Shoreline Changes at North Beach, Samish Island

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Preface

I first visited the North Beach community in 1993 after being contacted by local residents about an erosion problem. What I saw convinced me that the north side of Samish Island was a remarkably clear example of how a shoreline can be adversely impacted when the underlying geomorphologic processes are interrupted or disturbed. Subsequent background work indicated that I was not the first to note the significance of this shoreline - Ralph Keuler had discussed the potential impact of human actions on these beaches in a thesis almost twenty years earlier. As it usually does, more research led to more questions and led away from simple explanations, but did not alter the underlying thesis that recent erosion and human development were deeply entwined.

This report does not identify a single culprit, let alone a simple solution, but I trust it is helpful background for local residents who are now faced with trying to restore, or at least maintain, the beach that drew them to the shore in the first place. I am also hopeful that the report will serve as a valuable case study to guide shoreline management throughout the rest of Puget Sound, since many of the processes and problems discussed here apply equally well on many of our other beaches.

Acknowledgments

North Beach residents, including Kristin Schacht, Marge and Dick Dunnington, Ann Grace, and Garner Ekstran, provided anecdotal history and personal photographs that shed light on the history of the beach. Dick Dunnington lent me aerial photographs. Clayton Herzog provided photos and information, but also played an important part in focusing the community on the problem and in articulating the need for an innovative, cooperative solution. Oscar Graham and Zoe Pfall Johnson provided useful background on Samish Island shoreline issues. Douglas Canning of Ecology supplied photographs and contributed his observations of the area. Jim Johannessen of Coastal Geologic Services shared his observations and preliminary survey results. Wolf Bauer provided his experience on Puget Sounds's gravel beaches, insights into the mechanics of this particular beach, and the inspiration and the examples that may ultimately drive a solution.

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SUMMARY

During recent decades, residents of a portion of the North Beach community on Samish Island in Skagit County have observed substantial beach erosion. In this report, we seek to understand the reasons for this beach loss and to propose some general means of addressing the problem.

This report serves two purposes. The first is to provide background that might help assist and shape an effective and environmentally judicious community response to the ongoing erosion. The second is to document an excellent case study in shoreline erosion and the sometimes complicated role of human activities in coastal processes.

We found that the erosion observed in recent decades at North Beach results from a combination of factors, including the progressive demise of a groin-like structure immediately downdrift of the area of worst erosion and the loss of littoral sediment supplies due to updrift bulkheading and groin construction. We also found that the well-intentioned efforts of North Beach residents to protect themselves by building bulkheads may have aggravated the loss of the sandy berm and high-tide beach.

This report outlines several general approaches to addressing the erosion problem at North Beach, including traditional bulkheading, the use of groins, and beach nourishment. We conclude that a carefully designed beach nourishment project (adding sand or gravel to the beach), possibly supplemented with minor structural elements, may be effective but will require ongoing monitoring and periodic renourishment. North Beach residents, working together with a consultant, are currently examining options, including a community-scale beach nourishment effort.

INTRODUCTION

Samish Island is located along the western shore of Skagit County, in the northern portion of the Puget Lowland near the mouth of the Samish River (Figure 1). North Beach lies on the northern side of Samish Island, facing north across Samish Bay, on a large sand spit (Fish Point) and coastal marsh complex (drained for agriculture and residential development). Shoreline homes occur on the low berm of the sand spit and in low areas behind the berm. As a result, they lie on easily eroded sediment (primarily loose sand and gravel) in an area subject to periodic flooding.

The potential for erosion problems on North Beach was identified by Ralph Keuler, 1979, p. 111) in his Masters thesis (Appendix B.2 of this report). He specifically noted the north shore of Samish Island, where:

> some shore defenses were built as long ago as the 1930's. As more and more bulkheads have been built over the years, less sediment can be derived from bluffs. At the westerly extremity of the terminal, prograded beach [the North Beach community], erosion has been noticed within the last 10 years. This erosion could be a mostly natural occurrence but it is probably also linked to the partial cutoff of the beach sediment source, the bluffs.

Oscar Graham (1992), in a Skagit County report, discussed the potential for shoreline erosion and for coastal flooding in this low-lying area (Appendix B.5). In addition, Canning and Shipman (1995, p. 89) described the erosion problem based on familiarity with these earlier reports, observations made during a field visit, and subsequent analysis (Appendix B.4).

The primary focus of this report is several thousand feet of shoreline along North Beach Road, because this is where the erosion has been most significant. Much of the background information and subsequent analysis, however, applies to the entire north side of Samish Island and may be relevant to others on the north shore, including both bluff residents to the west and beach residents living farther east toward Fish Point. In conducting the work, we noted significant beach changes east of Blau Oyster, and recognized the potential for major erosion problems along the entire length of the spit, but have not elaborated on these issues in this report.

Study history

North Beach residents first contacted Ecology staff with erosion concerns in 1993. A site visit (7/2/93) confirmed these concerns, but also indicated that erosion was likely a localized symptom of a much broader geologic problem along the northern shore of Samish Island. Further analysis found a convincing connection between erosion at North Beach and historic shoreline modifications in the two miles west of North Beach.

Residents contacted Ecology again in late 1996 to further discuss possible avenues for addressing the erosion. The failure of several bulkheads in the week between Christmas, 1996, and New Years, 1997, provided dramatic evidence of the seriousness of the problem and galvanized community interest in a comprehensive solution. A series of discussions and field meetings involving neighbors, consultants, and county and state agency staff occurred during the spring of 1997.

Description of Erosion Problem

Residents along the west end of North Beach report major erosion of their beach since the 1960s. In particular, significant erosion occurred near the west end of the beach in the late 1960s and farther east in the late 1970s or early 1980s. Historical aerial photographs confirm that erosion has occurred in this area during these general time periods.

This beach erosion involved the progressive narrowing of the high tide beach and the loss of the berm and associated drift logs and beach grass. The proportion of sand on the beach diminished, whereas the coverage of coarser gravel and pebble appears to have increased. Property owners constructed bulkheads to address the erosion and increased flooding during this period. As the beach continued to erode, the level of the beach in front of bulkheads fell. This in turn exposed the bulkheads to far more serious damage during storms. In late 1996, several structures were damaged during a period of storm waves, high tides, and heavy precipitation.

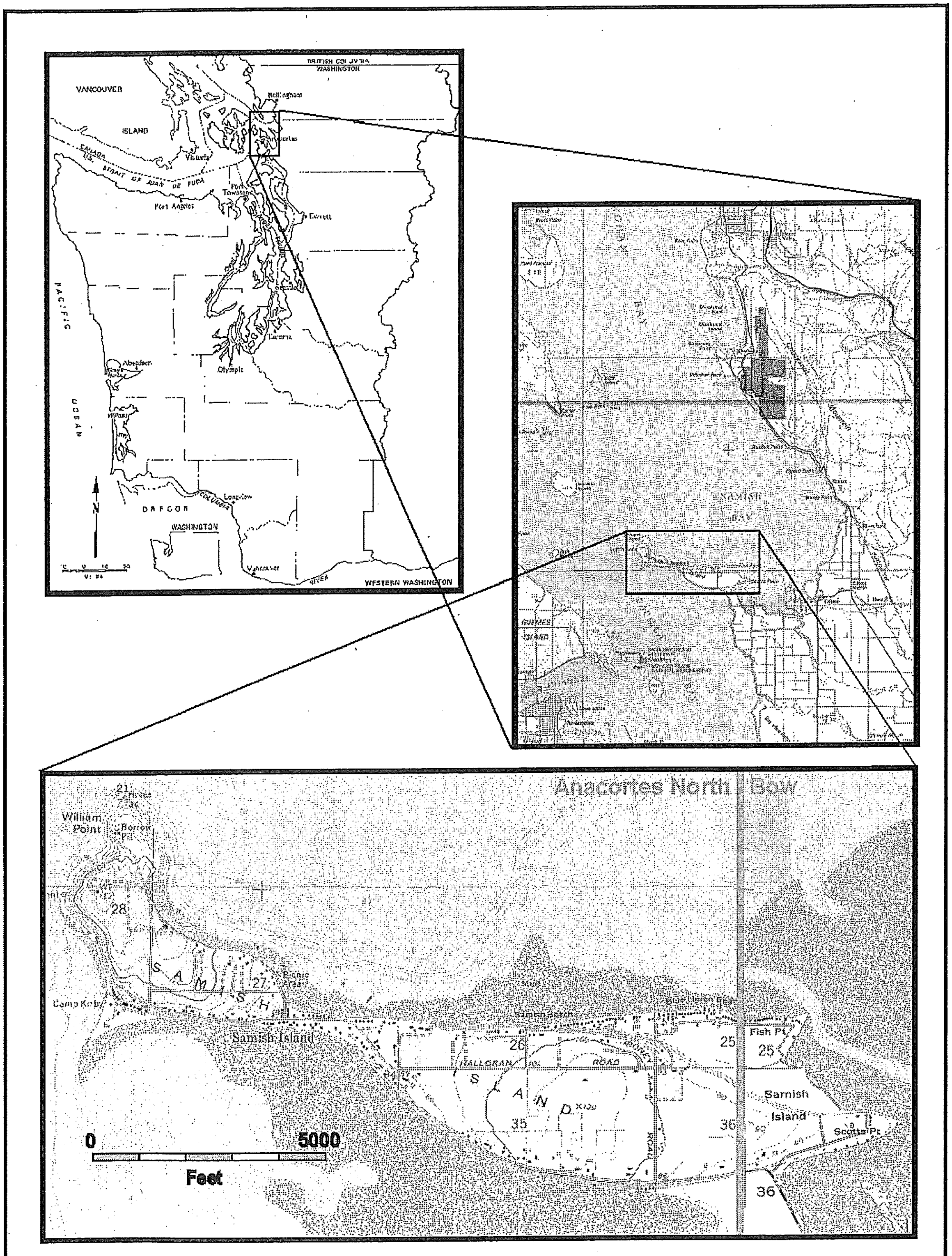
Beach erosion impacts the aesthetics and the recreational potential of North Beach. The erosion has led residents to spend significant sums of money to construct and repair bulkheads and it appears likely that the cost of maintaining erosion control structures will increase significantly in the future. The bulkheads in turn have made beach access more difficult and may have increased problems with elevated groundwater and periodic flooding landward of the beach. This causes property damage, limits access to homes during floods, and may impact the operation of on-site septic systems.

In addition, property owners each choose to deal with the erosion at different times and in different ways. Eventually, this raises concerns about how the actions of individual residents may adversely impact others. There are already strong opinions about the role of nearby structures in precipitating the erosion. Although the issues on western North Beach have some unique characteristics, much of the experience there may be eventually repeated farther east.

Beach erosion, combined with the bulkheads constructed to combat it, leads to significant changes to the beach that may adversely impact intertidal and nearshore ecology (Macdonald and others, 1994). Energy regimes are modified, intertidal zones shift or are lost, and shifts occur in substrate from finer-grained sediment to coarser-grained materials. This may impact the suitability of the beach for fish spawning, the distribution and quantity of aquatic vegetation such as eelgrass, the abundance of certain shellfish, the use of the shoreline for salmonid migration, and numerous other factors.

Figure 1 - Location Map.

Figure 1. Location Map



Location Map -- Samish Island, Skagit County, Washington

Shoreline Change on North Beach, Samish Island

Figure 1

BACKGROUND

Setting

Samish Island is actually a peninsula attached to the mainland at its southeastern end (Figure 1). It separates Samish Bay on the north from Padilla Bay on the south. Prior to this century, Samish Island was indeed an island, but one gradually being engulfed by the expanding Skagit/Samish River delta. Diking of delta marsh and mudflats to create agricultural land resulted in the permanent attachment of the island to the mainland (for geologic history of Samish River delta see Bortleson and others., 1980).

We did not undertake a thorough review of Samish Island history for this report, but we note that significant changes to the shoreline were already underway early in the century. Docks, shoreline fills, and rock erosion control measures appear to have been constructed in the vicinity of the platted communities of Samish Island and Atlanta, near the narrow neck of the island. In addition, we suspect that the original diking and draining of the large low-lying wetland area immediately behind (south) of Samish Beach and Fish Point also dates to the turn of the century.

The western portion of North Beach was subdivided by Jenne and Dunlap in the mid-1920s. We do not know how much development had already occurred, but by 1937 aerial photography indicates numerous homes along the beach. Subsequent maps and photographs track the continued construction of homes on vacant lots and the conversion of beach cabins into more substantial dwellings. Samish Island mirrors similar beach communities throughout the Puget Sound region where we see progressive increase in both the scale and style of waterfront homes as property values increase and greater numbers of people begin to use these areas for permanent residence, rather than as occasional retreats.

At this time, all properties along the west end of North Beach have shoreline bulkheads. Many of these are built from two or three tiers of 2'x2'x4' precast "ecology" blocks. Although not necessarily an optimum method of construction for shoreline bulkheads, such segmented walls are easy and relatively inexpensive to install. We also noted several poured concrete walls, some masonry bulkheads, and a few timber structures. Riprap (large loose rock) has been placed at the toe of bulkheads at the westernmost end of the beach.

Geology

Samish Island consists of two broad hills of glacial drift, with the underlying bedrock exposed at the northwestern end of the island. Most of the island is mantled with Vashon-age glacial till, with older geologic units exposed in the shore bluffs. A narrow constriction occurs near the west end of the island and separates the island into two distinct portions. William Point, at the northwest end of Samish island, consists of Tertiary-age bedrock and forms a distinctive erosion-resistant headland. The high north-shore bluffs, immediately southeast of William Point, contain glacial outwash of coarse sand and gravel but diminish in height to the east, where they expose finer-grained sediments (Washington Department of Ecology, 1978).

Shore bluffs east of William Point, toward North Beach, are generally between 30 and 80 feet in height, and appear to consist of glacial marine drift composed primarily of silts and fine sands along with scattered gravel and boulders. Toward the east, in the vicinity of the west end of North Beach, the bluff diverges inland from the shoreline in a southeasterly direction. The shoreline itself, continues eastward and North Beach (or Samish Beach), Blue Heron Beach, and Fish Point comprise an easterly-directed sand spit approximately one mile long. A broad back-barrier marsh originally filled the area between the spit and the bluff to the south (**Error! Reference source not found.** and **Error! Reference source not found.**), although it has been subsequently drained and farmed.

Littoral Drift. *Littoral drift* describes the process by which beach sediment is moved along the shore as a result of waves striking the shore obliquely (for more elaboration, refer to Downing, 1983 or Schwartz, 1989). Littoral drift plays an important role in the evolution of shorelines on Puget Sound and directly influences whether beaches grow, erode, or remain stable.

Keuler (1979) found littoral sediment movement to be from west to east on the north side of Samish Island (**Error! Reference source not found.** and Appendix B.2). This conclusion is well-supported by our own field observations and analysis of shoreline features. The shape and orientation of the spit that forms Samish Beach and Fish Point is, in itself, excellent evidence of this easterly movement of material. In addition, sediment accumulates consistently on the west side of groins, boat ramps, large drift logs, and other obstructions to littoral drift.

The Coastal Atlas (Washington Department of Ecology, 1978, and Appendix B.3) provides somewhat ambiguous information about drift, suggesting that net drift may actually be from east to west. Drift directions in the Atlas were derived from generalized estimates of wind direction and assumptions about typical beach sediment sizes and are often inconsistent with field observations and geomorphologic analysis. In most cases, including this, we consider the Atlas to be incorrect. It does suggest, however that conditions may be amenable to periodic reversals in littoral drift, and that the notion of uniform sediment movement from west to east may be simplistic.

Beach sediment on the north side of Samish Island is derived almost exclusively from bluff erosion. Although the glacial marine drift provides some sand and gravel to the beaches, we suspect that much of the gravely beach material derives from the eroding bluffs of glacial outwash on the western portion of the island toward William Point. The Samish River may contribute some fine-grained sediment (fine sand or silt) to the low tide flats offshore, but is not a likely source for beach sand and gravel.

Erosion Rates. Little information exists for shoreline erosion rates on Samish Island. Keuler (1979) determined a retreat rate of 1.5 cm/year (0.5 inches/year) in the bedrock at William Point and a retreat rate of over 12 cm/year (6 inches/year) at a bluff location on the north side of the narrow part of the island. These rates are consistent with our general understanding of erosion rates in similar settings around Puget Sound (Shipman, 1995) and also appear consistent with observations by local property owners. Note that once a bank is stabilized with riprap or with a bulkhead, the rate of retreat of the bank itself slows, but the beach will continue to erode. This can be seen in the continued lowering of the beach surface in front of bulkheads along the bluffs east of the narrow part of the island.

Shoreline Evolution

Coastal geological processes have strongly influenced the evolution of Samish Island's shoreline. Wave action over several thousand years eroded the northern side of the island, creating extensive bluffs that gradually retreated southward. Sand and gravel eroded from these bluffs was carried by littoral drift along the shore and redeposited elsewhere to form barrier beaches (sand spits) such as at North Beach and Fish Point (**Error! Reference source not found.**). The distinctive cuspate point at Camp Kirby (at the southwest end of island) also formed by this process.

Five thousand years ago, when sea level reached roughly the level it is today, William Point must have looked much as it does now. Very little erosion has occurred in the intervening period. Although the bluffs between William Point and North Beach may have also appeared much as they do today, they lay up to several hundred feet farther north into Samish Bay than they do today. Erosion has gradually moved the shoreline south to its current position.

The steep slope that lies behind (to the south of) North Beach, and that extends eastward to form Scott's Point, marks the maximum southward erosion that occurred prior to the formation of the spit that forms North Beach. At that time, North Beach, Blue Heron Beach, and Fish Point were simply shallow water offshore and waves broke on a beach at the base of the bluffs. With time, however, large volumes of sand and gravel transported by littoral drift from the west began to form the sand spit. The spit may have formed somewhat north of its current position and gradually migrated southward to its current position, although this is by no means proven.

As the spit grew to the east, waves could no longer reach the bluffs and a lagoon probably formed in the area between the bluffs and the newly formed spit. With more time, the lagoon filled with sediment and likely evolved from open water to a salt marsh to a restricted wetland complex. It may have existed as some combination of lagoon, brackish marsh, and freshwater wetland when humans arrived in the late 1800's and began to drain the marsh and build dikes to convert the area to agriculture.

Tides

Puget Sound experiences mixed, semidiurnal tides, meaning that we experience two highs and two lows each day, but that they are usually of different heights. In general, the highest and lowest tides near the solstices. In the summer, the lowest tides tend to occur in the daytime and the highest at night. In the winter, the highest tides occur in the daytime and the lowest at night.

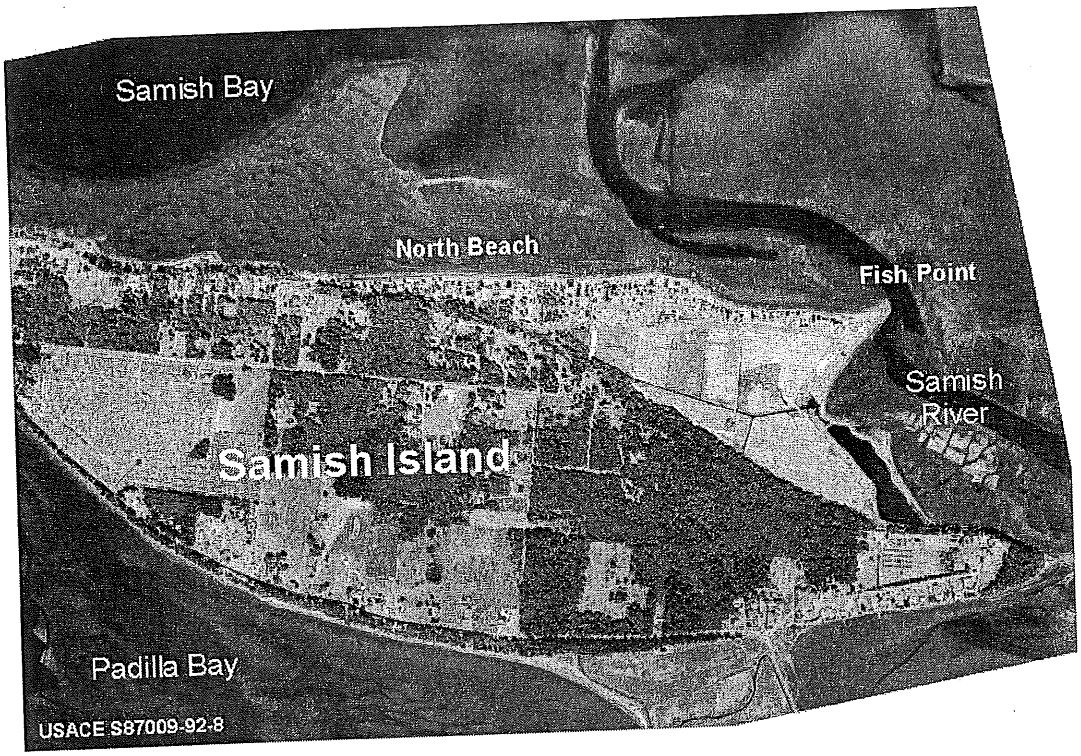
Tides on the north side of Samish Island are similar to those in Bellingham, located 12 miles to the north. Mean Higher High Water (MHHW) at Bellingham is 8.6 feet above Mean Lower Low Water (MLLW). The highest estimated tide at Bellingham is 11.5 feet (MLLW). Mean sea level, the datum generally used on topographic and engineering surveys, is 4.49 feet (MLLW).

The natural berm (the level portion of the beach on which drift logs typically accumulate and where beach grass first appears) is located at an elevation of approximately 10 feet (MLLW) or slightly higher in this area. Most bulkheads along North Beach are built with an upper elevation of at least 12 feet (MLLW). As a result, waves may overtop bulkheads when storm waves coincide with unusually high tides. The highest elevations on North Beach (besides the bluffs to the south) are along the line of the original berm, immediately behind the bulkheads. Much of the area between the berm and the bluffs lies lower and may flood when heavy precipitation and wave action results in large amounts of water collecting in this area. The area drains slowly and flooding conditions may persist for several days, as witnessed following the storms at the end of 1996.

Waves

Waves on the north side of Samish Island result from local wind conditions and are limited primarily by the extent of open water (the fetch) over which winds can blow. The north shore of Samish Island is sheltered from the southerly storm winds that dominate in this region. Wind data from Anacortes (Keuler, 1979) suggests that the strongest winds that impact North Beach are probably from the northeast, although weaker winds from the northwest occur more frequently.

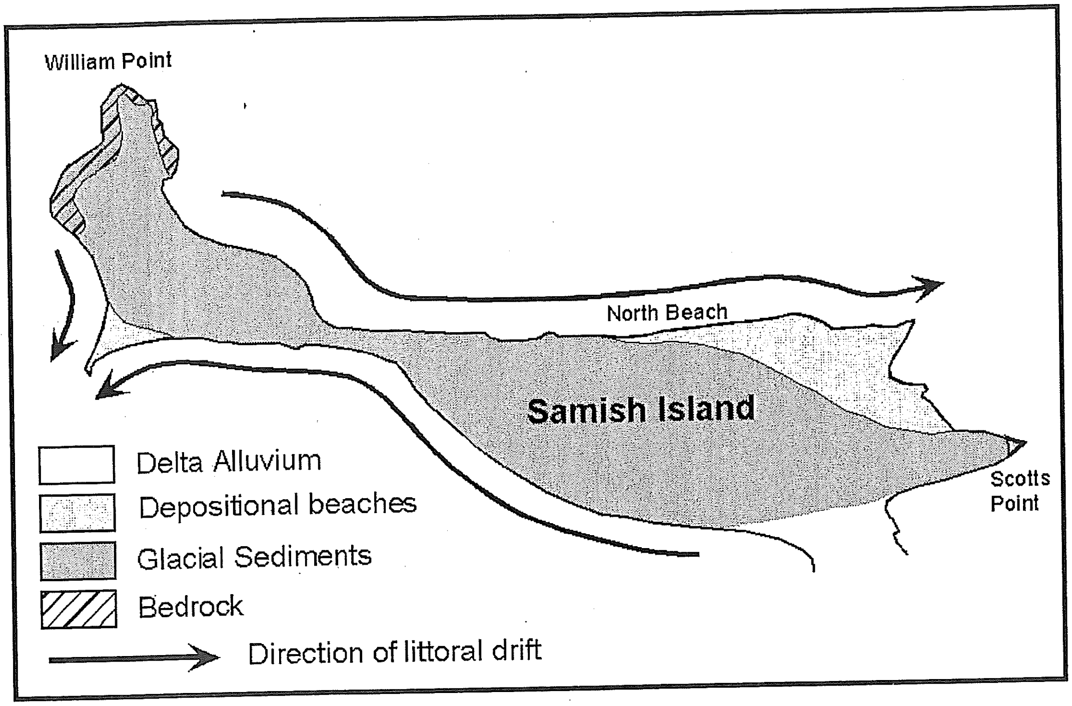
North Beach's greatest exposure is to the north-northwest, over Bellingham Bay, where the fetch exceeds 15 miles. The fetch from the northeast is only about 5 miles and although this does not preclude frequent wind and wave action from this direction, the potential wave energy that reaches the shoreline is probably less than from the northwest and north-northwest. Maximum wave heights, based on the fetch, are unlikely to exceed five feet (Keuler, 1979). Storm damage tends to be most severe between November and February, when frequent storms can occur in conjunction with extreme high tides.



1987 Aerial Photograph. Eastern Samish Island.

Shoreline Change on North Beach, Samish Island

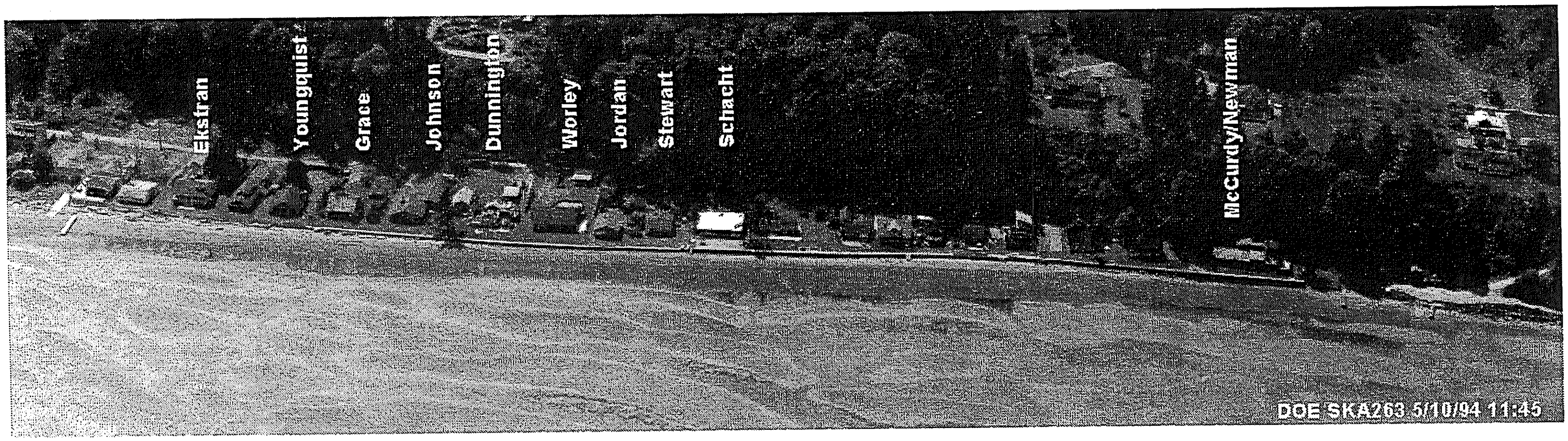
Figure 2



Geology and Littoral Drift on Samish island

Shoreline Change on North Beach, Samish Island

Figure 3



East ⟷ West

Oblique aerial photograph, looking south, of western North Beach, Samish Island. Property names for reference. Photograph taken in May, 1994. Note lack of drift logs and beach berm west of Dunnington residence and the two groins located at the west end of beach.

Western portion of North Beach. 1994 oblique aerial photograph.

Shoreline Change on North Beach, Samish Island

Figure 4

HISTORICAL SHORELINE CHANGES

Information on historical changes to the shoreline come primarily from historical air photos and discussions with local residents. Many of the properties along North Beach remain in the same families as they did when the area was originally developed and current residents have recollections of historical events and changes along the beach. Some provided copies of family photographs that show the beach.

In studying this area, we obtained historical aerial photographs from several sources. Most post-date the mid-1960's, although we did obtain one photograph flown in 1937 by the Army Corps of Engineers. A selection of these photos is reproduced in Appendix A, along with a list of the photos consulted. Unfortunately, many of the photos were taken when the sun was relatively low in the southern sky and portions of North Beach and the bluffs to the west are obscured by heavy shadow.

Chronology

The 1937 aerial photograph shows a distinct offset in the beach in the general vicinity of the Youngquist residence, indicating the presence of a groin, boat ramp, or similar structure that disrupts littoral drift (Figure 2). The line of vegetation behind the beach appears relatively straight, but the water lines on the beach are offset approximately 20-25 feet by the feature. Beaches several hundred feet east of the feature are about 20 feet wide (between the vegetation line and the distinct dark wrack line on the beach), but the beach west of the feature is 40-45 feet wide.

We believe this structure may be the rock and metal structure referred to in notes by Marge Dunnington (Appendix B.1), where logs were reportedly brought to the beach during the 1920s. Discussions with other residents hinted at the presence of this structure, but accounts varied regarding its location and exact nature.

Aerial photographs from the mid and late-1960s show no evidence of this offset, although there is some evidence that the beach in the area to the west remains anomalously wide (Figure 3). This indicates that the structure itself may have largely been destroyed or removed, but that the beach retained some of the form caused by its presence. We believe that the broad convex-seaward curve to the shoreline centered at Dunnington may be a relic of this historical modification to the shoreline.

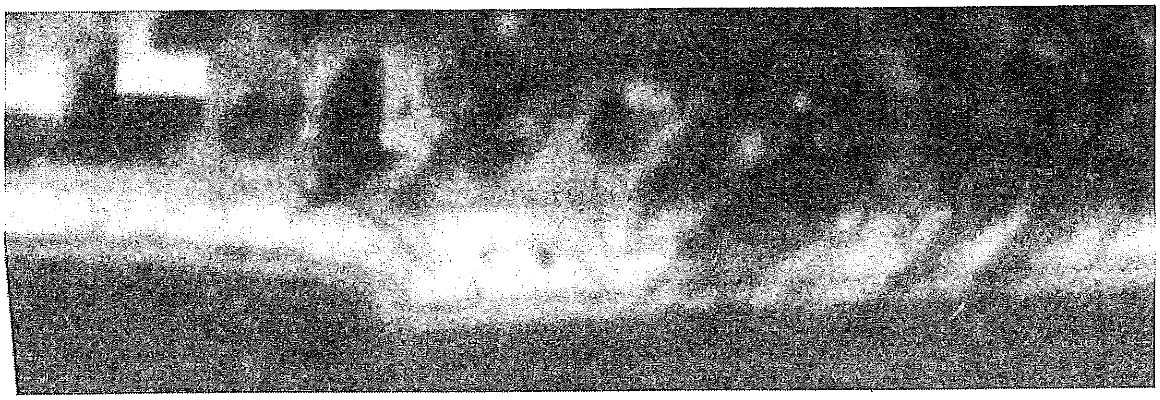


Figure 2. 1937 Aerial Photograph - beach offset near Youngquist property

Figure 3. 1966 Aerial Photograph
Same general area as Figure 5.

From our review of the photographs and discussions with property owners, it appears that no bulkheads existed between the McCurdy/ Newman (west) and the Youngquist (east) residences until at least the late 1960s. The Ekstran bulkhead (a sloped-face concrete wall) was reportedly built in the 1930s when the house was built (Garner Ekstran, personal communication). We suspect that the Youngquist bulkhead may also data to this general period.

In the mid-1960s, there appears no evidence of significant erosion from the Youngquist property westward to the bulkhead at the McCurdy/ Newman residence. The beach is wide and drift logs are easily noted in the aerial photos and family photos. Sometime in the 1960s Mercer Road was extended down the bluff at the western most end of North Beach. Concrete groins were also constructed in this vicinity at about the same time (Figure 4 and Figure 5). These groins remain in place today. Sediment has accumulated on their western sides.

Residents noted increased erosion in the late 1960s near the west end of North Beach. Property owners to the east generally attribute this erosion to the construction of the two groins discussed above, although it appears other factors were also relevant. In 1976, an application for a groin was submitted by Bailey (immediately east of McCurdy/ Newman?) but the proposal was eventually withdrawn. Riprap, log bulkheads, and concrete structures were built during this period. The 1977 photograph indicates bulkheads or anchored logs on the second, third, and fourth properties east of McCurdy/Newman. The property immediately east appears to have been protected with large rock.

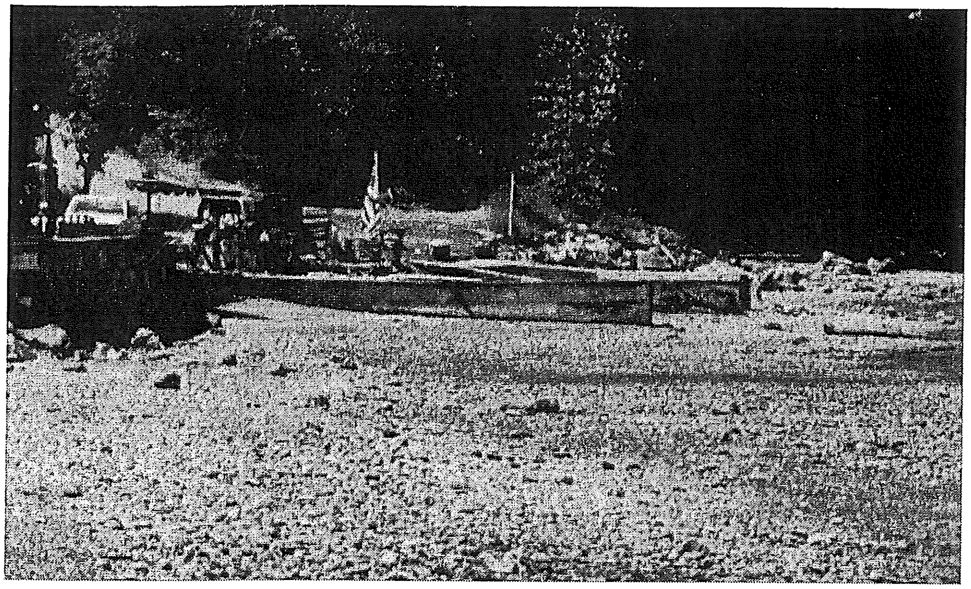


Figure 4. Concrete groins at west end of North Beach (Photo: 1993)

Figure 5. 1995 aerial photograph of groins

During the late 1970s and early 1980s, residents farther east began to experience erosion, which in turn precipitated the bulkheading of this entire stretch. The timing is not completely clear, but we know that the bulkheads at Stewart-Jordan-Worley-Dunnington were constructed in 1982 and that by 1983 all properties on western North Beach were protected by some sort of concrete or log structure. Storm damage in the mid-1980's apparently required some of these bulkheads to be repaired or rebuilt.

1977 and 1978 air photographs show a berm covered with drift logs and few bulkheads along this stretch of beach. By 1983, the high tide beach with logs and beach grass is observed only from the Worley property eastward. Photographs taken by residents during construction of the 1982 bulkheads show the construction of the ecology-block wall on the berm and the filling of some locations landward of the wall. Some of the observed loss of the high tide beach and berm during this period appears to be a result of the placement of the structures themselves.

Residents report that the beach has continued to erode since the mid-1980s. The aerial photographs indicate that there has been some additional erosion of the remaining high tide beach in the vicinity of the Dunnington and Worley residence, but we have found documentation of recent erosion difficult. Erosion during the winter of 1997 exposed weep holes on the Schacht bulkhead and one resident reported that portions of the beach a few hundred feet farther east were lower then they had previously seen them. Some of this may be a temporary result of the winter's storms.

In the week between Christmas and New Years, 1996, a combination of strong winds, high tides, and heavy precipitation resulted in extensive flooding of the North Beach area. The four ecology-block bulkheads (Stewart-Jordan-Worley-Dunnington) built in 1982 were damaged. The Stewart and Jordan walls toppled, allowing erosion of upland area between the wall and the homes. The Worley wall partially failed, and the Dunnington structure tilted forward, allowing a concrete sidewalk cap to break off. Repairs were made to provide protection until a more comprehensive solution could be pursued.

Summary

The lack of survey data for the beach and the limited number of historical photos makes tracking of changes at North Beach difficult and imprecise. Based on the information available, however, we find the following:

- A significant offset in the beach was present in 1937, probably resulting from the groin-like behavior of a structure built much earlier across the beach near the Youngquist residence. This resulted in an anomalously broad high tide beach extending several hundred feet to the west. By the mid-1960s, aerial photos do not detect this feature.
- Several modifications to the westernmost end of North Beach were made in the 1960s, including the construction of two concrete groins that exist in good condition today.
- In the late 1960s and early 1970s, property owners concerned about erosion began to construct bulkheads or place riprap in front of homes near the west end of the beach.
- Erosion continued in the 1970s and early 1980s and by 1983, the entire stretch of beach was armored - primarily with concrete or ecology block bulkheads. The only remaining high tide beach and associated berm occurred from the Worley property east.
- By the mid-1990s, the berm extends only as far west as the Dunnington residence. In very late 1996, several bulkheads were damaged during a week of heavy storms.

In summary, the western portion of North Beach displays a history of relative stability until at least the early 1960s, at which time erosion began to occur in a progressively eastward direction. This in turn resulted in increasing armoring of the shoreline and continued narrowing and lowering of the upper beach. Several significant events occurred prior to the onset of erosion, including the disappearance of a groin-like feature that may have stabilized the beach previously and the construction of two groins at the west end of the beach. In addition, we believe changes were occurring along the bluffs farther west that may also have impacted this area.

FACTORS AFFECTING NORTH BEACH SHORELINE

Shorelines shift for a variety of reasons related to changes in sediment supply, wave action, and human intervention. In this section, we evaluate several possible explanations for the observed changes of the North Beach shoreline. Not surprisingly, we find that no one single factor is responsible, but rather that a number of different factors all appear to contribute to the progressive erosion of the beach.

Natural rates of erosion

Beaches routinely shift position and change shape in response to storms and typically undergo seasonal variations due to difference between summer and winter wave conditions (Downing, 1983). These changes may affect beach height by several inches or a foot on Puget Sound, may cause significant short-term fluctuations in the proportion of sand or gravel on the beach, and may result in erosion of the upper beach (often indicated by a scarp in the berm), but do not necessarily indicate a long-term erosion problem, since beaches often recover within a few weeks or months.

Sand spits, such as the one on which the North Beach community is built, are depositional geologic features - formed by gradual accumulation of sand and gravel during hundreds or thousands of years. Severe erosion, therefore, on such a sand spit typically indicates a significant change in natural conditions. At the same time, however, such beaches are not necessarily stationary and often migrate (usually landward) with time as the regional shoreline gradually retreats. This may occur at North Beach and would suggest that the spit is eroding landward (to the south) at a rate comparable to the erosion rate of the adjacent bluffs to the west, which we have previously suggested is probably not more than a few inches per year (check to see if discussed earlier). This might explain 10-20 feet of erosion in the last fifty years, but does not seem to explain the unusually rapid rates observed in the last two to three decades.

Older shoreline modification

Rapid shoreline changes often reflect the beach's response to an historical disturbance or modification (for example, rapid erosion often occurs in areas of historical landfill, where the shoreline had been artificially extended waterward). On North Beach, the presence of a groin-like structure during, and possibly before the 1920s and 1930s resulted in substantial beach accretion in the same general area that has eroded the most during recent decades. Although the feature itself is no longer apparent in air photos from the 1960s, the broad beach it caused to form was still in evidence, suggesting the shoreline remains out of equilibrium. One factor in the erosion of western North Beach may be the relatively rapid return of this shoreline to its original position.

Littoral sediment budget

On Puget Sound, erosion commonly takes place where the supply of sediment by littoral drift is limited or reduced in some way, yet the natural loss of sediment from the area continues. This can occur for natural reasons - nearby eroding bluffs contain too little sand and gravel to support downdrift beaches, for example - or because of human interference with natural erosion processes (bulkheading of eroding bluffs) or with the movement of littoral sediment (the construction of groins or jetties).

Prior to development, the longshore movement of sediment on the north side of Samish Island was relatively unimpeded, and sand and gravel from bluffs to the west built beaches eastward to Fish Point, where the drifting sediment was ultimately captured by the river channel and redeposited in the deeper water of the river delta. North Beach was built on this eastward directed sand spit.

As a result, any reduction of sediment supply from the west is likely to diminish the volume of sand and gravel at North Beach, causing erosion. In our experience on Puget Sound, we find that the updrift portions of spits (near their bases) are typically most sensitive to changes in sediment supply and that erosion and flooding is first observed in these areas. Western North Beach is located in this potentially vulnerable area.

Bulkheading west of North Beach

Erosion of bluffs along the north side of Samish Island (west of North Beach) has led property owners to construct bulkheads and rock revetments (Figure 6). This bluff erosion, however, was the primary source of littoral sediment for beaches to the east, including North Beach, and therefore effective erosion control along the bluffs will likely lead to gradual diminishment of downdrift beaches. This problem has been addressed for Puget Sound in general (Macdonald and others, 1994) and for the north side of Samish Island in particular (Keuler, 1979). On bulkheaded shorelines, the beach continues to erode - witness the downcutting of the beach itself in front of the bulkheads near the neck of Samish Island (Figure 7) - but it provides only a small fraction of the sediment originally eroded from the bluffs.

Coarse sand and gravel constitute the most critical size of sediment needed to maintain beaches. The single most important source of this material on the north side of the island appears to be the bluffs of glacial outwash between the DNR Public Access site (northwest of the narrow part of the island) and the bedrock at the northwestern end of the island (William Point). Erosion of these bluffs has been curtailed through bulkheading, although the abundance of beach gravel at the DNR site indicate that substantial volumes of sediment remain in the system. Unfortunately, observations also suggest that little of this material travels much farther eastward.

The bluffs between the narrow part of the island and North Beach are generally finer grained, but still provided some beach sediment to the littoral system prior to development. Bulkheading is extensive, however, and few significant sources of sediment remain.

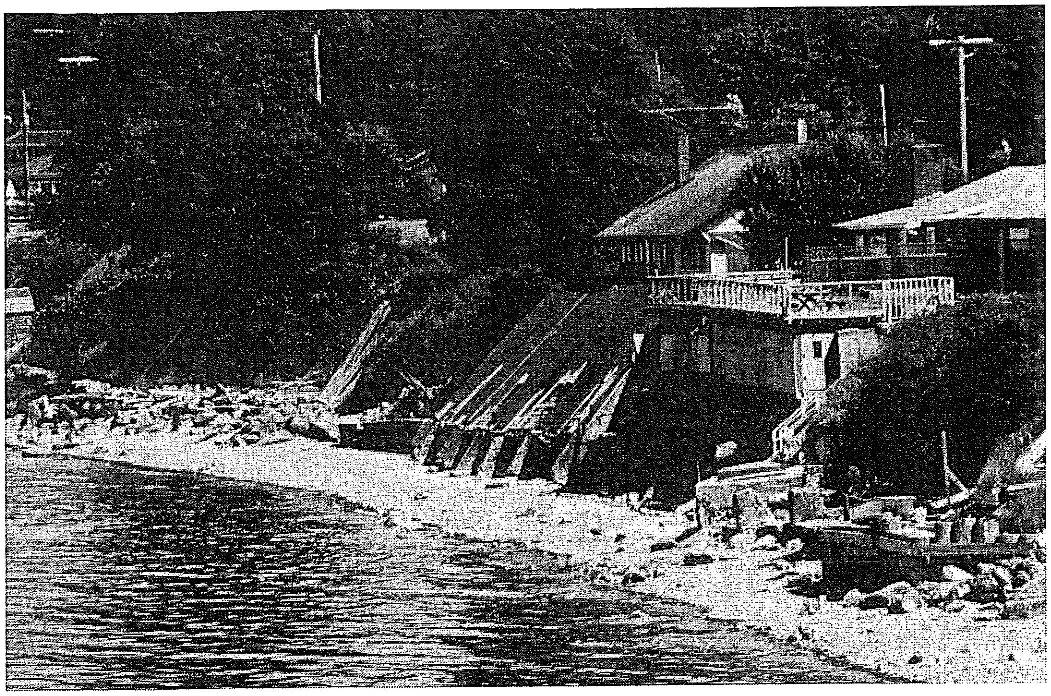


Figure 6. Shoreline bulkheads on bluffs west of North Beach. (Photo: D Canning, 1993).

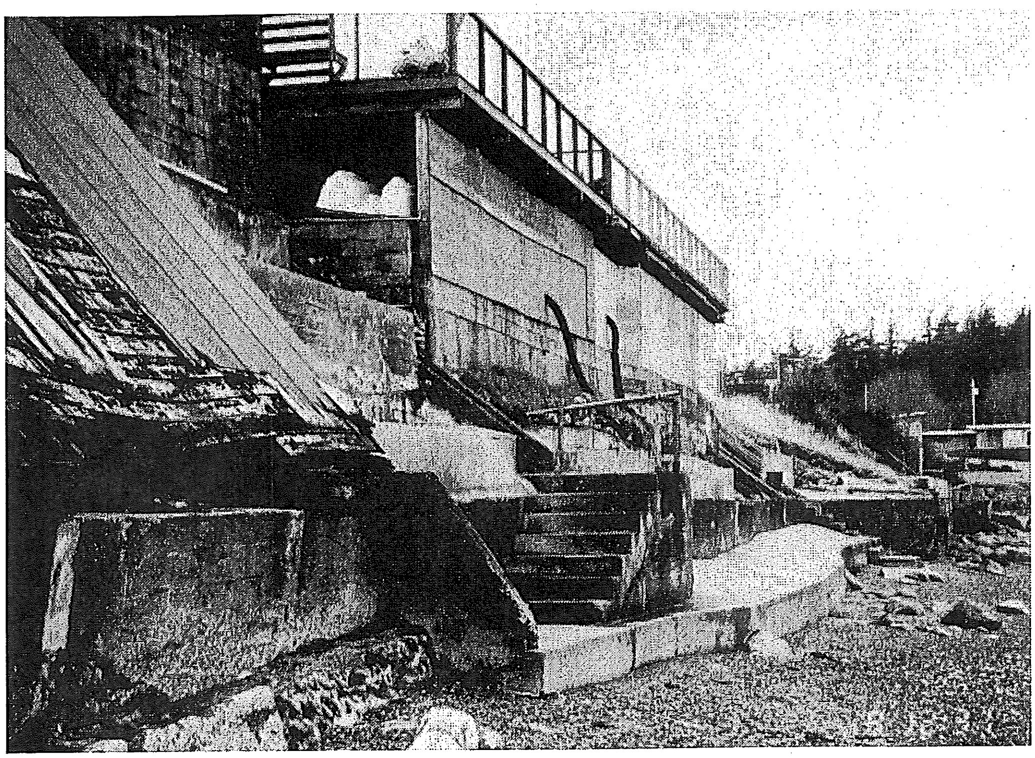


Figure 7. Close-up of structures in Figure 9.
Beach erosion and lowering has continued since bulkheads were installed, exposing footings, undermining walls, and leading to a variety of repairs and modifications (Photo: 1997).

Groins and promontories

In addition to the bulkheading of the bluffs, which reduces the supply of sediment to the beach, the movement of sediment along the beach can be affected by groins and beach fills that extend waterward of the bank.

Promontories. Possibly the most significant impediments to littoral drift are two small points or promontories that occur west of the western end of North Beach. These two points appear to be human in origin, having been created by cutting roads into the bluff to the beach, then depositing the resulting debris on the beach to form low-bank land. Once created, these points of new land were subject to significant erosion and have been armored with rock. Local residents suggest these were constructed in the 1960s.

The easterly of the two points is located about 1000 feet west of the western end of North Beach (Figure 8). It is the larger of the two promontories. Beach sediment trapped on its western side forms a crescent beach 500 feet long. The beach on the eastern (downdrift) side is eroded and numerous bluff failures have occurred.

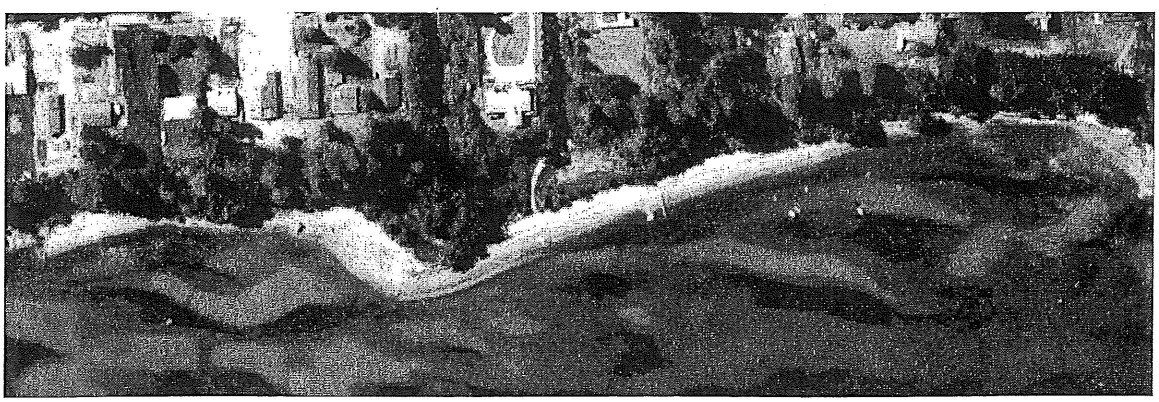


Figure 8. 1995 aerial photograph of large artificial promontory west of North Beach. Note broad beach accumulated on western side of point.

The westerly point is located on a private road that extends north from the eastern end of Wallen Road (Figure 9). This point extends over 100 feet waterward of the original shoreline and is heavily armored. A small cabin has been built at the tip of the point (Figure 10). A small gravely beach has formed on the point's western (updrift) side. The beach in front of the bluffs immediately east of the point is eroded down to glacial marine drift (hardpan). Not only is sediment trapped by this feature, but field observations suggest that littoral sand and gravel forced around this point might be diverted offshore into mid-tidal bars, and thus may be partially removed from the littoral drift.

Groins. Numerous rock groins, some extending more than 100 feet offshore, are observed along the shoreline toward the narrows (Figure 9 and Figure 11). Although these structures do not trap large amounts of material, they may be sufficient to trap much of the relatively small amount of sediment still in the littoral system.

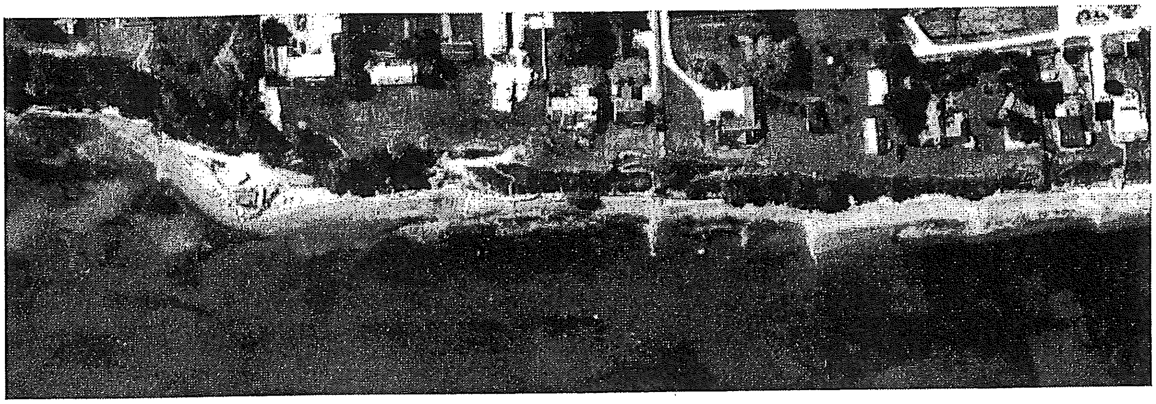


Figure 9. 1995 aerial photograph of second (western) promontory.
Also shows additional groins to the west. Note sediment accumulations on western side of obstructions.

Two concrete groins were constructed at the western end of North Beach in the 1960s. These groins, each about 20-30 feet long and about 100 feet apart, have trapped sediment on their western (updrift) sides (Figure 4). The volume of sediment trapped behind these structures may amount to several tens of cubic yards of material.

North Beach residents were particularly concerned about the possible impacts of these two groins on their beach, since the serious erosion was first noted immediately east of these structures shortly after they were built. We find it likely that these structures contributed to the onset of this erosion, but that the volume of sediment they trap cannot explain the ongoing erosion witnessed over the entire length of western North Beach.

Figure 10. Cabin constructed on artificial promontory seen in Figure 9 .
(Photo: 1997)

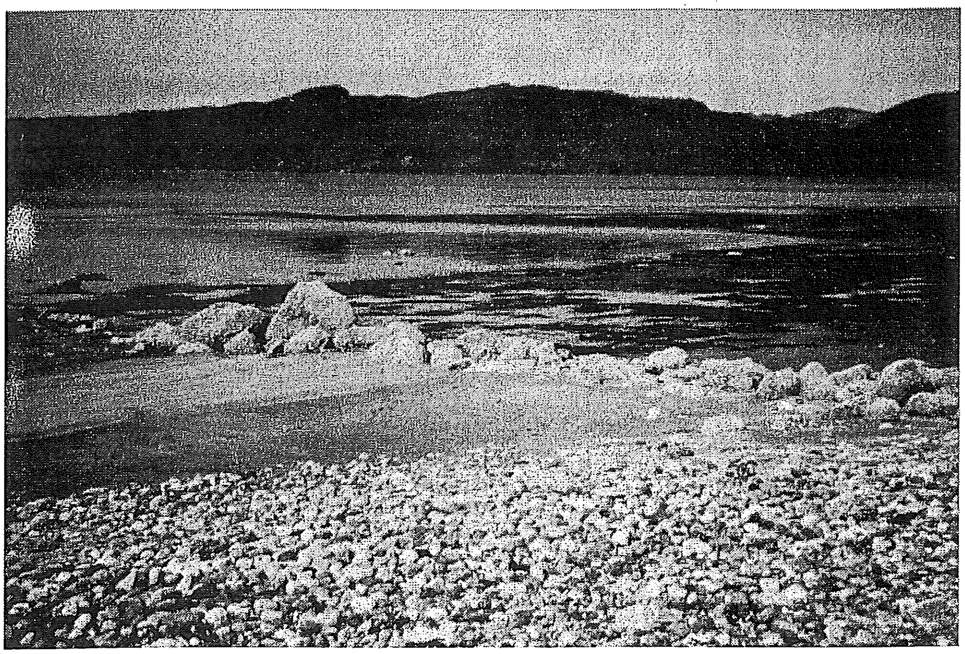


Figure 11. Largest of groins seen in Figure 9.
(Photo: 1997)

North Beach bulkheads

When faced with increased erosion in the 1970s and 1980s, property owners on North Beach began to construct bulkheads to protect their property from erosion and flooding. These bulkheads may have been effective at limiting the continued erosion of yards and at reducing the frequency with which wave action led directly to flooding and water damage, but they did not address the underlying beach loss.

Very often, when bulkheads are constructed, they are built over a portion of the berm. Although this may expand the area available for landscaping or upland improvements and it may provide more distance between the water and the home itself, it eliminates a crucial part of the beach and limits the ability of the beach to respond naturally to storm events, to dissipate wave energy, or to recover following seasonal erosion.

Ironically, bulkheads may in some circumstances actually exacerbate beach loss (Canning and Shipman, 1995). Bulkheads and similar erosion control measures may:

- Reflect wave energy back on the beach, promoting scouring of sediment and deposition of sediment farther offshore, and possibly changing the rate at which sediment moves along the shore;
- Increase pore pressures related to groundwater in the beach, which can increase the erodibility of beach sediment (see next section); and
- Prevent normal recovery of beaches after storms.

Even where bulkheads do not in themselves increase beach erosion, they represent a fixed structure on a dynamic beach and a retreating beach will be gradually squeezed out against the structure.

Hydrology

Beach hydrology can impact beach processes. Increased pore pressures (the pressure groundwater in soil or beach sediment exerts on neighboring particles) may increase the erosiveness of the beach, particularly on finer grained beaches (Macdonald and others, 1994). One concern about bulkheads is that they influence groundwater flow between the upland and the beach in such a way as to increase beach pore pressures, which in turn might lead to greater erosion or decrease the beaches ability to recover following a storm.

Groundwater levels at the west end of North Beach are influenced by upland runoff, seepage of regional groundwater from the bluffs behind the beach, direct precipitation, wave overwashing during storms, and on-site septic disposal. Upland runoff has likely increased for the same reasons it has increased in other developing areas: primarily from more impervious surface and less forest cover. Wave overwash becomes more significant as beaches narrow, particularly if bulkheads are not designed to reduce overtopping. On-site sewage treatment results in generally higher contributions as homes increase in size and vacation cabins evolve into year-round residences.

Prior to human development, drainage in this area was probably quite rapid - either through the sand and gravel berm to the beach or into the large marsh to the east and from there into the bay near the river mouth. The marsh was diked and drained early in the area's development, improving drainage in the reclaimed agricultural areas but likely restricting drainage from the North Beach area to the west. As homes have been built, naturally low areas in the berm tend to be filled in, restricting drainage towards the beach after periods of high water. Finally, the construction of bulkheads, unless extremely well drained, can significantly restrict drainage northward to the beach.

Residents reported that this winter's flooding was more extensive and more persistent than in the past (Figure 12 and Figure 13). This may reflect in part the unusually high amount of precipitation, combined with the windstorms in November and December that resulted in significant wave overtopping of bulkheads, but it may also be a symptom of increased runoff from upland areas and restricted drainage. The failure of the "ecology" block bulkheads (Stewart, Jordan, Worley, and Dunnington) in late December, 1996, appeared to be largely due to excessive hydrostatic pressure behind the poorly drained bulkheads - combined with the force of storm waves and lowering of the beach in front of the walls. Unrelieved buildup of hydrostatic pressure behind retaining walls is a common source of failure.

Figure 12. Storm conditions during November, 1996.
(Photo: C. Herzog, 1996)

Waves and storms

Most beach changes are driven by storms and wave action. A large proportion of the sediment movement on a beach may happen during unusually large storms, even if such events occur many years apart. Large storms, such as the strong northerlies of December, 1990, can cause major damage to coastal structures, lead to significant short term changes in beaches, and result in substantial permanent erosion on beaches undergoing chronic beach loss.

North Beach is exposed to wave action from both the northeast and northwest, to differing degrees. Although the geologic evidence indicates that net movement of sediment is from west to east, suggesting the predominant role of northwesterly winds, northeast winds could generate local reversals in littoral drift and might under the appropriate conditions lead to anomalous erosion. One would expect to see the beach recover, however, within a few seasons or possibly years.

Invoking storms and wave action to explain unusually rapid beach erosion, particularly on beaches that are relatively stable geologically, begs the question of whether recent weather conditions have truly been different than in the past. We have insufficient information to evaluate whether the last several decades have been stormier than average. We suspect that major storms may quite likely have affected the timing of major beach changes, but that they are unlikely to be the cause of chronic erosion. We have no reason to believe that the storms of the past few decades have been more serious than those of the past, when the beach appears to have been relatively stable.

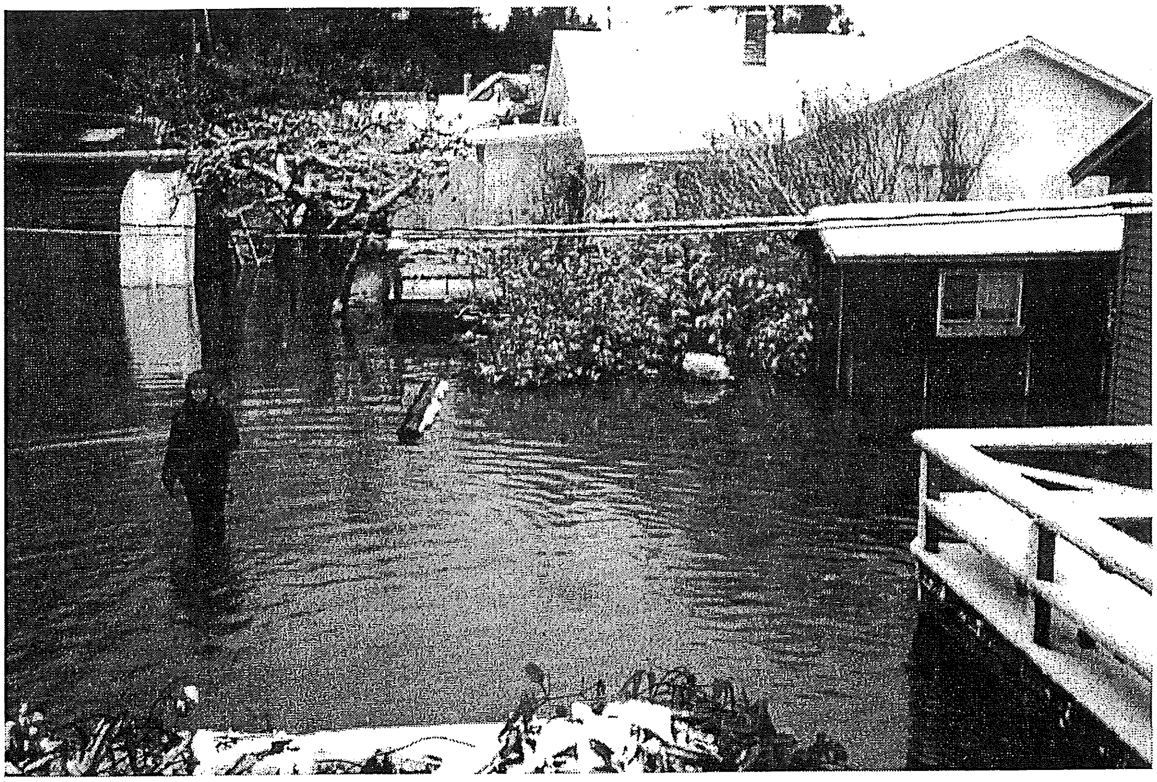


Figure 13. North Beach flooding in November, 1996.
(Photo: C. Herzog, 1996)

Tidal currents and sea level changes

Tidal currents, although capable of moving fine sediment, are generally not major factors affecting beach changes. Tidal currents moving into the Samish Channel, along with river flow itself, may prevent continued eastward growth of Fish Point (to the east of North Beach) and may influence erosion patterns near the eastern end of the point, but do not appear to affect other portions of the shoreline.

Sea level rise is believed to have been very slight at this location during the past century - possibly rising 3 inches during that period (Shipman, 1991). Increased water levels might result in erosion, but there appears little basis for believing this is a significant factor here. Accelerated sea level rise of several feet, as some authors have proposed might accompany the current observed warming of the global climate, would have significant impacts on North Beach (as at any shoreline location) - but cannot explain historical observations.

Offshore and nearshore bathymetric changes

North Beach lies at the front edge of the expanding Samish River delta. The delta front is an abrupt transition from shallow water on the east to deep water on the west. In addition, North Beach lies landward of a distinct offshore bank and a broad intertidal and subtidal sand/mud flat (**Error! Reference source not found.**). These offshore features may influence wave action and sediment movement on North Beach, but don't seem to explain why erosion may have increased recently.

On most Puget Sound beaches, the transition between the steeper coarse-grained beach and the low tide sand flat occurs near 0-1' MLLW. In the vicinity of river mouths, where there is a high influx of fine-grained riverine sediment, the elevation of this transition may rise appreciably (Keuler, 1979). At North Beach, we believe the transition occurs at 2-3' MLLW, likely indicating the influence of the river. It is quite possible that as delta sediment gradually buries the lower beach in areas such as this, the shoreline begins to behave differently - but such a process would only occur over an extended period of time.

Summary

The western portion of Samish Island's North Beach has undergone significant erosion during the past three decades. Since the mid-1960s, the broad sandy berm that previously extended along virtually the entire segment of shoreline has disappeared, generally from west to east. We examined several potential reasons for the rapid beach loss at North Beach. Some, such as a major shift in storm frequency or intensity, seem unlikely to cause the observed erosion, but cannot be categorically ruled out. The shoreline is likely impacted by gradual bathymetric changes offshore, growth of the Samish River delta, and long term sea-level rise, but these act far too slowly to explain the rapid beach shifts. Factors such as these would be expected to affect a large portion of the shoreline, not the relatively short section in question.

Geologic evidence indicates that the north side of Samish Island has gradually retreated southward over several thousand years, but the rate of this retreat is too slow to readily explain rapid erosion over several decades - and over a fairly limited length of shoreline.

Several factors, however, do seem to help explain the short-term and localized nature of the erosion on North Beach. They are:

- Retreat of the shoreline to an earlier, more stable position. Early in the century, a groin-like structure on the beach near the Youngquist property caused the beach to the west to accrete appreciably. This structure appears to be gone by the mid-1960s and much of the sediment previously trapped by the structure has eroded.
- Loss of updrift sediment supply. Bulkheading of eroding bluffs to the west, combined with groins and artificial promontories built across the beach, effectively eliminate much of the sediment that originally fed this beach.

- Accelerated erosion of the beach caused by structures built to protect upland property. Bulkheads on North Beach, built ostensibly to prevent erosion, may have exacerbated loss of the beach by increasing wave reflection, modifying the hydrology of the beach sediments, and decreasing the beaches ability to recover after storms.

These findings suggest that any viable solution to addressing the continued erosion must consider each of these factors. The current shoreline may still be out of equilibrium, suggesting that simply rebuilding bulkheads will do little to prevent the continued loss of the beach. In addition, considerable evidence indicates that there is little natural supply of sediment still feeding this beach. This implies that any effort to restore the beach will require the addition of sediment from elsewhere (it also suggests that areas farther east are vulnerable to a similar loss of the beach in coming years or decades). Finally, the existing bulkheads, even if successful at reducing upland damages during storms, may increase the difficulty of restoring or holding a beach in this location.

POSSIBLE RESPONSES

The western portion of North Beach is entirely bulkheaded at this time but property owners are increasingly concerned about both the viability of their current structures and, quite significantly, about the continued loss of their beach. This concern prompted serious discussions during the past year and a number of residents have joined together to investigate alternatives (as of January, 1998, residents are working with a consultant to design a beach nourishment project). In this chapter, we outline a number of generalized approaches to dealing with the beach erosion.

No Action

If no coordinated action is taken at this time, we can expect the basic natural processes governing the shore to continue and we can expect property owners to respond to future problems as they occur. We know several things:

- Existing bulkheads are vulnerable to damage during major storms. Additional failures such as the ones witnessed the past winter ('96-'97) could occur. Property owners will gradually need to replace the current bulkheads with more rigorously designed and constructed structures (see next section). Depending on circumstances and personal finances, property owners may either do this in advance of serious damage or more likely, they may wait until failure occurs. Property owners will undertake these actions independently, or possibly, in conjunction with immediate neighbors.
- As a result of modifications to the shoreline farther west, there appears no significant source of littoral sediment for western North Beach and therefore erosion is expected to continue. The rate at which this occurs is difficult to predict, but will likely be episodic, driven by major storms. Beaches will continue to lower and become more coarse-grained as finer sediment is preferentially eroded and moved to the east or offshore. As the beach erodes, the height of bulkheads will increase, restricting access and exposing the structures to greater damage during storms.
- We expect the berm to continue to disappear in an eastward direction - although it may currently be protected somewhat by the shape of shoreline. This will lead to loss of the high tide beach and eventual damage to bulkheads for properties east of Dunnington and Johnson.

Armoring - Seawalls and Revetments

Properly designed and constructed seawalls can be effective in preventing continued erosion of landward areas and in reducing wave overtopping and associated flooding. The existing ecology-block walls, although relatively inexpensive, are not well-suited for this shoreline. They offer the advantage, however, of being easily removed, modified, or repaired as circumstances warrant.

When the time comes to replace bulkheads, individual property owners may wish to investigate other types of structures. Poured concrete walls may have advantages over the existing walls, since they can include deep, cantilevered footings that resist toppling and return caps to prevent wave overtopping. On the other hand, concrete walls are vulnerable to tensional failure when undermined and must be adequately drained. Rock bulkheads, if built well, are effective and sufficiently flexible to withstand some undermining and settling. They may reflect less wave action directly back on the beach due to their uneven surface, but typically do not have lips or recurves to prevent overtopping or wave splash from flooding landward areas.

Sloped rock revetments (riprap), a traditional engineering solution in coastal settings, are often undesirable on residential shorelines, since they make beach access hazardous, cover a considerable amount of the beach, and are often perceived as visually unattractive. Without a deep footing, such rock may be undermined and maintenance costs can be significant as rock gradually settles into the beach. Placing riprap in front of existing bulkheads, a typical emergency response to storm damage, would likely be illegal due to the amount of waterward encroachment and should be avoided.

Wood bulkheads, of which many variations exist, might be employed. Untreated wood has a relatively limited lifespan, whereas treated wood can pose water quality issues. Wood structures include horizontal log bulkheads, continuous post (soldier pile) walls, plank structures, and many others. Plastic, including new recycled materials, can be used similarly to wood, and vinyl sheet-pile bulkheads, with a wood or concrete cap, might also be viable.

Regardless of the type of structure chosen, good drainage is critical in order to avoid excessive hydrostatic pressure from developing. Coarse-grained, rapidly draining material (usually gravel) should be placed immediately behind the structures and adequate drainage provided in the structure itself. Filter material should be placed between the native soil or fine-grained backfill and the drainage material to prevent the finer material from clogging the drain material or simply being eroded from behind the wall.

If property owners choose simply to build better protective structures, they may find advantages in working together, since mobilization and design costs might be shared many ways, and structures could be tied together more effectively.

Even the best-designed seawall is only intended to protect the upland - it will do nothing to preserve the beach and often exacerbates existing beach loss. Structural erosion control on eroding depositional beaches such as these generally results in progressive escalation of the scale and expense of structures as the beach drops and the effective height of the structures increases.

Many examples exist around Puget Sound where erosion on similar beaches has been met with progressively more substantial structures and rock work. These include Birch Bay (north of the state park), Lagoon Point (south of the jetties), Sandy Hook (on Cultus Bay, southern Whidbey Island), Days Island (Tacoma Narrows), Point Monroe (north end of Bainbridge Island), and Sandy Point (north of Bellingham), to name a few. In each, the underlying beach loss was not addressed and therefore continues. In several, it appears that the bulkheads and riprap may have actually aggravated the continued erosion of the beach, or at least prevented natural recovery following storms.

Groins

Groins, structures constructed across the beach to trap sand and gravel, are not new to North Beach and many of the current problems originate in part with groins built in the past. In general, the more effective the groin, the greater its negative impact on downdrift neighbors. Groins, whether built of concrete or simply consisting of logs anchored across the beach, are strongly discouraged by regulation and rarely contribute to good will among neighbors.

We described earlier in this report the possible beneficial impact the groin near Youngquist had on the western portion of North Beach earlier in the century. We note, however, that simply reconstructing the structure today would be unwise (and illegal). The success of the old structure in building a beach depended heavily on a substantial supply of sediment from the west - a source of sediment now largely lost to updrift bulkheading and groins. In addition, the 1937 air photo indicates that one effect of the earlier structure may have been to exacerbate erosion to the east. It is very likely that if the groin existed now, erosion on the beach east of Youngquist, toward Blau Oyster, might be far worse.

Groins can only work if there is sufficient sand or gravel moving on the beach to be trapped. On North Beach, unfortunately, we see little sign of this being the case. The success of groins on North Beach, if allowed in the first place, would hinge on: 1) a supply of sediment (possibly imported from elsewhere) sufficient to build the beach, 2) a design that locates a groin or groins in such a way as to minimize waterward encroachment of the shoreline and burial of intertidal biological resources, and 3) assurance that there would be no diminishment in littoral drift to properties located farther east along North Beach.

Groins vary greatly in design and construction. They may be constructed of wood, rock, or concrete. They may be long, high structures that completely block littoral drift or they may be much smaller features that influence the shape of the beach but continue to allow drift to pass over or around the structure.

Beach Nourishment

Beach nourishment refers to the intentional addition of sand or gravel-size sediment to the shoreline. Whereas traditional erosion control structures protect the upland from wave action, nourishment directly addresses the loss of sediment that defines the erosion. Nourishment still does not address the underlying cause of erosion and must generally be undertaken with an ongoing commitment to monitor and renourish.

Beach nourishment (also referred to as replenishment or restoration) allows erosion to be addressed while maintaining a beach, for either ecological or recreational benefit. Miami Beach, Waikiki Beach, and many of the beaches of southern California survive only by virtue of continued nourishment. We have far less experience with beach nourishment in Puget Sound, and the lower-energy gravel beaches of our area pose unique design issues, but beaches have been restored successfully using nourishment techniques (Johnson and Bauer, 1987; Domenowske, 1987; Johannessen, 1996; Shipman, 1996).

Beach nourishment encompasses a wide range of designs and construction techniques. Many factors can be varied, depending on the site, the project's objectives, and economic or environmental constraints. Some options include:

- Size of material. Beach nourishment may involve sand, gravel, or some mixture. In general, gravel is preferred in Puget Sound since beaches tend to be naturally more gravely and because gravel builds berms more effectively.
- Placement. Sand or gravel might be placed along the entire length of the project, or it might fed at one or more discrete locations along the shoreline, allowing wave action and time to distribute the material. Material may be brought by truck or barge.
- Maintenance. Some projects have been designed with periodic renourishment in mind, whereas others have been designed to avoid the need for future maintenance (the latter approach is often optimistic and also tends to result in larger or more complex initial projects).
- Secondary structures. Nourishment projects may or may not include the use of groins or similar structures to stabilize or control the position of the beach.
- Alteration of existing structures or grade. Nourishment may be simply placed on top of or in front of the existing grade or existing rock or concrete structures, whereas in other situations, substantial excavation of the existing shoreline is necessary and old structures are removed.

Typically, beach nourishment on Puget Sound uses gravel-sized material, placed by truck or barge along the upper beach, and spread to the design contour by bulldozer. Most projects in the region have involved 5-10 cubic yards of material per linear foot of shoreline (3000 cubic yards of material for 500 feet of shoreline, for example). Often, existing bulkheads or riprap are removed, although in some cases, the beach has been built in front of structures or existing large rock has been buried beneath the backshore (in part as a failsafe in the event of a particularly large storm and in part as a simplified means of disposal). Most beach designs attempt to imitate the natural profile of beaches in the general area. Some projects have employed secondary structures such as low groins as a means of stabilizing the new beach profile, whereas others have simply counted on periodic renourishment to maintain the beach. Renourishment intervals depend both on project design and storm history and may range from just a few years to a decade or more.

Nourishment, groins, and bulkheads can be used in conjunction with one another in some cases - although complexity should not be employed for its own sake. Nourishment offers a chance to restore appropriate size sediment to the beach, to address erosion caused by loss of historic sediment supplies, and to minimize impacts to downdrift areas. Groins can be used to stabilize the restored beach and minimize future erosion. Bulkheads can provide backup protection for extreme storms, and in some cases, existing bulkheads can be retained to avoid complications associated with removal. It is highly unusual in Washington, however, for nourishment to be carried out entirely waterward of an existing line of bulkheads because it increases the ecological and public impacts of the project and may reduce the long-term stability of the project itself (the farther waterward new sediment is placed, the more this material will be subject to wave action and redistribution to adjacent shorelines).

Nourishment poses significant regulatory issues. For one reason, the general lack of familiarity with the technique raises legitimate questions among communities and agencies about its potential adverse consequences - both on downdrift neighbors and on natural resources. Nourishment also raises regulatory concerns because it involves burying existing beach area and often directly impacts aquatic habitat. In addition, placing sediment over the beach as nourishment differs only in degree from placing beach fill to create new land - a practice rigorously restricted under modern regulations.

A beach nourishment project on Samish Island would require a Hydraulics Project Approval (HPA) from the Washington Department of Fish and Wildlife and would likely require a Shoreline Conditional Use Permit from Skagit County. Unless the placement of fill could be kept entirely landward of high water, a permit would also be required from the Corps of Engineers (this should not be viewed as the final word on permit requirements and project applicants should confirm which authorities need to be contacted). As a consequence of this increased scrutiny, proponents of beach nourishment projects benefit by discussing projects early with their local jurisdiction and permit agencies.

Monitoring is an important element of nourishment projects due to their dynamic nature and the difficulty in anticipating their effect on the shoreline. Monitoring provides a means of evaluating project performance and maybe more importantly, it indicates when renourishment may be necessary and when design modifications may be appropriate. Monitoring provides a basis for demonstrating the effect of the project on downdrift shorelines and shoreline resources. Monitoring can vary in complexity, but may be as simple as a series of topographic profiles across the beach from previously surveyed monuments once or twice a year.

CONCLUSIONS

North Beach lies on a developed sandspit toward the eastern end of the north side of Samish Island. The spit formed over thousands of years from the eastward movement of sediment (derived from bluff erosion farther west) by littoral drift. Human modifications of the system, including the construction of groins, the stabilization of eroding bluffs with bulkheads, and the conversion of the active beach berm to upland uses during the past 100 years resulted in fundamental changes to the littoral system along the north shore of the Samish Island. As a result, the relatively stable beach that had existed at the western end of North Beach for hundreds, if not thousands, of years began to change rapidly.

In this study we looked specifically at the west end of North Beach, where erosion has prompted considerable community interest. We found that much of the erosion can be explained by the loss of littoral sediment supplies due to updrift bulkheading and groin construction, combined with the decay of a structure that may have artificially stabilized the shoreline earlier in the century. We believe that the construction of bulkheads to control this erosion may have had the unintended consequence of accelerating the loss of the beach itself.

Property owners have a number of options available for protecting their homes. Better designed and constructed bulkheads would last longer and provide more protection than current structures, but would be very expensive and would not address the loss of the beach. Groins are unlikely to succeed due to the lack of sediment in the littoral drift and might adversely impact shorelines downdrift (to the east). Beach nourishment, most likely with gravel, offers a more satisfying solution since it could provide protection to upland property while also maintaining the beach. Successful nourishment, however, entails careful design and would require a relatively large group of property owners to participate.

One of our original concerns about North Beach was that the western end of the beach was simply one small part of a much larger problem and that the erosion faced there was likely to be faced by others in the vicinity within a decade or two. In looking at the history of this shoreline, we noted evidence of existing, undocumented problems elsewhere on the north side of the island. Areas that may warrant further examination include: 1) the eastern end of North Beach (between Blau Oyster and Fish Point), where air photos indicate a fairly complicated pattern of erosion, shoreline armoring, and littoral sediment supply, and 2) the bluffs between the island's narrow neck and the west end of North Beach, where beach loss has been significant and many existing bulkheads require substantial repair or redesign, and where the beach itself has been severely eroded.

Although a good example, North Beach is by no means unique on Puget Sound. Numerous other beach communities suffer chronic erosion due to the loss of littoral sediment supplies or as a consequence of historic shoreline modifications.

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APPENDICES

Appendix A. Air Photos

Sources

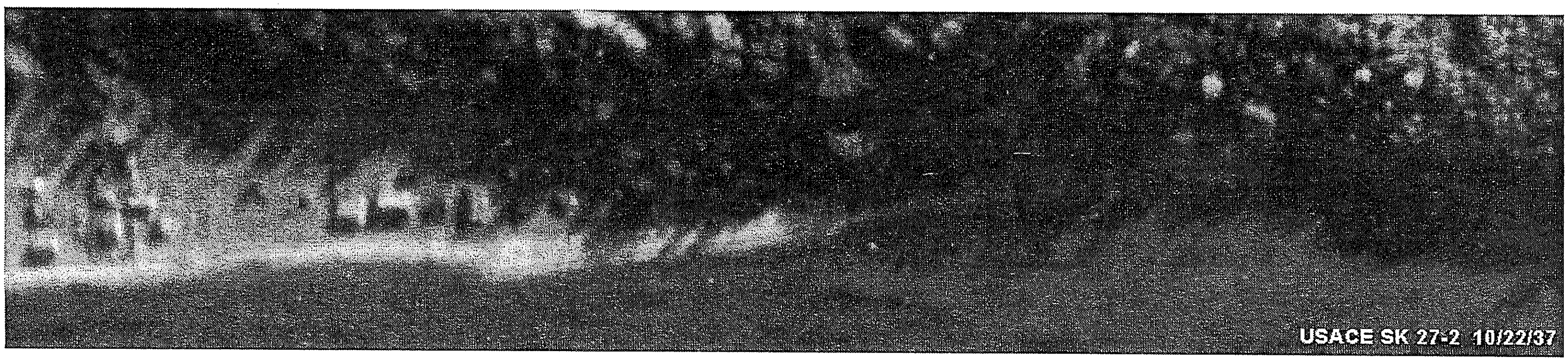
We examined a large number of aerial photographs during the course of this project. A list of photos consulted and their source is listed below. In addition to the photos reproduced in figures within this report, Figures A-1, A-2, and A-3 provide additional views of western North Beach.

Year	Date	Project	Number	Source	Notes	Location in Report
1937	10/22/37	SK26-25		USACE		Figure 5; A-1
1966	9/4/66	WFPA65	32B-9	DNR		Figure 6
1969	6/16/69	NW69	41-34B-3	DNR		
1970	2/26/70	S704	92-8	USACE		A-1
1976	6/5/76	NW-C-76	18B-123	DNR		
1977	4/5/77			DOE		A-2
1977	6/5/77	DOE 77	104-105	DOE	Oblique photos	
1978	5/19/78	NW78	47C	DNR		
1983		NWC83	1-34-39	DNR		
1983	8/13/83	S83020	92-6	USACE		A-2
1987		NW87	7-34-39	DNR		A-3
1987		S87009	92-8	USACE		Figure 2
1991	6/19/91	NW91	24-34-16	DNR		
1991	8/19/91	NW91	4-35-48	DNR		
1994	5/10/94	DOE 94	SK 263	DOE	Oblique photos	Figure 4
1993	8/5/93	S93003	92-8	USACE		
1995	5/24/95	NW95	23-34-50	DNR		Figs 8, 11, 12; A-3

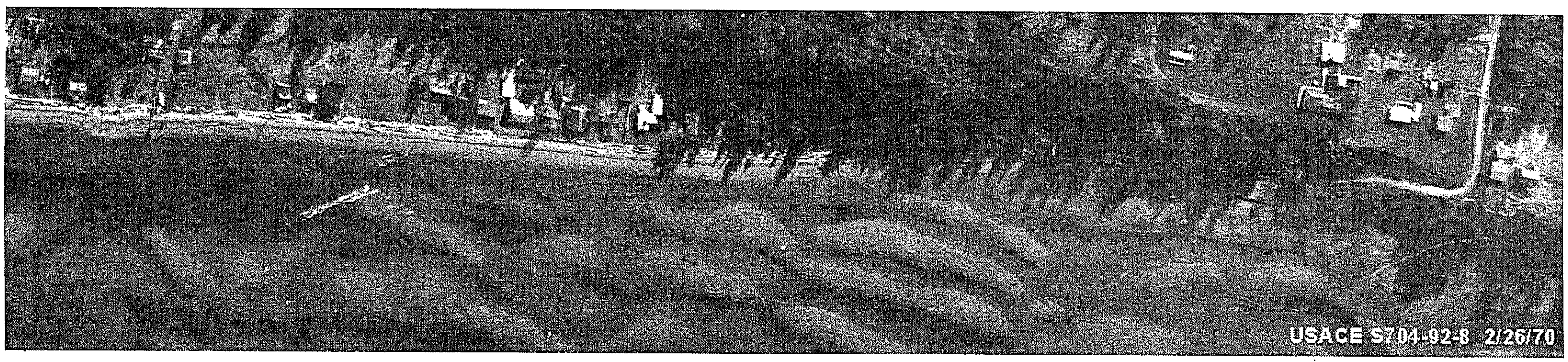
USACE = United States Army Corps of Engineers

DNR = Washington Department of Natural Resources

DOE = Washington Department of Ecology



1937



1970

1937 and 1970 Historical Air Photos

Shoreline Change on North Beach, Samish Island

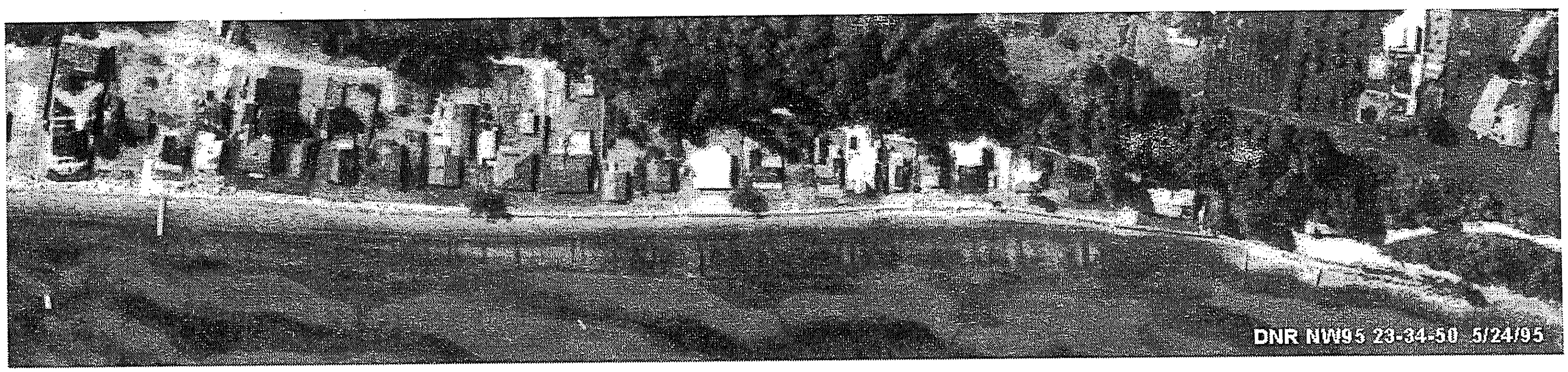
Figure A-1

Figure A-2

1977 and 1983 Historical Air Photos

Shoreline Change on North Beach, Samish Island

1987



1995

1987 and 1995 Historical Air Photos

Shoreline Change on North Beach, Samish Island

Figure A-3

Appendix B. Supplemental Information

The following materials relate directly to North Beach on Samish Island.

1. North Beach Chronology
2. Masters Thesis of Keuler, 1979
3. Coastal Zone Atlas - Skagit County
4. Coastal Erosion Management Studies, 1995
5. Skagit County Coastal Zone Disaster Mitigation Report

1. North Beach Chronology

This document was graciously provided by Marge (Jenne) Dunnington.

SHORELINE W.NORTH BEACH, SAMISH ISLAND 1925-1996 *

1925: Jennes and Dunlaps purchased tract from bottom of hill to west end of (now) W. North Beach. Upland was level with sand beach. Wide sand and log area above normal high tide accommodated large bonfires and groups of residents on sand beach when tide was high. Logs and cabin from washed-ashore boat remained on beach for years.

?? 60s ? Road was pushed down from top of hill at west end of beach area -- down from Mercer Road (off Haviland) -- west of the original Hegewald cabin, depositing large stones at beach edge. Previously, Hegewalds accessed their cabin from a path down the hill since the North Beach Road ended at the cabin to the east.

Late 60s/early 70s: Properties east of new driveway eroding seriously. Cement groin was installed between former Hegewald property and next-east cabin.

Jan., 1976: Owner of next western-most house applied to Army Corps of Engineers for permit to construct a groin to "create a beach" and "provide access from boat to shore". (copy attached)
Grace Carroll (Mother/Grandmother of Jordans) alerted North Beach neighbors, all of whom wrote in protest since erosion had begun creeping east several properties from the earlier-built driveway.
(Copy of M.Dunnington letter of 3/30/76 attached): Applicatn Withdrawn.

Residents at western end of tracts brought in large stone to try to protect now-eroded beaches and hold the land.

Owners of homes along the high bluffs west of the North Beach area were installing cement walls to hold their hillsides.
Houses to the east of the originally-eroding beaches put in log shore-holders, others other types of retainers.

1982: Four owners installed bulkheads (Dunnington-Worley-Jordan-Stewart) (Dunnington/Jenne at east end of original Dunlap Jenne Tracts). The bulkhead at Worley/Dunnington bows northward, returning to straight line at Johnson, to the east. Johnson and Grace, next cabin to the east, installed bulkheads, also.

A natural rock protrusion/protection was and is in front of the next house to the east: now Youngquist. (This had been a metal/rocks structure in the teens and 20s when logs were brought down the hill and floated out from that spot.)
Beaches to the east of Dunnington have continued to retain logs and sand. Beaches east of Youngquist are nearly original level with land.

Mid to?Late 80s? Beach protections (logs), etc., damaged by winter storms, (Schacht through Spearin??) Cement bulkheads installed.

I think about 1990 or 91 - fairly recent
?? ?? year? State put cement wall/walkway on hill public access -- West "L" of the Island.

Dunnington/Worley/Jordan/Stewart increasingly losing beach, both width and height. Logs deposited only to the east.

12/96: Bulkheads of Stewart and Jordan collapsed; Worley partial; Dunnington partially tilted at the western half. Minimal or no change eastward.

*Compiled by Margaret (Jenne) Dunnington

2. Masters Thesis of Keuler, 1979

The following includes an excerpt relevant to North Beach, along with a map of littoral process. This thesis is available through the library at Western Washington University. Figure 4 (p. 16) in the thesis contains a field photograph of North Beach (but which could not be reproduced clearly here).

COASTAL ZONE PROCESSES
AND GEOMORPHOLOGY
OF
SKAGIT COUNTY, WASHINGTON

A Thesis

Presented to

The Faculty of

Western Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Ralph F. Keuler

June 1979

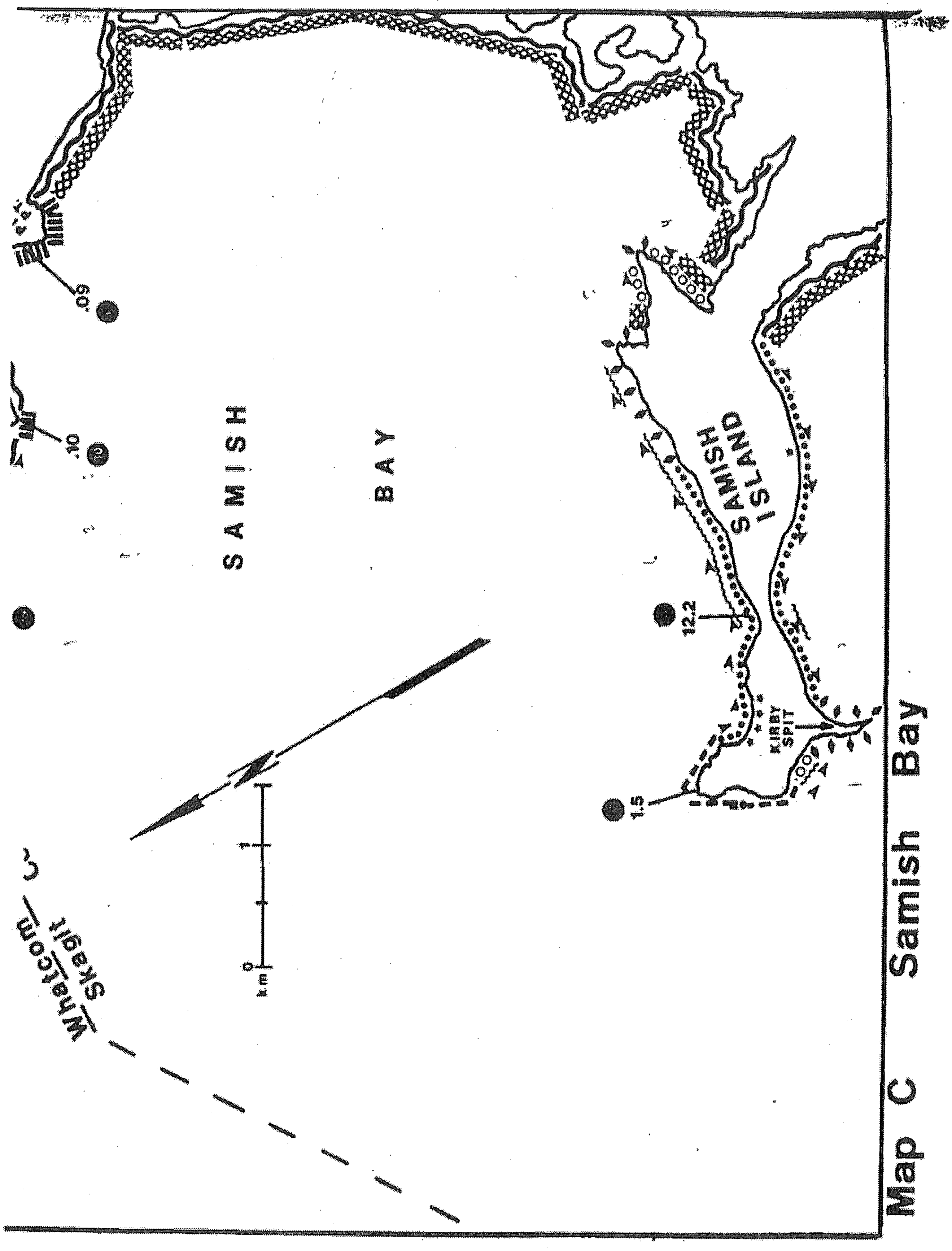
and spatial variability (dependent on tide and wind patterns) discussed on page 62. On a geographic basis, the undercut, vertical bluffs and eroded beaches that occur at drift sector beginnings indicate that the highest erosion rates occur there. Although the evidence for faster erosion there is clear, not enough erosion measurement sites were found along the length of any one sector to conclusively prove this supposition inferred from geomorphic evidence.

Shoreline Modification

Though many areas of the county's shoreline have not been defended by man-made structures, there is at least one shore segment (north-central Samish Island, Map C) where defense structures appear to be exacerbating an erosion problem. There, some shore defenses were built as long ago as the 1930's. As more and more bulkheads have been built through the years, less sediment can be derived from bluffs. At the westerly extremity of the terminal, prograded beach, erosion has been noticed within the last 10 years. This erosion could be a mostly natural occurrence but it is probably also linked to the partial cutoff of the beach sediment source, the bluffs. The northern Puget Sound region shorelines are particularly vulnerable to this type of man-caused (or man-aided) erosion because nearly all beach sediment is derived from bluffs.

Longshore Geomorphic Trends within Drift Sectors

As this report has shown, within Skagit County there are systematic variations in geomorphic and sedimentologic features that can be used


Map C Samish Bay
SAMISH BAY
SAMISH ISLAND
KIRBY SPIT
Whatcom
Skagit
km
0
1
.09
.10
12.2
1.5

KEY FOR MAP SYMBOLS

oooooo	Bluffs composed of unconsolidated materials, less than 10 meters (30 feet) high
	Bluffs composed of unconsolidated materials, more than 10 meters (30 feet) high
	Rock shoreline with abrasion platform
	Plunging rock cliffs, no abrasion platform
	Bluffs composed of mixed or alternating unconsolidated materials and rock
	Prograded beaches
	Fine-grained tidal flats
	Direction of net, long-term, sediment transport
	Lightly modfied shoreline, small shore defense structures
	Significantly modified shoreline, large shore defense structures
	Completely modified shoreline, industrialized or filled, original shoreline now nonexistent
	Major landslide zones
49	Erosion measurement site
8.5	Mean minimum erosion rate in centimeters per year

3. Coastal Zone Atlas - Skagit County

The following four maps cover Geology, Slope Stability, Coastal Flooding, and Coastal Drift for the north side of Samish Island. Original (color) copies of the Skagit County Coastal Atlas (Washington Department of Ecology, 1978) are out of print, but should be available for examination at county offices or possibly at local libraries.

The scale of these maps is 1:24,000 (1 inch = 2000 feet).

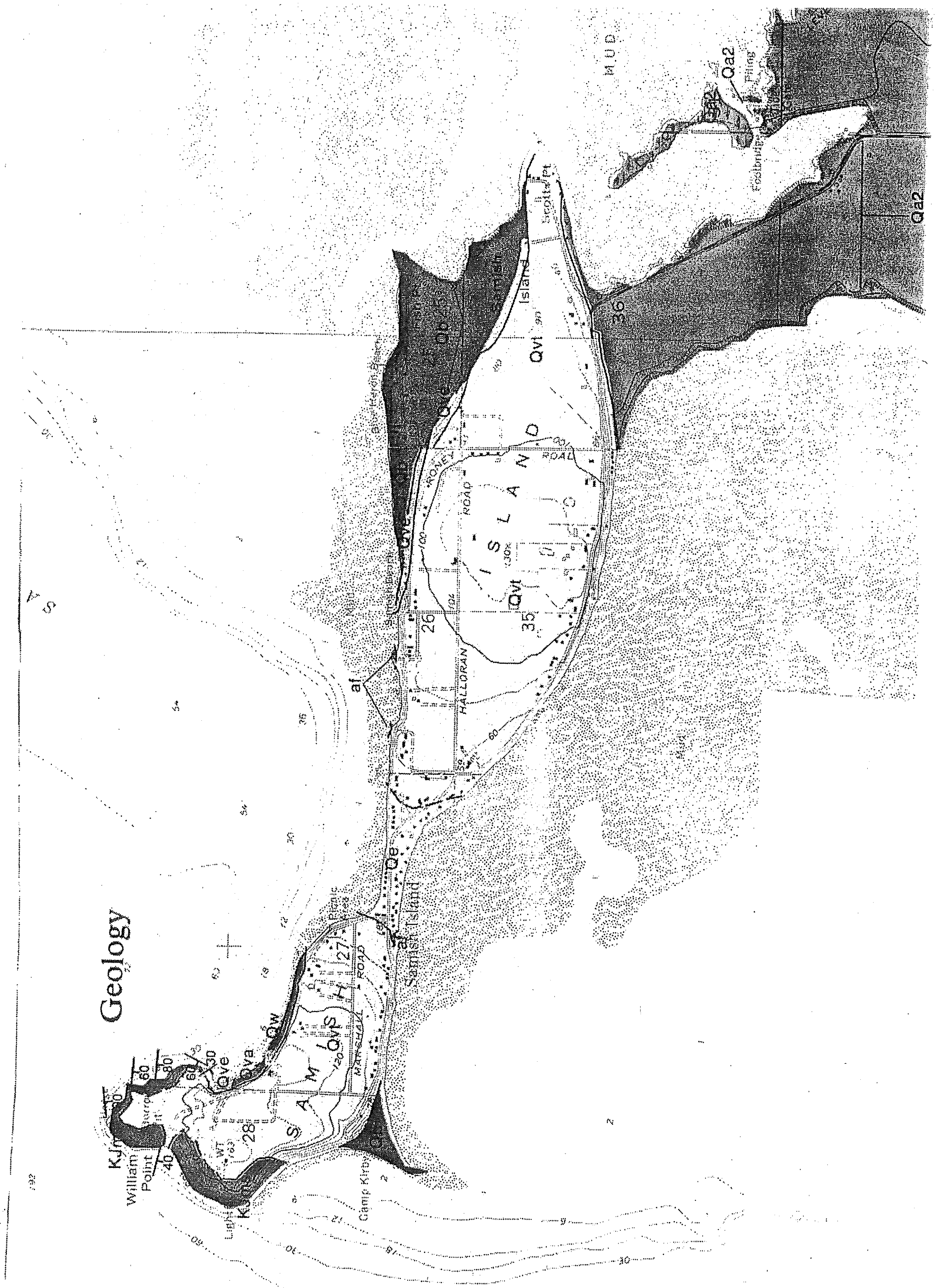
Notes

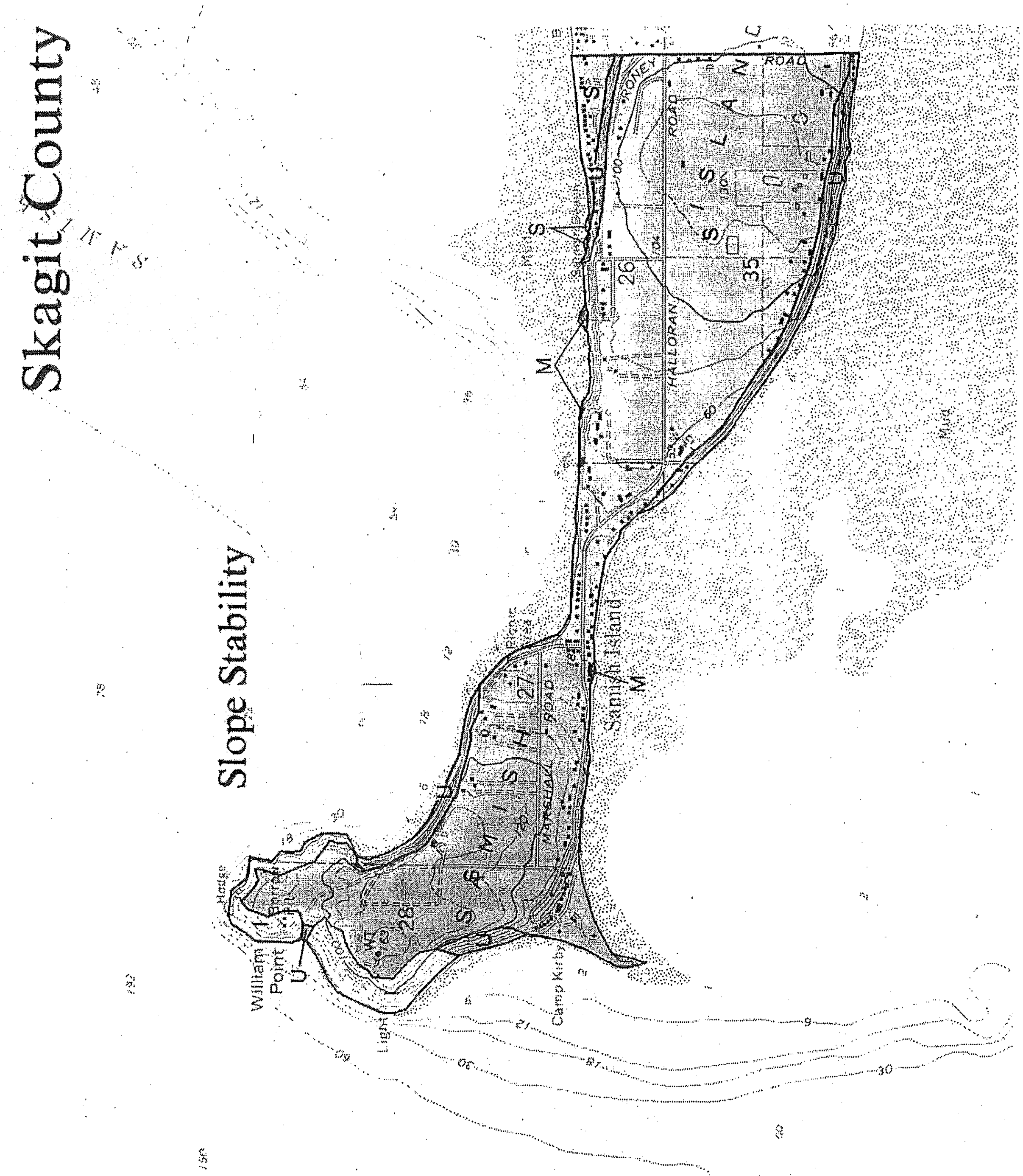
Geology. **KJms** are Tertiary metamorphic rocks. **Qw** is the Whidbey Formation. **Qvt**, **Qva**, and **Qve** are Vashon Till, Vashon Advance Outwash, and Esperance Sand, respectively. **Qe** is Everson Glaciomarine Drift. **Qb** indicates post-glacial beach sediment. **af** is artificial fill.

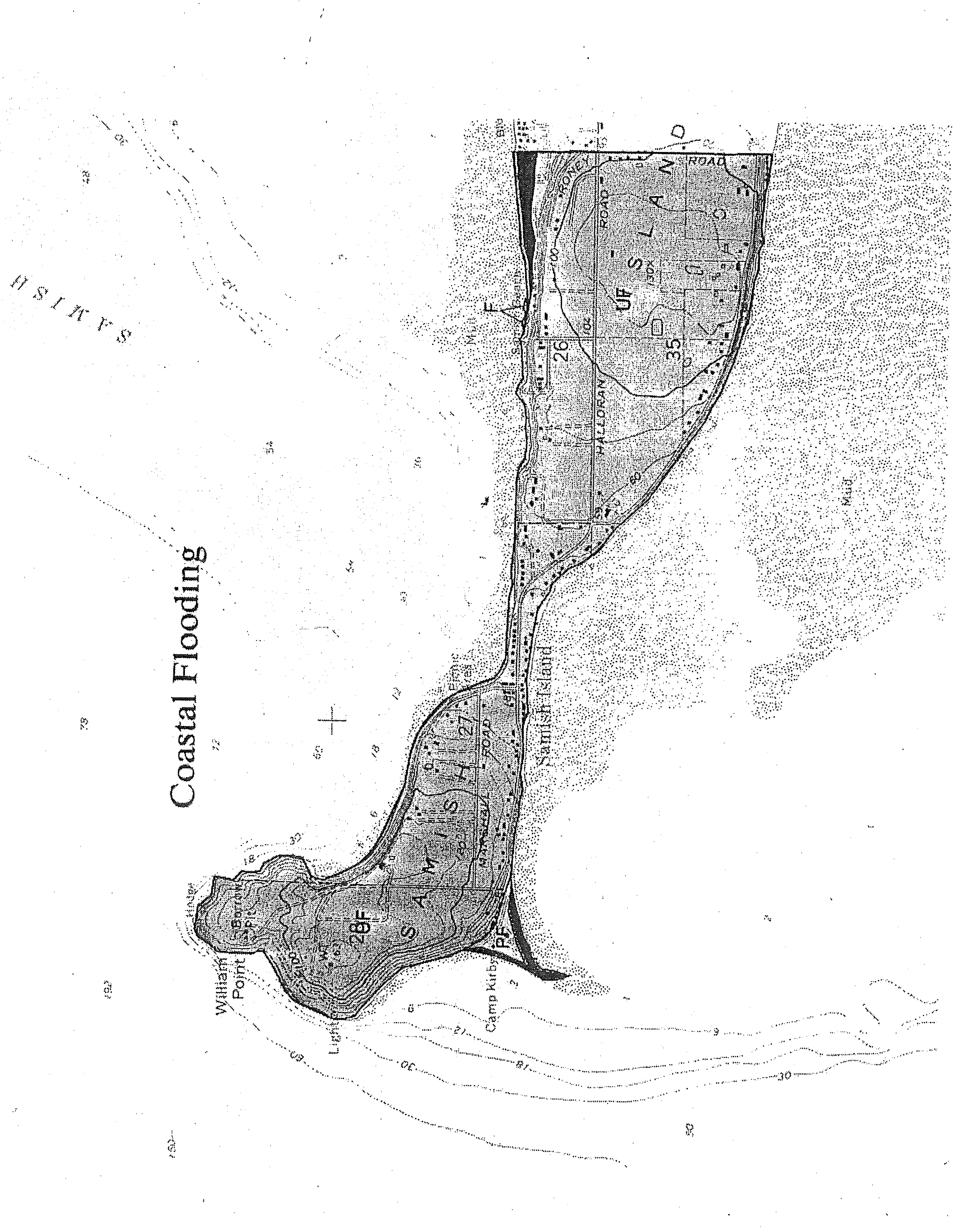
Slope Stability. **U** is Unstable. **I** is slopes of intermediate instability. **S** is stable areas. **M** represents modified areas such as artificial fills over tidelands.

Coastal Flooding. Dark areas, marked **F**, reflect areas that have experienced historical flooding. **PF** indicates areas potentially subject to flooding, but where historic flooding is not recorded.

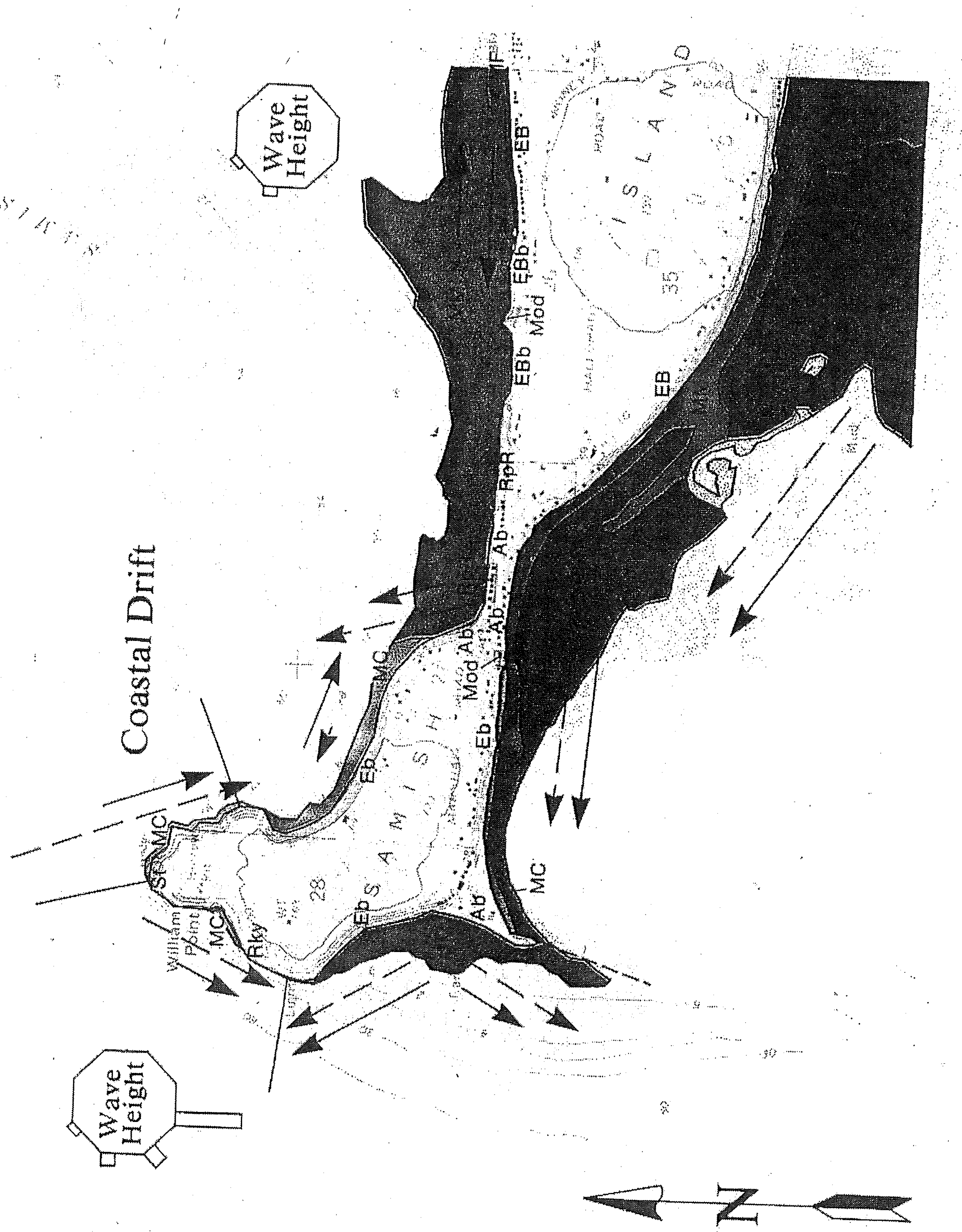
Coastal Drift. Arrows are direction of littoral drift based on wave hindcasts and are not reliable (see discussion of Littoral Drift, in Geology Section of main report). Shading reflects differences in substrate (sand, mud, etc.).


Geology
William Point
Samish Island
Scotts Pt
Camp Kirby
HALLORAN ROAD
RONEY ROAD
MARSHALL ROAD
ISLAND
MUD
Qvt
Qa2
Qve
Qva
Qw
Qe
Qb
KJm
af


Skagit County
Slope Stability
Samish Island
William Point
Camp Kirby
Light
HALLORAN ROAD
MARSHALL ROAD
RONEY
ROAD
Mud



Coastal Flooding
Samish Island
William Point
Camp Kirby
HALLORAN ROAD
Mud


Coastal Drift
Wave Height
Wave Height
William Point
MC
St
Rky
Eb
Ab
Mod
RpR
EBb
EB
28
35
N

4. Coastal Erosion Management Studies, 1995

This brief excerpt from the Executive Summary (Canning and Shipman, 1995) of the Coastal Erosion Management Study reflects the authors experience following a 1993 site visit to North Beach. The cartoon in Figure 7.1 captures quite well the basic process by which beaches begin to diminish on developed shorelines throughout Puget Sound, but was based specifically on the Samish island example.

Coastal Erosion Management Studies in Puget Sound, Washington: Executive Summary

Coastal Erosion Management Studies, Volume 1

January, 1995

Prepared by:

Douglas J. Canning and Hugh Shipman
Washington Department of Ecology

Report 94-74

Water and Shorelands Resources Program
WASHINGTON DEPARTMENT OF ECOLOGY
Olympia, Washington 98504-7600

sediment sources. The result of sediment starvation may be difficult to document. The impact will be gradual and may lag the causal activity by decades. The impact will be confounded by many other variables in sediment supply and in downdrift beaches.

Two expected consequences of decreased sediment supply are a gradual coarsening of the beaches, as finer sands are preferentially moved downdrift and not replaced, and a narrowing of the beach due to its decreased volume and elevation. Lowering of the beach surface also results in exposure of the underlying shore platform.

Ediz Hook at Port Angeles provides an extreme example of the effect of shoreline armoring on downdrift sediment supply (Galster and Schwartz, 1989). Ediz Hook is a spit extending across the entrance to Port Angeles harbor on the Strait of Juan de Fuca. The construction of a water supply line along the base of the bluffs in 1930, and its subsequent armoring, led to a loss of 80% of the traditional source of sediment to the spit (the other 20%, from the Elwha River, had been reduced by the damming of that river earlier in the century). Serious erosion on the spit itself has resulted in extensive efforts by the Corps of Engineers to stabilize the shoreline. Initially this was done through large-scale armoring with rock, but more recently has involved the periodic nourishment of the spit with gravel and cobble.

Ediz Hook is only one of hundreds of depositional landforms and barrier beaches in Puget Sound. Each depends for its maintenance on continued updrift erosion. Because these features occur at the termini of littoral transport cells, their response to sediment restrictions may be delayed. They also are highly dynamic features and separating chronic influences of sediment deprivation from seasonal and interannual variations in sediment supply and storminess may be difficult. The narrow necks of spits and bars appear to be particularly sensitive to changes in sediment supply.

7.3.3 Confirming Observations

In recent years we have conducted a number of marine shoreline reconnaissance studies on the request of local government staff, elected officials, private property owners, and home owners associations. While lacking in the rigor of a formal investigation, our observations tend to support the conclusions of the CEMS consultant team.

Samish Island, Skagit County
On 2 July 1993, at the request of a local shoreline property owner, we conducted a reconnaissance inspection of the north shore of Samish Island in the vicinity of Section 26, T36N, R2E. Their stated concerns were recent beach erosion and lowering. The subject property is located along the transport portion of a two-mile-long drift cell, approximately mid-way between the feeder bluffs to the west and the deposition zone to the east. Most of the drift cell up-drift (west) of the subject property had been armored, some of it as early as the 1930s. At least two groins were in place west of the subject property.

Based on historical photographs, property owner testimony, and on-site measurements, we concluded the following. A concrete bulkhead was constructed at the subject property in 1982; bulkheads on nearby up-drift properties were constructed in the 1970s and earlier. Since the construction of the bulkhead at the subject property, the beach had lowered at least 1.0 to 1.5 feet, and possibly as much as 2.5 feet. The groins updrift of the subject property appeared to be trapping little sand, indicating that sediment transport through the drift cell is now scant. A few hundred feet east of the subject property the elevation of the upper beach was a few feet higher than at the subject property; here the beach dune included growths of Beachgrass and stranded drift logs which are absent along armored portions of the shore. This process is pictorially diagramed in Figure 7.1.

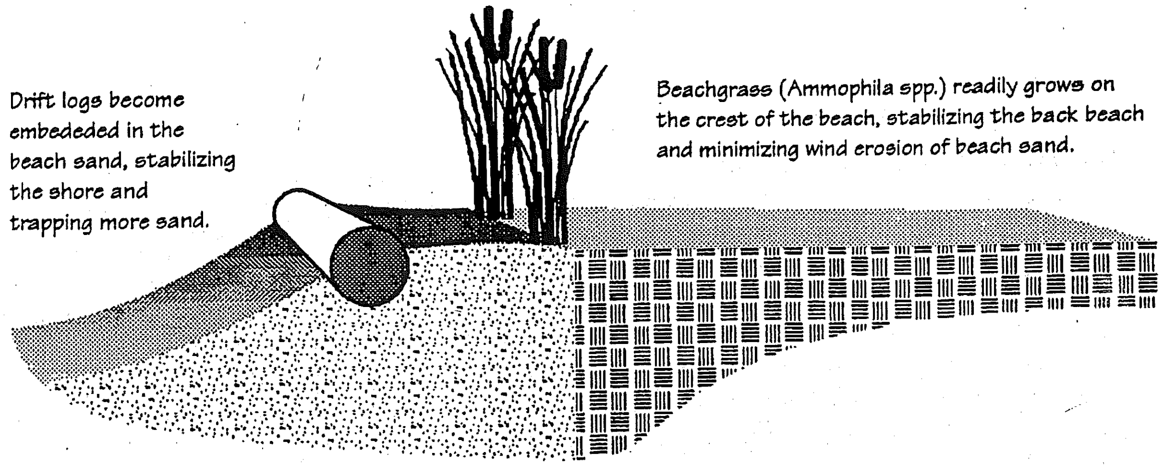
In essence, the sediment supply for the beach had been cut off beginning 60 years ago, and the beach is now exhibiting symptoms of starvation and lowering, consistent with the findings summarized in Chapter 5.

Rich Passage, Kitsap County
On 21 July 1990, at the request of then-Senator Bill Smitherman, we accompanied a group of legislators, local government staff, and shoreline property owners on an inspection of beach erosion allegedly caused by Washington State Ferry boat wakes on the south shore beaches of Rich Passage. We walked approximately 1.5 miles of shoreline from Waterman Point to Manchester State Park.

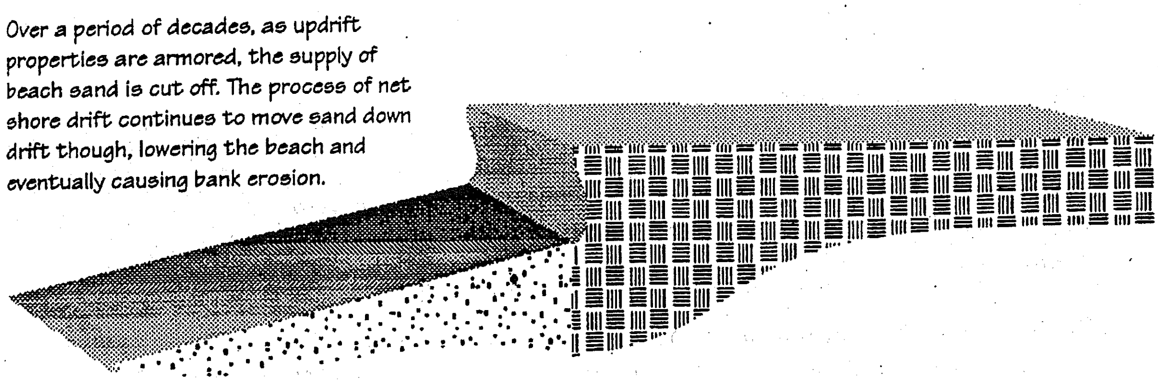
We noted that this portion of the shoreline was heavily armored, and that the armoring (mostly concrete bulkheads, with some rock revetments) was old, of poor design and construction, and deteriorating. Erosion, bank undercutting, and armoring damage was evident. Some bulkhead footings were exposed, indicating that substantial beach lowering had occurred. Except for shoreline indentations, the beaches appeared to have less sand and gravel and more cobbles and boulders than might be expected .

The beaches here showed evidence of lowering and coarsening, consistent with the findings summarized in Chapter 5. Factors other than extensive shoreline armoring could include geologic conditions[11] along the relatively narrow Rich Passage, as well as boat wakes.

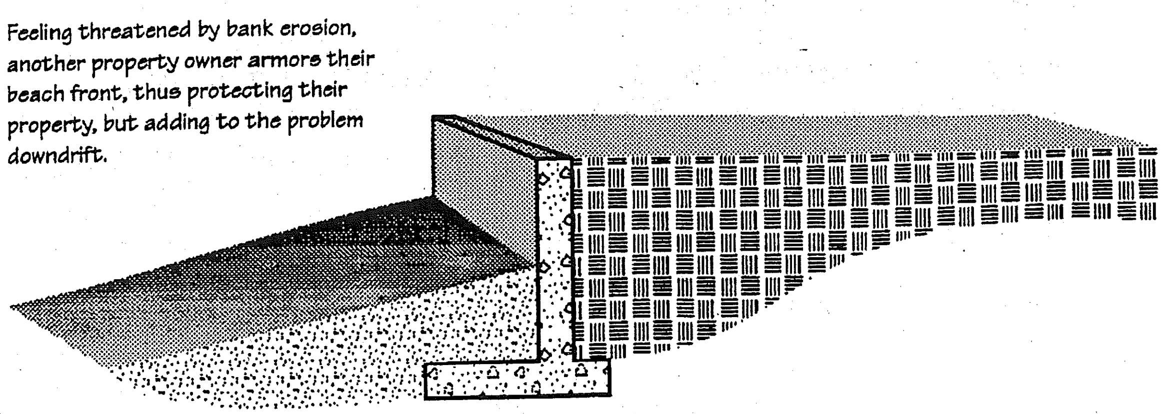
[11] Rich Passage lies over a fault where large scale, sudden vertical land movements have occurred in the past few thousand years in association with seismic events. It may be that a higher than regionally normal rate of current, chronic vertical land movement along Rich Passage contributes to both shoreline erosion and a coarse beach.



a. 'Natural' Beach with no Erosion and Abundant Drift Logs and Beachgrass



b. Early Stage of Beach Lowering and Erosion Due to Updrift Armoring



c. Bulkhead Constructed in Reaction to Erosion

Figure 7.1 Evolution of Samish Island Shoreline Erosion Due to Shoreline Armoring

5. *Skagit County Coastal Zone Disaster Mitigation Report*

These excerpts from Graham (1992) relate to Samish Island and North Beach in particular.

Master File

Skagit County Department of Planning and Community Development

Grant No. G9200020

Date: 6-29-92

Initial: Date:

7/1/92

6/30/92

7/8/92

☐ Payment is being withheld pending your review. Please be timely.

Coastal Zone Disaster Mitigation

Skagit County, Washington

This report was funded in part through a cooperative agreement with the National Oceanic and Atmospheric Administration

ABSTRACT

Coastal Zone Disaster Mitigation: Skagit County, Washington was researched and written by Oscar Graham, Senior Planner/Shoreline Administrator with the Skagit County Department of Planning and Community Development. The subject of this report is the mitigation of coastal zone disasters. The report was printed in June of 1992 and is 89 pages in length including appendices.

The report proposes a working definition of disaster mitigation and addresses hazards commonly associated with the coastal zone of Skagit County: marine flooding, erosion and slope failure. Methods utilized to mitigate these hazards are examined in the context of the geohydraulic processes that shape the coastal environment. The placement of flood control and shore defense devices are examined as typical approaches to averting or arresting flooding, erosion and failure. The potential long term cumulative impacts of shoreline hardening are reviewed in the context of diminishing shoreline resources and increasing developmental pressures. Short case studies describing flooding, erosion and failure at specific locations within the coastal zone are included with a detailed analysis of precipitating events and proposed mitigation measures. County codes and federal and state statutes applicable to mitigation projects are summarized as well as detailed recommendations for Master Program amendments addressing such projects. Finally the development of the County comprehensive plan, resource lands and critical areas protections and implementing ordinances mandated under the Growth Management Act are examined as evolving planning tools to be utilized in conjunction with the Shoreline Management Act.

This report was prepared pursuant to Task 1 of Coastal Zone Management Grant #G9200020. Additional copies of this report are available at:

Skagit County Department of
Planning and Community Development
Room 204, County Administration Building
Mount Vernon, WA 98273

maintenance funds force landowners to rely heavily upon intertidal materials, macadam and other debris for dike maintenance. Because of the steadily declining condition of these dikes and the substantial expense of improving them to acceptable standards, adjacent dike districts are reluctant to annex these facilities. Failure of these dikes could result in the salt water flooding of large expanses of the coastal floodplain. With increasing regulatory pressure to discontinue utilization of intertidal materials and debris for maintenance private property owners find themselves increasingly at odds with resource management agencies and public policy.

Potential salt water flooding of the coastal floodplain appears to hang in a delicate and intricate balance of regulatory enforcement, non compliant maintenance practices and the need of communities to protect themselves from inundation. In the political arena human needs and resources are played off against natural resource protection. A predictable process for negotiating solutions has yet to emerge.

The Skagit County Planning and Community Development Department has identified difficulties with the permit/review process, as it relates to emergency and maintenance projects undertaken by the diking districts, as a fundamental issue of the coastal zone. In recognition, the Planning Department co-sponsored a permit/review workshop with the Public Works Department on March 12, 1992. The workshop was geared towards familiarizing district commissioners with the permit and review requirements of local state and federal agencies. Representatives of the County Planning and Public Works Departments, State Departments of Ecology and Fisheries and the U.S. Army Corps of Engineers made presentations on the permit/review requirements of their agencies. Emphasis was placed on developing an understanding of the permit process, the relationship between agencies, environmental review associated with the State Environmental Policy Act, and the need to plan into annual maintenance projects time for review and permitting. The opportunity for agency staff to listen to the needs of the districts was of equal importance. The goal of the workshop was to take an important first step in improving communication and coordination between the Diking Districts and Resource Management Agencies. Developing a working knowledge of the permit/review process may help enable the districts to plan and complete their projects with confidence that they have addressed agency requirements.

Isolated residential beaches are located throughout the islands of Skagit County. The North Beaches of Samish and Guemes Islands and Alexander Beach of Fidalgo Island are typical of these areas. Developed as weekend or vacation communities, they consisted of modest residences built near attractive shoreline resources such as hunting and fishing areas and accreting shoreforms. As the availability of waterfront property has diminished the older homes are being removed in favor of larger year round residences. These areas are designated as A zones on the Flood Insurance Rate Maps. However, it should be noted that these communities differ significantly from developments located within the coastal floodplain in that no marine dike or protective features shelter them from tidal or storm generated floods.

Developed, for the most part, during the first half of this century, these communities are often located just landward of the Ordinary High Water Mark on lots which would be classified as substandard under today's Zoning Ordinance. As a result zoning and shoreline setbacks for new construction often require variances. The above referenced communities are built upon accreting beaches. As material sources are altered within the drift sector, beach profiles may be altered in an unfavorable manner. Tied as they are to the geohydraulic (erosion/accretion) process, these communities will be discussed in greater detail under the heading of shoreline erosion.

Increased development immediately adjacent to shoreline areas may contribute to coastal flooding. Newly developed residential subdivisions located on the steep hillsides of Fidalgo Island east of Burrows Bay discharged heavy volumes of stormwater during the fall rains of 1990. Incomplete retention and drainage facilities failed to slow stormwater runoff which literally cascaded down upon the community of Alexander Beach. Runoff from the incomplete subdivisions filled and flooded a tidal lagoon which lies landward of the residential beach. The community found itself threatened by surging seas to the west and uncontrolled runoff to the east. Mitigation of this potential disaster is proposed in the form of a large pipe which will bypass Alexander Beach and discharge into Burrows Bay. Poorly planned facilities associated with the subdivisions are mitigated by blighting the shoreline with a by-pass pipe and outfall.

In summation, coastal flooding, flood prevention and control have played a key role in the evolution of Skagit County's coastal zone. Early diking and drainage efforts placed thousands of acres of the coastal lowlands into agricultural production. These rich farmlands continue to contribute to the economy, character and heritage of the County. Utilization of the coastal floodplain for developmental purposes including residential and commercial uses has required an increasing commitment to public sponsored construction and maintenance of a flood control infrastructure. Increased protection in the form of diking and drainage facilities produces an illusion of security for continued flood plain development. Economic incentives encourage potential developers to run the land use approval gauntlet. Though the Comprehensive Plan, implementing ordinances and good sense discourage flood plain development; development continues to occur. In addition a growing environmental awareness reflected in public resource policy has come into conflict with maintenance and flood control procedures practiced for over a century. The value of our estuarine wetlands is recognized at an international level of significance. Developmental pressure focussed on the diminishing shorelines of the County has led to increased residential development of coastal flood zones. During 1991 approximately fifty new residential lots were created in the lower floodplain through subdivisions. Coastal flooding may occur in combination with other types of shoreline disasters, some induced or exacerbated by human developments outside of the immediate coastal zone, including erosion and or slope failure. In this context public health and safety concerns become compelling issues which are played off against public policy, political realities and profit.

environments found in Puget Sound. The major islands; Cypress, Sinclair, Guemes and Fidalgo, though close in proximity, are unique in their physiographic make-up and shoreline characteristics. Their shoreline geomorphology range from dune and marsh lowlands to cobble and rocky beaches backed by gently rolling uplands, to terraced or benched uplands with or without definite beach zones, to more steeply sloping uplands in the forms of cliffs or bluffs whose faces originate far below the waters surface.

Erosion shoreforms are subject to the erosive power of waves, either on a daily basis at all tide levels or at infrequent intervals during high tides or storms. Their physiographic profile is generally in the form of a bluff measuring several feet to several hundred feet in height and may be composed of bedrock, glacial till, glacial outwash, sand and clay silt or other holocene deposits. Each type of material is subject to its own rate of erosion and possesses varying degrees of suitability for different land uses. Examples of these erosional shoreforms can be found along the west side of Fidalgo Island in Burrows Bay, along Similk and Dewey Beaches, the west and east shores of Guemes Island, the shores of Sinclair Island and the north and south shores of Samish Island. In addition, numerous crescent shaped "pocket beaches" are located throughout the islands owing their origins to bedrock erosion and/or bank and bluff erosion an deposition. Erosional shoreforms provide the sediment source in the geohydraulic process.

Accretion shoreforms or beaches are characterized by a relatively permanent backshore composed of a berm of sand, gravel, and drift debris that is wetted only under extreme wave and tidal conditions. They owe their formation and existence to material provided by the erosional shoreforms (banks and bluffs) described in the previous paragraph which is transported by longshore or littoral drift and deposited where wave and current influences diminish. These deposits take the form of spits, points, bars, barrier beaches and tombolos. Accretion shoreforms are the end result of the geohydraulic process and represent a limited recreational and aesthetic resource.

Samish Island provides a condensed ready made study area for geohydraulics and remedial erosion control methods. In the north, a coastal drift sector runs between the predominantly rocky Point Williams in the west and the accreting North Beach approximately two miles to the east. Between these two features lie a variety of eroding beaches and bluffs. These beaches and bluffs have been developed for residential purposes with few waterfront lots remaining. The shoreline has been modified with a variety of shore defense works designed to arrest shoreline erosion in the vicinity of the toe of the bluffs. Shore defense works range from rock rip rap revetments to log and plank bulkheads. One rock groin was also installed in an attempt to nourish an eroding beach.

The community of North Beach is located on an accreting beach at the eastern terminus of the above described drift sector. As the northern shoreline becomes increasingly hardened through the placement of shore defense works the source of sediment materials nourishing North Beach is diminished. As a result of the arctic storms of 1990, wave action erosion of the bluffs and beaches along the northern shoreline was extreme. Soils, saturated as a result of the fall rains of that year were also susceptible to extreme freeze thaw dynamics and accompanying bluff failure. As a direct result of these weather events property owners in the effected area responded with requests for exemptions from the shoreline permit process to allow placement and replacement of bulkheads. The net effect is additional shoreline hardening in the form of bulkheading and the removal of the accretion source of North Beach.

The community of North Beach is designated as an A-7 Flood Zone on the Flood Insurance Rate Maps. The area has a base flood elevation of 7 feet. This elevation refers to the height in relation to mean sea level expected to be reached by the base flood at this point in the coastal zone. As the source of accreting sediments is removed from the beaches and bluffs to the west the accretion rate of North Beach may diminish correspondingly. Starved of sediments, the beach profile may begin to flatten exacerbating coastal flooding. Periodic flooding has been experienced at this location in recent years. The removal of the protective profile of the accretion beach can only increase the flood potential of such a low lying coastal flood zone.

By comparison, the southern shoreline of Samish Island is relatively free of shore defense works. The majority of the residences along the southeastern shoreline are located north of Samish Island Road leaving a buffer of approximately 100-300 feet consisting of eroding bluff and beach. A drift sector is designated for this shoreline in the Washington Coastal Zone Atlas. The drift sector runs from southeast of Samish Island north to the island then west along the eroding beaches and bluffs ending at an accretion spit at the southwest tip of the island. Though several grandfathered residences are located along the beach and near the bluff edge there are few bulkheads. The south central portion of the island remains undeveloped. Isolated attempts at residential development have failed to obtain the necessary land use approvals.

The relative health of this sector can be attributed to a number of factors: The construction of Samish Island Road along the high bluff makes development within the shoreline area difficult. The community values the buffer lying between the road and Padilla Bay and has entered into an informal agreement not to disturb the bluff. Finally, local and state land use regulations including zoning, shoreline and health codes limit use of the area. The net result is a shoreline dominated by natural features and processes buffered from adjacent residential use by county infrastructure. Many of Skagit County's northern shorelines experienced accelerated erosion during the winter of 1990. The heavy rainfall of October and November primed shoreline soils for the high winds and tides of December. Timber blowdowns exposed loosely consolidated soils to wind driven wave erosion. The freeze thaw cycles of January and ensuing winter rainfalls further exacerbated the loss of shoreline property. Approximately one fifth of all shoreline permit exemptions issued during 1991 were for marine bulkheads. Of twenty two bulkhead exemptions seven were issued for the northern shoreline of Samish Island.