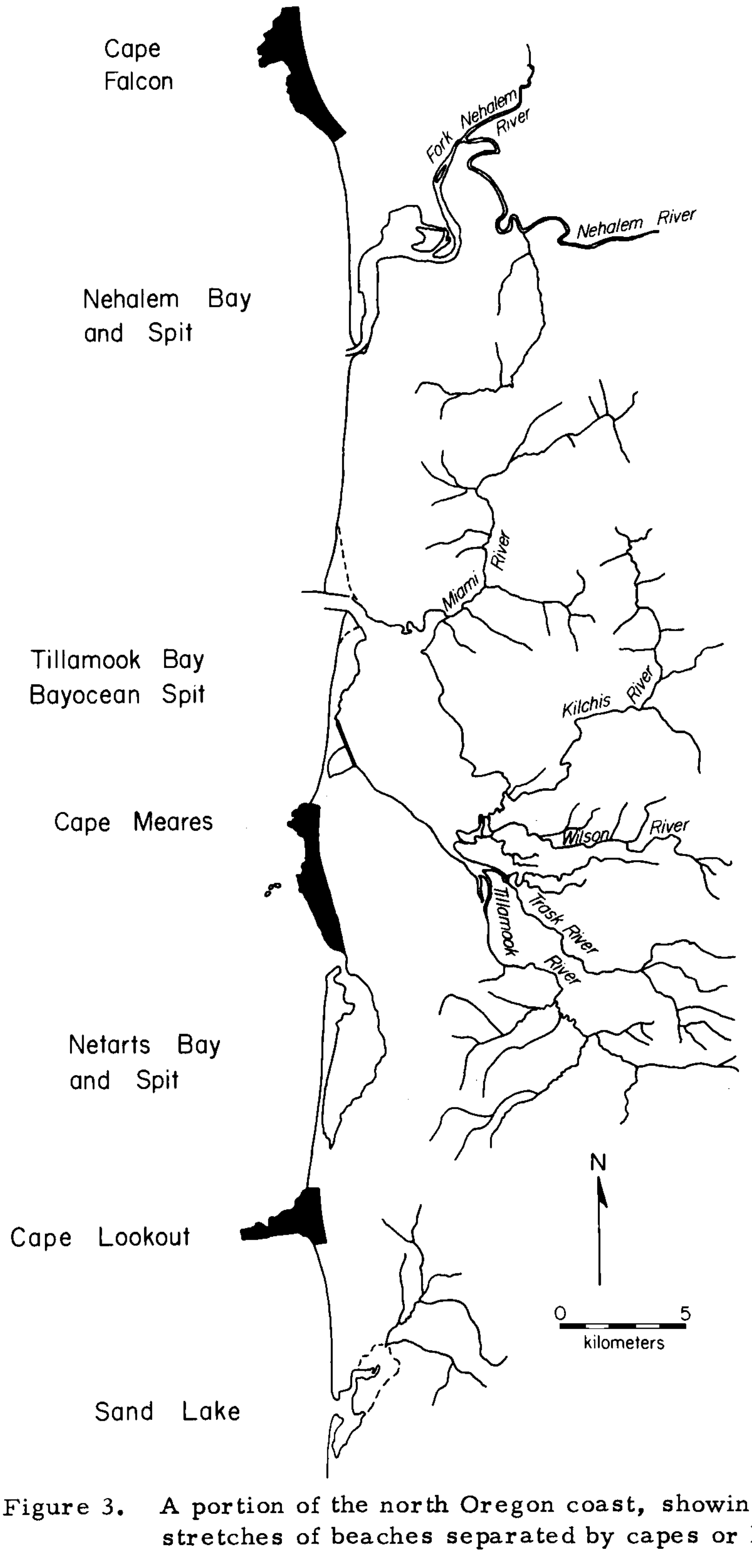


Figure 3. A portion of the north Oregon coast, showing stretches of beaches separated by capes or headlands.

evidence indicates that at present there is a condition of zero or near-zero net sand transport along the coast of Oregon. The present study of the effects of jetty construction on the beach configuration supports this conclusion.

Wave Conditions on the Oregon Coast

Waves reaching the coast account for most of the physical changes that occur. They play an important role in eroding sea cliffs and headlands. This erosion often leads to large landslides (North and Byrne, 1965), providing material to be transported along the shore by wave-induced currents, some being lost offshore as well.

Unfortunately, until recently only scattered measurements had been made of waves off Oregon. O'Brien (1951) reported on visual observations made on the Columbia River lightship. Table 1 gives a summary of the wave height, length and period, and Table 2 indicates the directions. National Marine Consultants (1961) provided wave hindcast data of sea and swell. Data obtained by Neal et al. (1969) during the period September 1968 to August 1969 are shown in Table 3. Figure 4 shows wave data from Rogers (1966) obtained from an oil rig off the Oregon coast. Rogers reported seas with waves of 50 ft. (15 m) occurring under winds gusting up to 150 mph (67 m/sec). These do not represent average wave conditions during the severe

TABLE 1. DIMENSIONS AND PERIODS OF WAVES OBSERVED AT COLUMBIA RIVER LIGHT VESSEL (O'Brien, 1951).

Month	Percent of total observations exceeding figure specified								
	20			50			80		
	H_o	L_o	T	H_o	L_o	T	H_o	L_o	T
	ft	ft	sec	ft	ft	sec	ft	ft	sec
January	8.4	310	8.9	5.3	187	7.2	2.9	68	5.6
February	6.6	280	8.4	3.8	130	7.0	1.9	82	4.8
March	8.4	326	9.5	4.4	242	7.5	2.5	159	6.1
April	4.5	227	10.0	2.7	112	7.5	1.3	65	4.8
May	6.2	252	7.9	3.9	172	6.4	2.1	88	5.0
June	5.7	192	7.6	3.3	125	6.0	1.3	71	4.2
July	4.4	275	9.0	2.5	178	6.7	1.2	45	4.0
August	6.1	193	8.1	3.6	168	6.1	1.6	134	4.1
September	6.4	238	8.1	3.8	180	6.5	1.8	78	4.6
October	7.9	293	9.5	4.9	210	6.9	2.4	110	4.6
November	9.9	296	8.5	4.8	223	7.0	2.7	177	4.3
December	10.6	325	9.2	6.3	239	7.2	4.0	153	5.5

H_o = wave height L_o = wave length T = wave period between crests

TABLE 2. WAVE DIRECTIONS OBSERVED FROM COLUMBIA RIVER LIGHT VESSEL (O'Brien, 1951).

Direction	Percentage of total observations	Percentage weighted in proportion to H^2
N	0.73	0.57
NE	1.80	1.44
E	3.18	1.26
SE	2.38	3.30
S	15.02	25.14
SW	18.74	36.36
W	30.03	23.70
NW	16.57	8.24
Calm	11.54	---

TABLE 3. MONTHLY AVERAGE WAVE CONDITIONS AT NEWPORT, OREGON, SEPTEMBER 1968 TO AUGUST 1969 (Neal *et al.*, 1969).

Month	Sept. '68	Oct.	Nov.	Dec.	Jan. '69	Feb.	March	April	May	June	July	Aug.
Direction From	272°	276°	268°	277°	280°	271°	282°	283°	292°	297°	320°	324°
Period (sec)	11.4	9.7	12.5	11.5	10.5	11.8	12.3	11.3	11.6	9.3	9.8	7.4
H_o (feet)	6.8	7.5	7.0	10.4	9.0	8.3	8.3	8.4	6.1	5.2	6.6	4.5

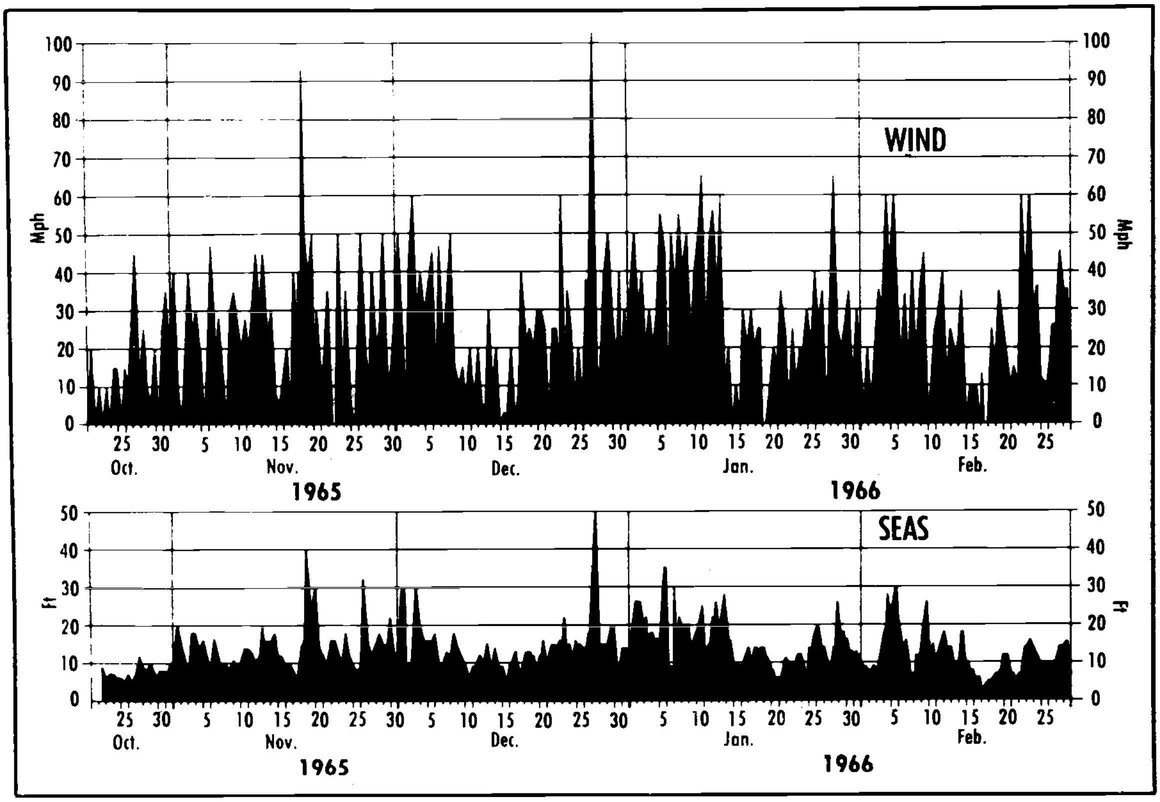


Figure 4. Wind and wave conditions recorded from an oil rig off the coast of Oregon (Rogers, 1966).

storms, but exceptional waves produced by the chance constructive interference of several large waves. Similarly, from observations from an oil rig, Watts and Faulkner (1968) reported waves up to 58 ft (18 m) with one 95 ft (29 m) wave generated by two separate storms.

In general the sea and swell arriving on the Oregon coast display a definite seasonal pattern in direction of approach and intensity. High waves approach from SW-W from November through March, tending to drift the beach sands to the north. In contrast, from April to September lower waves come from W-NW causing a southward transport. Sand moved to the north during winter wave conditions of five months is returned to the south during the remaining months of the year. Thus there is a seasonal reversal in the direction of littoral sand drift. As indicated above, the evidence indicates that the net transport over many seasons is approximately zero.

As part of an attempt to define the environmental conditions on the Oregon coast, this study has analyzed wave data collected from the seismic recording system at the Marine Science Center, Newport. This system is described by Quinn et al. (1974) and Bodvarsson (1975). This is the only source of daily wave data on the Oregon coast, measuring the significant wave period and significant wave height every six hours (4 times a day). This height is obtained from the seismic record and empirically refers to the wave height in 12 meters (40 feet) water depth. For wave periods less than about 12 seconds this water depth can be considered as "deep water." Since nearly all records obtained are for shorter periods, the significant wave height provided by the system is the deep water significant wave height. With this data the expected breaker heights were calculated using the equation of Komar and Gaughan (1973):

$$H_b = 0.39\, g^{1/5} \left(T H_{\infty}^2 \right)^{2/5} \qquad (1)$$

where H_b is the breaker height, T the wave period, and H_{∞} the deep water wave height provided by the seismic system. The four measurements for each day were averaged so that the analysis provided an average significant wave breaker height for each day. Such an analysis was performed for data obtained during the period November 1971 through January 1975. Figure 5 shows ten day averages, that is, averages for each one-third month, for this time span. It is seen that larger breaker heights prevail during the winter months, reaching a maximum of about 4.5 meters in this period. During the summer months of June through September the breaker heights average only a little over one meter. Also shown is a plot of the maximum average daily breaker height that occurred within the ten day averaging period. On several occasions during the winter months, daily average significant breaker heights were 6 to 7 meters.

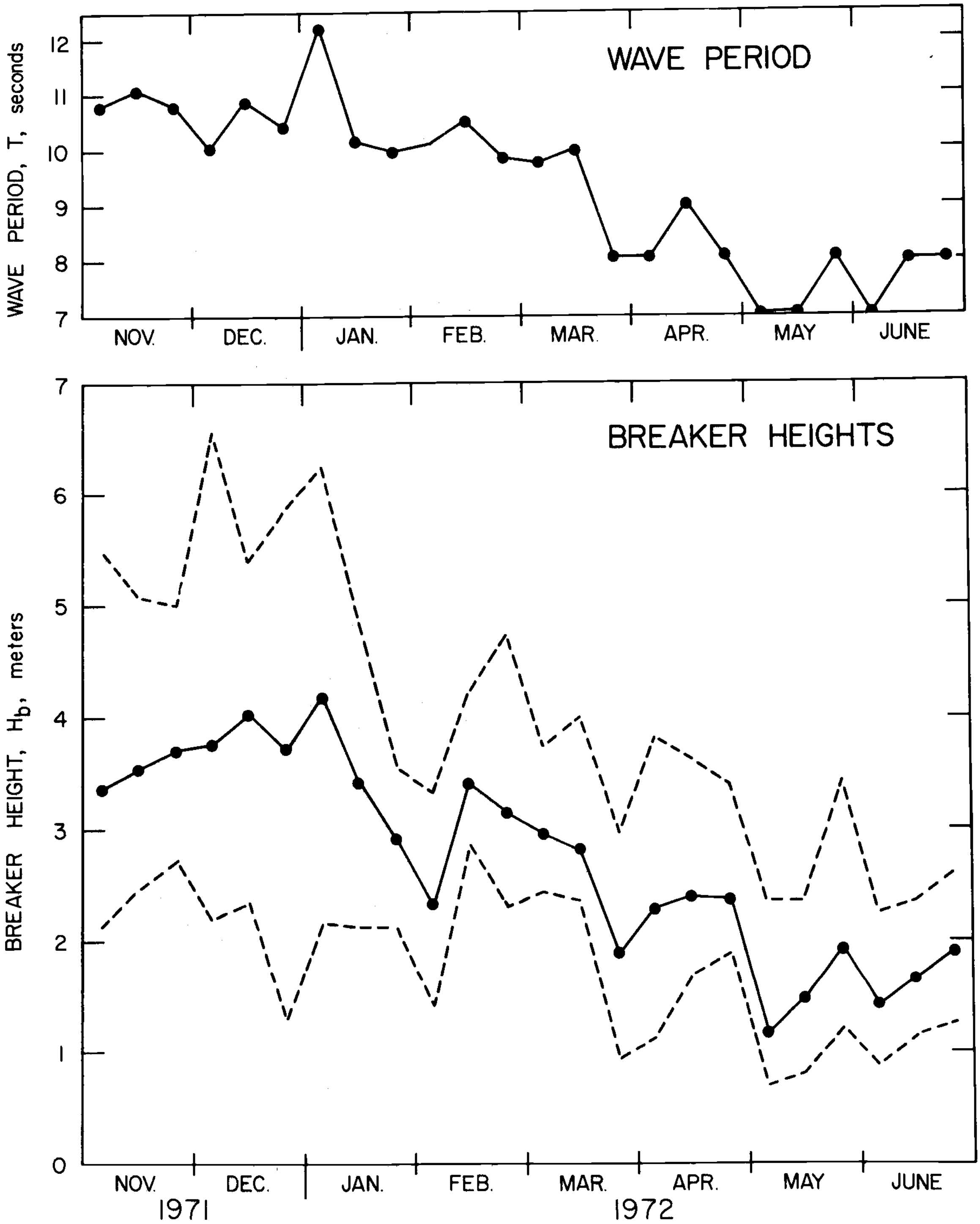


Figure 5A. Wave data from the seismic system at Newport, Oregon for November 1971 through June 1972. Each average H_b and wave period datum point represents a ten day average. Also shown are the maximum and minimum breaker heights that occurred within that ten day period.

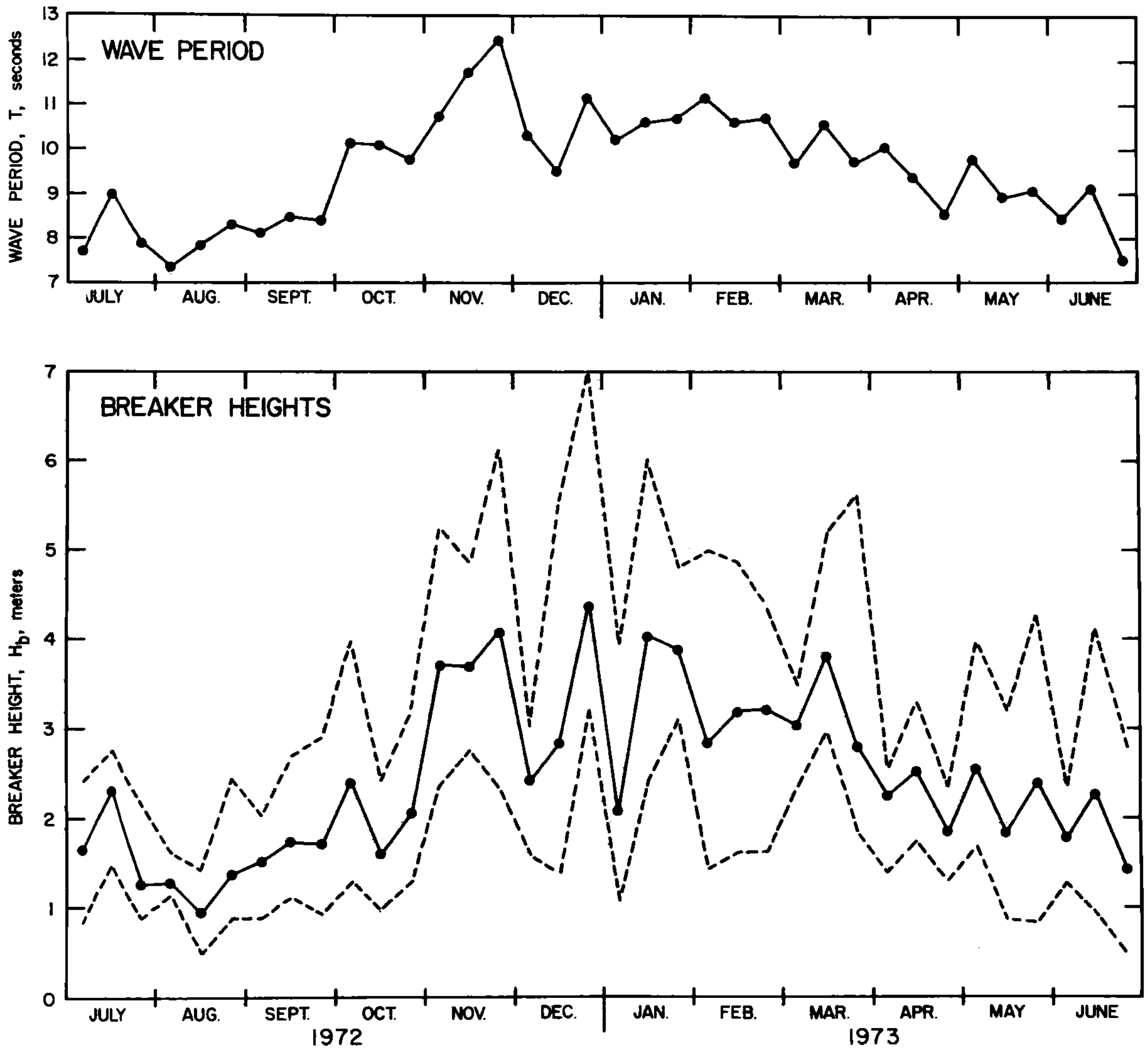


Figure 5B. Wave data from the seismic system at Newport, Oregon, for July 1972 through June 1973.

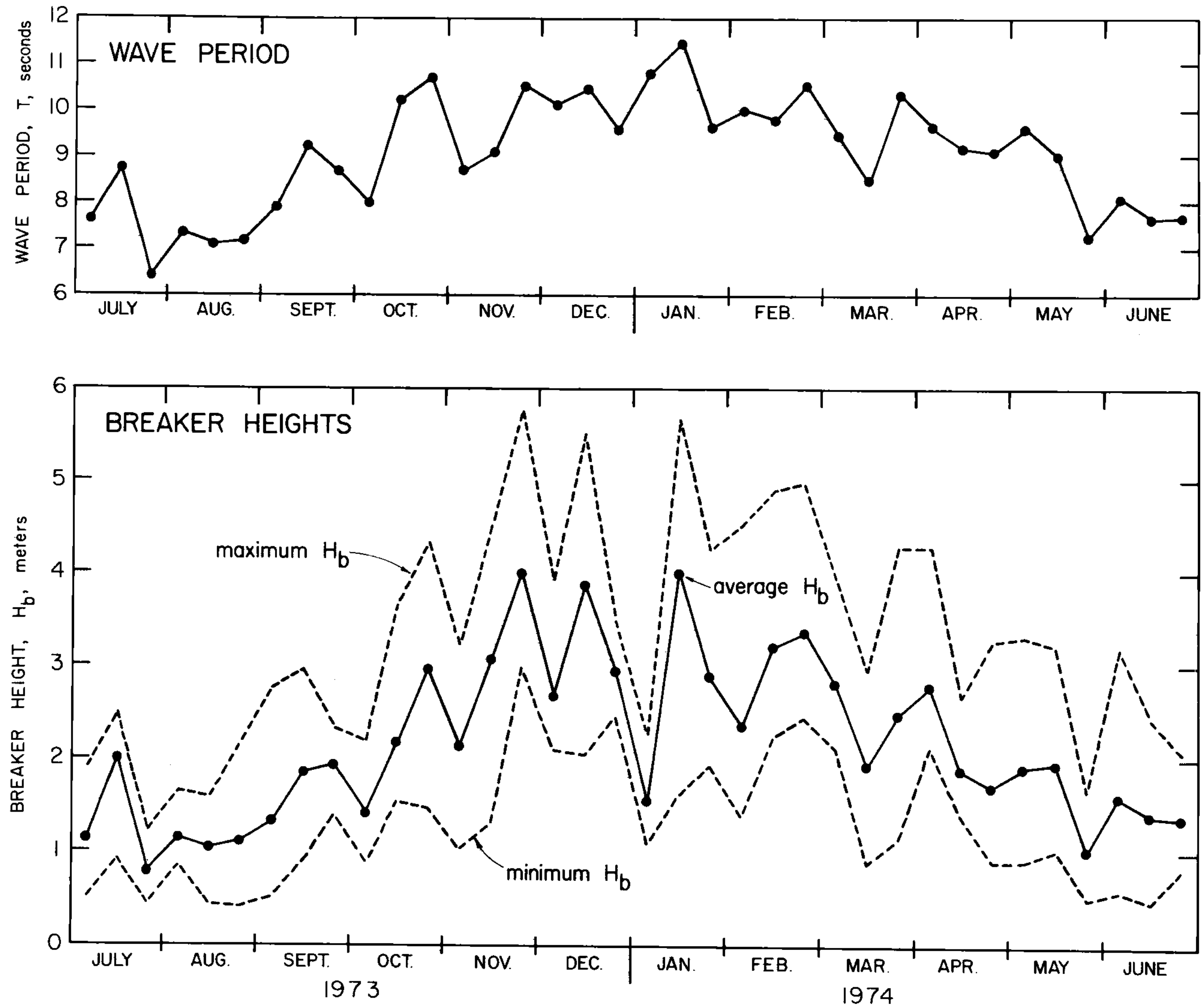


Figure 5C. Wave data from the seismic system at Newport, Oregon, for July 1973 through June 1974.

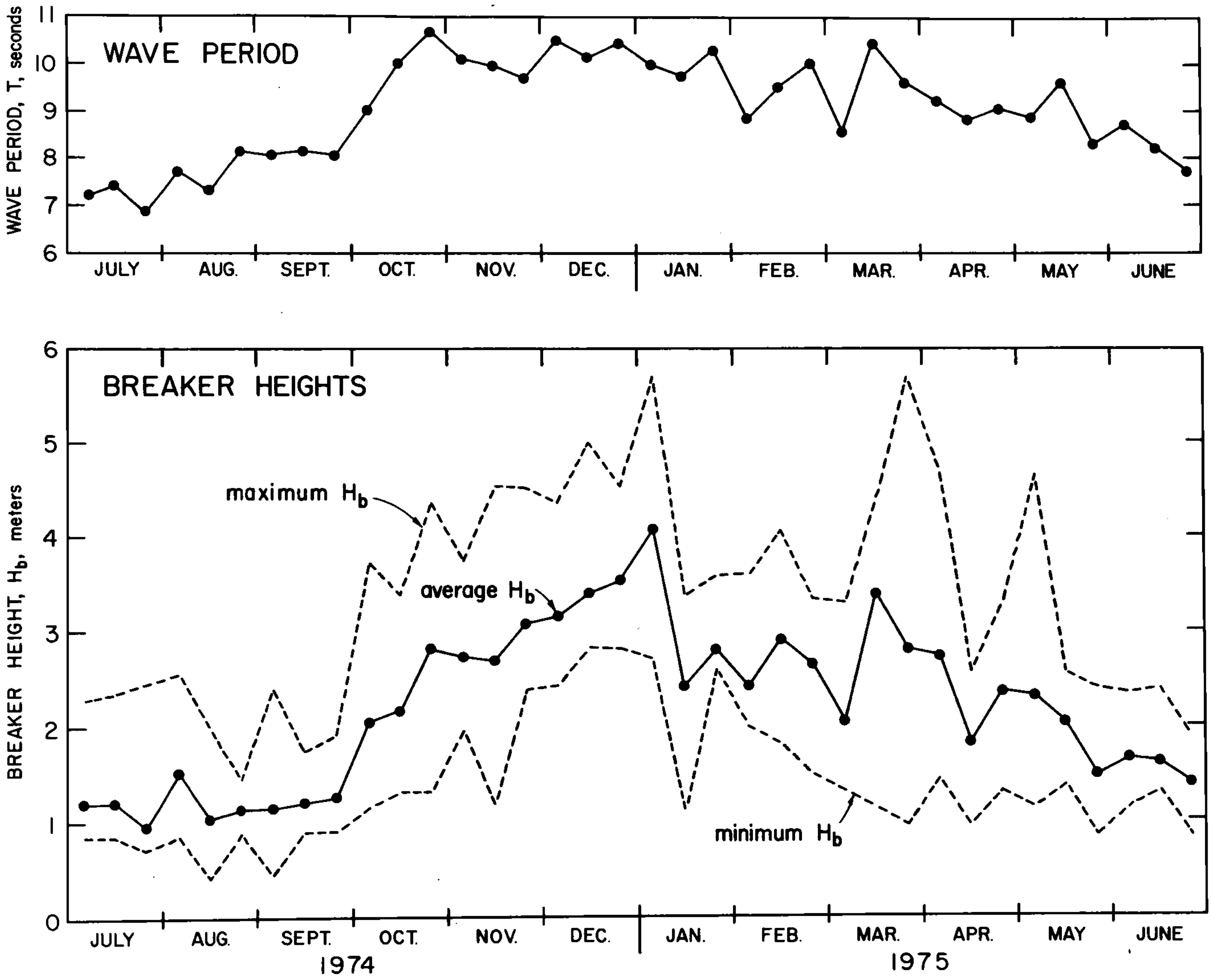


Figure 5D. Wave data from the seismic system at Newport, Oregon, for July 1974 through June 1975.

Oregon Coastal Winds

The wind regime along the Oregon coast is greatly influenced by the interaction of the North Pacific High pressure center and the Aleutian Low pressure center. Shifting positions of these centers throughout the year causes the wind to display a seasonal pattern (Bourke et al., 1971).

In summer the high pressure center lies at about 40°N and 150°W, causing the wind to blow from N-NW showing a high frequency of winds occurring at speeds of 4 mph or more; the highest average velocities also come from this quadrant (Table 4). During the winter months the high pressure center moves southward by about 10° and the Aleutian Low intensifies (Bourke et al., 1971). The prevailing wind direction is then from S-SW with predominance of winds greater than 4 mph but less than 16 mph (Cooper, 1958). Most of the winds over 16 mph come from the south in this season (Table 4). Winds during both seasons tend to follow the trend of the coastline due to the presence of the Coast Range and the Northern Klamath Mountains. Bourke et al. (1971) also presents a summary of the data on wind direction and speed, compiled from published and unpublished sources.

The seasonal reversal in the wind direction is responsible for the seasonal change in wave approach to the Oregon beaches, already

TABLE 4. FREQUENCY AND VELOCITY OF WINDS AT TWO STATIONS ON THE OREGON COAST (Cooper, 1958)

	Newport, Oregon Lat. 44°38' 1936-1942			North Bend, Oregon 43°25' 1937-1942		
	Frequency		Av. velocity	Frequency		Av. velocity
	4 m.p.h. and over	16 m.p.h. and over	m.p.h.	4 m.p.h. and over	16 m.p.h. and over	m.p.h.
			July			
N.	389	135	11.9	351	130	12.6
N.-N.E.	6	---	4.9	36	2	7.8
N.E.	2	---	2.5	37	---	5.2
E.-N.E.	2	---	3.0	2	---	3.3
E.	34	---	3.0	6	---	3.1
E.-S.E.	11	---	3.8	2	---	3.6
S.E.	35	1	3.6	52	---	4.5
S.-S.E.	9	---	5.4	20	---	5.3
S.	60	5	6.4	24	---	4.3
S.-S.W.	48	1	7.9	19	---	7.1
S.W.	117	---	6.2	39	---	5.7
W.-S.W.	34	---	6.7	19	---	7.5
W.	55	---	4.7	16	---	4.8
W.-N.W.	27	---	5.6	12	---	7.6
N.W.	160	15	7.9	330	70	10.1
N.-N.W.	212	60	12.6	172	45	11.3
			January			
N.	33	3	7.3	28	---	5.4
N.-N.E.	6	---	6.4	4	---	6.2
N.E.	17	---	5.7	52	1	6.1
E.-N.E.	97	---	7.2	5	---	6.0
E.	415	6	7.3	19	---	4.8
E.-S.E.	160	2	8.5	12	---	4.4
S.E.	235	2	6.7	614	5	7.2
S.-S.E.	25	4	10.5	149	2	7.3
S.	122	59	14.1	114	15	8.9
S.-S.W.	46	23	16.1	28	5	12.1
S.W.	75	20	11.2	93	23	11.2
W.-S.W.	28	10	13.1	7	1	9.9
W.	76	7	8.7	12	1	7.2
W.-N.W.	17	1	8.1	3	---	5.8
N.W.	32	5	9.5	66	9	8.9
N.-N.W.	6	---	9.7	11	---	5.3

discussed. In addition, the winds are locally important in eroding sand from the beach and carrying it inland to form dunes (Cooper, 1958; O'Brien and Rindlaub, 1936). Strong onshore winds may pile water on the shore to give a local rise of sea level (Patullo et al., 1955) such that waves are better able to reach the sea cliffs and cause erosion.

Oregon Coast Tides

Mixed tides occur on the Oregon coast in which there are two high tides and two low tides per day with inequalities in the heights of successive tides. During one part of the month there is a tendency for the diurnal tides to prevail with the second tide of the day a mere dimple on the water level cycle. At another time in the same month the tides are essentially semidiurnal with two tides a day of nearly equal height. The tide range varies from +10 ft (3 m) to -2 ft (0.6 m) and averages about 7 ft (2.1 m) above mean lower low water (Dicken, 1961). In the context of this study, tides are important in that their flow in and out of estuaries and bays acts to help maintain the opening to the ocean. The well known studies of O'Brien (1931, 1969) relate the equilibrium self-maintaining entrance area to the volume of the tidal prism of the bay or estuary. Johnson (1972) has specifically examined this relationship for the Oregon coast entrances.

Hydrology

There is a strong seasonality of rainfall in Oregon, and this is reflected in the river discharge. Figure 6 gives the mean monthly discharge of the Siuslaw River, one of the major rivers on the Oregon coast, the largest on the mid-coast. The discharge is given for the Mapleton gage which is at mile 23.7 on the river. The Austa gage station, near the headwater of one of the tributaries to the river, is included as it is above any dams. Data for other rivers on the Oregon coast are given in Table 5. All the rivers show highest runoffs in the months of November through April, which are also the highest precipitation months. This period contributes about 80 percent of the average annual water yield with 50 percent of the annual yield occurring in December through February. The lowest yields occur during July through September, which contributes only about 3 percent of the average annual yield.

The exception to this pattern of river discharge is the Columbia River which drains some 671,000 km^2, being the third largest river in discharge within the United States (Highsmith, 1962). The Columbia shows an annual biomodal discharge (Table 5), resulting from heavy precipitation west of the Cascade Range in autumn and winter and a snowmelt giving a peak in June.

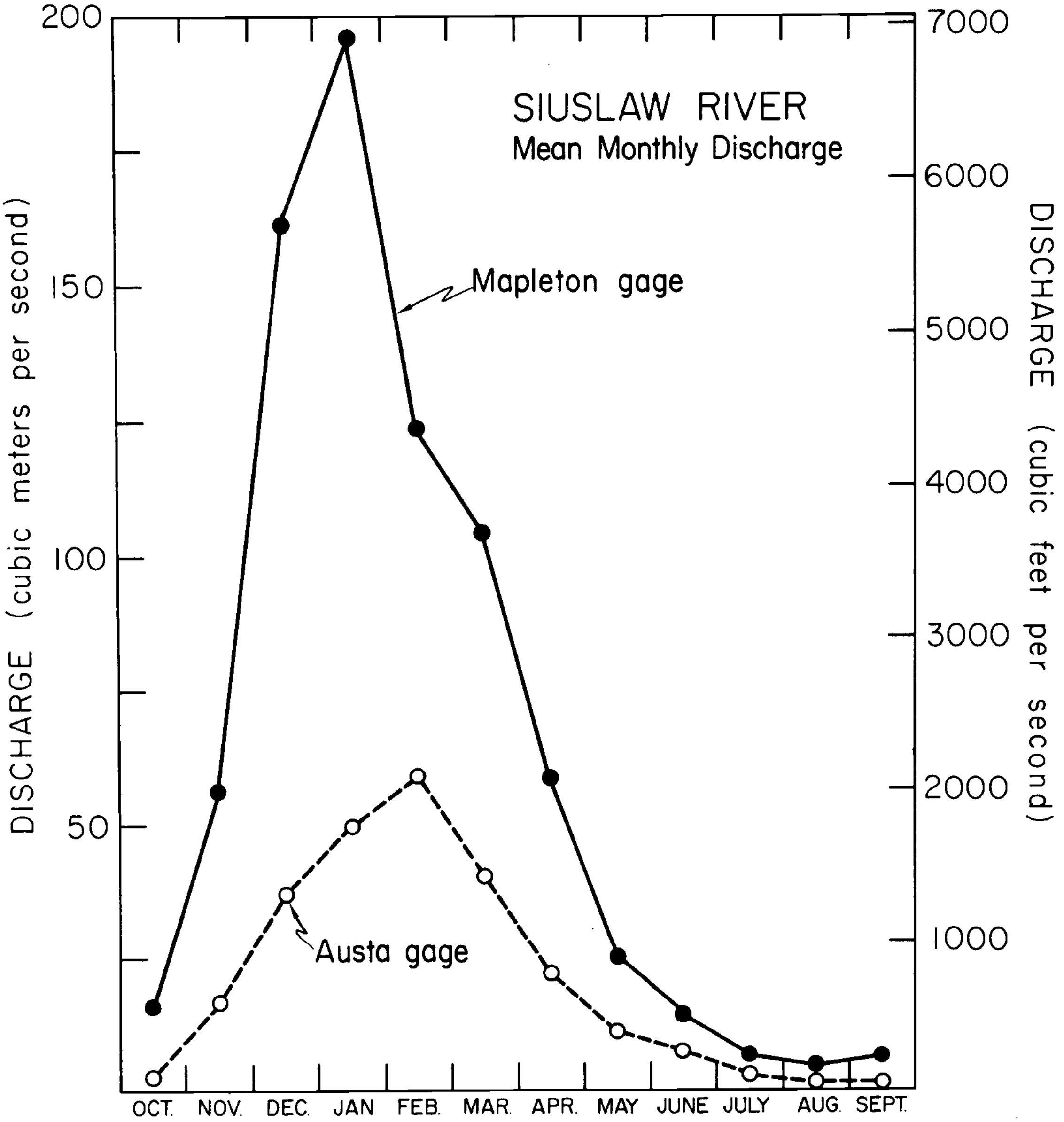


Figure 6. Mean monthly discharges of the Siuslaw River at two stations, the Mapleton gage near the estuary, and the Austa gage in the headwater. Data from USGS Water Supply Papers.

TABLE 5. RIVER DISCHARGES, m^3/sec (data from U.S.G.S. Water Supply Papers)

River	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Period
Columbia	7748	7533	6768	7901	11045	15236	9572	5040	3709	3965	5437	6967	1953-67
Nehalem	31.9	131.2	120.8	51.9	29.9	14.3	6.5	4.4	5.1	20.9	112.9	190.0	1964-73
Tillamook Bay													
Wilson	113.5	53.2	45.2	24.4	15.0	8.3	4.4	3.9	3.7	14.6	61.2	88.4	1964-73
Trask	95.9	42.5	39.5	20.4	13.1	7.7	4.1	3.1	3.1	9.5	43.3	60.2	1964-72
Siletz	150.2	59.1	56.1	30.4	17.1	10.6	5.6	4.7	4.4	14.5	71.1	118.1	1964-73
Alsea	169.0	67.1	63.1	29.7	16.2	8.9	4.7	3.3	3.0	7.2	51.5	128.0	1964-73
Siuslaw	195.4	124.0	104.6	58.7	25.2	14.2	6.5	4.4	6.3	15.8	56.2	161.3	1937-73
Umpqua	797.8	332.3	331.1	227.3	157.5	106.6	48.3	36.5	33.7	42.3	209.0	711.5	1964-73
Coquille													
S. Fork	81.4	31.1	33.4	23.1	10.4	3.6	1.6	0.94	0.90	2.7	34.9	81.8	1964-73
N. Fork	31.7	11.9	12.1	6.5	3.4	1.4	0.6	0.3	0.4	1.0	14.7	26.6	1964-73
Sixes	67.9	47.4	19.8	8.9	5.7	3.0	1.2	1.2	1.6	7.5	20.4	64.7	1968-70
Elk	61.3	43.6	21.8	10.8	8.4	5.0	2.3	2.6	3.1	8.0	19.8	51.9	1968-70
Rogue													
Agness	632.2	285.1	251.0	205.1	151.4	105.9	51.9	40.8	39.7	47.8	139.5	573.7	1964-73
Illinois	437.0	173.9	151.5	122.4	57.2	34.7	10.5	6.8	5.9	12.8	146.3	394.0	1964-73
Chetco	247.9	96.2	135.0	6.28	24.6	10.2	5.2	3.0	5.2	11.5	95.5	172.3	1970-73

CHAPTER III

JETTY CONSTRUCTION AND THE RESULTING BEACH CHANGES

As stated in the Introduction, the principal purpose of this study is to examine shoreline changes resulting from jetty construction in an area of zero net littoral sand drift. Such conditions have been shown to prevail along the Oregon coast except immediately south of the Columbia River.

The study of Terich and Komar (1973, 1974) of the jetties at the entrance to Tillamook Bay led to the conclusion that the severe erosion to Bayocean Spit resulted not from the blockage of a net littoral drift but a rearrangement of the shoreline configuration locally within an area that still maintains a zero net drift on a larger scale. Because this case of jetty construction caused the largest shoreline changes, it will be examined first. The other jetty systems demonstrate the same effects but to smaller degrees. They will be examined in order of decreasing enlightenment as to the responses of the shoreline to jetty construction.

Tillamook Bay Jetties

The one severe case of erosion on the Oregon coast due to jetty construction is that of Bayocean Spit, separating Tillamook Bay from the Pacific Ocean. The erosion of this spit has been investigated by Terich and Komar (1973, 1974). Additional data have been obtained for the present study on the response of the coastline to the recent completion of a new south jetty at the bay entrance.

As is seen in Figure 7, upon completion of a north jetty in 1917 the shoreline north of the jetty advanced seaward. Simultaneously but not as apparent, a shoal developed south of the north jetty tending to close the mouth of the bay and causing some shoreline advance to the immediate south of the jetty and bay entrance. Further to the south along the remainder of Bayocean Spit severe erosion occurred. This erosion particularly accelerated in about 1932-33 when the north jetty was extended and repaired. The overall pattern of erosion and beach deposition is shown in Figure 8. The conclusion of Terich and Komar was that the jetty was constructed across a seasonally reversing littoral sand transport along the beach, but with a zero or near-zero net transport. The jetty construction forms an embayment with the pre-jetty shoreline which curves inward toward the bay entrance. This embayment is out of equilibrium with the wave conditions as the waves strike the curved shoreline at pronounced angles transporting sand toward the jetty. Previous to jetty construction, this transport by the waves toward the bay mouth must have been offset by tidal and river flow moving sand away from the mouth so that the curved shoreline was in near equilibrium. This readjustment of the shoreline to

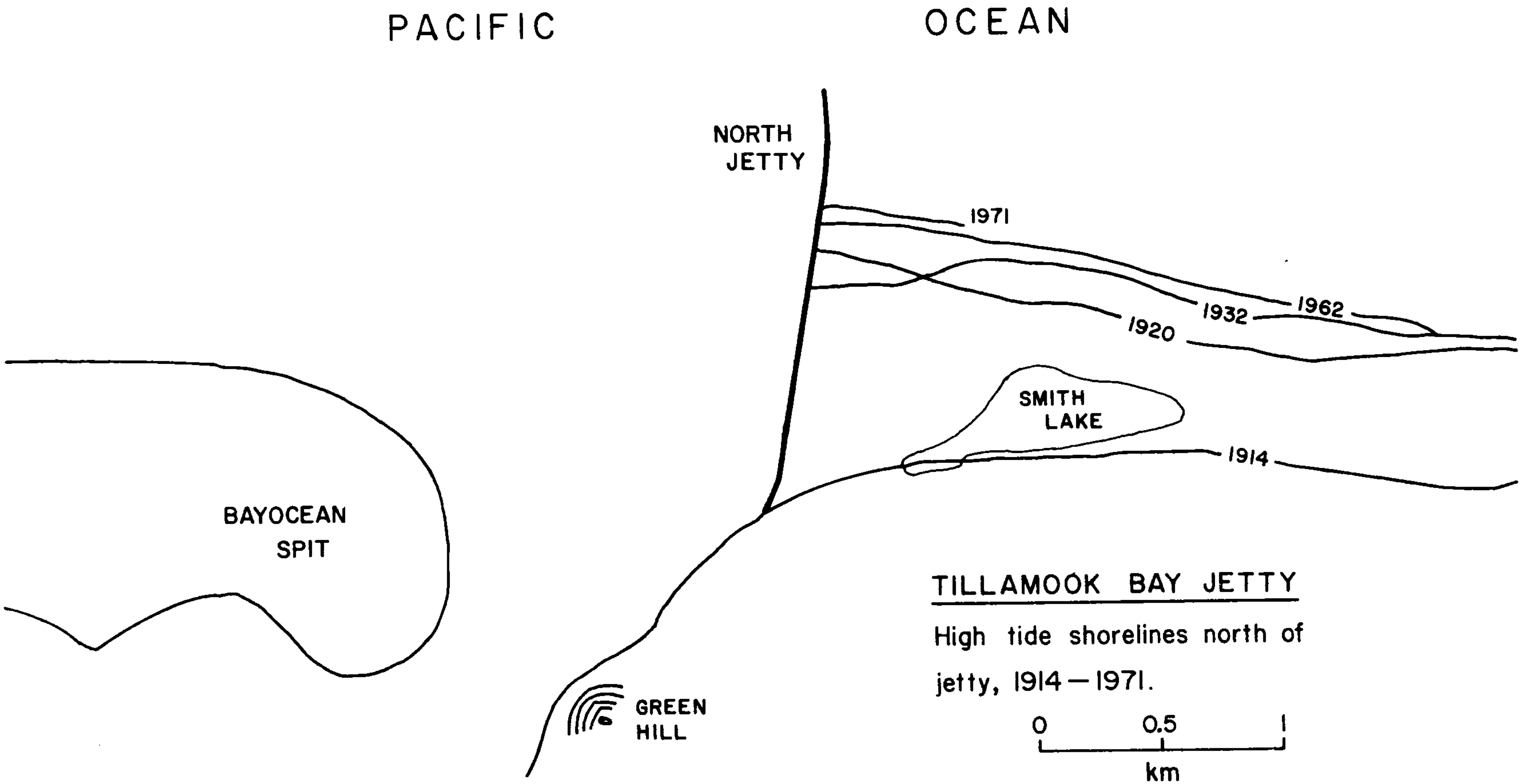


Figure 7. Shoreline advance north of the north jetty at the entrance to Tillamook Bay, resulting from jetty construction (from Terich and Komar, 1974).

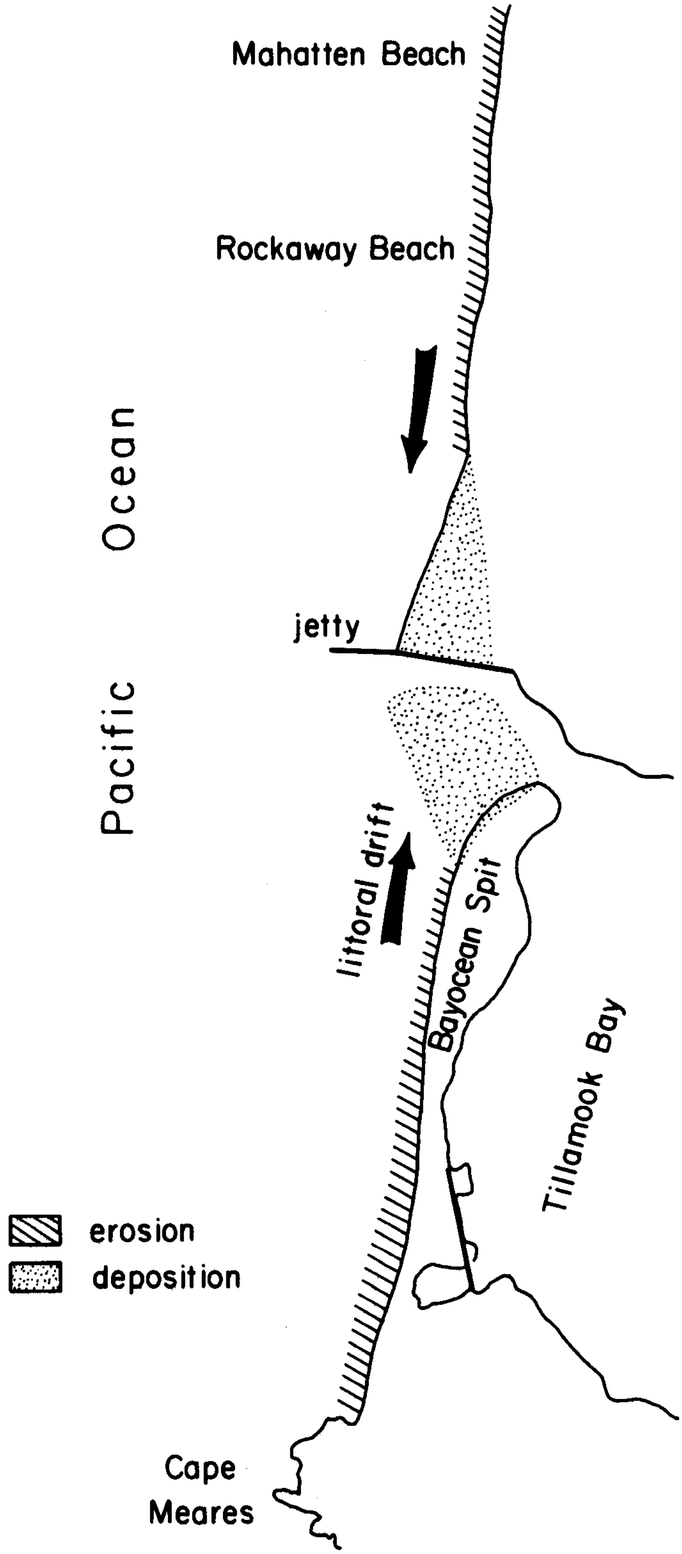


Figure 8. Pattern of deposition and erosion resulting from the construction of the north jetty at the entrance to Tillamook Bay (from Terich and Komar, 1974).

fill an embayment is better shown by the Siuslaw jetties which will be examined next. Later in this study a computer simulation model will be developed which will further illustrate the process.

The deposition of sand near the jetties must be derived from somewhere, and Terich and Komar (1973, 1974) concluded that it came from beach erosion at greater distances from the jetty. To the north of the Tillamook jetty there is a long stretch of beach (some 19 km) so that each unit length of beach had to supply only a small quantity of sand. Therefore, erosion to the north was negligible. In contrast, to the south there is only a short stretch of beach along the length of Bayocean Spit (7.5 km) between the jetty and Cape Meares (Figure 8). Therefore an appreciable quantity of sand had to be eroded from each unit of shoreline to provide sand to the shoal that formed south of the north jetty. This erosion along Bayocean Spit eventually led to the breaching of the spit in 1952 along its narrow mid-section. The breach was subsequently repaired by construction of a dike.

This pattern of erosion and deposition has been confirmed by the construction of the new south jetty, completed in September 1974. As is seen in Figure 9, sand has been trapped south of the jetty and the shoreline has advanced seaward. This sand comes from continued erosion to Bayocean Spit.

Terich and Komar (1973, 1974) concluded that the significance of the erosion at Bayocean Spit due to jetty construction is that it

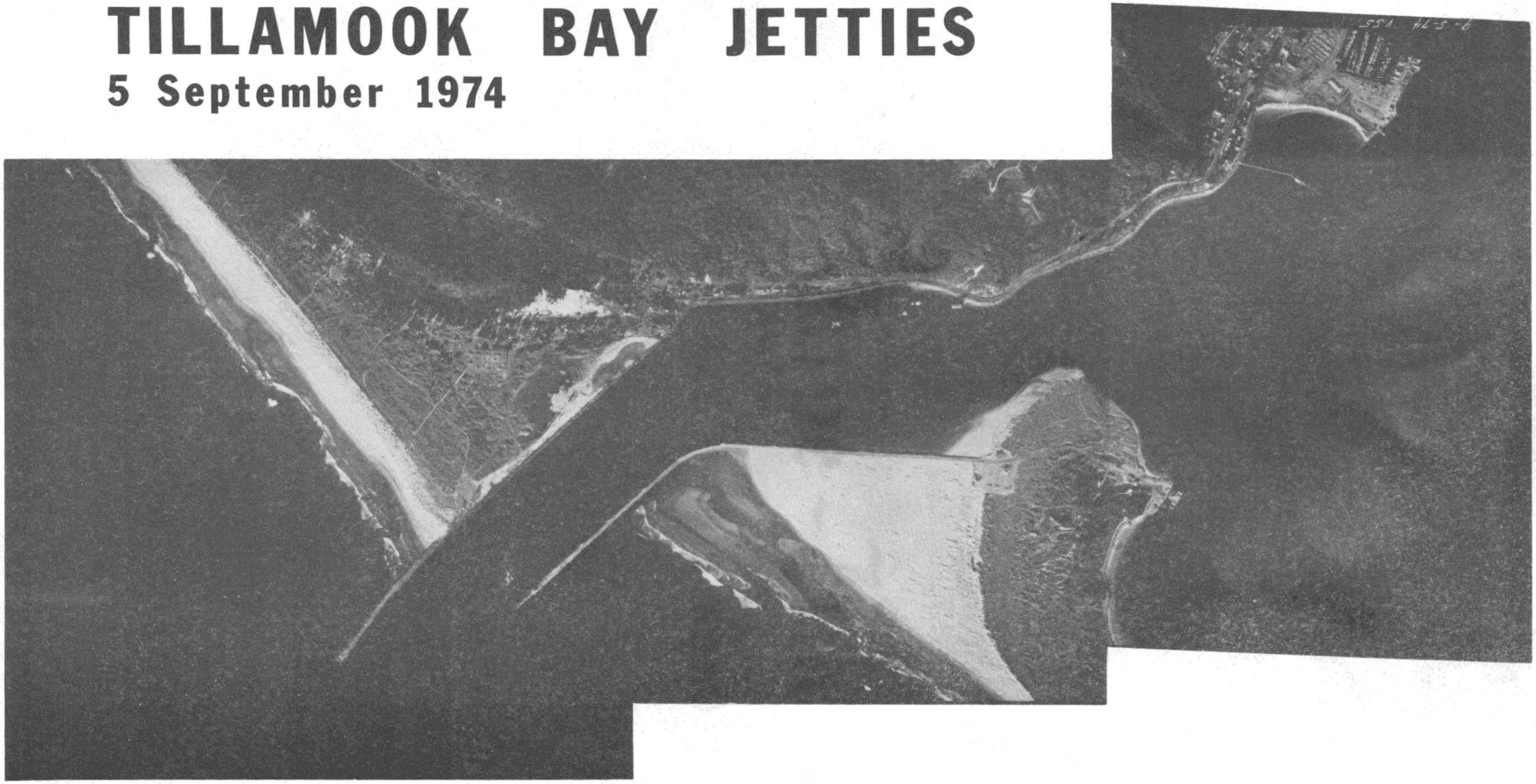


Figure 9. Aerial photo mosaic of jetties at Tillamook Bay showing sand accumulation south of the new south jetty.

demonstrates that severe erosion can occur even though the overall pattern is one of zero net sand transport. Jetty construction can still cause local accretion adjacent to the jetties. This sand comes from beach erosion further from the jetty, and if a headland is nearby the amount of erosion to a unit length of beach may be appreciable.

Siuslaw River Jetties

Construction of jetties on the Siuslaw River produced a large embayment with the pre-jetty shoreline to the north side of the entrance. There resulted pronounced changes in the shoreline position following jetty construction. Figure 10 includes a compilation of high tide shorelines through time, obtained from surveys made by the U. S. Army Corps of Engineers. The 1889 shoreline is given as the pre-jetty position. Actually, prior to jetty construction the river mouth migrated considerably north and south so that selecting a pre-jetty configuration is somewhat subjective. Figure 11 shows a survey when the river mouth extended far to the north in 1891. Evidence for that channel position can still be seen, Figure 12, as a low close to the old bluff, the low being occupied by a small pond.

The compilation of shorelines in Figure 10 demonstrates progressive accretion both north and south of the jetties. South of the jetties some reversals are indicated. The 1916 shoreline to the south is seen to be especially anomalous. Differences such as between 1914

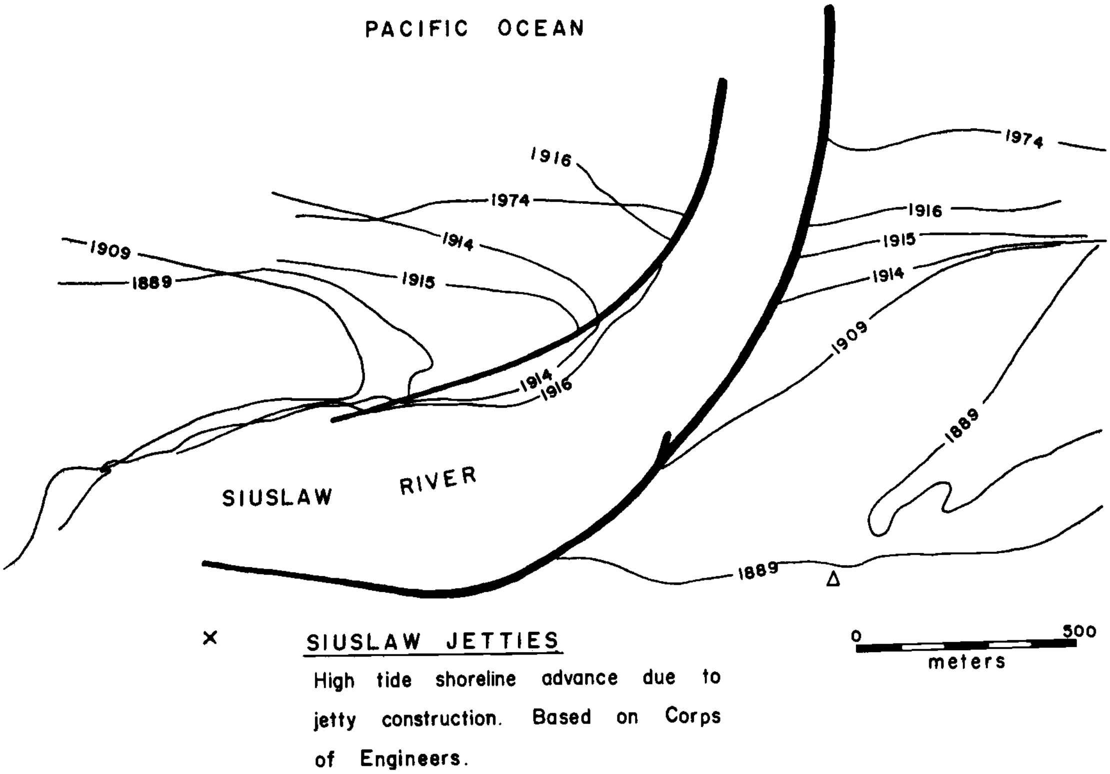


Figure 10. Compilation of shoreline changes resulting from jetty construction at the mouth of the Siuslaw River, obtained from surveys and 1974 aerial photographs. The 1889 shoreline pre-dates jetty construction.

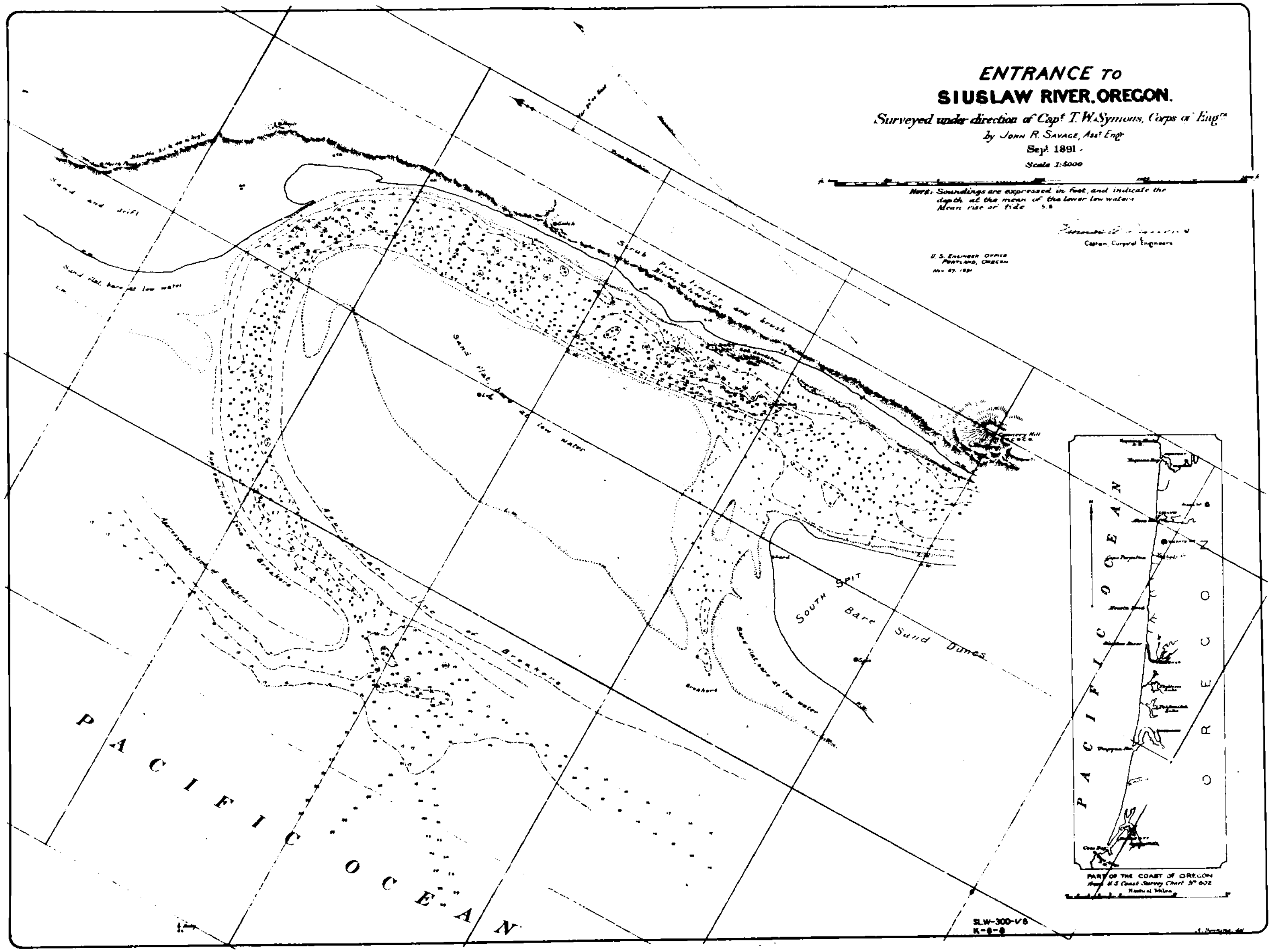


Figure 11. Survey of Siuslaw River entrance in September, 1891.

SIUSLAW RIVER JETTIES
20 January 1975

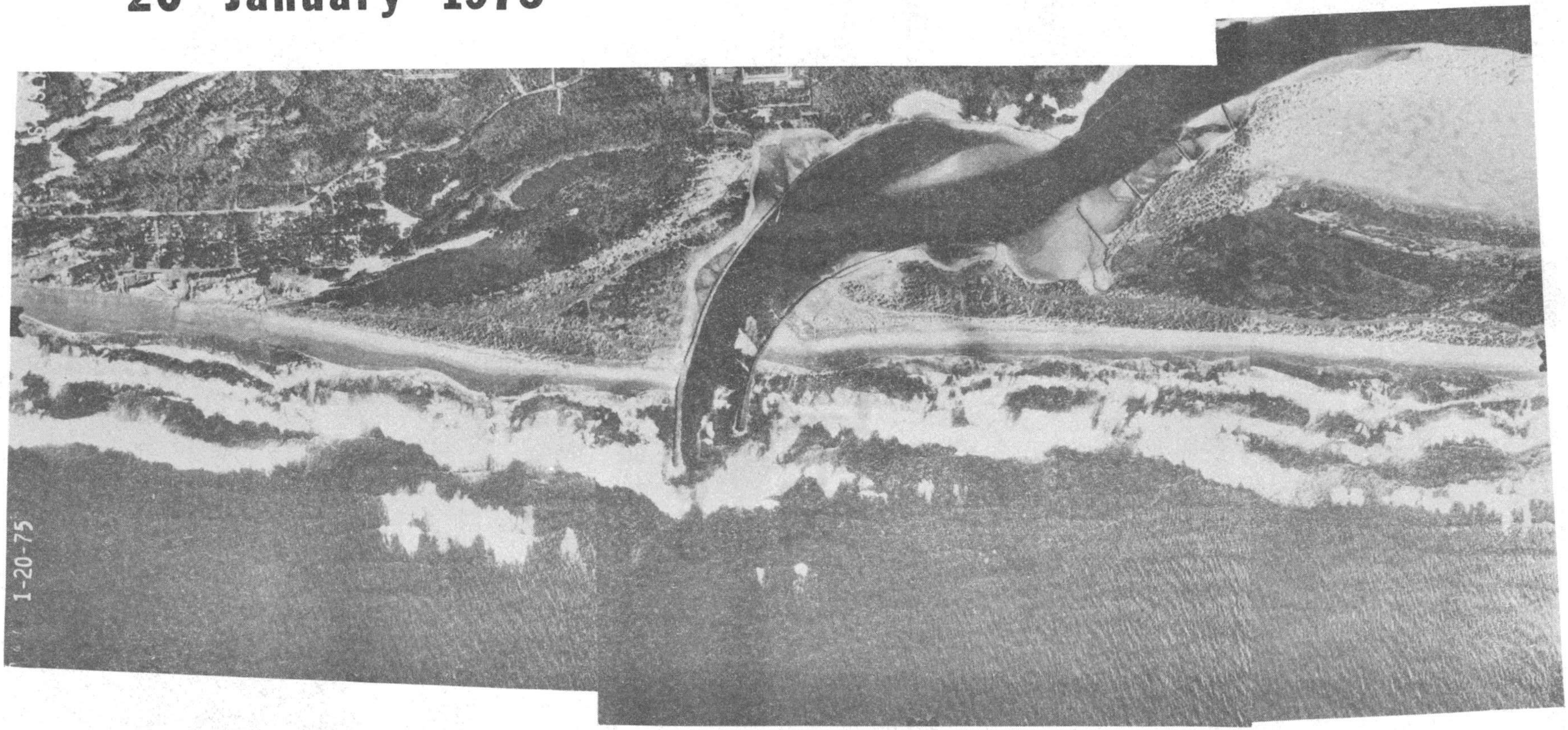


Figure 12. Aerial photo mosaic of Siuslaw River jetties.

and 1915 may in part be due to seasonal changes in the shoreline position, but the 1916 position must certainly be in error. In addition, the 1909, 1914, and 1916 shoreline directions indicate shoreline trends that are directly out to sea. Note the contrast with the present (1974) shoreline. Thus there appears to be considerable error in the locations and trends of the shorelines to the south of the jetties. On the other hand, the shorelines to the north appear to be fairly reasonable. Through a comparison with recent aerial photographs, some of the old shorelines can be identified with ridges and other features.

Figure 13 shows the areas of land advance due to the jetty construction on the Siuslaw River, 1889 being taken as the pre-jetty shoreline and the 1974 aerial photographs giving the present shoreline. The surveys apparently do not cover the entire areas of land accumulation, but approximately 2.8×10^5 m^2 of new land formed south of the jetties, and 6.3×10^5 m^2 to the north. Using a thickness of fill on the average of about 6 meters, including the thickness of dunes as well as fill below sea level, 1.7×10^6 cubic meters of sand accumulated to the south and 3.8×10^6 cubic meters to the north of the jetties. This greater accumulation to the north of the jetties might at first impression be taken to indicate a prevailing littoral sand drift from north to south. However, the larger quantity of sand accumulation to the north resulted from the jetty construction leaving a larger area to be filled before the shoreline was straightened into an

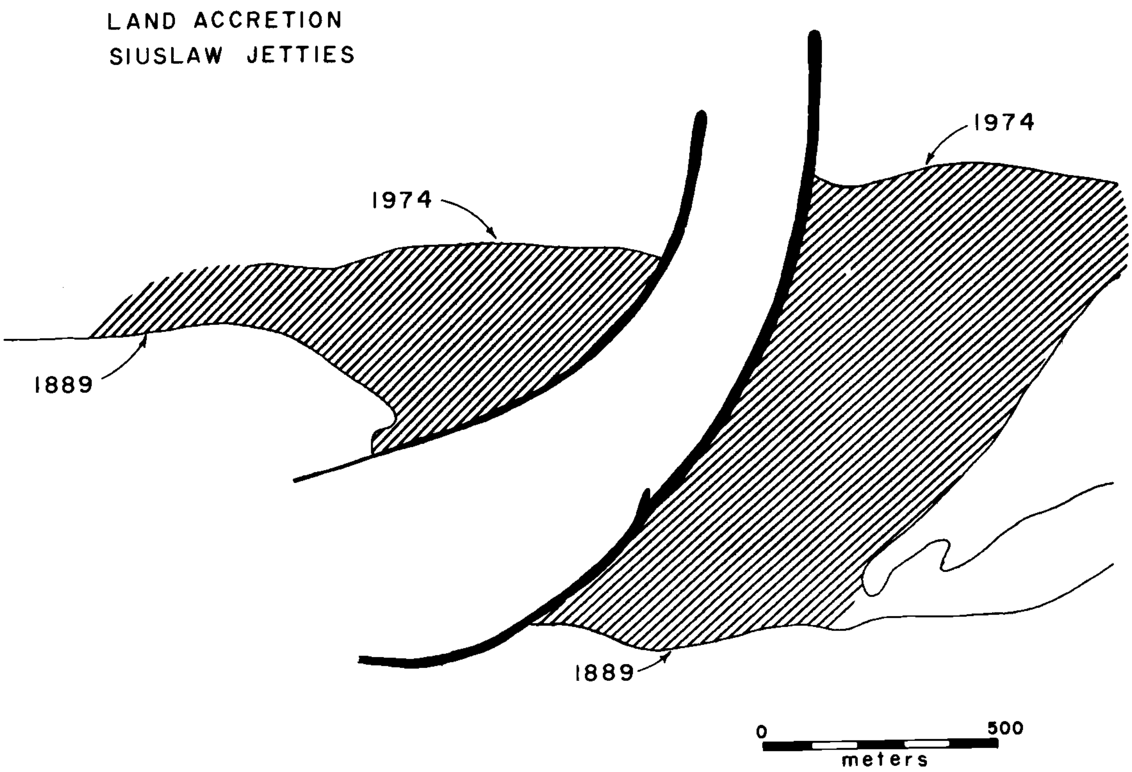


Figure 13. Areas of land accretion north and south of the Siuslaw River jetties, resulting from their construction.

equilibrium configuration where the net transport is again nearly zero over the long term. Comparisons with aerial photographs dating 1939, 1957, and 1963 indicate that little or no change in the shoreline position or configuration has occurred in the past 36 years.

The conclusion is that the shoreline changes produced by jetty construction on the Siuslaw River entrance were, like those at the entrance to Tillamook Bay, due to local readjustments with accretion near the jetties and erosion at greater distances north and south of the jetties. Again, on a larger scale the net transport in the area is concluded to be zero. This will be further demonstrated later in this study when a computer model is developed that simulates the changes which occurred north of the Siuslaw jetties (Figure 36). Erosion further to the north of the jetties was probably appreciable as only a 9.7 km stretch of beach exists between the jetties and Heceta Head. Evidence for this is the truncation of old dunes by the modern shoreline trend. At the time of jetty construction no homes or other habitations existed along that stretch of coast so that the erosion is not recorded by its destructive effects. Unlike Bayocean Spit, the erosion did not produce the breaching of a sand spit and so the erosion went unnoticed. To the south of the Siuslaw jetties exists a long stretch of beach, 87 km distant to Cape Arago. Therefore, erosion in that direction would not have been significant.

Yaquina Bay Jetties

Jetty construction at the entrance to Yaquina Bay also caused a shoreline advance. Figure 14 shows the high tide shorelines prior to jetty construction (1830) and following construction. A large quantity of sand accumulated to the south of the jetties and the shoreline showed an appreciable advance. In contrast, there was almost no accumulation to the north. As at the Siuslaw River jetties, the reason for this difference in accumulations is due to the orientation of the jetties and the areas left to either side of the jetties to be filled before the shoreline is straightened into a new equilibrium configuration. The Yaquina Bay jetties extend outward to the southwest at an oblique angle to the trend of the coastline. Such a jetty orientation provides a large area to the south that is partially sheltered from wave attack and only a small area to the north that need be filled to straighten the shoreline. Sand transported to the north under waves arriving from the southwest would be blocked by the jetties and accumulate south of the jetties. When waves arrive from the northwest this oblique jetty orientation would provide a large protected area to the south where only weakened diffracted waves could reach the shoreline. These weakened waves are therefore not able to remove this accumulated sand and transport it back to the south. In contrast, to the north of the jetties little or no protection is given to the beach by the jetties from waves arriving

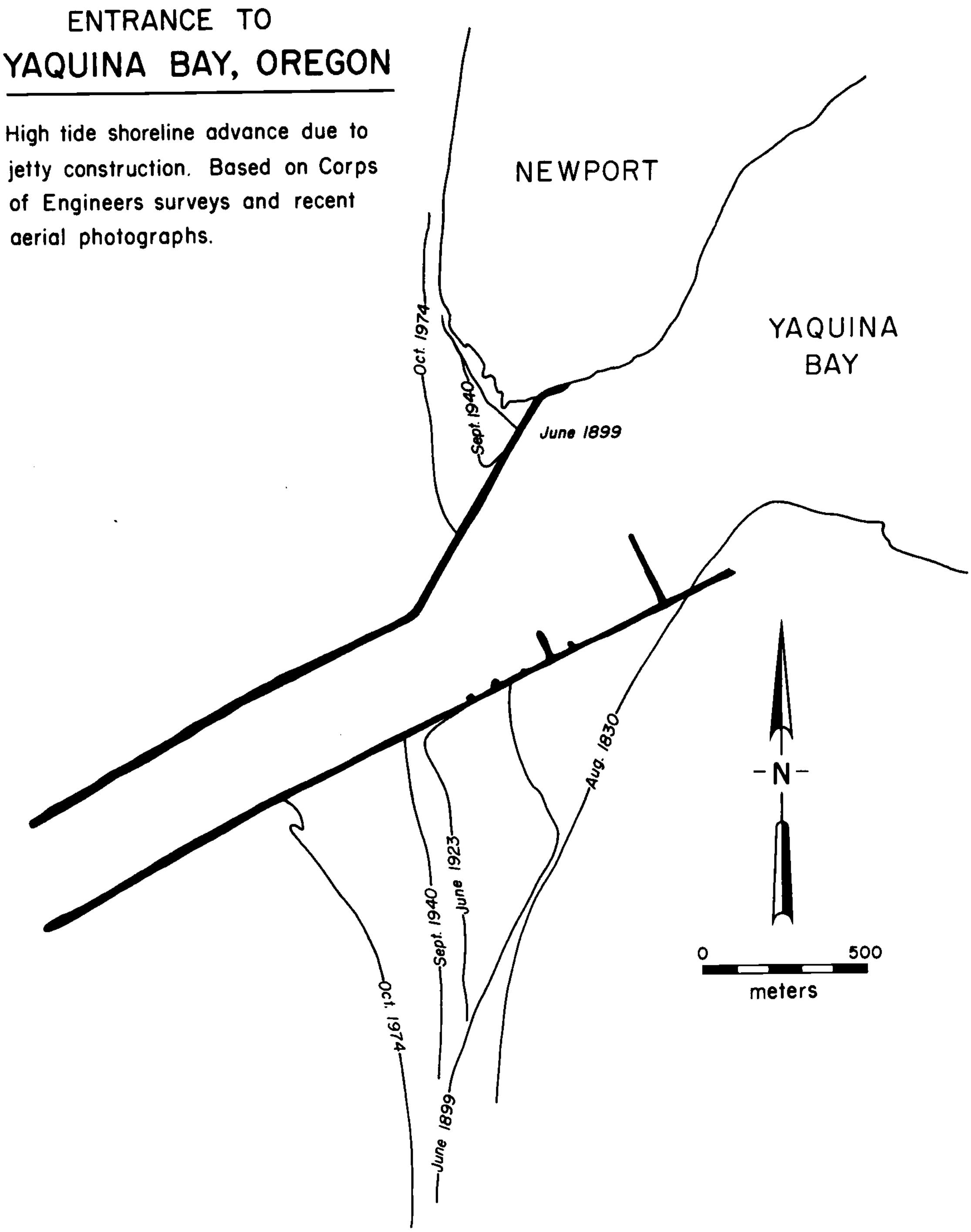


Figure 14. Compilation of shorelines at the Yaquina Bay jetties from surveys of the Corps of Engineers, Portland District. Aug. 1830 shows pre-jetty shoreline.

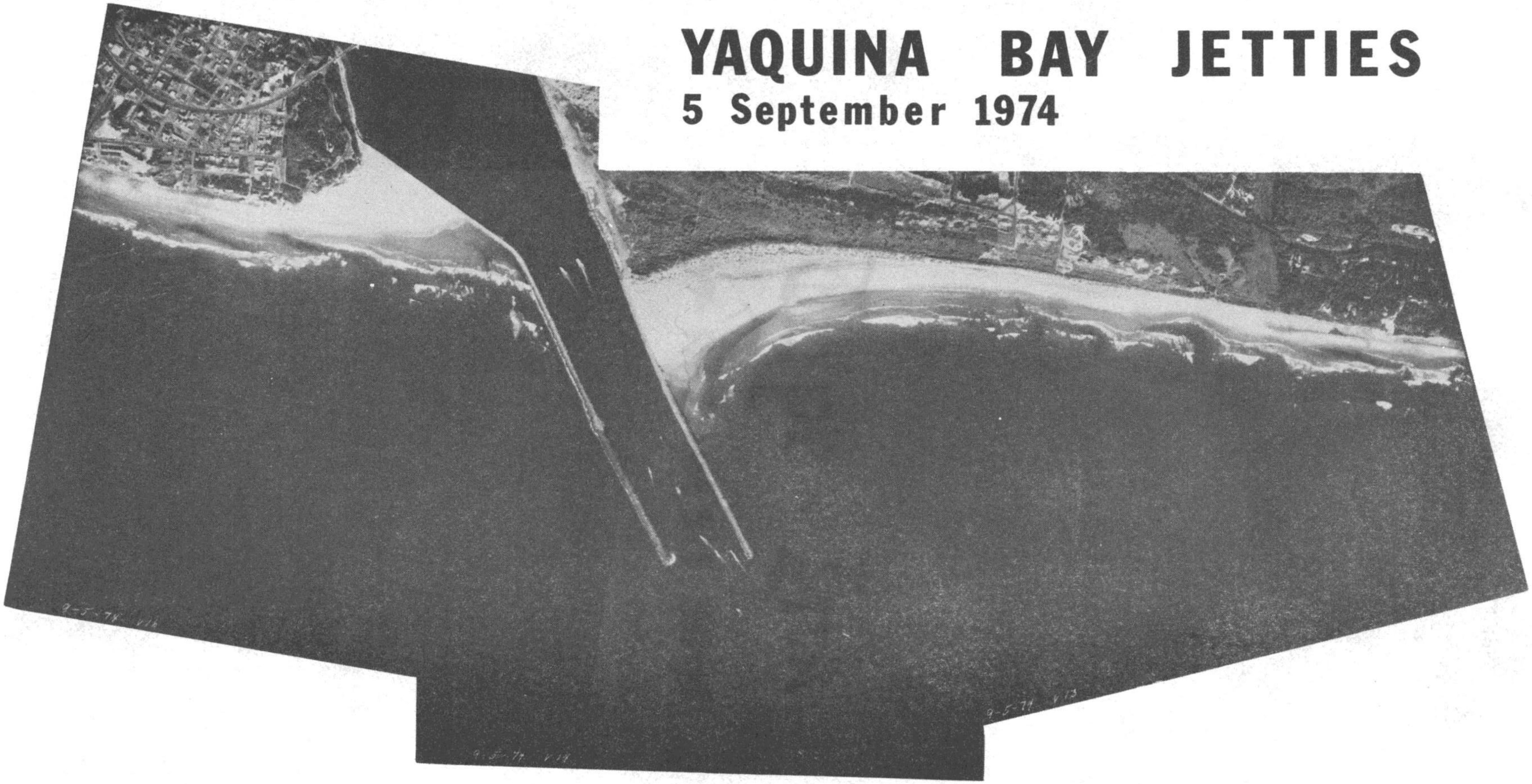


Figure 15. Aerial photo mosaic of jetties at the entrance to Yaquina Bay.

from the southwest. Sand that may accumulate north of the jetties during waves from the northwest is thus moved back to the north under the southwest waves. Only a minor trapment of sand occurs to the north in order to straighten the beach. In this way sand is permanently trapped to the south of the Yaquina Bay jetties but little is trapped to the north.

It is seen in Figure 14 that there was a significant shoreline advance between September 1940 and October 1974. This resulted from extension of the jetties during the interval. Some of this indicated accumulation may be due to the jetty extension and part may be due to seasonal shifts in the berm extent and to tide level. An attempt was made to eliminate the tide level effect by using the berm edge rather than the water's edge in defining the 1974 shoreline from aerial photographs. This is difficult, however, so some error may be introduced. Since the September 1940 and October 1974 shoreline positions are essentially at the same time of year, there should not be too much error introduced by seasonal shifts in the shoreline position between the winter storm months and the summer low wave conditions. In spite of all this uncertainty in the shoreline positions to be compared between 1940 and 1974, it appears that we can conclude that some accumulation has taken place in response to the extension of the Yaquina Bay jetties. This is estimated to be on the order of 1.5×10^6 cubic meters south of the jetties with only negligible accumulation to the north. The difference north and south of the jetties again reflects the fact that the jetty extension produced a greater incremented area of protection south of the jetty than to the north.

The effects on the shoreline due to jetty construction and extension at the mouth of Yaquina Bay demonstrate that shoreline advancement may result from local protection from the waves produced by the construction. The accumulation was only in part due to a straightening of the shoreline as found at the Tillamook Bay and Siuslaw River jetties. The oblique orientation of the Yaquina Bay jetties enhanced this protection effect. Again the changes can be explained in terms of local accretion within an area that is otherwise experiencing a zero net sand transport. The large accumulation to the south of the jetties and negligible changes to the north therefore do not reflect a net south to north transport along the beach.

Umpqua River Jetties

Shoreline changes due to the construction of jetties at the mouth of the Umpqua River were much the same as those at the other sites already discussed. Figure 16 shows the shoreline advancement north of the north jetty, which was the first jetty constructed. The 1903 and 1916 surveys indicate the pre-jetty shoreline location. Following jetty construction the shoreline advanced in order to produce a

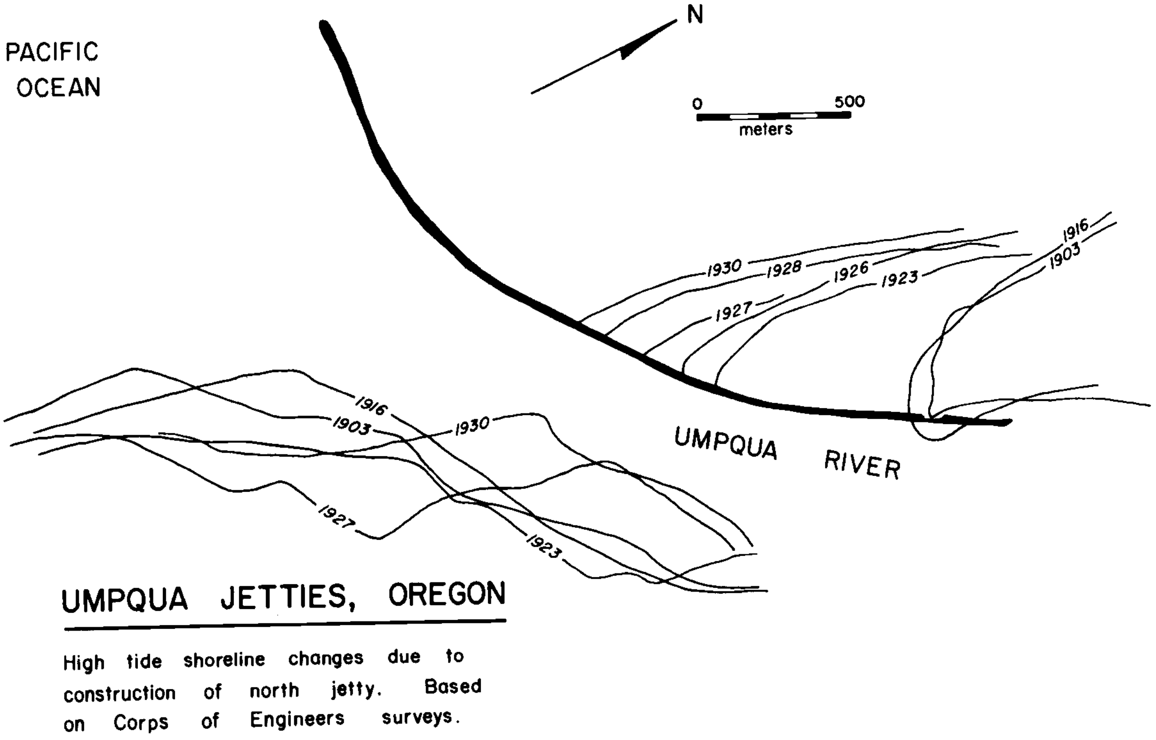


Figure 16. Compilation of shoreline changes due to north jetty construction on the Umpqua River. The 1903 and 1916 shoreline surveys show pre-jetty configurations.

straight shoreline essentially parallel to the crests of the prevailing waves of the area such that the beach would again experience a zero net sand drift. The uncontrolled shoreline south of the river mouth is seen to have fluctuated widely, but there was a definite tendency for the shoreline to shift toward the jetty, decreasing the width of the river entrance.

Figure 17 shows the modifications produced by the construction of the south jetty. As construction of this jetty proceeded, erosion occurred at its base so that a segment had to be added onto the shoreward side. This erosion is seen by comparing the 1930 and 1940 surveys. By 1948 the shoreline had built out south of the jetty, but erosion continued on the beach between the two jetties. North of the north jetty the shoreline continued to advance but more slowly than shown in Figure 16 as the beach had nearly reached a new equilibrium configuration with the wave conditions.

A middle jetty was subsequently constructed, Figure 18, to confine the river flow and to control the shoreline between the north and south jetties. This middle jetty is seen to have caused marked shoreline changes, its construction having formed a small pocket beach with the south jetty. A comparison between the 1948 pre-jetty survey and the 1951 post-jetty survey shows that the pocket beach rotated to orient itself parallel to the incoming wave crests, eroding on the south end and advancing on the north end. Following this

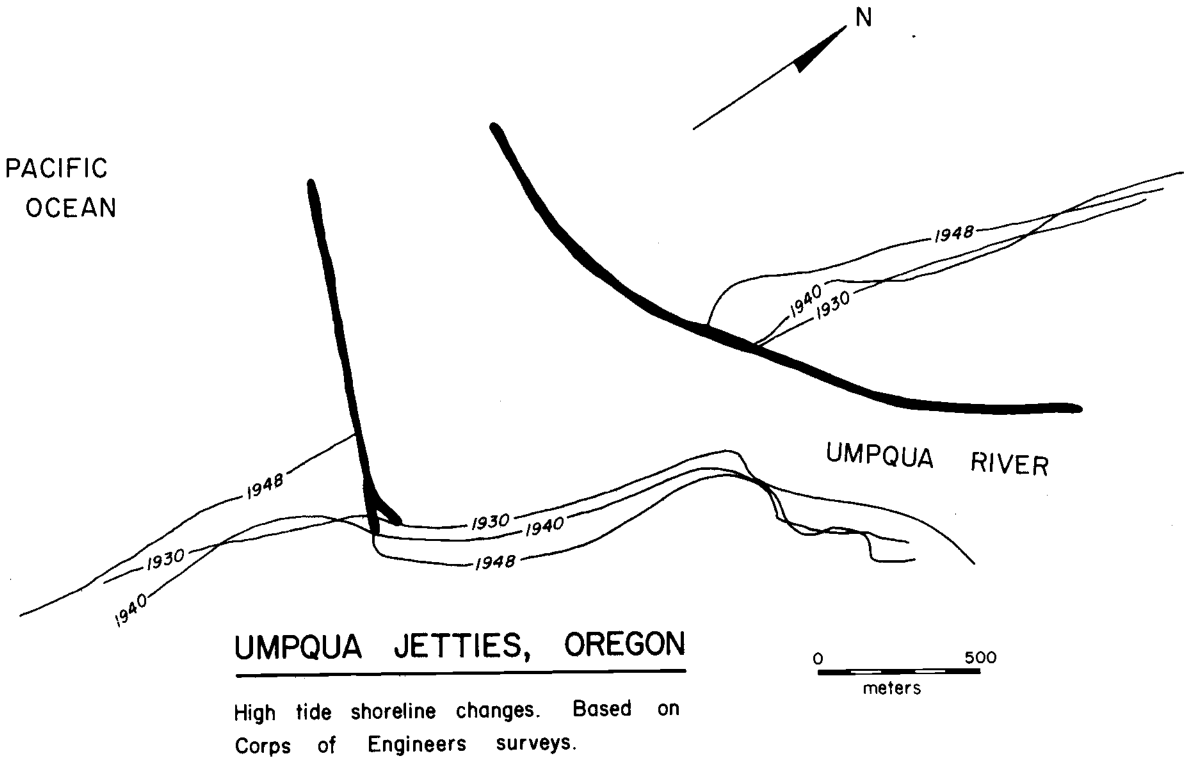


Figure 17. Compilation of shoreline changes due to construction of south jetty on the Umpqua River.

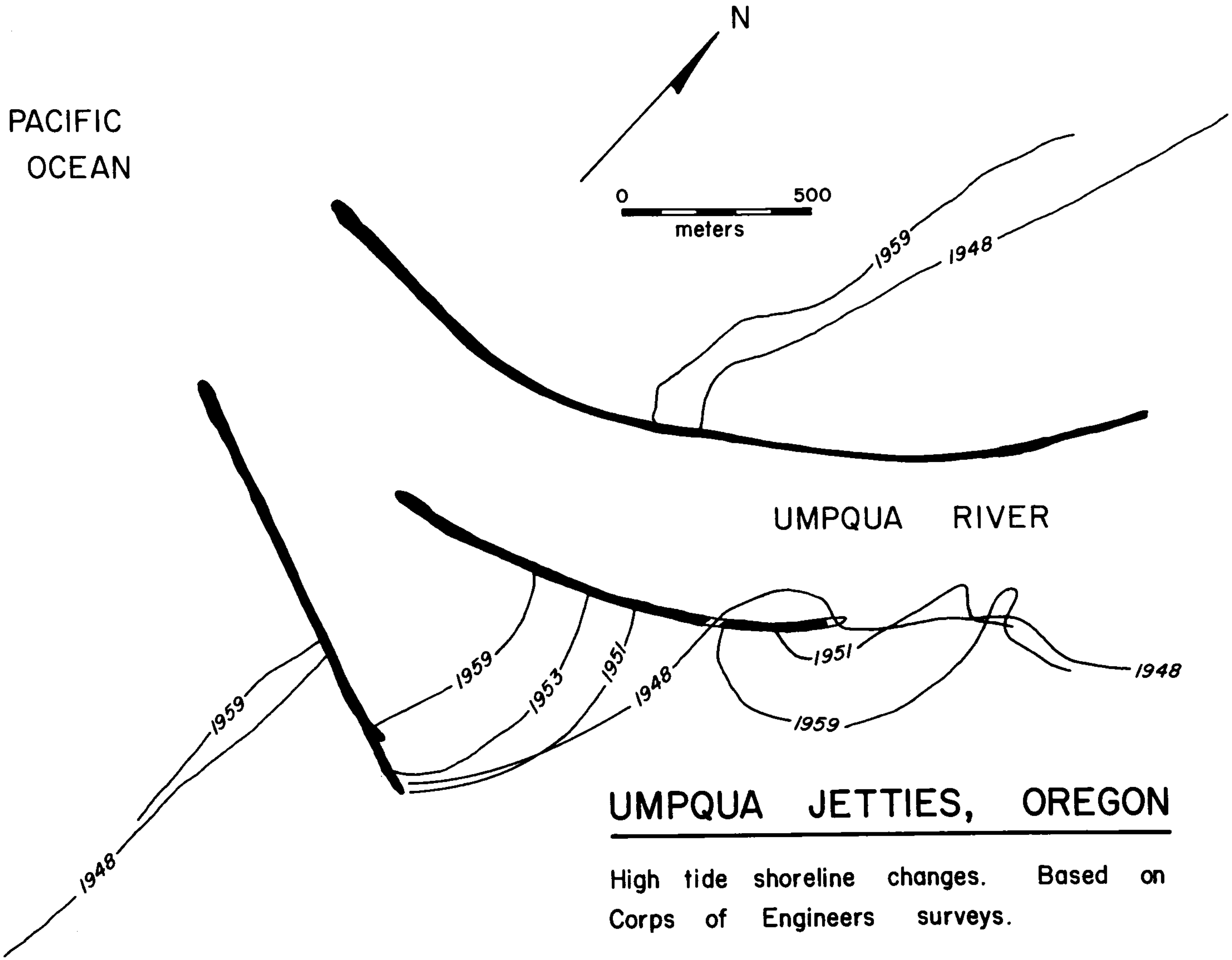


Figure 18. Shoreline changes due to the construction of a middle jetty on the Umpqua River.

rotation the shoreline of the pocket beach advanced between 1951 and 1959 with the same arcuate shape as sand was apparently added to the pocket by tidal and river flow. The aerial photographs of Figure 19 demonstrate that this pocket beach is oriented with the waves such that the wave breaker angles are everywhere zero and the sand transport is zero. Figure 18 shows that some erosion has occurred at the up-river end of the middle jetty.

The shoreline changes produced by jetty construction on the Umpqua River entrance can again be explained in terms of local adjustments from one equilibrium to another. The change in eqiulibrium was necessitated by the jetty construction. The shoreline changes demonstrate that in both cases the equilibrium is one of a zero net sand transport.

Rogue River Jetties

Figure 20 of the mouth of the Rogue River illustrates the great variability of the mouth position prior to jetty construction. This was true of all the river and bay mouths. Figure 21 shows the effects of jetty construction at the entrance. As in the other examples, sand accumulated adjacent to the jetties, both to the north and south. To the north the shoreline advanced in order to fill the embayment formed between the jetty and the pre-jetty shoreline. To the south of the south jetty the shoreline advance was due more to the protection

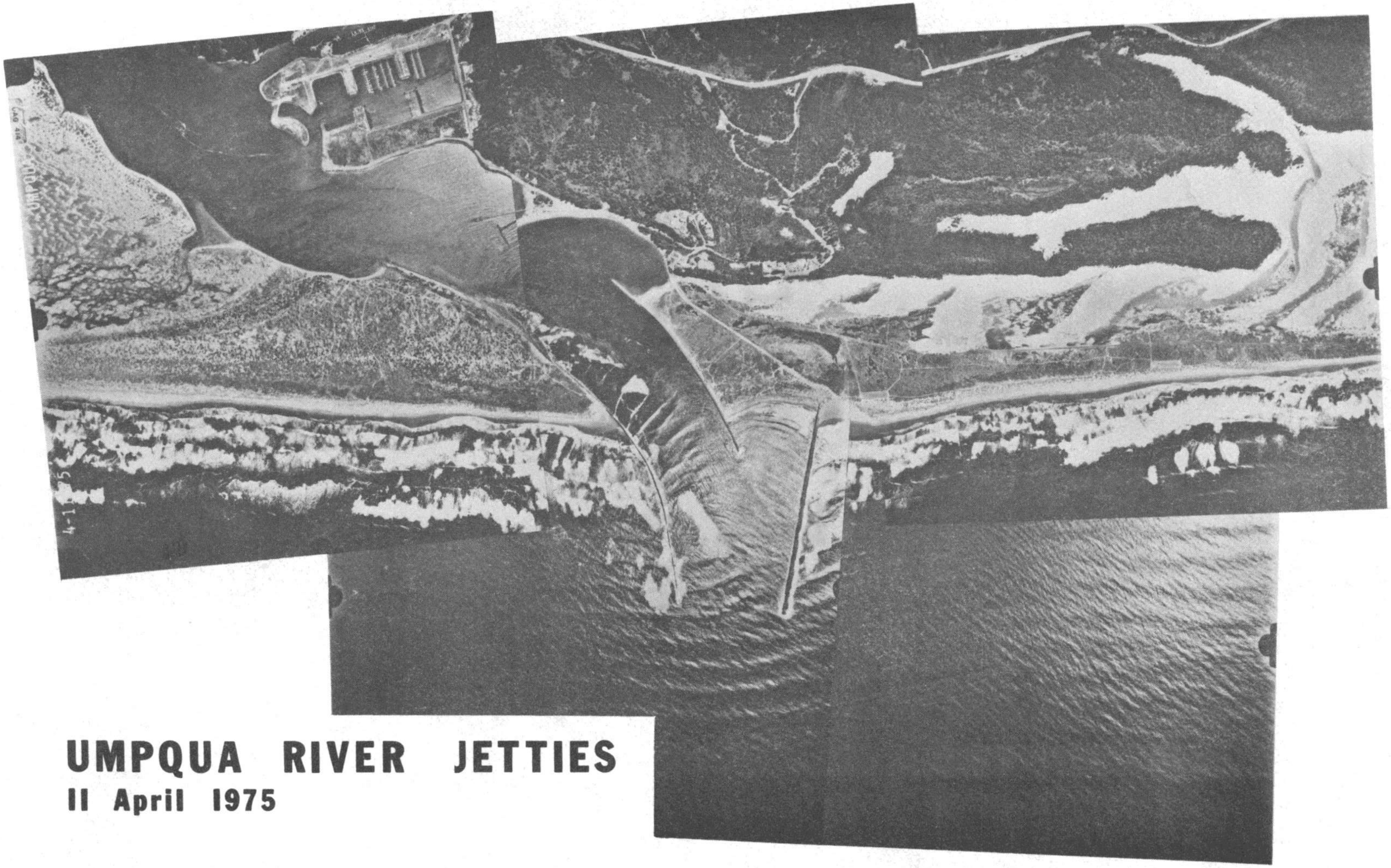


Figure 19. Aerial photographs of the jetties on the Umpqua River.

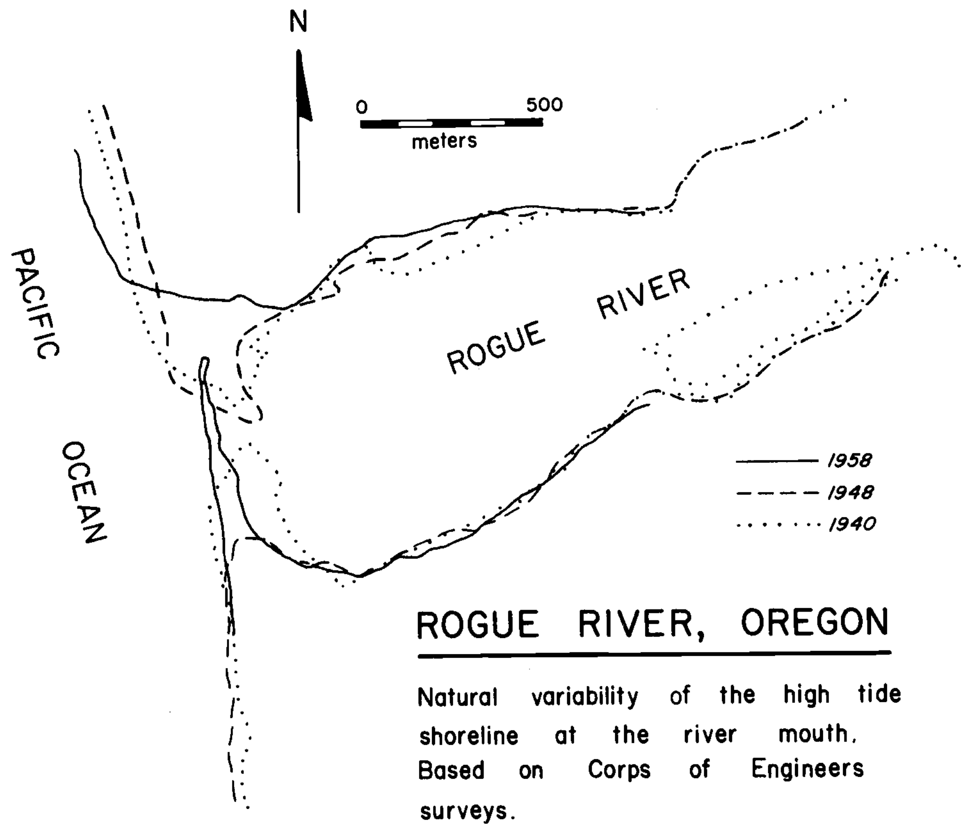


Figure 20. Migrations of the mouth of the Rogue River prior to jetty construction.

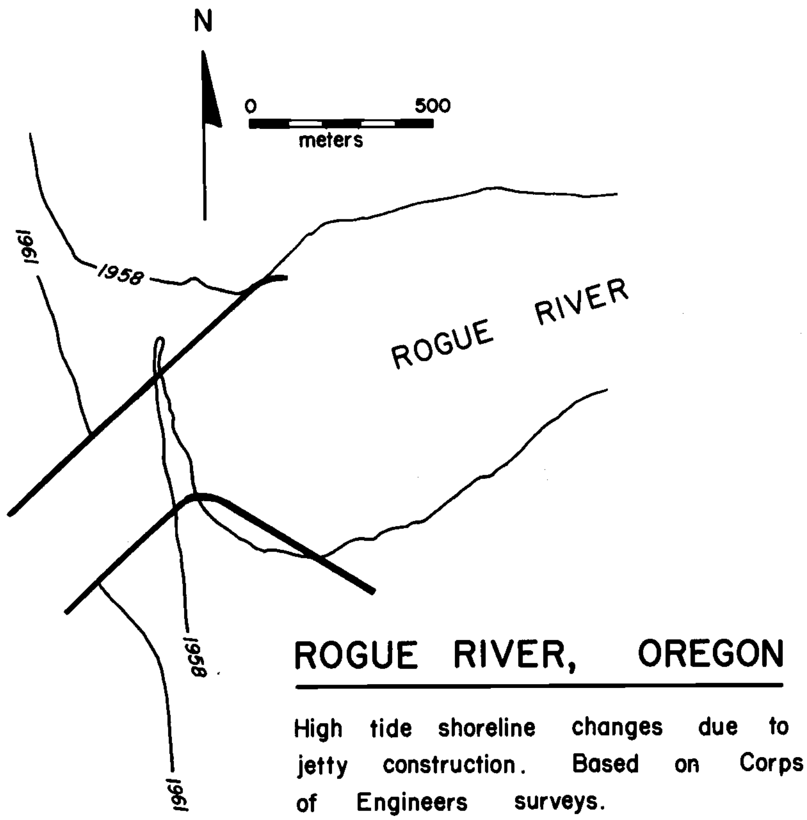


Figure 21. Shoreline changes due to jetty construction on the Rogue River. The 1958 survey shows the pre-jetty configuration.

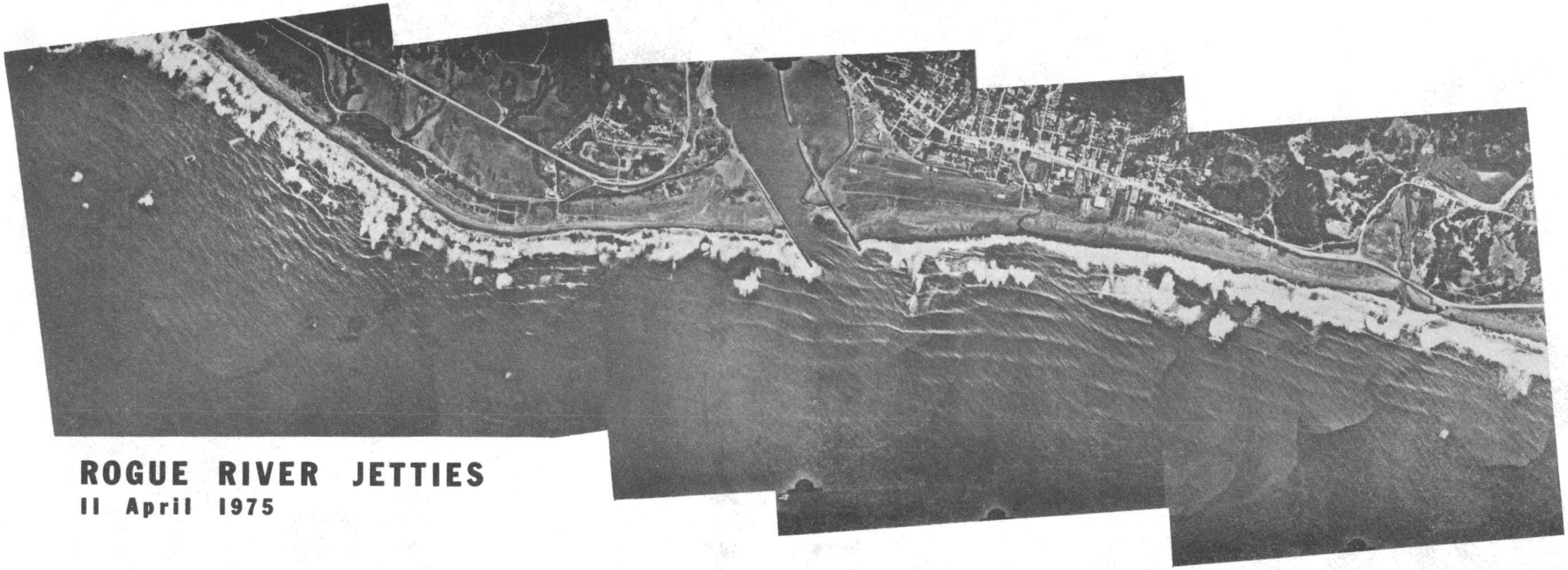


Figure 22. Aerial photographs of the Rogue River jetties.

offered by the jetty as at Yaquina Bay, the jetties being oblique to the coastal trend.

Coquille River Jetties

Figure 23 summarizes the history of shoreline changes at the mouth of the Coquille River. Prior to jetty construction the river mouth shifted position considerably. The eroded bluff to the south indicates its southernmost migration, the survey of Figure 24 in 1874 showing this situation. The principal shoreline advance seaward following jetty construction occurred to the south of the jetties. It is seen that a lagoon was trapped in the process. This greater shoreline advance south of the jetties resulted from a larger embayment having been formed on that side due to the jetty construction. In contrast, north of the jetties only a small pocket beach was formed so that only minor shoreline advance was required to straighten the shoreline. It is interesting that the shorelines north and south of the jetties have the same orientation, necessary if they are to be in equilibrium with the existing wave climate such that there is a zero net sand transport. However, the shoreline south of the jetties extends further seaward than that to the north indicating an independence between the two. In this regard the jetties and river flow are acting as a barrier between two pocket beaches. The pocket beach to the south is much smaller than that to the north. If sand were removed from the south pocket or

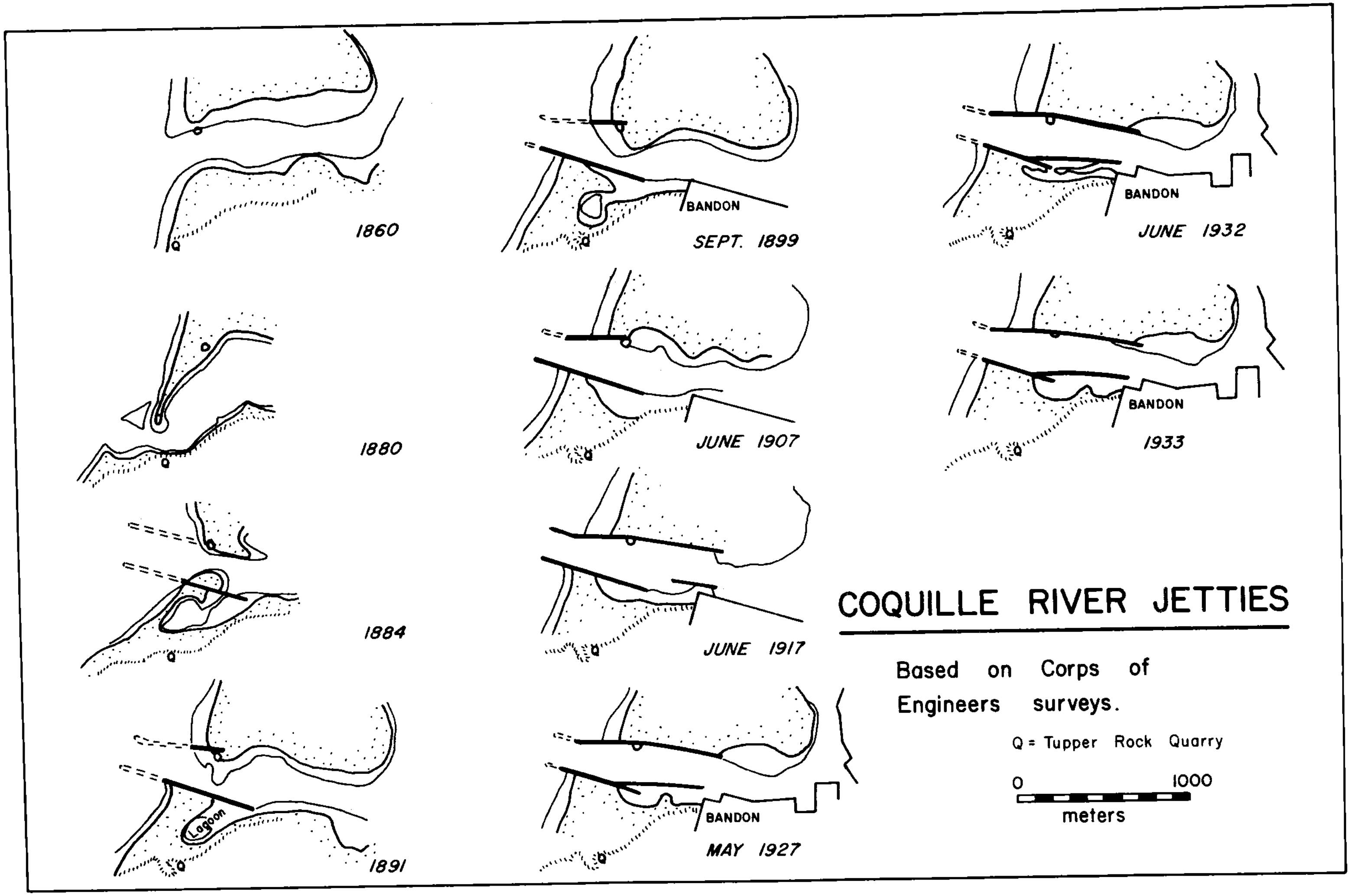


Figure 23. Compilation of shoreline surveys showing the effects of jetty construction on the Coquille River. The high tide shoreline is given as a dark line and the low tide as a thinner line.

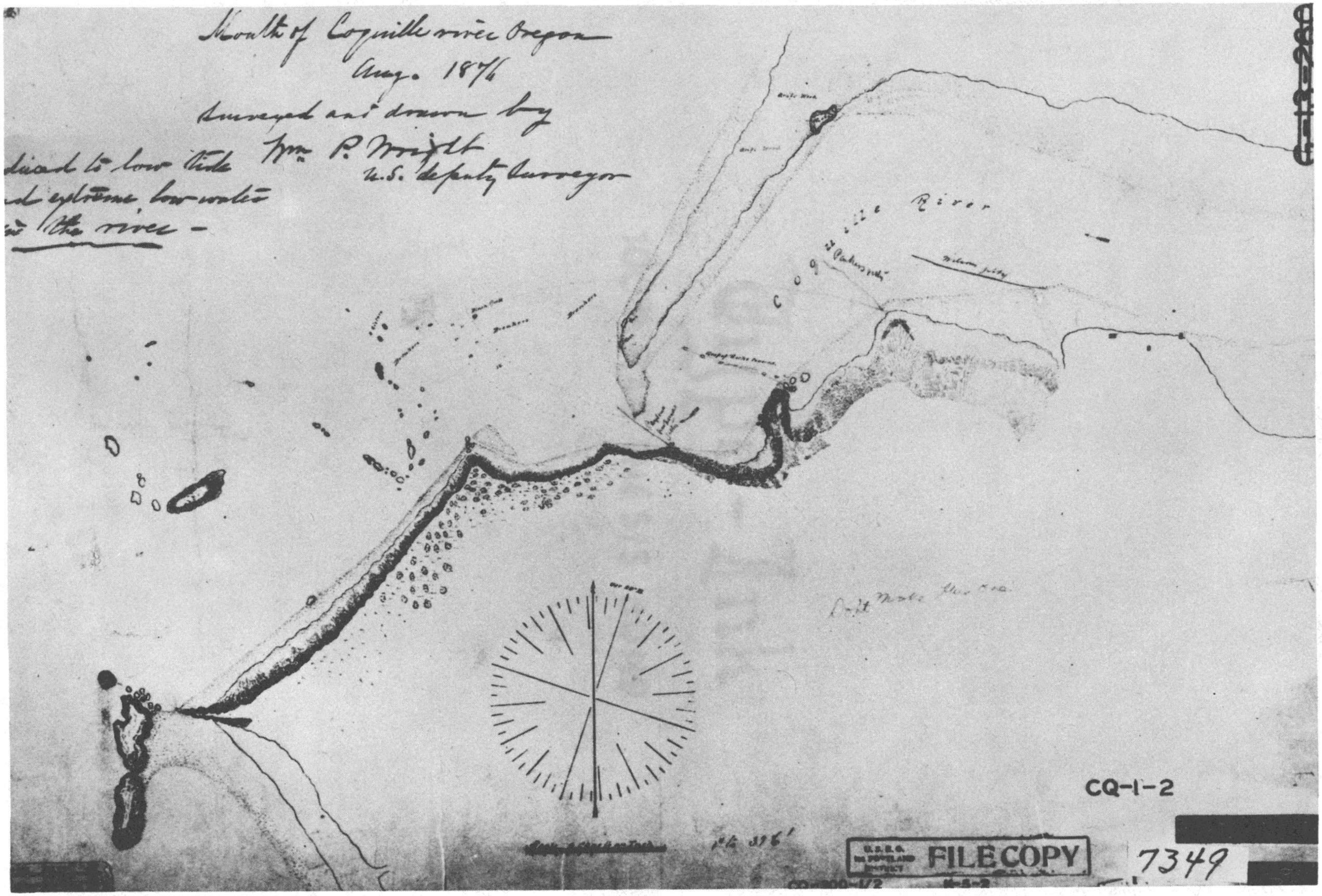


Figure 24. An 1874 survey of the mouth of the Coquille River, showing rocky formations as its south bank.

Figure 25. Aerial photographs of the Coquill River jetties, 11 April 1975.

added to the north pocket, the shorelines would eventually have the same extent in the seaward direction.

Coos Bay Jetties

Prior to jetty construction, the entrance to Coos Bay had a rocky stretch of coast as its south bank, Figure 26. A long stretch of sand beach exists to the north. Figure 27 shows the shoreline changes produced by the north jetty construction. The shoreline advanced considerably from its pre-jetty position (1892). The post-jetty shoreline (1899) is seen to be very straight, again in equilibrium with the wave conditions to produce a zero net sand drift. Apparently degradation of the jetty made it partially porous to the sand movements as the 1916 shoreline indicates some erosion of sand from the beach, the sand being carried into the entrance forming a shoal. Figure 28 shows the shoreline changes resulting from the construction of a south jetty and a reconstruction of the north jetty. The south jetty formed a pocket beach with the rocks jutting seaward to the south. Sand was trapped in this pocket forming a beach, the shoreline slowly advancing seaward. As at the Coquille River jetties, the pocket to the south of the jetties and the long stretch of beach to the north have the same orientation with respect to the wave climate but have different seaward extents. It is concluded that the shoreline changes produced by jetty construction at the Coos Bay entrance were

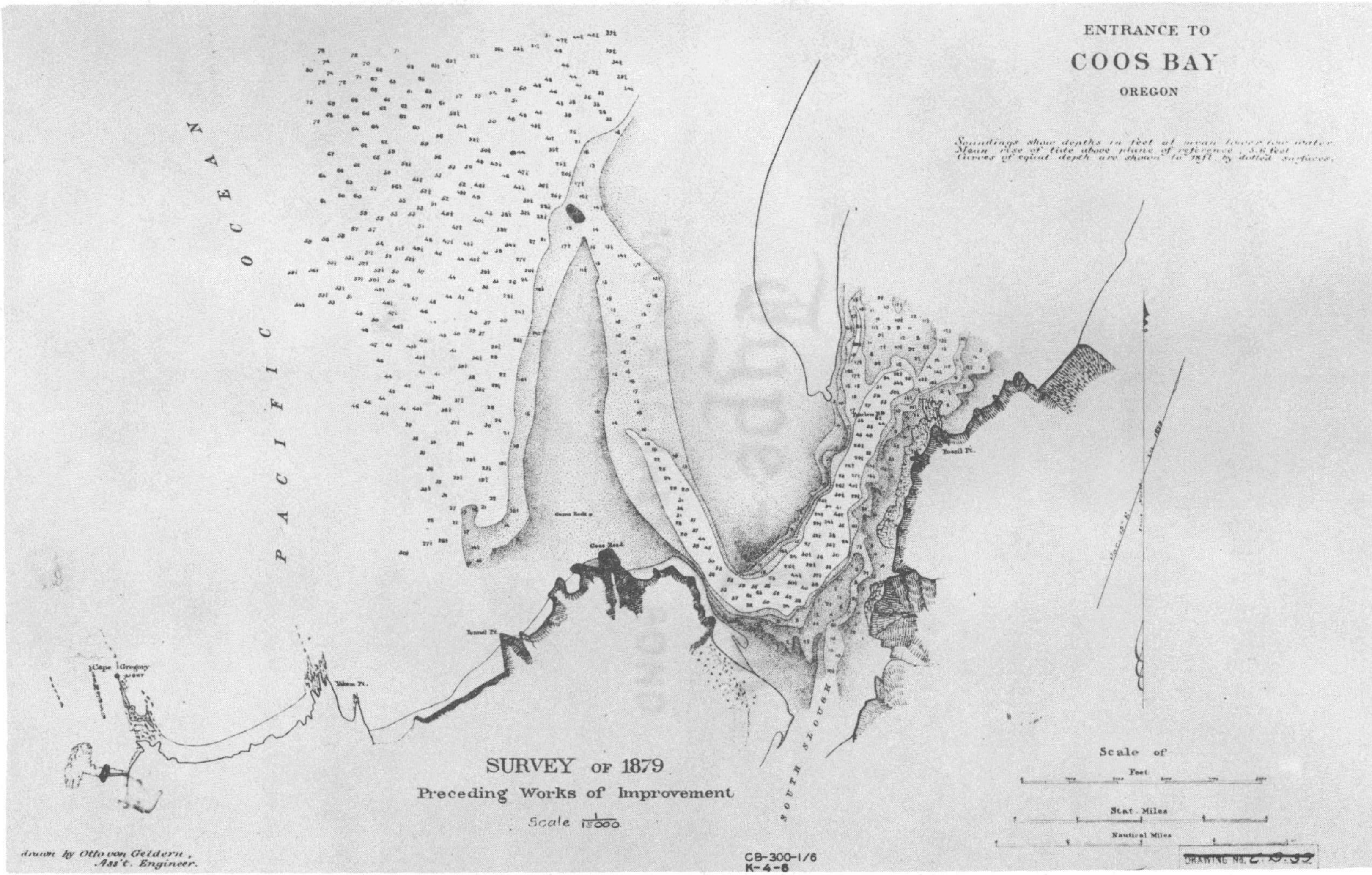


Figure 26. An 1879 survey of the entrance to Coos Bay, showing the configuration prior to jetty construction (Portland District, U. S. Army Corps of Engineers).

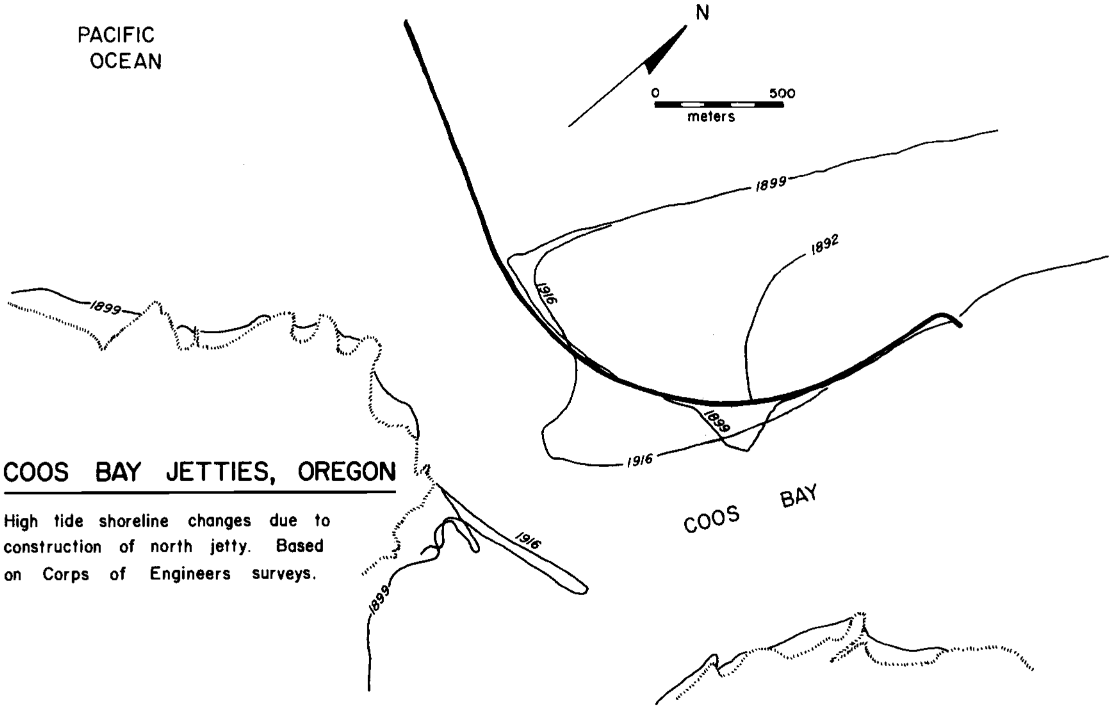


Figure 27. Shoreline changes resulting from construction of a north jetty on the Coos Bay entrance. The 1892 survey shows the pre-jetty configuration.

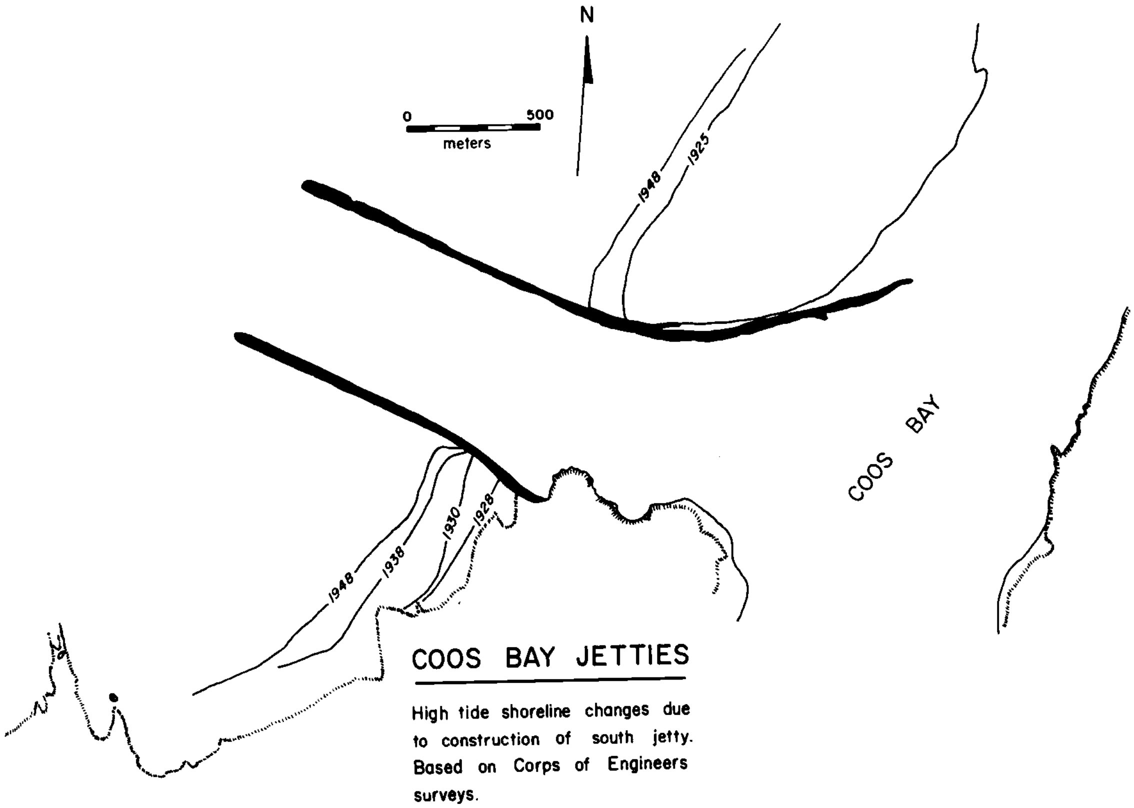


Figure 28. Shoreline changes resulting from construction of a south jetty on the Coos Bay entrance. Note the pocket beach formed south of the south jetty.

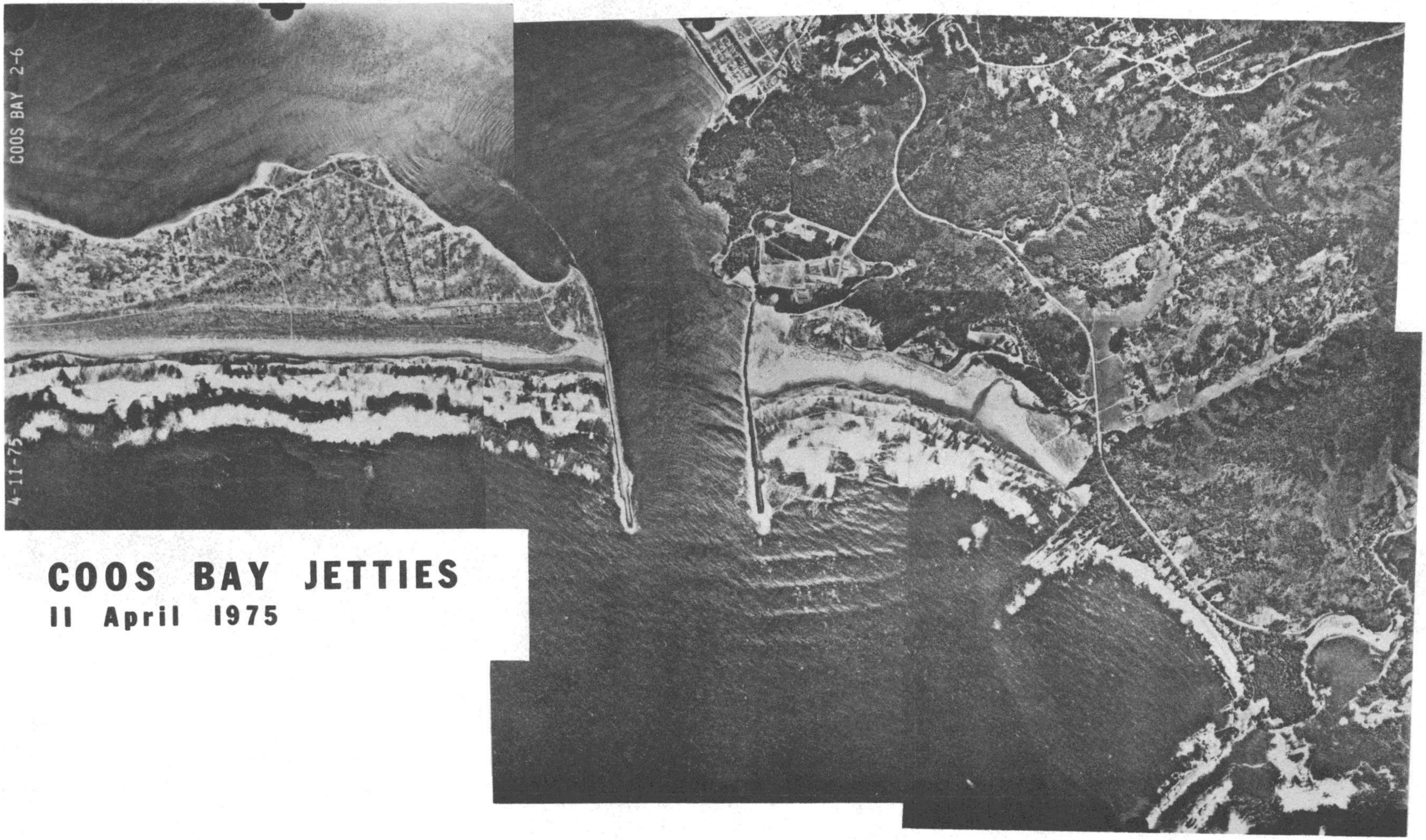


Figure 29. Aerial photographs of the jetties on the entrance to Coos Bay.

due to local readjustments to a new equilibrium within an area that is otherwise experiencing no net sand transport on the beaches.

Nehalem River Jetties

A pre-jetty shoreline (1916) and post-jetty shoreline (1918) at the Nehalem River mouth are shown in Figure 30. It is seen that there was some shoreline advance adjacent to the jetties, both to the north and south. The present-day shoreline configuration (Figure 32) does not differ too much from the 1918 shoreline. Therefore, there was a tendency for the shoreline to straighten to a new equilibrium with the wave climate, but this has not been entirely achieved. The shoreline still curves inward as it did prior to jetty construction. The reason for this is that the jetties are very low and porous so that they do not completely block the sand. Sand can still be carried from the beach into the mouth and up into the river. The beginnings of such a situation were seen in the 1916 survey of the Coos Bay entrance (Figure 27), the shoreline curving inward when the north jetty deteriorated. After the north jetty at Coos Bay was reconstructed, the shoreline again became straight (Figure 28). Presumably, if the Nehalem River jetties were improved so as to not pass sand from the beach into the entrance, the shorelines there would also become straightened, giving a condition of zero net sand drift.

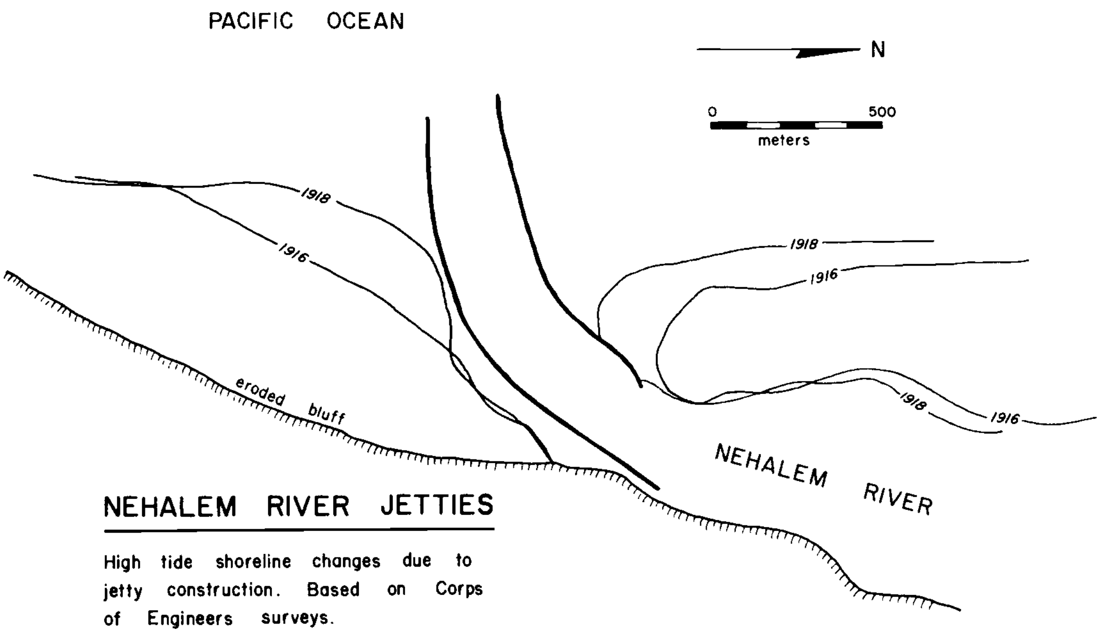


Figure 30. Shoreline changes due to jetty construction on the Nehalem River. The 1916 survey gives the pre-jetty configuration.

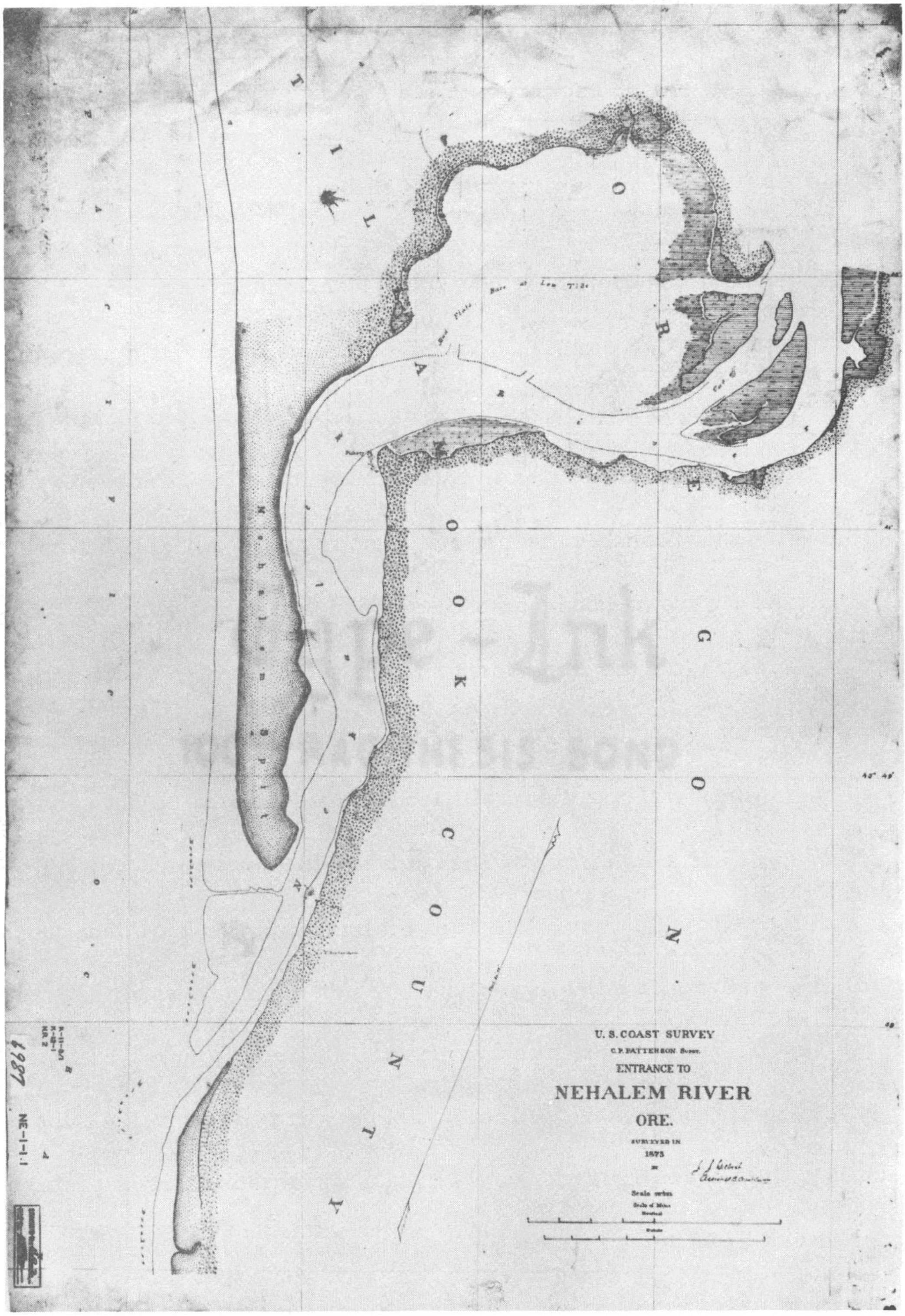


Figure 31. The mouth of the Nehalem River in 1975, prior to jetty construction. At that time the rocky cliffs formed the south bank.

Figure 32. The Nehalem River mouth and jetties on 5 September 1974.

Chetco River Jetties

The Chetco River entrance (Figure 33) is on a relatively small pocket beach. Prior to jetty construction the position of the river mouth varied widely. As with the other jetty systems, the jetties on the Chetco River produced deposition both to the north and south. Sufficient surveys are not presently available to accurately assess this deposition nor to examine the scale of erosion elsewhere along the stretch of pocket beach. Perhaps an examination of local property surveys would be useful in this regard, but that was beyond the scope of the present study.

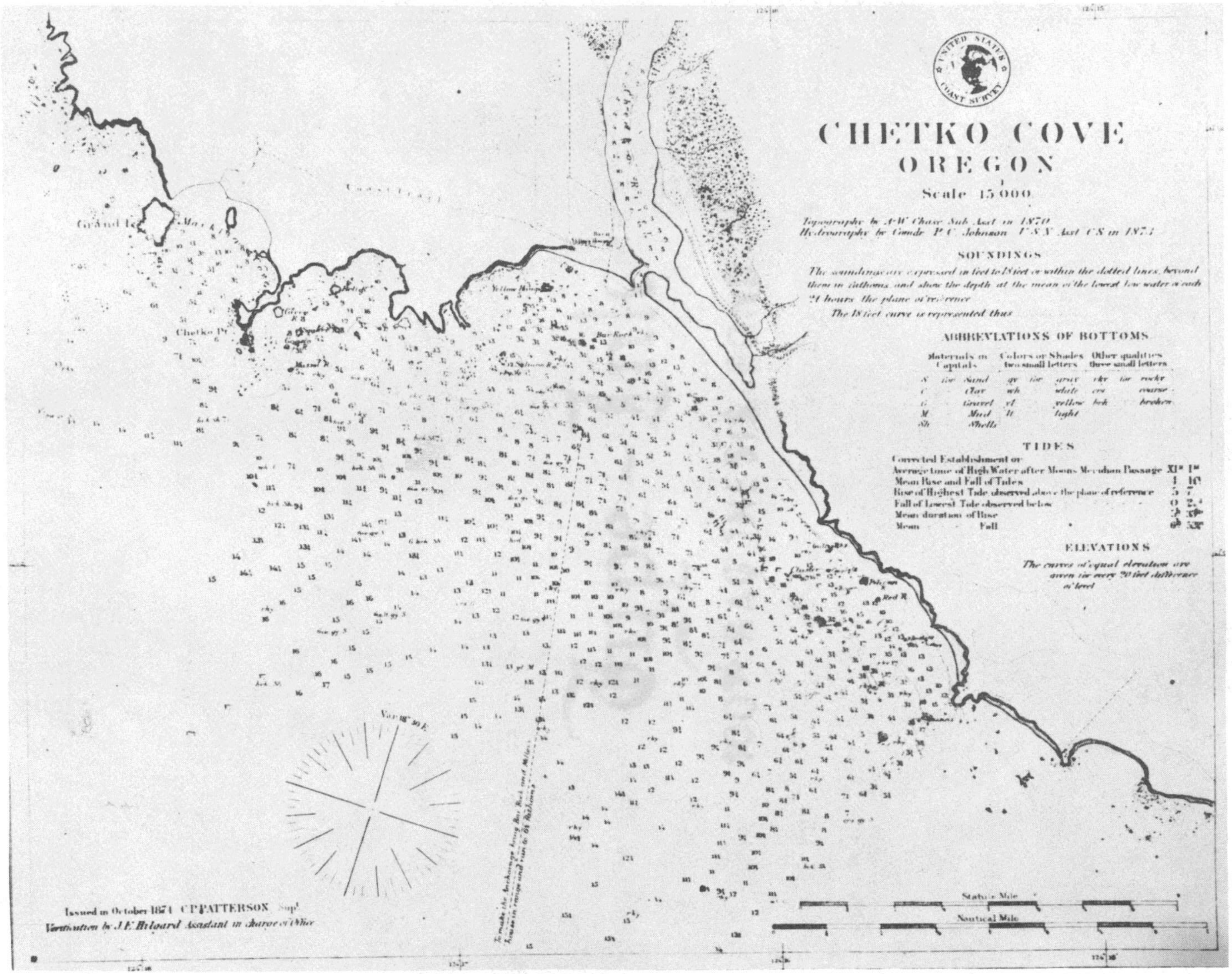


Figure 33. An 1873 survey of the Chetco River area, showing a small pocket beach.

CHAPTER IV

COMPUTER SIMULATION OF SHORELINE CHANGES DUE TO JETTY CONSTRUCTION

The effects of jetty construction on the shoreline, discussed above in the previous chapter, can be further illustrated through application of computer simulation. In a numerical simulation model on a computer the equations of sand transport along a beach are solved together with a continuity equation for the beach sand. The studies of Price et al. (1973) and Komar (1973) first attempted to simulate on a computer beach processes which govern the configuration of the shoreline. Both apply the equation

$$I_{\ell} = 0.77 \, (ECn)_b \sin\alpha_b \cos\alpha_b \qquad (2)$$

to evaluate the sand transport rate I_{ℓ} from the energy flux $(ECn)_b$ of the breaking waves and α_b, the angle the breaking wave crests make with the shoreline. The dimensionless 0.77 coefficient is that determined by Komar and Inman (1970). I_{ℓ} is the immersed weight sand transport rate which has the same units as energy flux so that equation (2) is dimensionally correct. However, in the model we want the volume of sand that is being transported. The volume transport rate, denoted by S, is given by

$$S = (6.85 \times 10^{-5}) \, (ECn)_b \sin\alpha_b \cos\alpha_b \qquad (3)$$

which is derived from equation (2) on the assumption that the sand is composed of quartz (density 2.65 gm/cm^3). Equation (3) also includes a factor change such that if $(ECn)_b$ is given in ergs/cm· sec, the value of S obtained is in m^3/day, the form most suitable in the present context (Komar, 1973).

As diagrammed in Figure 34, the shoreline is divided into a series of cells of uniform width Δx and with individual lengths $y_1 \ldots\ldots y_i \ldots\ldots y_n$ beyond some base line. Each cell is depicted as a wedge of sand as seen in Figure 35. Changes in the shoreline configuration are brought about by the littoral drift S (m^3/day) which shifts sand alongshore from one cell to the next. From the continuity relationship for the sand in any one cell we have

$$\Delta y_i = (S_{i-1} - S_i) \frac{\Delta t}{d \ \Delta x} \qquad (4)$$

for the shoreline advance or retreat, Δy_i, in the cell i which is governed by the rate at which sand leaves the cell, S_i, versus the littoral drift into the cell, S_{i-1}. The factor Δt is the increment of time (days) over which the model is run, and d in equation (4) is the depth to which sand is deposited or eroded (Figure 35).

Any simulation model of shoreline changes then simply involves: (a) defining an initial shoreline configuration, (b) establishing the sources of sand to the beach such as rivers, and possible losses, (c) giving the offshore wave parameters (height, period, approach

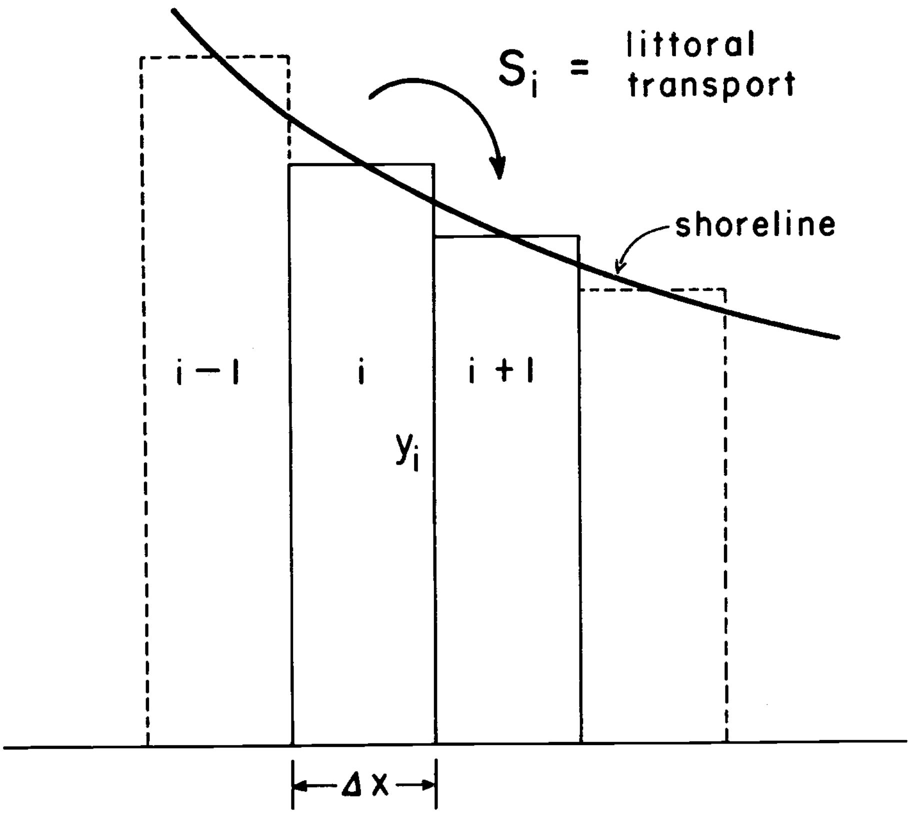
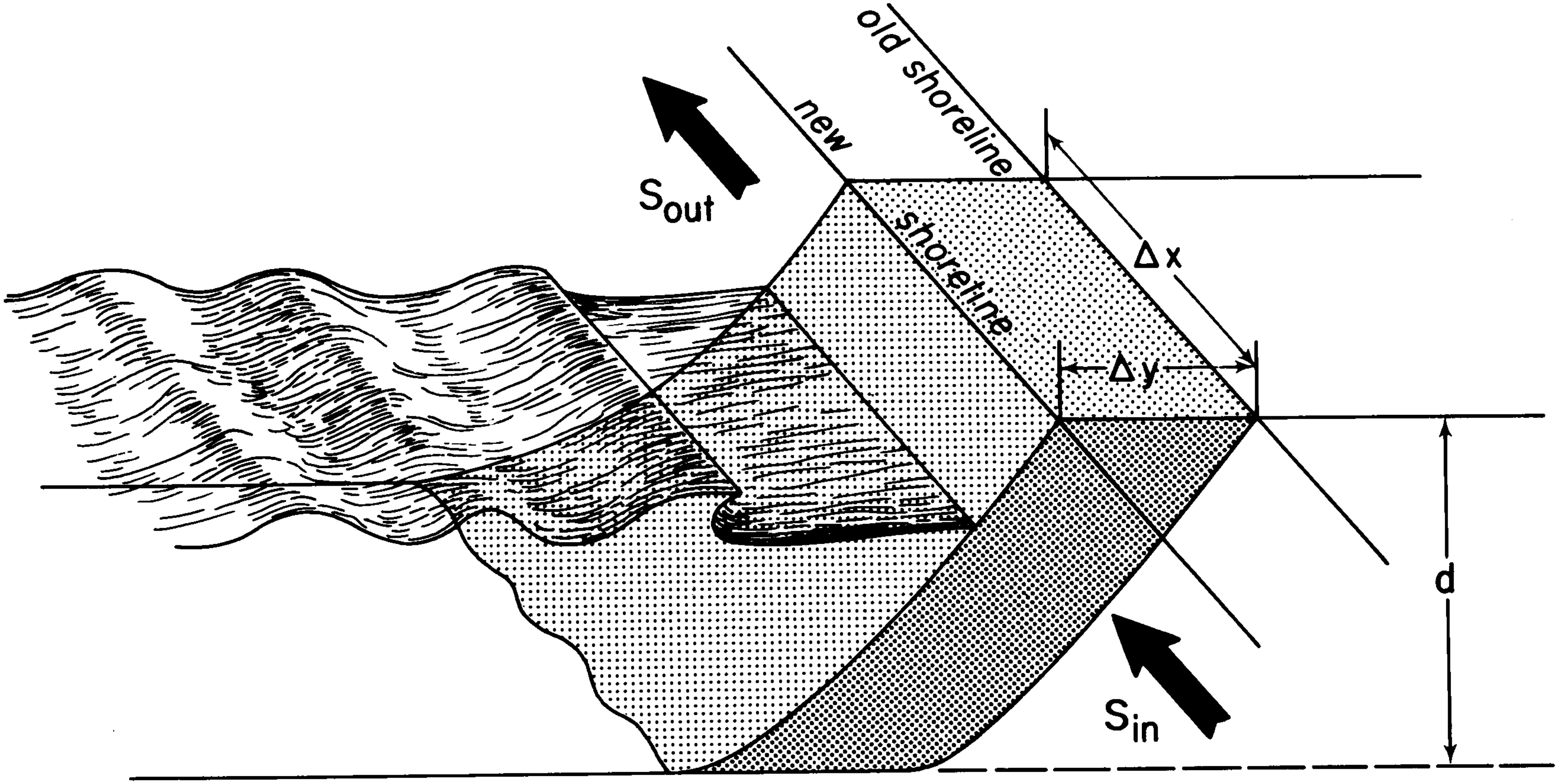


Figure 34. Shoreline approximated as a series of cells for development of computer models.



$$\text{Volume, } \Delta V = d \cdot \Delta x \cdot \Delta y$$

Figure 35. A single shoreline cell for the numerical models, showing that the shoreline change is related to the amount of sand coming into and going out of the cell.

angle), (d) indicating how the littoral transport of sand along the beach is to be governed by the wave parameters [equations (2) or (3)], and (e) determining how the shoreline is altered from its initial configuration under these conditions at increments of time for some total span of time.

Figure 36 shows the results of such a computer model that simulates the accretion of land north of the Siuslaw River jetties due to the initial jetty construction. The 1889 shoreline of Figure 10 is used as the initial shoreline prior to jetty construction. A cell width $\Delta x = 50$ meters is used and some cells are eliminated close to the jetty as they fill out to the jetty and can accept no additional sand. The waves are made to approach parallel to the shoreline to the north of the jetties beyond the embayment area between the north jetty and the pre-jetty shoreline. Closer to the jetties the waves reach the shoreline with oblique angles and therefore cause a sand transport toward the jetties, filling the embayment created by the jetty.

Figure 36 must be taken as only illustrative of the shoreline changes that occurred following jetty construction. Wave refraction patterns were not computed for the waves passing into the embayment as this would have greatly complicated the model. Such a coupling of shoreline configuration models with computer routines for wave refraction leads to more realistic simulation models but they necessitate a complete three-dimensional model in order to follow the

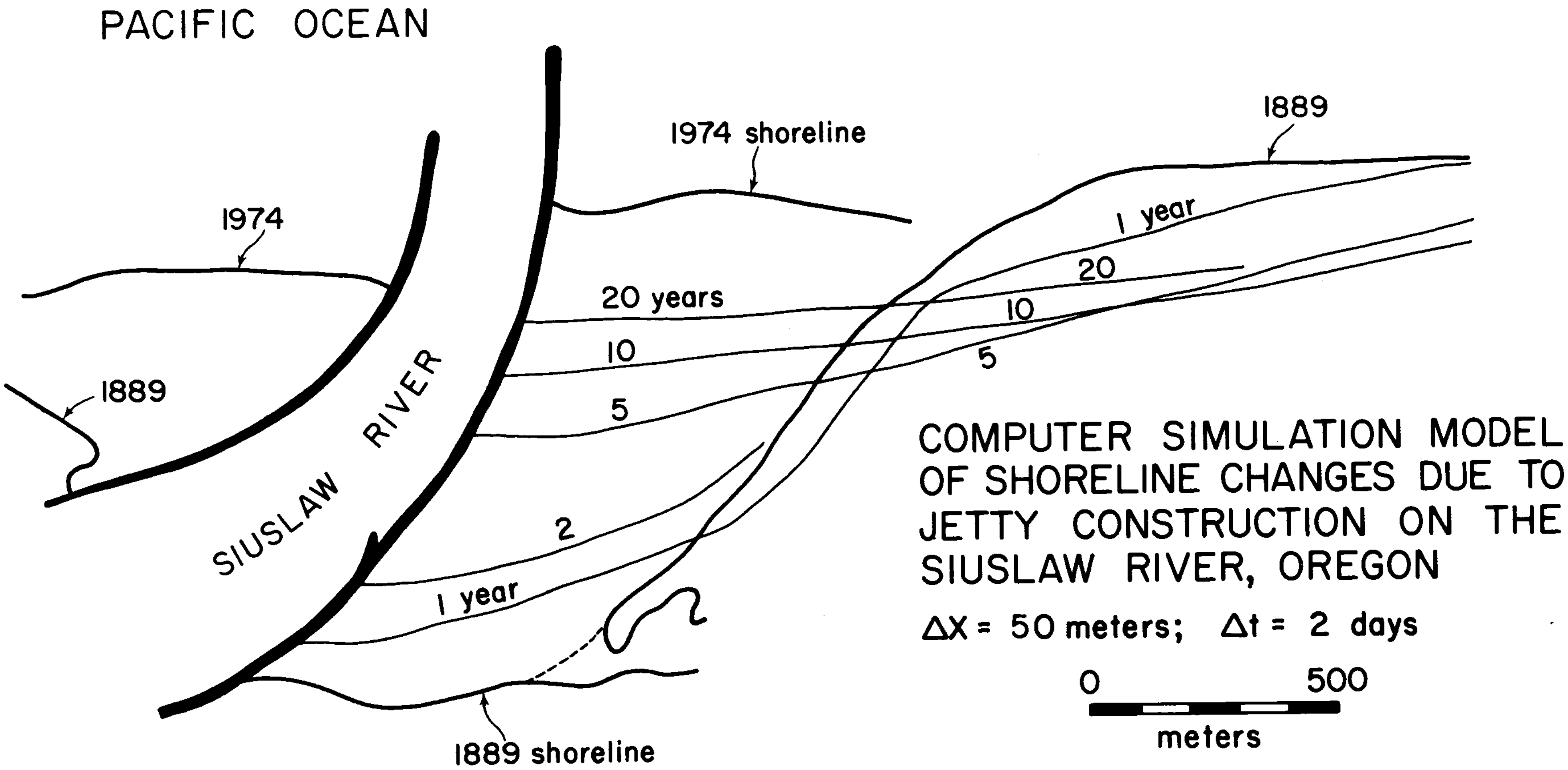


Figure 36. Computer simulation of shoreline changes brought about by the construction of jetties on the Siuslaw River. The 1889 shoreline is an actual shoreline and was used as the starting configuration for the model. Compare with Figure 10.

waves into shore. This also requires a description of the offshore bathymetry as this affects the wave refraction. Only the study of Motyka and Willis (1975) has attempted such models, directed toward an examination of offshore dredging effects on the wave refraction which in turn modifies the shoreline configuration.

Wave refraction within the embayment would reduce the breaker angles that the waves make with the shoreline below values obtained in the computer computations of breaker angles where refraction is not included. Thus with wave refraction included the sand transport rates computed with equation (3) would be lower due to the direct dependence on the angles of breaking. To compensate for not including wave refraction, the value of the energy flux of the waves entering the embayment was reduced to 1×10^8 egs/cm· sec, a factor of ten below that outside the embayment. This had the effect of reducing the sand transport to a more reasonable rate. The overall changes in the shoreline are not greatly affected by this reduction in energy flux, but the rate at which they take place is decreased.

In addition to this approximation of the wave refraction, in the development of the model it was presumed that the jetty was completed in a very short time so that sand was not lost around the jetty end as the shoreline advanced. This was not the case as there was a delay in jetty extension around 1909.

Because of these assumptions, the results of the model,

(Figure 36) must be taken as only illustrative of the shoreline changes that occurred following jetty construction. In spite of the model's inability to take into consideration wave refraction and the progressive extension of the jetty, it is seen that the model depicts reasonably well the advance of the shoreline shown in Figure 10 and demonstrates approximate agreement with the time of actual shoreline position. The departure of the model from the 1909 shoreline with a continued embayment was due to only partial jetty completion.

The model illustrates the previous discussion that erosion of the coast distant from the jetties provides the sand for the shoreline advance close to the jetties. In the model as in the prototype, Heceta Head to the north blocks any longshore movements of sand. Erosion occurs in the model along the coast south of Heceta Head, the quantity of sand equaling the amount of sand required to fill the embayment created by the jetty. Note in Figure 36 that at intermediate distances from the jetty there is erosion as sand shifts closer to the jetty, but this erosion is followed by deposition and a seaward shoreline advance. This transfer and redistribution of the sand continues until the shoreline is everywhere straight and parallel to the incoming wave crests. At that point the transport reduces to zero as $\alpha_b = 0$ everywhere and no additional shoreline changes occur. If the complete wave climate were included in the model rather than a single wave train from a set direction, then there would be slight seasonal oscillations as the direction of transport changed, but the long-term configuration would be established in which there is a net zero long-shore sand drift. This equilibrium indicated by the models was seen to exist as early as 1939, aerial photographs of that year showing a shoreline essentially the same as the present configuration. Probably this equilibrium existed as early as the late 1920's.

This computer simulation model of the changes north of the jetties on the Siuslaw River helps to confirm our conclusion that the changes resulted from local readjustments of the shoreline within an area that was otherwise in equilibrium with the waves such that there is a long term zero net sand transport. Similar models could have been developed for the other jetty systems. Such models would have shown, for example, that the longer the stretch of beach between the jetties and the next headland that blocks the littoral drift, the smaller the amount of erosion that occurs along that stretch of coast. This model in part explains why more erosion occurred on Bayocean Spit than to the north of the Tillamook Bay jetties. Similarly, the smaller the embayment formed by the jetty construction, the smaller the amount of sand needed to fill the embayment and the less erosion experienced along the remaining coast.

In this study computer simulation models were used to confirm a hypothesis concerning local shoreline changes in response to jetty construction. However, the techniques employed could also be used to predict future shoreline changes and areas of erosion or accretion that would result from a proposed jetty construction or extension. In an application such as that, more elaborate models would be preferable, ones that do include wave refraction and the complete wave climate at the proposed construction site.

CHAPTER V

SUMMARY OF CONCLUSIONS

Jetty construction along the coast of Oregon has caused modifications to the shoreline, both erosion and accretion. These changes occurred in spite of the clear indications that there exists a zero or near zero net littoral transport of sand on a larger scale. The patterns of erosion and deposition are therefore not the typical examples of jetties blocking a net littoral transport of sand.

In general, accretion and shoreline advancement took place adjacent to the jetties following their construction, both to the north and south of the jetties. The accretion resulted from (a) the embayment formed between the jetty and the pre-jetty shoreline, the embayment becoming filled until the shoreline is straight and again in equilibrium with the waves such that there is a zero net sand drift, or (b) local protection from the waves is produced by the structure, especially when built with an oblique trend to the shoreline (eg. Yaquina Bay jetties). Most of the larger changes of the shoreline resulted from (a) rather than (b). The actual amount of sand accretion depends on the size of the embayment created or the area of protection formed by the new jetty. For this reason, more accretion can occur to the north than to the south of the jetties, or visa versa; the differences in accretion on the north and south sides do not reflect a prevailing net littoral sand transport.

Sand for the accretion adjacent to the jetties is derived from beach erosion at greater distances from the jetties. The severity of the erosion depends on the total amount of sand required for the beach accretion to a new equilibrium, and to the length of beach that is undergoing erosion. The longer the stretch of beach, the less the sand eroded per unit length of beach to supply the required sand. When a short stretch of beach is undergoing erosion, as at Bayocean Spit south of the jetties to Tillamook Bay, then the resulting erosion is particularly severe, resulting in considerable property damage.

Further confirmation of the overall pattern of erosion and deposition from jetty construction is provided by the computer simulation model for the Siuslaw River jetties. The model demonstrated deposition and shoreline advance next to the jetty to fill the embayment created by the jetty, and erosion at greater distances from the jetty to supply the sand. Shoreline changes continued until the beach was straight and in a new equilibrium with the waves such that a zero net sand transport again prevailed. The techniques of computer simulation of shoreline changes thus provide a powerful tool for predicting responses to future construction of coastal structures.

The study demonstrates that considerable shoreline changes can occur from jetty construction, even when in an area of zero net sand transport. The difference from cases where jetties block a net sand drift is that with a zero net drift the shoreline reaches a new equilibrium with the waves. After that equilibrium has been reached little or no subsequent shoreline changes occur. Thus all of the pronounced shoreline changes occur within a few years after jetty construction, unlike the continuous changes that occur when blocking a net sand drift.

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