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The Severe Erosion of Cape Shoalwater, Washington[1]

Thomas Terich and Terrance Levenseller

Department of Geography and Regional Planning
Western Washington University
Bellingham, Washington 98225

ABSTRACT

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Cape Shoalwater on the southwest Pacific coast of Washington State has been eroding at rates in excess of 30 meters per year since the turn of the century. It is the most active coastal erosion site along the Pacific coast of the United States. The region receives a plentiful supply of littoral sediments and the neighboring coastlines are advancing. Study reveals the erosion is resulting from the long term northward migration of the tidal channel towards the Cape leading to very rapid shoreline retreat. There is some evidence of a slowing erosion rate due to the development of a secondary channel opening to the south of the main channel.

ADDITIONAL INDEX WORDS: *Beach ridges, channel migration, dredging, erosion, Pacific coast, sediments, spit, storm waves, Washington.*

INTRODUCTION

The contemporary shoreline of Washington State's southern coast began to take shape with the post-glacial stabilization of sea level approximately 4,000 to 5,000 years BP. At that time great quantities of sediment were delivered to the coast by the Columbia River draining eastern Washington and the Chehalis River which for a period of time was the only major meltwater outlet for the ice-filled Puget Lowland (McKEE, 1972). The sediments were worked by littoral and eolian processes into the coastal configurations observed today. One of the most prominent features is Long Beach Peninsula, a spit 43 km long (27 miles) trending north from the Columbia River (Figure 1).

The northward growth of the spit progressed until only a relatively narrow channel connected the sheltered waters of Willapa Bay with the Pacific Ocean. Concurrently a smaller, less prominent south trending spit, Cape Shoalwater, also grew into the mouth of the channel from the north. As the converging spits grew toward one another, the channel narrowed and tidal velocities increased.

The two spits probably evolved through several periods of advance and retreat. The most recent maximum approach of the two spits was just after the turn of this century. A sequential development of relict beach ridges on both the Long Beach Peninsula and Cape Shoalwater confirm their convergent development (U.S. ARMY CORPS of ENGINEERS, 1967).

Until recently there was some controversy among coastal reseachers regarding the net movement of littoral sediments along this part of the coast. The development of converging spits at Willapa Bay and Gray's Harbor, approximately 32 km (20 miles) to the north, have helped to fuel the controversy. TWENHOFEL (1943) was among the first of the researchers to argue for a net northward sediment transport based on the predominent northward growth of Long Beach Peninsula and southerly storm waves that frequent the coast. COOPER (1958) acknowledged the importance of the southerly storm waves, but maintained that the more gentle prevailing northwesterly swells were more effective movers of beach sediment. He promoted a net southerly sediment transport along the Washington coast. BALLARD (1964) investigated the energy component of waves striking the shores of the Pacific Northwest. His studies showed a distinct seasonality of the wave regime. During summer, waves are predominantly from the northwest causing longshore currents and sediment transport to the south. In

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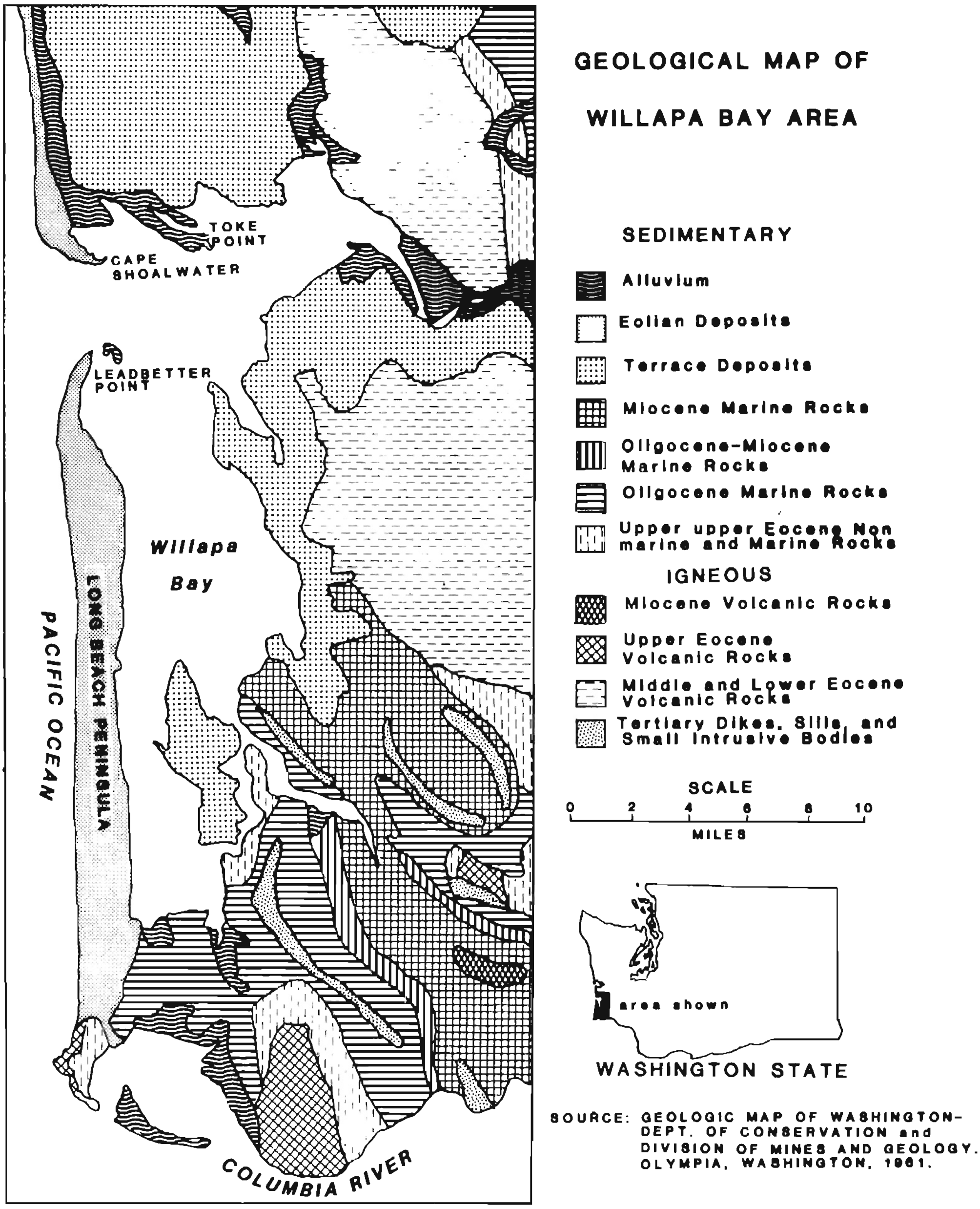

Figure 1. Location and regional geology of Willapa Bay and Cape Shoalwater.

winter the directions are reversed, however, winter storm waves drive strong northerly longshore currents and carry large volumes of littoral sediments. The result is a seasonal reversal of sediment transport, however, with a net dominant northerly flow. Studies of the longshore energy flux conducted by the U.S. ARMY CORPS of ENGINEERS (1967) also showed a predominant net northerly littoral transport. Sedimentological studies by VENKATARATRHNAM and McMANNIS (1973) and

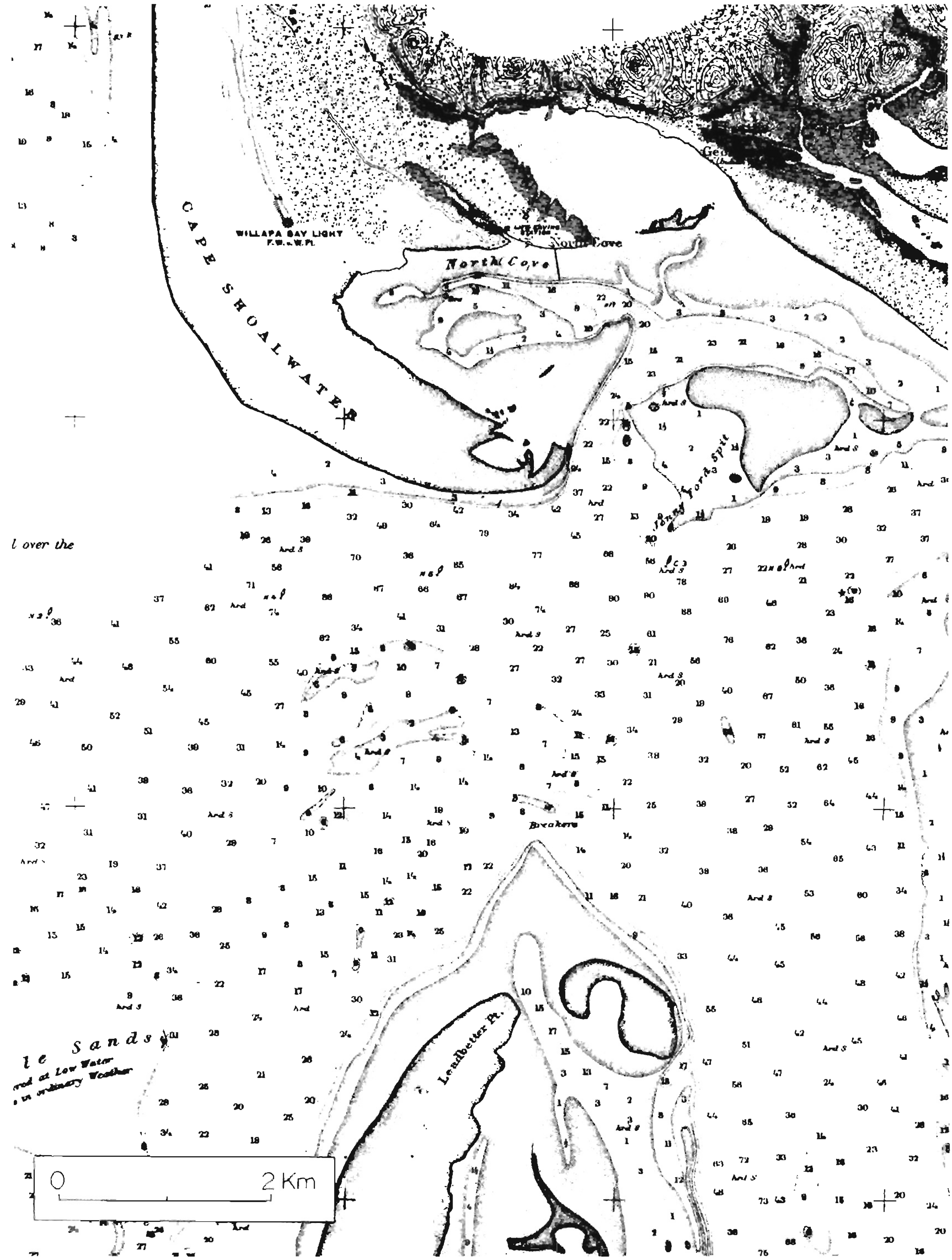

Figure 2. Coast and Geodetic Survey chart from 1911 with survey data to 1991 showing the southerly extent of Cape Shoalwater.

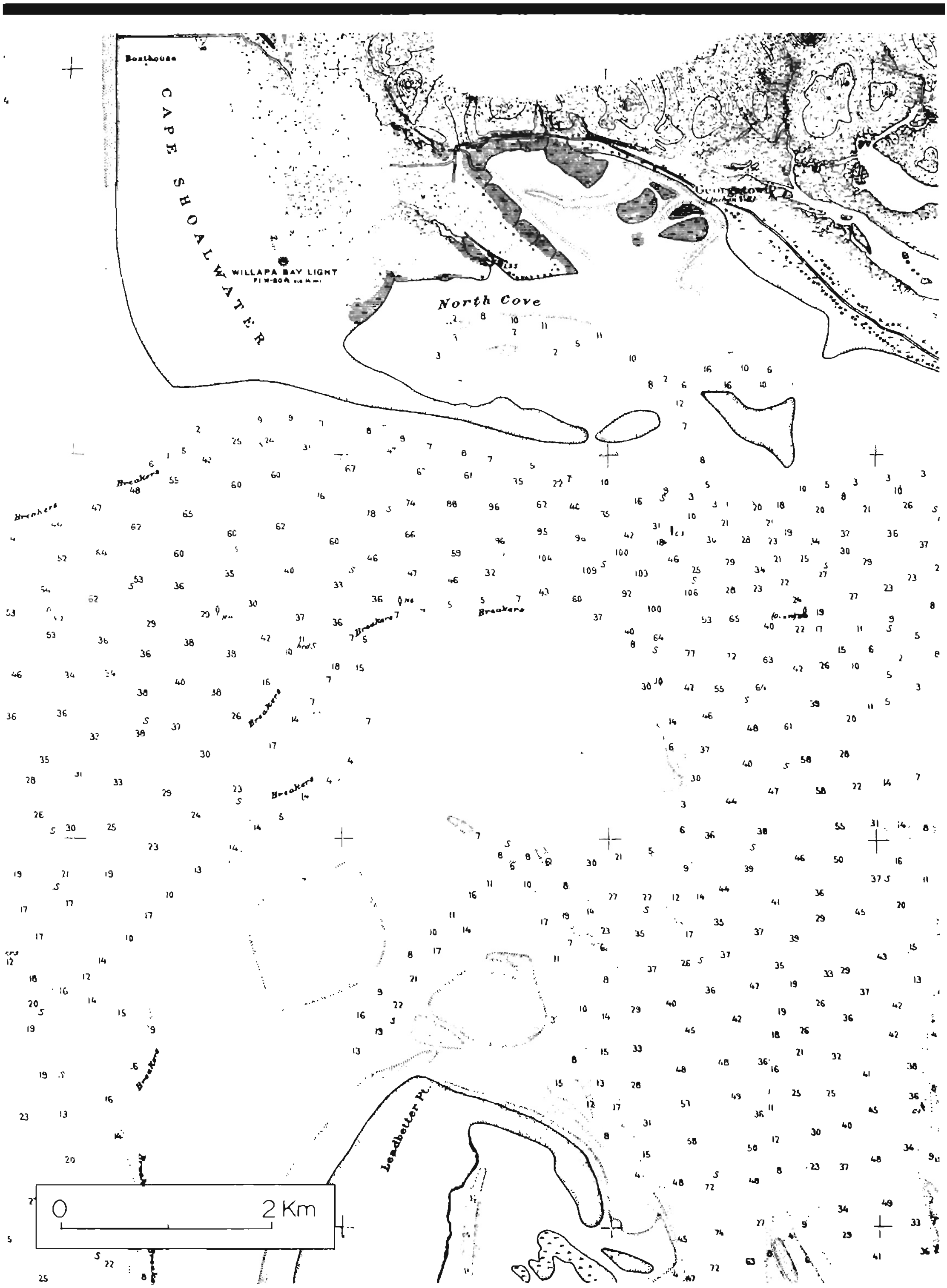

Figure 3. Coast and Geodetic chart from 1912 with survey data to 1911. Note the significant retreat of the Cape Shoalwater shoreline.

more recently PLOPPER (1978) provide additional evidence for a net northerly sediment transport along this part of the coast. Plopper investigated the hydraulic sorting and mineralogical characteristics of littoral sediments along the entire Washington coast. He found both the mineralogy and sorting characteristics to complement Ballard's wave energy studies. The relative sizes of the two opposing spits projecting into the Willapa Channel provides further empirical support for these findings. Recently SCHWARTZ *et al.* (1985) have confirmed a net northerly flow of beach sediment along this part of the Washington coast with one short divergent segment from Cape Shoalwater southeasterly into Willapa Bay.

EROSION HISTORY

Cape Shoalwater has had a very long continuous erosion history. U.S. Coast and Geodetic Survey charts dating back to the turn of the century provide evidence of the shoreline changes. One of the earliest known charts for the area, published in 1911, shows Cape Shoalwater with topographic, triangulation, and hydrography surveys dating from 1871 to 1891 (Figure 2). The Cape is shown as a pronounced south trending spit projecting southeasterly into Willapa Channel. The configuration of the shoreline appears relatively smooth, giving no indication of erosional retreat. At the time of the survey, the navigable channel was approximately 1.5 kilometers wide with maximum depths to 26 meters (85 ft.).

In 1912 another Coast and Geodetic Survey chart was published updating survey data to 1911. This chart clearly shows erosion of the Cape (Figure 3). Thus, erosion must have begun sometime between 1891 and 1911. Comparative measurements of these two early charts reveal a total shoreline retreat of approximately 760 meters (2,500 ft). Assuming an average annual recession rate of 45 m/yr (150 ft/yr), erosion would have had to commence in the mid 1890s. Four years later, the 1916 chart shows the southern projection of the spit to be completely missing. The shoreline along the Cape no longer gently curved to the southeast into the channel but turned abruptly to the east. Concurrently the large shoal north from Ledbetter Point appeared to have grown significantly in size. Charts subsequent to 1928 showed relatively minor shoreline configuration changes, but the overall recession of the shoreline proceeded.

In 1955, the U.S. Army Corps of Engineers was authorized by the Public Works Committee of the U.S. Senate to begin investigating the effects of erosion on the navigation channel across the outer bar and erosion control measures at Cape Shoalwater. In 1956 the committee concluded its study recommending against an immediate enginering solution to the erosion problem. They concluded that further study was necessary to determine the most feasible solution to the serious erosion and navigation problems and that prospective benefits were insufficient to justify the cost of rectifying the problems (U.S. ARMY CORPS of ENGINEERS, 1956).

Additional study was initiated in January 1966 at the request of the Washington State Department of Conservation. The study was conducted by civil engineering and oceanography professors from the University of Washington along with staff from the U.S. Army Corps of Engineers. The committee was known as the "Erosion Advisory Committee." Their studies showed the long-term erosion rate to average 42 m/yr (140 ft/yr). Some periods of very little erosion were followed by accelerated erosion rates of up to 75 m/yr (250 ft/yr). During the times of active erosion, it was estimated that 20 hectares (50 acres) of land were lost annually.

The committee concluded that the erosion is a symptom of a much larger problem, namely the progressive northward migration of the main channel entrance to Willapa Bay. As the channel moves toward Cape Shoalwater, southerly storm waves break close to shore easily eroding the beach. The eroded materials are then carried into the bay or out to sea by tidal currents. The committee estimated mean maximum tidal flow through the channel to be 53,000 m^2/sec (400,000 c.f.s.), roughly equal to the flow of the lower Mississippi River. An attempt to halt the channel migration was therefore compared to similar projects along the Mississippi River. A concrete or asphalt mattress revetment, a design to stabilize similar channel migrations along the Mississippi was estimated to cost a minimum $2,000,000.

Several other alternatives to slowing the erosion were explored, among them were jetty construction, pile diking and groin emplacement. No short-term measures seemed feasible to the committee. any long-term solutions were very costly. The committee also explored a nonstructural alternative. Diversion of the main channel to a shorter more efficient route might halt its northern migration. A smaller secondary channel near Ledbetter Point could be dredged, encouraging tidal currents to flow through it, thus reducing the volume of flow through the main channel. There was concern whether the shorter channel, once dredged, would widen and deepen naturally. Furthermore, there was no assurance that this newer channel would itself remain in a stable location.

The committee concluded there were no interim or temporary engineering solutions that were economically justifiable. They recommended that any funds dedicated to alleviating the erosion would perhaps be better spent purchasing the threatened land in the path of the erosion rather than attempting to resist the erosion itself.

EROSION RATES

There is no other place along the Pacific Coast of the United States that has had such a rapid and sustained erosion history as Cape Shoalwater. The U.S. Army Corps of Engineers have monitored the erosion using charts and field surveys. These data show an average annual erosion rate of 37.8 m/yr (126.0 ft/yr) from 1890 to 1965 (Figure 4). During this seventy-five year erosion history, the shoreline has retreated a total of 3750 m (12,500 ft).

There was some concern that channel dredging, which began in 1930, might have contributed to, or accelerated, the erosion of the Cape. Average annual erosion rates prior to channel dredging (1890-1922) were compared with subsequent years (1930-1965) when dredging was done yearly, some during World War II. Shoreline measurements between 1890 and 1922 yielded an average annual erosion rate of 44.5 m/yr (148.5 ft/yr). Measurements taken during the period of annual dredging from 1930 to 1965 showed an average annual erosion rate of 42.9 m/yr (143 ft/yr). There clearly was no significant difference between the erosion rates

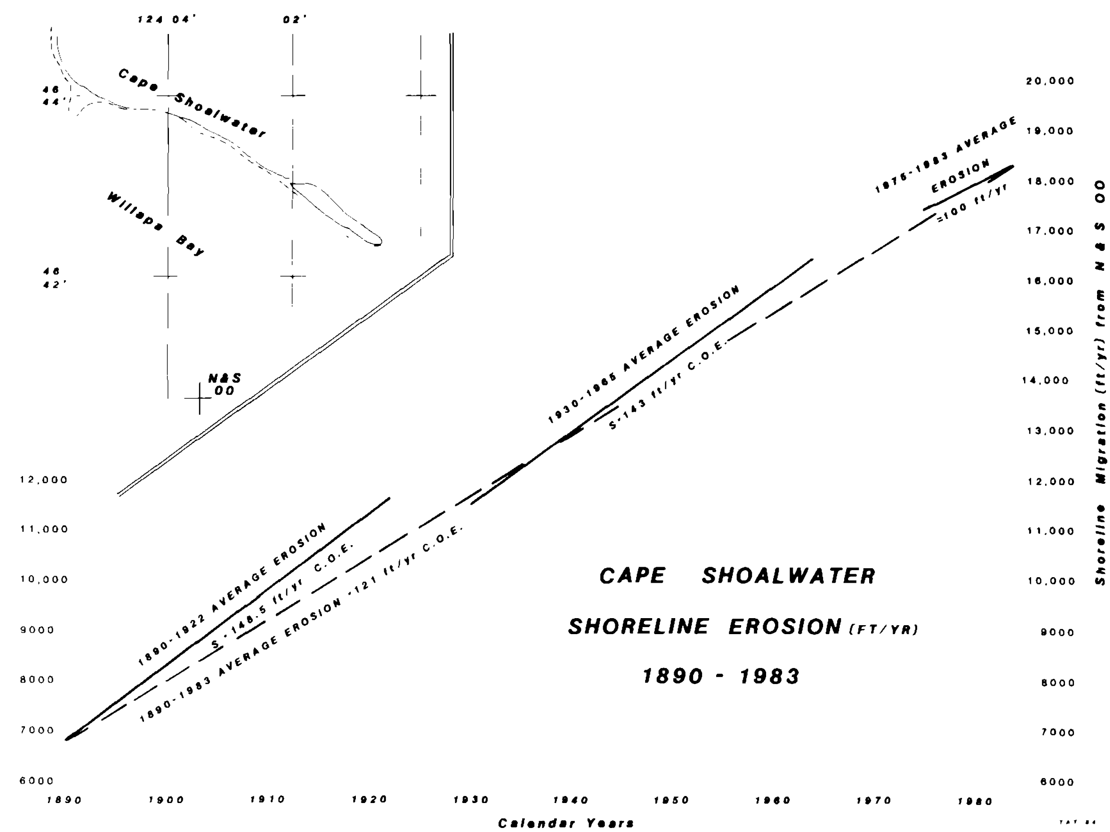

Figure 4. Erosion rates 1890 to 1983. Data 1890 to 1965 by U.S. Army Corps of Engineers, Seattle District. 1975 to 1983 erosion rates calculated by author by measurements from National Ocean Survey charts.

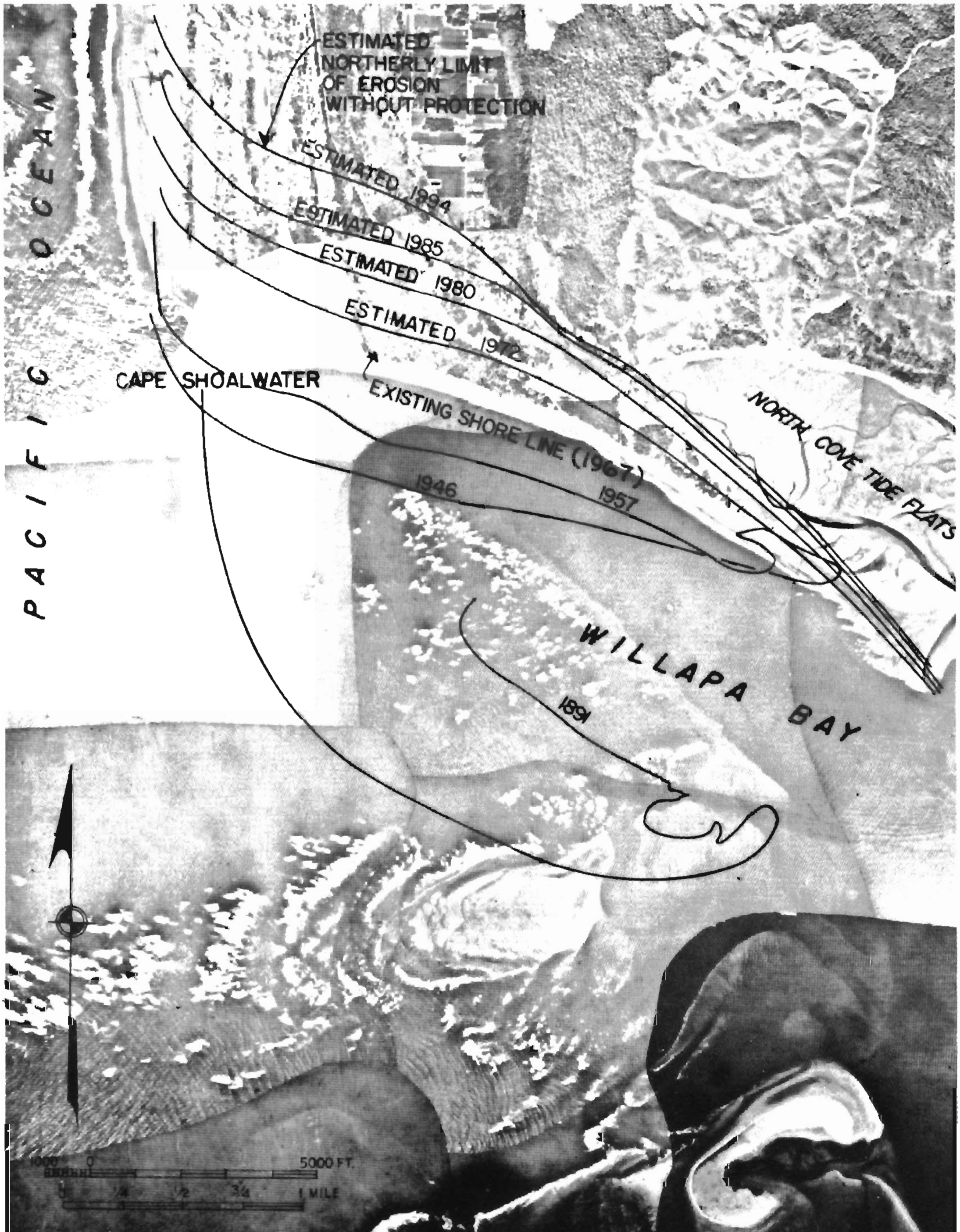

Figure 5. Cape Shoalwater shoreline configurations from 1891 with estimated northerly limit to 1994 (U.S. Army Corps of Engineers, Seattle District)

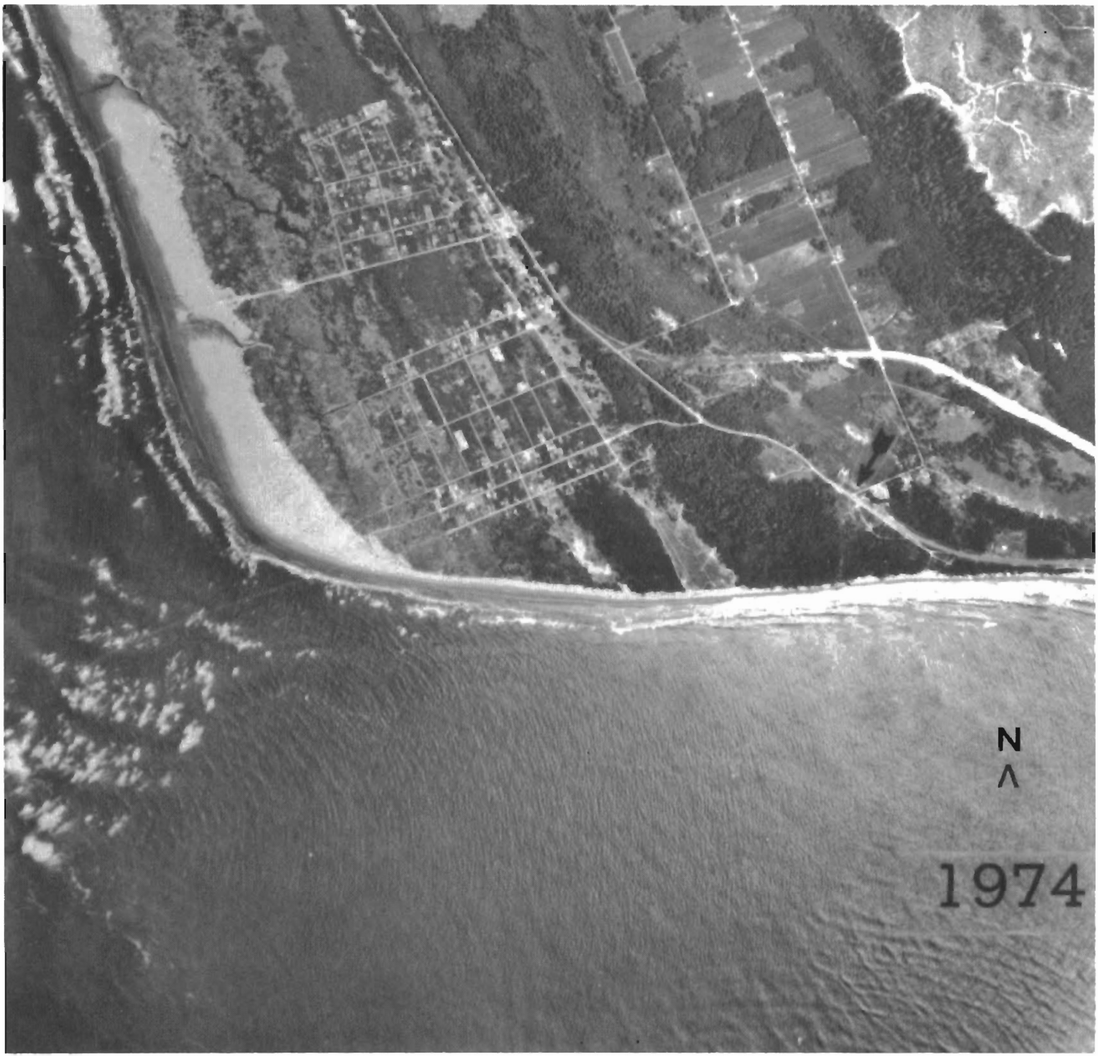

Figure 6. Aerial photograph of Cape Shoalwater taken in 1974. The black arrow indicates the location of the old coast highway threatened by the erosion. The new alignment is under construction to the north.

for the two periods indicating that the channel dredging had no apparent effect of the erosion on Cape Shoalwater.

The erosion data for the 75 year period from 1890 to 1965 clearly showed a trend of sustained erosion. There was no evidence indicating that the erosion would slow or stop. In 1967, the U.S. Army Corps of Engineers projected the sequential retreat to the shoreline at Cape Shoalwater through 1994 (Figure 5). They concluded that the erosion would continue unabated through the low dune areas to the west, but slow to the east where uplands composed of more resistant terrace deposits are located. The projections show slightly greater accelerated erosion than has actually occurred. The 1985 shoreline configuration is farther south by nearly 100 meters more than projected.

Of great concern in the late 1960s and early 1970s was the inevitable breaching of the State Highway 105 (Figure 6). In 1971 the State of Washington prepared a new alignment 1 km north along the base of the uplands. By the mid 1970s the old highway

Figure 7. A 1976 view to the east of the old coastal highway eroding away.

was being undermined and was soon completely severed (Figure 7). At this same time controversy also emerged about the fate of an old pioneer cemetery adjacent to the eroding highway. Some suggested leaving it to erode away, as moving it would be too costly. Other pleaded for relocation of the cemetery. Several prominent public officials were brought into the issue, including the Governor of the State (Seattle Times, April 18, 1976). In spite of the cost, the cemetery was moved and sited adjacent to the new alignment of the state highway.

In order to update the erosion rates as determined by the U.S. Army Corps of Engineers since 1965 (see Figure 4), the location of the Cape Shoalwater shoreline was measured from National Ocean Survey charts for 1975, 1980, and 1984 by the author. The comparative measurements for the nine-year period yielded an average annual erosion rate of 30 m/yr (100 ft/yr). This rate is lower than the 37.8 m/yr (126.0 ft/yr) annual erosion rate from 1890 to 1965. The lower rate might reflect some measurement inaccuracies that are inherent with map measurments or indicate actual slowing of the erosion rate. There is some additional evidence supporting a slowing of the erosion rate. Over the last several years the Pacific County Assessor's Office has plotted the approximate high water mark as shown on aerial photos to section maps scaled at 1 inch to 400 feet. The high water lines were not plotted with cartographic precision, yet comparative measurements taken several points along the lines plotted between 1976 and 1981 yield average annual shoreline recession rate of nearly 30 m/yr. This erosion rate is very close to the 30 m/yr average erosion rate between 1975 and 1984 as measured from National Ocean Survey charts.

CAUSES OF THE EROSION

The persistent, severe erosion of Cape Shoalwater presents a perplexing problem. The severity of erosion suggests the area is starved of sediment and that a lack of sediment is primarily responsible for the erosion. There is, however, no evidence of sediment starvation in the area. On the contrary, PHIPPS and SMITH (1978) have shown this coastal region to have an abundance of littoral sediment. The sediment supply has resulted in many decades of net shoreline accretion to the Long Beach Peninsula exceeding 6 m/yr (20 ft/yr). The shoreline north

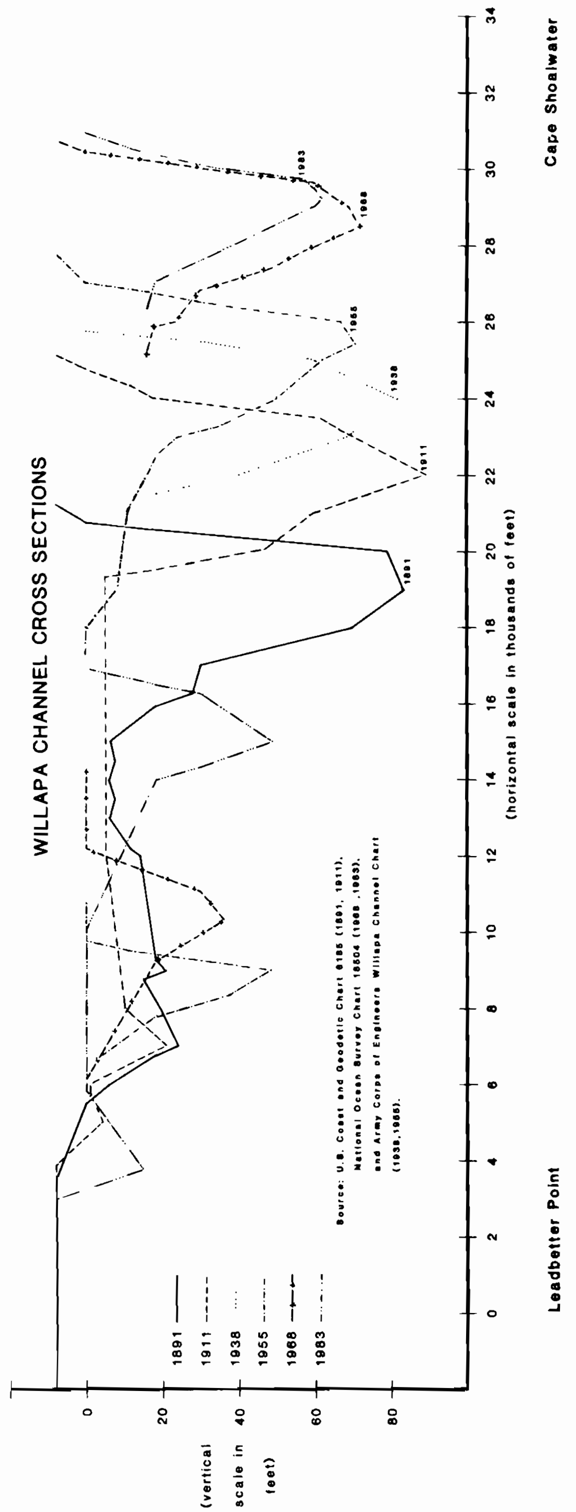

Figure 8. The progressive migration of the Willapa Channel thalweg toward Cape Shoalwater 1891-1983.

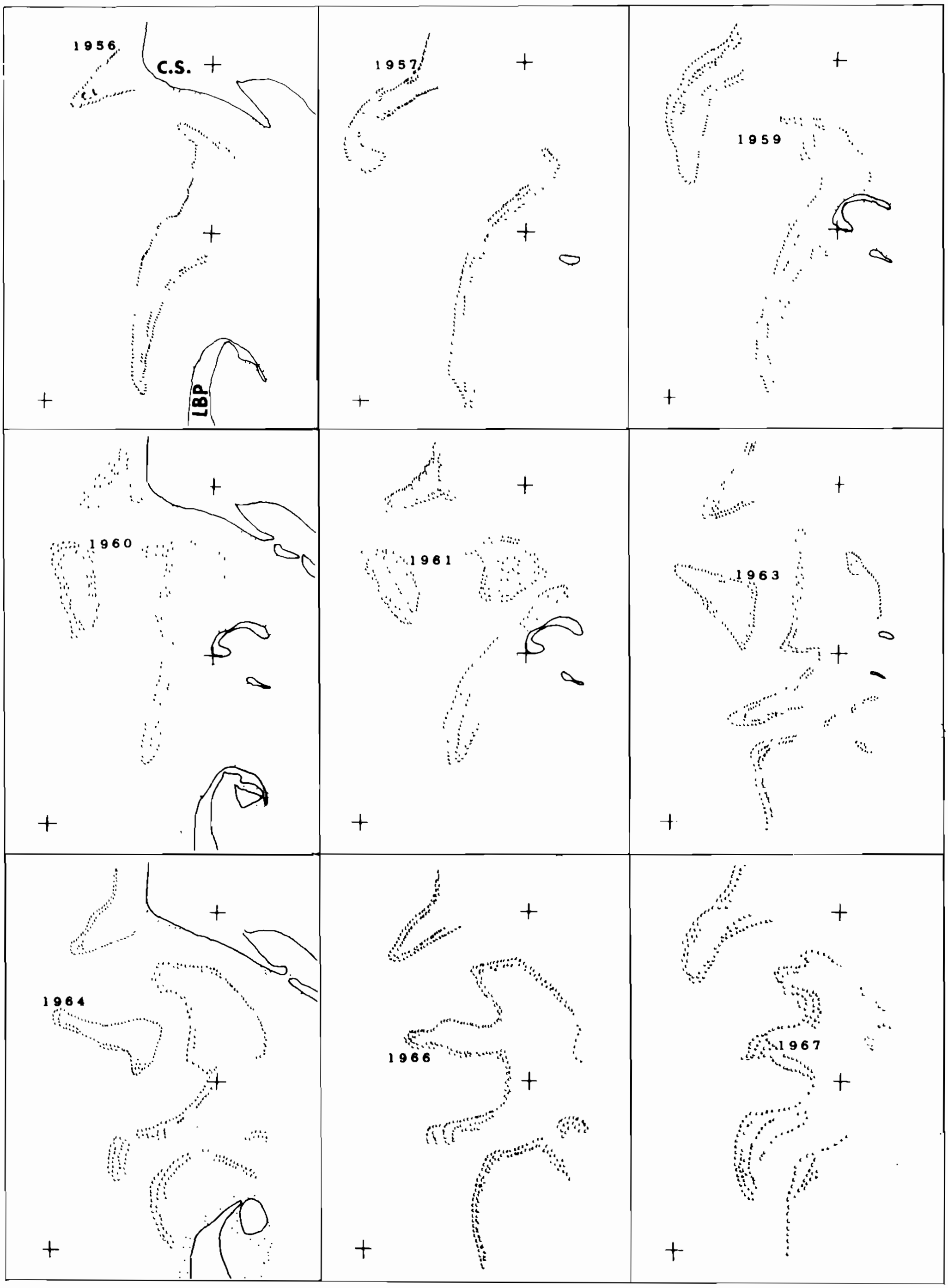

Figure 9. Migration of an embryonic spit south from Cape Shoalwater 1956-1959, then east to eventually join the Willapa Channel Shoals 1960-1967. (C.S. = Cape Shoalwater; L.B.P. = Long Beach Peninsula).

of Cape Shoalwater has also accreted westerly at rates ranging from 1.2 to 3.9 m/yr (4.0 to 13 ft/yr). Thus, a lack of regional sediment supply is not the cause of the erosion.

It is possible that the abundant sediment supply might acutally be contributing to the erosion of Cape Shoalwater. As prevailing longshore currents transport sediment to the north along the Long Beach Peninsula, the wide Willapa Channel is encountered. Tidal currents flowing transverse to the prevailing longshore transport significantly alter the littoral transport regime (PLOPPER, 1978). This leads to the growth of large shoals and sand bars within the channel. As the shoals grow and migrate, they continually force the tidal channel to the north closer to Cape Shoalwater. Storm waves breaking close to the shore in concert with the scouring action of the northward migrating channel result in the active erosion of the Cape. Cross sections of the channel show a steady, uninterrupted northward migration of the primary channel since 1891 (Figure 8). The average rate of northward movements over the 92-year record is approximately 33 m/yr (110 ft/yr). This rate is very close to the 36 m/yr (121 ft/yr) average erosion rate for Cape Shoalwater from 1890 to 1983.

The erosional retreat of Cape Shoalwater has not been matched by a northerly growth of the Long Beach Peninsula. Historical comparisons of Ledbetter Point at the north end of the Long Beach Peninsula show periods of advance and retreat with no significant northward growth (PHIPPS and SMITH, 1978). The long period of erosion has, however, significantly widened the channel entrance. In 1873 the straight line distance between Ledbetter Point and the south shore of Cape Shoalwater was approximately 4.75 km (2.96 miles). In 1983 that same distance was 9.75 km (6.09 miles), 5 km (3.12 miles) wider. Extensive shoals have grown in the channel since the turn of the century. There is evidence that the channel shoals are also periodically nourished by sediments north from Cape Shoalwater. A pattern of bar development and migration is observed from a sequence of Coast and Geodetic Survey charts (Figure 9). A bar, resembling the embryonic image of the former spit that occupied this nearby site in the 1890s was shown west of Cape Shoalwater. Between 1956 and 1959 it grew in a southwesterly direction. The tidal channel breached the bar and the severed portion migrated to the south and east between the years 1960 and 1967 eventually welding onto the main shoal in the channel. There is evidence that this might be a cyclic phenomenon and is contributing, along with littoral sediments from the south, to the overall growth of shoals in the channel (U.S. ARMY CORPS of ENGINEERS, 1967). As the shoals grow in size, they force the tidal channel to the north, closer to Cape Shoalwater, perpetuating the erosion.

CONCLUSION

Cape Shoalwater has been eroding faster and for a longer time than any other site along the Pacific Coast of the United States. The problem has received little attention beyond the immediate region. Up to now most of the eroded land has been rural, endangering or destroying relatively few man-made structures. Should the erosion continue as predicted, it will soon advance upon a developed subdivision of small cottages. As this occurs there will undoubtedly be some greater attention focused on the area.

There is little doubt that the erosion of Cape Shoalwater is due to the northward migration of the Willapa Channel. The abundance of littoral sediments in the region and the net northerly longshore current are forcing the channel thalweg to the north against the Cape. The greatest source of these channel sediments is from the south; however, there is evidence of some cyclic contribution of bar sediments from the north as well.

Recent measurements indicate that the erosion rate is slowing. There are several possible reasons. One of the less obvious is the relatively recent development of Ledbetter Channel, a new secondary channel just north of Ledbetter Point at the north end of the Long Beach Peninsula. Navigation charts show that over the last several years it has become deeper and longer. By 1983 it had developed into an unobstructed channel penetrating through the shoals out to sea. Its hydraulic efficiency might increase to a point where it significantly reduces the volume and velocity of flow through the main channel. This could result in the slowing of erosion at Cape Shoalwater.

By any relative measure, even a slowing of the erosion rate to 30 m/yr (100 ft/yr) is still very active erosion. A housing subdivision is endangered and the new highway, moved to the north in 1977, is once again being threatened. The severe retreat of the shoreline over the last 90 years indicates that there is little evidence for any significant change in the erosion rate of Cape Shoalwater in the near future.

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