Economic Costs of Long-Term Sea Level Rise on the Oregon Coast: A Case Study of the Siletz Littoral Cell

by

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Project Report

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Abstract

Given the broad scientific consensus that global climate is changing, it is no longer a question if sea level will rise, but rather by how much will it rise. The regional estimates for the Eastern Pacific suggest that the Northwest coastlines will experience a greater eustatic sea level rise than most areas, with 50-year estimates of sea level rise on the order of 0.3 meters. This rise in sea level, while not extraordinary, will exacerbate an already ongoing coastal erosion problem in the region. The majority of Northwest ocean shoreline is experiencing tectonic uplift that more than negates the effects of sea level rise. However, there are portions of the Oregon coast that have essentially zero uplift and it is these locations that are already experiencing severe episodic erosion problems. The typical response to coastal erosion along the Oregon coast has been to install hard shore protection structures (SPSs). The Siletz littoral cell, the case study, is one such case. It is one of the most developed portions of the Oregon coast and is already more than half protected by SPSs. The trend for this area has closely mimicked episodic climatic events in that after such events there are bursts of SPS construction. The risk with such an approach is that there will, over the long-term, be a narrowing and eventual loss of oceanfront beaches. Because the Oregon coast is highly dependent on tourism and travel for its economic base, the loss or decrease in the beach resource would have a substantial effect on the region's economy. More than 2 million visitors recreate annually just within our case study area—the Siletz cell beaches. There have been attempts to place economic value on non-consumptive uses such as beach recreation in other parts of the country, but not in the Pacific Northwest.

Given the potential adverse impacts of fixing the shoreline in place with hard SPSs, this option designed to protect uplands (not beaches) should not be the only management choice utilized to address the issue of coastal erosion in the region. This project starts the process of comparing other options to the typical option of hardening, from an economic perspective. An analysis of the different options was conducted for 20-year and 50-year scenarios. The results show that in the 20-year scenario, the 'protect' option is clearly the least costly option due to the existing high levels of development and it makes economic sense to protect the existing infrastructure. However, the results for the 50-year scenario show an interesting cost shift taking place between two of the options. The low range of the 'retreat' option is now more favorable economically then the low end of the 'protect' only option. The conclusion is that over a longer time frame, it simply becomes costlier in losing more beach visitors than it is to continue protecting the existing infrastructure.

Introduction

The coastal zone has always been a favored location for settlement. Centuries ago the draw of this region was the great biological productivity and access to transportation via ship. Although people have settled inland as well, today they are still drawn to the coast for its bountiful recreational activities and more moderate climates. A study of coastal populations shows that while coastal counties comprise only 17 percent of the land area in the contiguous United States, they are home to more than 53 percent of the total U.S. population (Culliton, 1998). Population growth rates of coastal counties are generally not greater than other areas of the country, however, the absolute number of people living in the coastal zone continues to increase significantly.

Despite its attractiveness, there are inherent dangers associated with living in a dynamic region like the coast. These dangers can express themselves in dramatic fashion, as is the case with hurricanes and tsunamis, or they can occur gradually over the long-term as is the case with global warming, sea level rise, erosion, and beach narrowing, the focus of this paper. Both kinds of processes are problems for the growing coastal populations and damages associated with each can reach into the billions of dollars. The scientific community is making significant progress in understanding how these processes work, but there still is a long way to go to achieve good predictability, particularly at regional scales.

The goal of this paper is to further the understanding of climate change impacts by attempting to assess and quantify the economic costs of sea level rise on the Oregon coast for available adaptation options. Another goal is to provide an economic perspective to policymakers, planners, and the public about the long-term risks, impacts, and costs associated with sea level rise and help guide decision making.

The first section provides the reader with general information related to climate change and variability, focusing on three primary time scales: long-term, decadal, and inter-annual. Each of these will be introduced, with the focus being on the longer time scale changes related to global warming and sea level rise. This is followed with a discussion of the general impacts associated with sea level rise, and the factors that make the Oregon coast especially vulnerable. Given these general impacts, the available responses to sea level rise for threatened shorelines are explained from both physical and political perspectives. Why this is of importance to Oregon's beaches and the coastal tourism industry and how this could impact local economies is discussed. Finally, this section concludes by introducing the valuation terminology, definitions, and techniques used to determine the economic valuations of environmental amenities such as beach recreation.

The second section outlines the methods utilized for the various portions of the project. Part one starts with a description of the case study including its physical characteristics and latest development trends. The second part describes the history of shore protection structures (SPSs) along the Oregon coast, followed by the manner in which the SPS status was updated and analyzed. The third part discusses how the impacts associated with sea level rise will vary with each option. A comparison of the different approaches taken by various states is presented. The last part describes the specific economic valuation techniques that were used to determine the costs for each option.

The third section discusses the results for the three options that were selected: protect, protect with sand nourishment, and gradual retreat. Each option starts with a general discussion in which the assumptions for each option are clearly defined. The advantages and disadvantages of each option are discussed. Finally, the analysis is presented along with the findings, which includes the present value of the economic costs associated with each option.

Finally, the fourth section includes the conclusions and recommendations. This compares the present value economic costs for all three options for both a 20-year and 50-year time period. The recommendations portion discusses a possible fourth option and numerous recommendations directed toward local and state municipalities.

Background

Climate Variability and Long-term Directional Change

Climate variability and change generally occurs over three different time scales: long-term, intermediate, and inter-annual. Global warming, Pacific Decadal Oscillations (PDO), and El-Niño-Southern Oscillation (ENSO) serve as the primary examples of each of these time scales and each will be introduced and their potential impacts assessed. The discussion starts with global warming because it is the hardest to predict, yet it provides a 'big picture' of the potential impacts of sea level rise. We end our discussion with the short-term time scale because much more information is known about El Niño and the temporarily elevated sea level that accompanies these events. This provides us with a "snapshot" about what life at the beach might be like in the future with higher sea level year-round.

Long-term time scale: Global Warming

For the last several decades, global warming and what to do about it has been one of the most contentious of global environmental issues. Human activities have substantially increased the atmospheric concentrations of the so-called greenhouse gases: carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide. Carbon dioxide concentrations have increased 25% since pre-industrial times, methane concentrations have doubled, and chlorofluorocarbons have been introduced into the atmosphere for the first time. Warming occurs when these gases are trapped in the atmosphere and block the escape of the earth's radiation to space. This process is better known as the "greenhouse effect"(Edgerton, 1991). Some of the ramifications of global warming include shifting temperatures across land masses, changes in precipitation patterns, melting of the polar icecaps, and rising sea levels. The focus for this project is the last outcome, rising sea levels.

Unfortunately, global warming is difficult to predict due to the long time frame and inherent uncertainty. Numerous general circulation models (GCMs) have been designed in an attempt to predict climate change patterns around the world. These ocean predictors change various factors such as future temperature and precipitation patterns. Using these GCMs as a starting point, other simulations have attempted to predict the amount and rate of sea level rise caused by global warming temperature scenarios. One model that looks at the potential changes that might occur in the Eastern Pacific is the Canadian Regional Climate Model. This model suggests that the greatest rise in sea level is going to occur in the Eastern Pacific (Figure 1). This

Canadian model predicts that by the Year 2091 the Eastern Pacific will rise by almost 0.7 meters or approximately 2.3 feet.

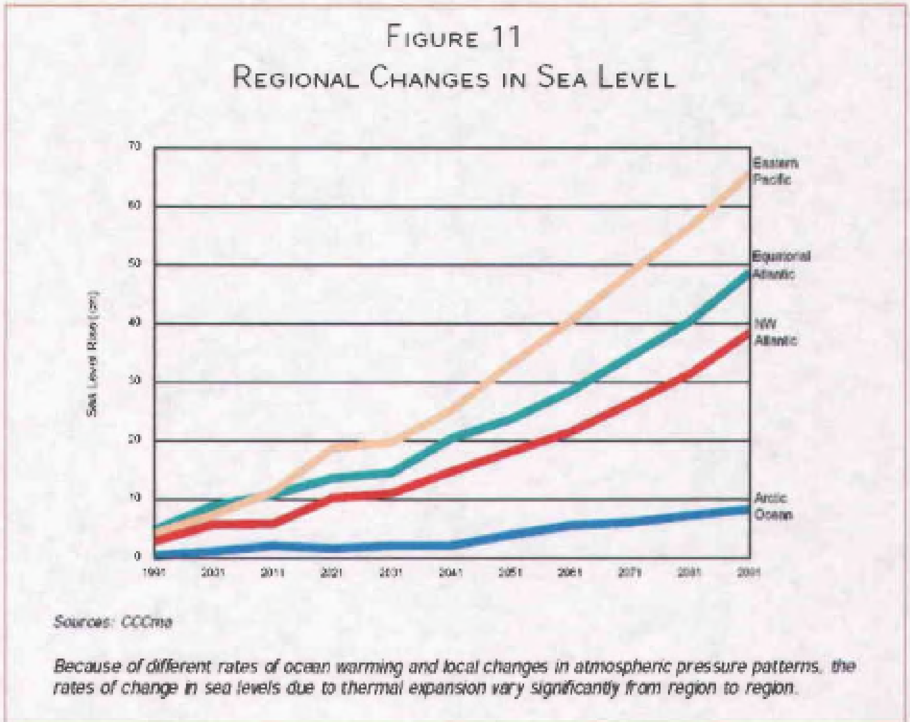

Figure 1: Canadian regional climate model (Canada, 2002)

Research has added some certainty to the subject because originally the question was *if* sea level was rising. Now, it is no longer a question of whether sea level will rise, rather at what rate it is rising. The global sea level is currently estimated to be rising at an average rate of 5mm/year, within a range of uncertainty of 1.5-9 mm/year (IPCC, 2001). However, as seen from the Canadian GCM, there are significant regional differences that need to be accounted for. This paper uses the range from the Intergovernmental Panel on Climate Change (IPCC) study and the figures from the Canadian GCM. These sea level rise forecasts can be found in the Beach Inundation Scenario Table in Appendix B.

Intermediate-term time scale: The Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) is a recently discovered and named phenomenon that has been occurring for the past couple of centuries. Causes for the PDO are not currently known. Likewise, the potential predictability for this climate oscillation is not known. What is understood is that it consists of two major phases: a warm (positive) phase and a cold (negative) phase. Figure 2 shows the PDO Index since 1900. According to this index, there have been two complete PDO cycles with each phase of each cycle lasting between 20-30 years (Mantua, 2004).

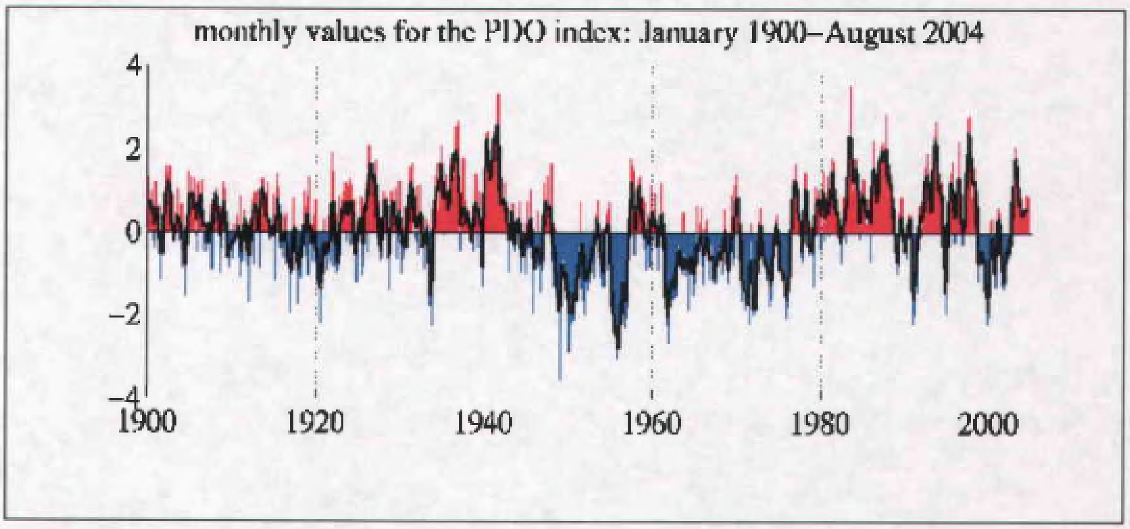

Figure 2: PDO Index for the 20th century with anomalies shown in degrees Celsius (Mantua, 2004).

In a warm phase (~1925-1950 and ~1975-2000), the Pacific Northwest experiences below normal air temperature and sea level pressure, and above normal coastal region sea surface temperatures (SSTs). As a result of these climatic changes, the mountainous regions have reduced snow pack levels in winters, which in turn result in lower than normal river discharge levels. For coastal areas, mean sea level will be higher on average due to the higher than normal water temperatures, resulting in more severe coastal erosion. However, because there are reduced discharge levels from the rivers, bay-side erosion may be less severe.

In a cold phase (historically ~1900-1925 and ~1950-1975), the Pacific Northwest experiences above normal air temperature and sea level pressure, and below normal coastal region SSTs. The mountainous regions receive enhanced snow pack levels, which result in higher than normal water discharge levels from rivers. For coastal areas, mean sea level will be lower on average due to the below normal water temperatures, resulting in less severe coastal erosion. However, with increased discharge levels from the rivers, bay-side erosion may be exacerbated.

The interaction between the PDO and the ENSO climate patterns are clearly related but not yet fully understood. How these different climatic events constrain or impact each other remains to be seen.

Inter-annual Variability time scale: El-Niño-Southern Oscillation (ENSO)

ENSO is a disruption of the ocean-atmosphere system in the tropical Pacific having important consequences for weather around the globe. Of all the climate change activities discussed, ENSO is by far the most well understood phenomenon. Several decades ago, ENSO was thought to be no more then a shift in currents and a warming of the ocean waters west of South America, of interest only because it caused extensive fish kills off the coast of Peru. No one imagined that an ENSO event had such far-reaching consequences, especially such a major role in beach erosion along the west coast of the United States (Komar, 1997). The ENSO index in Figure 3 shows the patterns of this climatic event since 1950 (NOAA, 2004). The major El-Niño events from 1982-83 and 1997-98 are obvious.

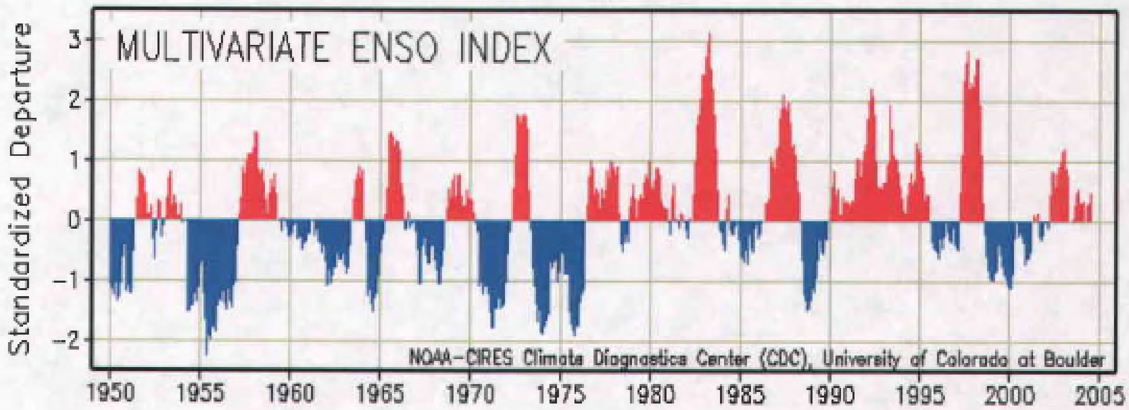

Figure 3: ENSO Index (Climate, 2004)

El Niño and La Niña are opposite phases of the El Niño-Southern Oscillation (ENSO) cycle, with La Niña sometimes referred to as the cold phase of ENSO and El Niño as the warm phase of ENSO. El Niños are initiated by the breakdown of the equatorial trade winds in the central and western Pacific. Shortly after the winds stop blowing, the water surface that it was exerting a force against is released. This creates an eastward flow of warm water known as a Kelvin Wave. This wave moves along the equator toward the coast of Peru and once it reaches and collides with the South American land mass the flow splits into two waves. One heads to the North and the other to the South. These waves maintain their amplitude for many physical and scientific reasons. The important point is that this heightened wall of water moves unimpeded up along the West coast, elevating water levels and increasing storm intensities. A comparison of normal versus El-Niño conditions in the equatorial Pacific is shown in Figure 4. It will be explained later how this also increases the northward transport of sand along Oregon beaches.

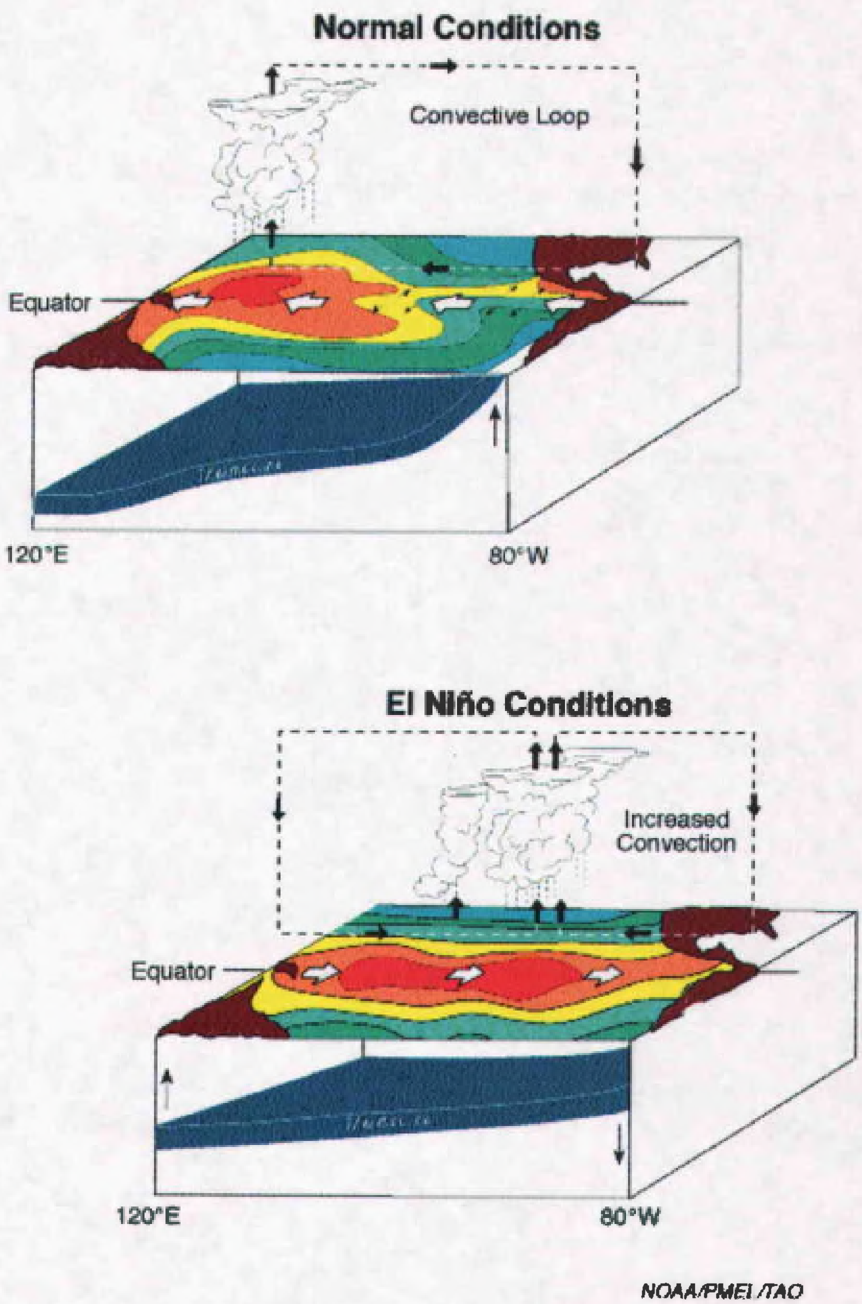

Figure 4: Normal vs. El-Niño conditions in the equatorial Pacific (NOAA, 2004)

El Niño episodes occur roughly every four-to-five years and can last up to 12-to-18 months. It has been nearly four years since the end of the 1997-1998 El Niño, which was followed by three years of La Niña. La Nina conditions involve unusually cold ocean temperatures in the Equatorial Pacific, cooler than normal temperatures, and increased precipitation. It should be noted that La Niña's do not always necessarily follow an El Niño and the intensities can vary from event to event (NOAA, 2004).

Climate, Sea Level Rise, and the Oregon Coast

What does global climate change and sea level rise mean to the Oregon coastal environment? The remainder of this paper focuses on the impacts of sea level rise on the coast and examines Oregon's vulnerabilities and coastal hazard history.

Impacts of Sea Level Rise

The principal environmental effects of sea level rise will be the erosion of beaches, bluffs, and dunes, inundation of low-lying areas like small islands or subsiding delta areas, saltwater intrusion into aquifers and surface waters, higher water tables, and increased flooding and storm intensities and damage. Wholesale losses of coastal wetlands can also be expected, particularly along low-lying coasts like Louisiana (Leatherman, 2001). Wetlands are lost when a shoreline is protected with hardened SPSs, as there is little to no room for wetlands to migrate upland. SPSs are structures that restrict the natural migration of the shore landward, as is the situation with coastal erosion. Consequently, wetlands get squeezed against these SPSs until they are inundated by the rising seas. Finally, numerous natural habitats will be impacted and altered due to intensified flooding and greater intrusion of saltwater into estuaries and coastal aquifers. Estuaries serve multiple functions along coastal regions. The functions relevant to the Oregon coast include serving as nursery grounds for commercially valuable fish and shellfish species, and as effective systems for the dispersal of pollutants. These latter impacts are important and demand further research, but are beyond the scope of this project as the focus is on coastal erosion along ocean beaches.

Oregon's Chronic Hazard Vulnerabilities

The Pacific Northwest coastline is known for its high wave energy and severity of storms. Development along Oregon's coast has historically been threatened by many types of chronic natural hazards. These include beach and dune erosion, sea cliff recession, bluff slumping and landslides, and coastal flooding (Johnson, 1998). Long-term sea level rise is expected to exacerbate all of the above conditions and increase the vulnerability of the Oregon coast with increased erosion, flooding, and higher levels of property damage. Much of Oregon's coastal erosion has occurred in conjunction with ENSO events. Comparing mean sea level for the Oregon coast during an 'average' year and the ENSO events of 1982-83 and 1997-98 illustrates why (Figure 5). Increases up to 20 inches occur during El-Niños typically within 4-6 months (Komar, 1997). Research on El-Niños over several hundred years shows that strong to very strong events occur every 8-9 years (Quinn et al., 1987 as cited in Good, 1992).

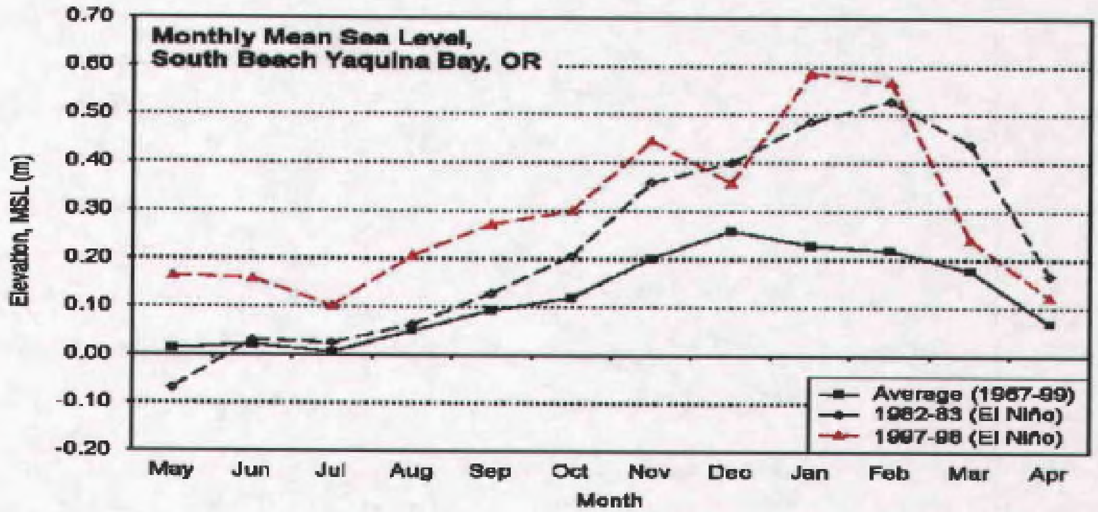

Figure 5: Average sea level vs. major El-Niño sea level (Komar, 1997)

Another trend that increases the vulnerability of Oregon's coasts is an increasing average wave height (Figure 6). Over the past 25 years, the average wave height off the Oregon coast has increased almost three-quarters of a meter. Whether or not this can be attributed to climatic changes is another question that needs further research, but the potential of larger waves hitting the Oregon coast could greatly exacerbate the coastal erosion problem.

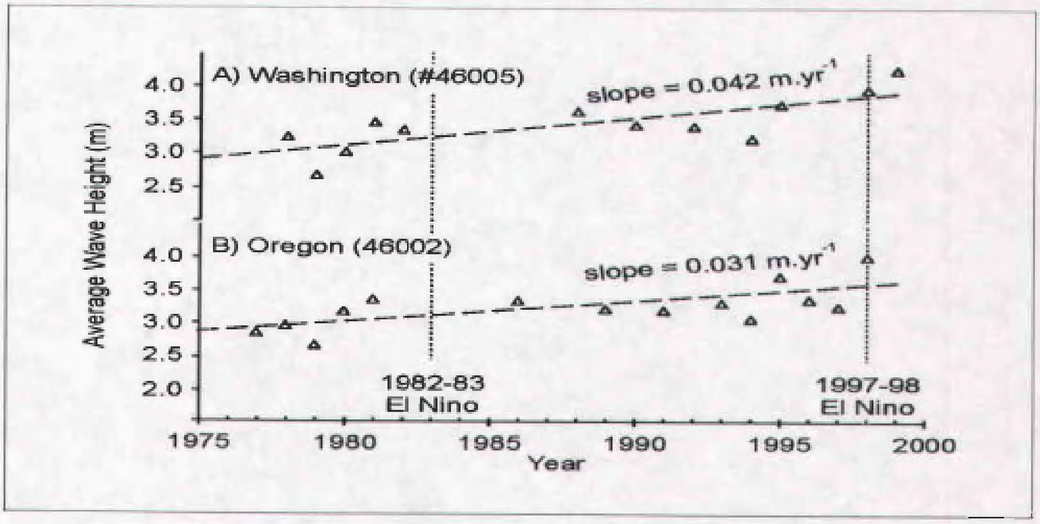

Figure 6: Average wave height for Oregon (Allan & Komar, 2000)

Case Study Selection Criteria

The Siletz littoral cell was selected as a case study for several reasons. For one, this region has been extensively developed and has a long history of shore protection and coastal erosion. The Oregon coast is experiencing tectonic uplift along approximately two-thirds of its shoreline (Figure 7). The southern half of the Oregon coast is rising faster than the recent global rate of sea level rise, and most of the northern half of the coast is being submerged by the rising sea (Komar, 1997). Not surprisingly, it is this northern half of the coast that is experiencing the worst cases of coastal erosion. Siletz littoral cell location is marked on Figure 7 with an asterisk.

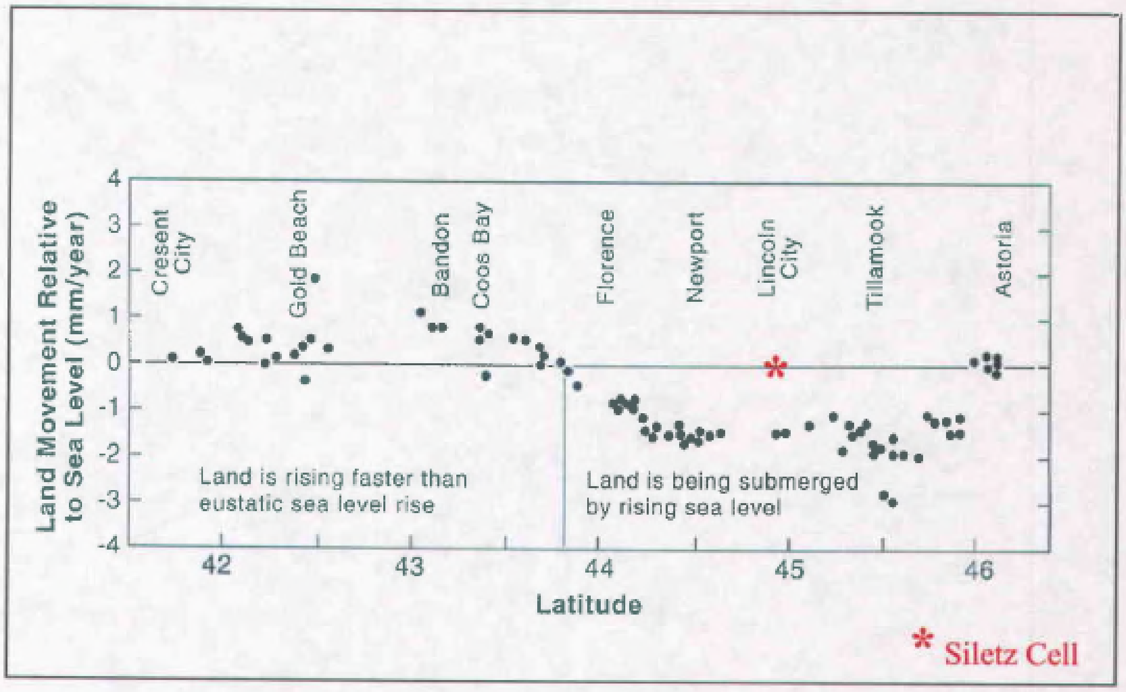

Figure 7: Elevation change along the Oregon coast (Komar, 1997)

Secondly, the beaches in the Siletz area are some of the most popular in Oregon and littoral cells offer a great opportunity for independent study. The majority of sand remains trapped between the headlands and is either transported into the bay or on or off shore. It is thought that the major headlands prevent most sand from being transported north or south of an individual cell. This sand movement is highly dependent on the seasons as sand generally is transported to the north during the winter and to the south during the summer (Figure 8).

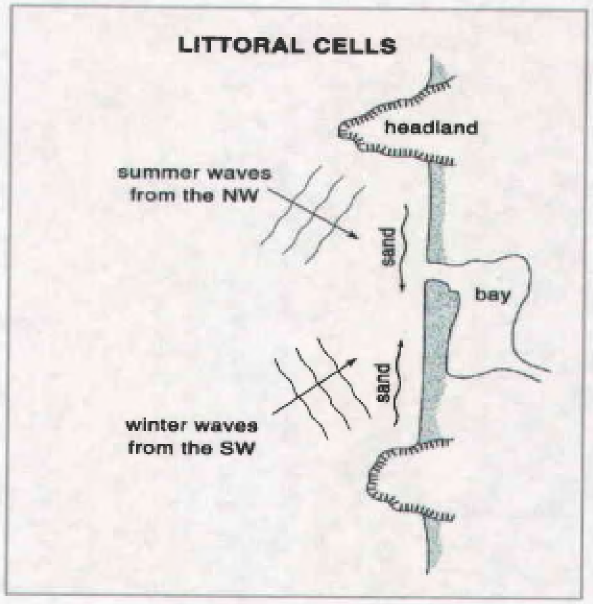

Figure 8: Wave direction and sand movement for a typical Oregon coast littoral cell (Komar, 1997)

Finally, the Siletz littoral cell serves as a great example for assessing the cumulative economic costs of having a hardened shoreline in relation to beach loss and the availability of it for recreation.

Responses to Sea Level Rise

Most municipalities around the U.S. and virtually all along the Oregon coast, did not take sea level rise into account when they developed comprehensive land-use plans and established construction setbacks. In addition, some proposed and platted development sites fall well within flood and coastal erosion zones. Until recently, the Federal Emergency Management Agency (FEMA) was essentially promoting this type of development by offering subsidized flood insurance. This changed on May 1, 1999 when FEMA published a final rule that increased the insurance rates for riskier type properties such as oceanfront or flood zone properties (Federal Register, 1999). However, the principal portion of the Siletz littoral cell that would be affected by this rule is the sand spit enclosing Siletz Bay (Salishan), and that shoreline is fully protected with SPSs (Good, 1992). In addition to this federal policy change, perhaps the erosion associated with the latest El-Niño (97-98) will create the increased awareness needed to facilitate consideration of climate variability and change factors into the management and planning process (JISAO, 1999).

When a community does prepare for sea level rise through planning, there generally three policy choices in response to sea level rise (Table 1).

Table 1: Typical responses to sea level rise (Fankhauser, 1995).

Retreat	abandon or move back structures in currently developed areas, resettle the inhabitants, and require that any new development be set back specific distances from the shore, as appropriate.
Accommodate	continue to occupy and use vulnerable areas, but accept the greater degree of flooding and erosion.
Protect	defend vulnerable areas, especially population centers, economic activities, and natural resources.

The optimal protection strategy will vary depending on the coastline and its characteristics. Every coastline faces a different set of circumstances, such as the level of development, the presence of natural resources, and the rate of tectonic movement (uplift or subsidence). The optimal policy response to sea level rise is really a problem of regional coastal zone management (Turner, Doktor, and Adger, 1995). The one scenario that seems to be consistent on a region-wide basis assumes that if extensive development already exists, then the *protect* strategy is generally economically justifiable. That assumption is tested later in this report.

Oregon's Policy Response to Coastal Erosion

Public policies have often addressed natural hazard mitigation without incorporating climate change and variability. For example, in response to beach development, state legislators aimed to protect the public's access to Oregon beaches by implementing and regulating the use of SPSs through the 1967 Beach Law and associated permit program. This law created a permanent public recreational easement to the ocean shore—the wet and dry sand beach from low water up to the vegetation line. It also declared a public interest in the aesthetic qualities of the beach, thereby enacting the permit program for shore protection structures (Good, 1992). The other major Oregon policy affecting beaches, the Statewide Planning Goals, are standards for comprehensive planning and set requirements on how land-use decisions are to be made. Specifically, Goal 18 (Beaches and Dunes), Goal 17 (Shorelands), and Goal 7 (Natural Hazards) were enacted to address coastal natural hazards, ocean shore protection, and to protect beach access and recreation. Relevant to this project is Goal

18's requirement that permits for beachfront protective structures be issued only where "development" existed on January 1, 1977. It defined development as houses, commercial and industrial buildings, and vacant subdivision lots which are physically improved through construction of streets and provision of utilities to the lot, or areas where special exceptions have been approved (Oregon LCDC, 1977).

Oregon's beaches are located primarily in littoral cells or pocket beaches. The management/policy regime that created numerous policy objectives were supposed to consider cumulative impacts and long-term considerations on events that will impact beaches. It failed to do this because SPS permits are issued on an individual basis and to date there still is no statewide setback requirement for developed properties. Each jurisdiction handles it differently (e.g., Lincoln City and Lincoln County for the Siletz Cell).

Oregon's Beaches and the Coastal Tourism Industry

Over the past several decades, tourism has become increasingly important to Oregon's economy. Some regions within Oregon depend on tourism more than others and the coast is one of them. One of the big attractions for visitors is the length and access of the public beaches. Visitors traveling to the Oregon coast represent a substantial component of the region's economic base. The Siletz littoral cell, being centrally located along the coast, draws from Oregon residents (Corvallis, Salem, and Portland Metro areas), as well as out-of-state and international visitors. The two primary economic engines for Lincoln City and surrounding areas are tourism and retirement (Chamber of Commerce, 1999). In 2002, 26.3% of employment in Lincoln

County was travel and tourism generated (Runyan, 2002). As might be expected, tourism is highly seasonal, with the majority of the visitations occurring during the late spring, summer, and early fall months. Visitation rates at day use parks and waysides from 1993-2003 for the Siletz littoral cell show that visitor numbers have averaged 2,115,736 per year (Figure 8). Graphically, a noticeable downward trend in visitation rates is observed, with a 17% decrease overall and a 1.5% per year decrease from 1993 to 2003 (Figure 9). More recent years (1998-2003) show a smaller annual decline of only 0.4%/year. While there are likely many possible explanations for these visitation trends, one contributing factor might be sea level rise and the consequent narrowing of the beaches in the Siletz cell. Another factor might be a change in the type of visitors and their activities, such as visitors to the Chinook Winds Casino, which was built around 1995. However, the drop in visitation rates appears to have started before the Casino was finished. Again, there are many potential reasons why beach visitation rates are declining and this will require further study. It should be noted that a similar trend was observed for the entire North Lincoln County area, including Newport to the south.

Table 2: Visitation rates for recreation sites in the Siletz littoral cell

Day-Use Visits for Siletz littoral cell Recreation Areas						
Visitation Rates	**D River SRS**	**Fogarty Creek SRA[1]**	**Gleneden Beach SRS**	**Roads End SRS**	**Siletz Cell Totals**	**Total Vehicles[2]**
1993	1,500,432	243,982	229,684	389,466	2,363,564	590,891
1994	1,407,924	209,530	236,828	409,616	2,263,898	565,975
1995	1,331,208	184,548	258,132	417,718	2,191,606	547,902
1996	1,141,048	181,106	298,644	338,246	1,959,044	489,761
1997	1,347,328	209,206	307,124	381,094	2,244,752	561,188
1998	1,172,256	181,728	320,184	387,624	2,061,792	515,448
1999	1,115,396	183,108	332,404	449,850	2,080,758	520,190
2000	1,155,876	189,598	297,976	398,306	2,041,756	510,439
2001	1,219,676	173,688	235,400	401,422	2,030,186	507,547
2002	1,224,684	185,974	255,068	404,616	2,070,342	517,586
2003	1,162,272	162,876	271,176	369,074	1,965,398	491,350
11-Year Annual Average	**1,252,555**	**191,395**	**276,602**	**395,185**	**2,115,736**	**528,934**

Source: Oregon State Parks and Recreation Department- Tom Hughes
[1] Day-use fee park.
[2]Visitation totals assume 4 people per vehicle

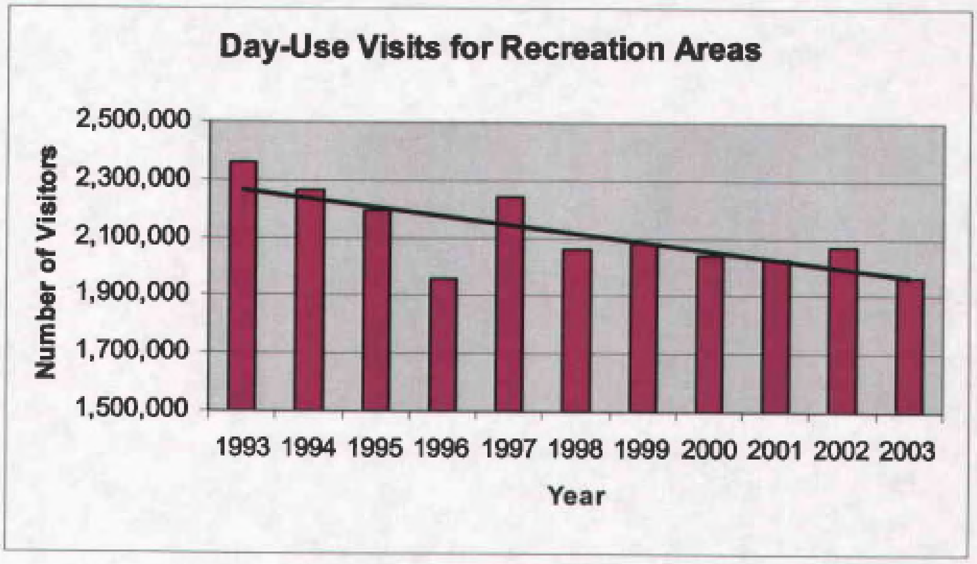

Figure 9: Total visitation rates for Siletz littoral cell

Methods

Objectives

The Third Assessment Report of the IPCC made specific note that little progress had been made in costing and valuation methodologies between 1995 (Second Assessment Report) and 2001. This international perspective stated that much work was needed to fill the large research gap of our inability to quantify the costs and benefits of climate change on the economy. Some recommendations for future work included:

- increased consideration of community characteristics (e.g., socio-economic, political, cultural) in costing studies, to provide policy-makers with a better understanding of the regional impacts of climate change;
- improved understanding and quantification of the connections between sectors and regions;
- enhanced estimates for losses involving non-market goods;
- incorporation of vulnerability and the process of adaptation in the models;
- evaluation of the importance of extreme events and climate variability; and
- examination of the role of adaptive capacity in influencing the magnitude and nature of climate change costs (of both impacts and adaptation)(IPCC, 2001).

The objectives of this project begin to address several of these needs. The three primary objectives are as follows:

1. To evaluate the status of shore protection construction in the Siletz Cell, determine whether or not the current trends are as expected, greater than, or less than the historic trends.
2. To estimate the physical impact of long-term SLR on beaches of the Siletz littoral cell.
3. To estimate the economic costs of possible beach narrowing and loss.

Case Study Area: The Siletz Littoral Cell

Physical Description

The 16-mile Siletz littoral cell is bounded on the north by Cascade Head and on the south by Government Point, two erosion-resistant basalt headlands that effectively isolate it from adjacent cells (Figure 10). The majority of the cell is fronted by beaches with the primary stretch of beach extending 12.5 miles from Roads End at the north to Fishing Rock at the south, with the only major interruption being the mouth of the Siletz River at Siletz Bay. The cell contains two major coastal drainages—the Siletz and Salmon Rivers—and several minor ones. Sea cliffs back the beach along nearly 10 mi of the cell, averaging more then 50 ft in elevation (MSL). Dune fields are found on the Salmon River spit at the very north end of the cell and the Siletz spit in the central part of the cell (Good, 1992). It appears that much of the sand on the present-day shore has been derived from erosion of sea cliffs with a smaller portion of the sand budget being supplied by the Siletz and Salmon River outflows (Komar, 1997).

Figure 10: Siletz littoral cell looking south from Cascade Head (J. Good photo)

Development Trends

The Siletz littoral cell is one of the most extensively developed and heavily protected areas along the Oregon coast, with nearly continuous residential, commercial, and recreational beachfront development. There are 874 buildable lots located in this area which includes Lincoln City and the unincorporated communities of Roads End, Salishan, Gleneden Beach, and Lincoln Beach. As of 1991, only 25% of these lots were undeveloped (Good, 1992). To obtain a current estimate of undeveloped lots and other information, a 1-mile sample population was analyzed. From this, it is estimated that only 10% of the lots remain undeveloped. Other information estimated from this sample includes the approximation that 75% of the developed properties are single-family residential dwellings, and the other 25% consist of motels and multi-family dwellings.

Coastal Hazards History

As revealed by a series of aerial photographs of the Siletz spit, a natural cycle of erosion events existed well before its development occurred in the 1960s. This natural cycle consisted of intermittent erosion events typically followed by a long period of foredune rebuilding. Historically, the major erosion problems in the Siletz cell have taken place along the Salishan spit and just to the south along Lincoln and Gleneden beaches due to a combination of beach characteristics and ocean processes. Developments first started appearing along the spit in the early 1960s. During each erosion period, the maximum period of erosion corresponded to the largest storm wave heights, demonstrating that this is the primary cause of erosion (Komar 1997). The formation of numerous rip embayments, coupled with the fact that the beaches in this part of the cell consist of coarser sand, caused them to respond more rapidly than fine-sand beaches to storm waves, and as a result underwent dramatic profile changes (Komar, 1997). The other type of erosion affecting the spit is that of erosion on the bay-side of the spit caused by the drainage of the Siletz River. This type of erosion has been exacerbated due to the landfills in Siletz Bay for new developments in the late 1960s. These landfills prevent river floodwaters from spilling into the south part of the bay. This causes the same volume of river outflow to be funneled out a narrower portion of the mouth, with less time to dissipate, thereby forcing it into the back side of the spit. As most of the spit is currently "hardened" on both sides, the erosion has lessened substantially, however, in many areas the natural sand has been replaced by a mound of rocks (Komar, 1997).

Even though the extent of erosion of the spit has been constrained by riprap protective structures, coastal erosion is still affecting the beaches themselves and the uplands along cliff-backed portions of the cell. All areas of the cell, except the northernmost portion around the Salmon River mouth (foreground of Figure 10), are experiencing cliff erosion. For example, the portion of the cell north of the Siletz Bay mouth is experiencing cliff erosion at a rate of approximately 3-10 cm/year (Komar, 1997). As cliffs are more resistant to erosion than dune backed bluffs, it took longer for erosion to become a hazardous event. The 1982-83 El-Niño was considered a strong event and its high-powered storms and wave levels exacerbated the amounts of erosion along these cliffs. As events like these are predicted to occur more frequently under climate change, there clearly is a need to better understand the impact climate change and variability will have on the coastal hazards.

SPS Status Methods

Along with development comes the risk of structures on the upland being affected by natural processes such as coastal erosion. For the past several decades, the typical response to coastal erosion has been to install shore protection structures (SPSs). Figure 11 shows the cumulative mileage of SPSs that have been built between 1967 and 1991 (Good, 1992).

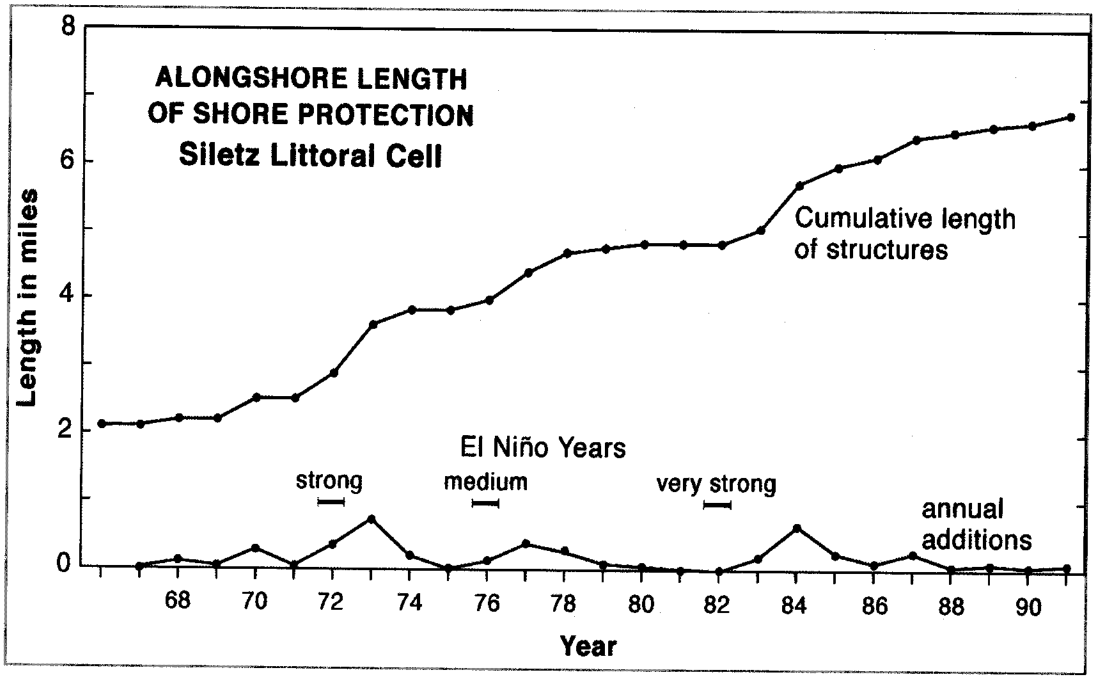

Figure 11: Cumulative length of and annual contribution to SPS construction along the Siletz littoral cell.

To determine the current SPS status in the Siletz littoral cell, two primary sources were utilized. Good (1992) provided detailed data on SPS construction rates and linear footage from 1967 through 1991, as seen in Figure11. The second source was the recently updated SPS database developed by the Oregon Parks and Recreation Department (Steve Williams, pers. comm, 2004). However, the database was structured such that comparable data to Good (1992) was available. Thus, while it would have been ideal to get a year-by-year update for SPS construction, the only data readily available was the total SPS linear footage to date. With this number, numerous rates were determined, including the rates from 1991 thru the present, as well as the historical rate of 1967 thru the present.

The trends revealed in the above data show that the rate of SPS construction has varied greatly since 1967. Overall, from 1967 thru the present, SPS construction was built at approximately 800 linear feet per year. Data from OPRD for the 1991-2003 period revealed a construction slowdown to just less than 400 linear feet per year, when only one major El Niño event took place. During the period of 1967-1991, when SPS construction occurred at the rate of just over 1000 linear feet per year, there were three major El Niños. Therefore, this project assumed that the future SPS construction rate will follow the historical pattern of 800 linear feet per year. Maintenance of SPSs will vary depending on which policy option is selected.

SLR Impact Methods

The impact of sea level rise on the shoreline depends primarily on how humans choose to deal with it. The states of Maine, North Carolina, and South Carolina have enacted legislation prohibiting the use of hardened SPSs in combating coastal erosion. Numerous other states have enacted minimum setback requirements based on historic erosion rates. However, some states, like Maryland, fully support hardened shore protection structures when managing coastal erosion. The end result is that Maryland will face drastically different impacts than states that have restricted SPS use as a shoreline management response. Oregon has prohibited SPS construction for properties developed after 1977. The impacts of SLR on the Siletz littoral cell will be assessed for three different policy scenarios: (1) protect, (2) protect with beach nourishment, and (3) gradual retreat of development from the shoreline.

Economic Costs Methods

To account for the economic costs of SLR in the Siletz Cell, several economic data sources and techniques were utilized. For the Siletz situation, cost data from other studies and projects are being used. There are several conditions that need to be met in using other studies/projects. Some of these include pursuing similar measurements of value for similar amenities, ensuring the markets for both the study site and policy sites should be the same, and making sure the data being 'transferred' is drawn from an adequate number of individual studies (Rosenberger & Loomis, 2000). Other sources of economic estimates, (e.g., for construction of riprap revetments) come from numerous local contractors and the Lincoln County assessor's office.

As noted above, there are several approaches used to determine the impacts of sea level rise. The following case study methodology and steps for economic analysis will be adhered to as closely as possible:

1. Development of regional scenarios of relative sea level change
2. Development of an analysis linking relative sea level change with zone-specific physical hazards- flooding, inundation, and erosion;
3. Subdivision of the hazard zone into separate physiographic units, based on the risk of flooding and erosion
4. Collection of asset data for the hazard zone, in order to establish an inventory of natural and artificially constructed capital assets;
5. Quantification and evaluation of the in-place sea defense and coastal protection system in the hazard zone;
6. Definition of relative sea level change response options and an assessment of their impact on coastal hazards and assets in the zone;
7. Economic valuation of the costs of the various response options, including the 'do nothing' option (Turner, Doktor, and Adger, 1995).

This case study methodology enables coastal communities to walk through the economic valuation process and determine the best course of action, or inaction, in some cases. Research within this project focuses on Steps 6 and 7, with informed assumptions and data drawn from other sources to meet the requirements of steps 1-5.

In calculating the present value of costs for each scenario, we use a 3% discount rate and a 7% discount rate for valuing environmental resources. The high end of the range (7%) is used to reflect expected inflation of benefits and costs. The low end of the range is what is currently being used to value other natural resources like wildlife refuges (OMB, 2004).

Results and Discussion

The three options analyzed for this project are protect, protect with beach nourishment, and gradual retreat. In performing the economic analysis for each of these options, it was necessary to select a smaller sample population (case study) within the Siletz littoral cell to make the assessment manageable. Specifically, the sample population is a one mile section located in the Lincoln City area (from 16th Street up to 34th Street). This area was selected because it is an uninterrupted stretch of development consisting of mostly residential and small commercial properties. The following photos show various views of this stretch of beach as well as typical properties that are in this case study section (Figures 12 to 16).

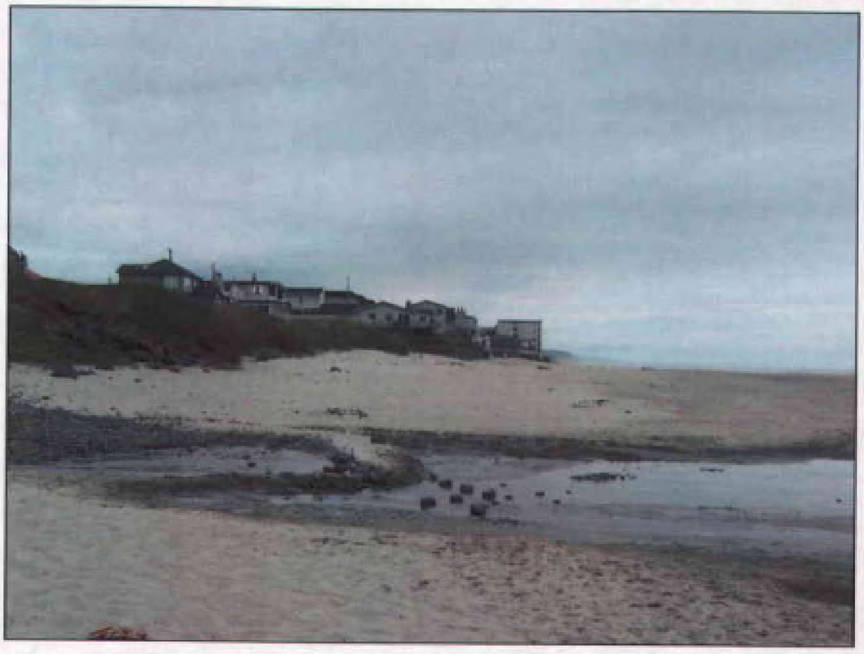

Figure 12: Case study from the north looking south

Figure 13: Case study from the south looking north

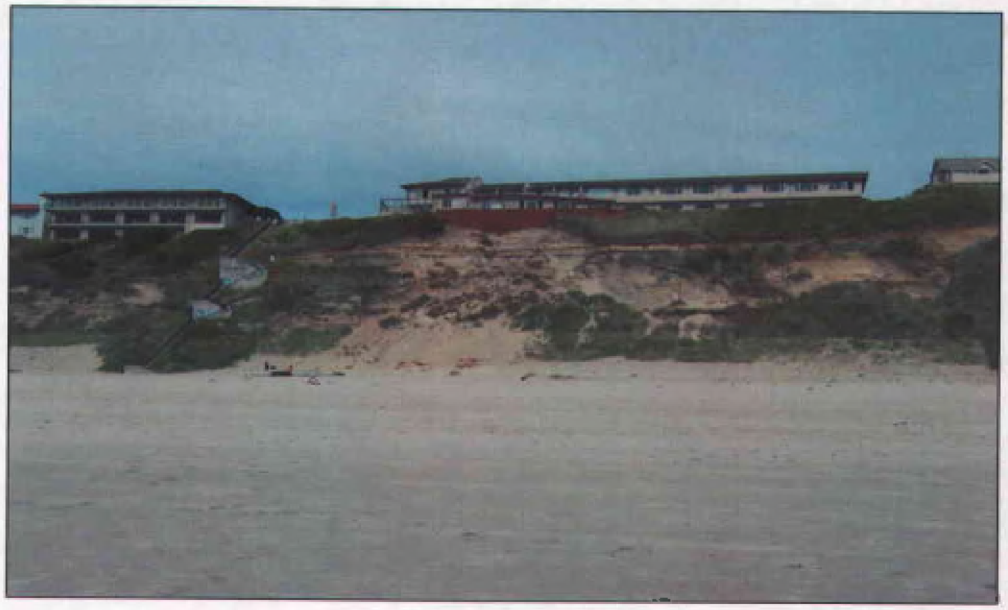

Figure 14: Sample of erosion within the case study (~23rd Street)

Figure 15: Commercial structure in case study (~21st Street)

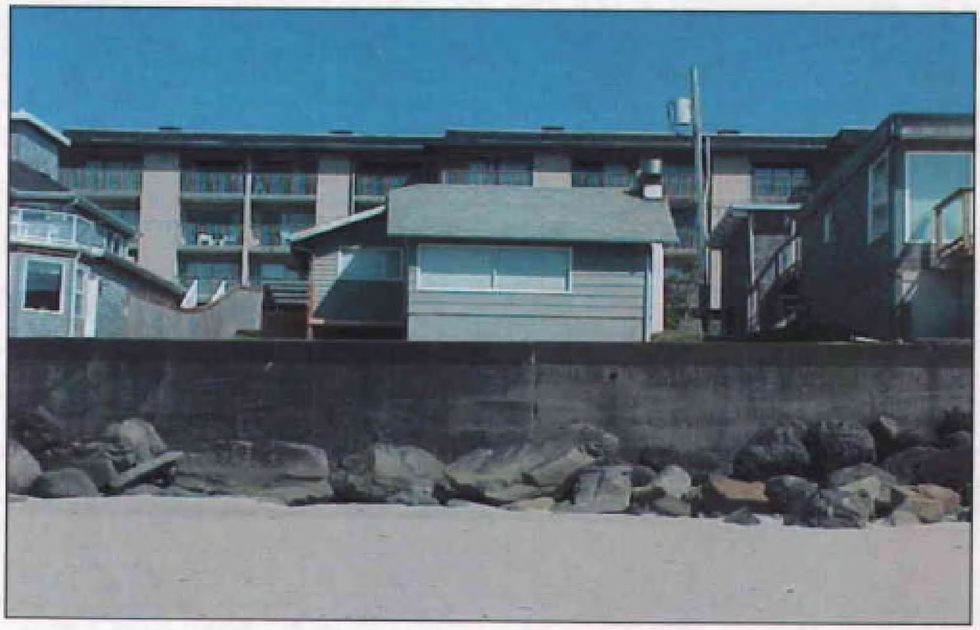

Figure 16: Residential homes in case study (~33rd Street)

Property information from this section was collected from the Lincoln County assessor's office. The contractor estimates, percentage of vacant lots, and other relevant information were based on this information. See Appendix A for details.

Option #1: Protect Only

General Discussion

The first scenario assessed in this project is the 'protect only' option. This option assumes that shore protection structures will continue to be built whenever oceanfront properties become impacted by coastal erosion and that the Statewide Planning Goal 18 SPS prohibition on undeveloped as of 1977 property is either not applicable or that the policy will be overturned. The construction of SPSs will thus continue until the entire shoreline length is completely hardened. In the face of SLR, the beach will gradually narrow and eventually be lost to sea inundation. It is assumed that as the beach narrows, the number of visitors will decline due to decreased lateral access, quality of experience, and safety concerns. However, it is also assumed that these lost expenditure costs pertain only to the Siletz littoral cell as these visitors will be able to find substitute beaches either to the north or south of the cell. Therefore, the state of Oregon as a whole will experience a zero net change in expenditures related to beach recreation. Therefore, the goal of this option is to determine the cost to construct and maintain the SPS system, and the locally lost expenditures associated with a narrowing beach.

Cost for SPSs

As of the spring of 2003, 54.5% or 40,304 feet of beachfront land was protected with SPSs, with the remaining 33,669 feet unprotected. As discussed earlier, it is assumed that the SPSs will be built at the historic SPS construction rate of 800 linear feet per year. To find the cost of SPSs, conversations were held with Steve Williams, SPS Permit Coordinator for the Oregon Park and Recreation Department, and with private contractors located in the Lincoln City area. From these conversations, it was determined that the cost to install a new SPS is approximately $200 per linear foot. Since it is assumed that 800 linear feet will be built every year, the annual cost for new SPSs will be $160,000 annually ($200 X 800) or $800,000 every 5-year period.

The maintenance costs are much harder to determine, since there is a wide range and timeframe in which SPSs might need maintenance (Williams, Personal

Communication). Based on the same conversations, it was determined that the cost to maintain SPSs would be approximately $100 per linear foot and that 50% of the existing SPSs would require maintenance every 10 year period. For example, in Table 3 at Year 0 there is 40,304 feet of SPSs. By year 10, 8000 linear feet (800ft/yr X 10 years) of SPSs will have been constructed, bringing the total existing SPSs at year 10 to 48,304 feet. Taking 50% of this number and multiplying it by $100 per foot results in the SPS maintenance cost for that time period, $2,415,200. This same process is continued out thru year 20 and year 50.

Lost Expenditure Costs

Given that the erosion of cliffs provides an important source of sediment for natural beach replenishment, the placement of SPSs between the beaches and the cliffs effectively eliminates this source. When the beach sand is removed via storms and wave activities, it is not being replenished at its historical rates. As the beaches narrow, it is assumed that fewer people will visit the beach due to narrowing (overcrowding) and safety issues associated with the SPSs and increased run-up of ocean waves, thereby reducing the expenditure costs linked to beach recreation. It was mentioned earlier that visitation rates within the Siletz Cell have been decreasing anywhere from 0.4% to 1.5% annually over the past 11 years. Since there could be many reasons for this decline, it is assumed that this rate will continue to decline by 0.5% per year in order to calculate lost expenditure costs.

To determine the costs associated with a narrowing beach and subsequent decline in beach recreation quality, the visitor data from the previous section is coupled with expenditure studies to determine the annual expenditure costs on beach recreation for the Siletz Cell (Table 3).

Table 3: Annual revenue for Siletz recreation sites

Annual Revenue for Siletz Recreation Sites			
Location	11-year Average for Annual Day-Use Visits	Annual Expenditure Costs @ $25/day	Annual Expenditure Costs @ $48/day
Siletz littoral cell	2,115,737	$52,893,425	$101,555,376

The average daily expenditures are based on a series of studies from Oregon and California (Table 4). These studies determined what consumers actually spent to recreate at the beach and involve both direct and indirect costs. For example, direct costs would include such items as entrance/admission fees, parking fees, equipment rentals, and guides/lesson fees. Indirect costs would include fuel expenditure, food and drink purchases while traveling, and other transportation costs.

Table 4: Beach recreation expenditure studies (Rettig, 1999) (California, 2001)

Beach Recreation Expenditure Studies	
Survey/Year	in 2004 dollars
Oregon/1989	$41.00-$48.00
Southern California/2000	$25.00
Southern California/2000	$37.00
Range in values	**$25.00- $48.00**

The primary study was conducted in 1988-1989 by the Department of Agricultural and Resource Economics Department at Oregon State University. It attempted to assess the value of recreation on Oregon beaches as it surveyed a sample population of 870 Oregon residents via a telephone questionnaire. The data collected from the survey focused on recreation activities, socioeconomic characteristics, expenditures, and valuation. It is from this study that we hope to obtain a range of costs that helps identify what consumers are willing to spend to recreate at the beach.

To support the Oregon numbers, two expenditure studies from southern California for the summer of 2000 are utilized. These studies also involved questionnaires and surveys about expenditure related costs towards beach recreation.

From the expenditure cost studies, the values ranged from $25.00 to $48.00. These numbers will represent the low end and high end of our range. Taking the assumed annual decline in visits of 0.5% for each time period gives you the cumulative lost expenditure costs over time as seen in Table 5. For example, for every 5 year period the visitation rate will drop by 2.5% (0.5% X 5 years). At year 5, the expenditure costs lost will be 2.5% times $52,893,425, or $1,322,336.

It should be noted that these expenditure studies represent only the costs expended to travel to the site, recreate at the beach, and travel back home. These costs do not include the value of the consumer's time, that is, their opportunity cost that could have been spent doing some other activity.

Aggregate Economic Costs of Protect Only Option

The complete economic costs associated with this option is the summation of the new SPS construction, the maintenance costs of the existing SPS, and the lost recreation expenditures as a result of narrowing beaches. See Table 5 for detailed breakdowns of the costs.

The formula for calculating the present value of the costs is:

$$\textbf{PV(costs)= [(E)n + (C)n + (M)n]/(1+r)n}$$

where n is for the time periods 5 through 50 (every 5-year period); E equals the lost expenditure costs; C equals the amount of new SPS construction; and M equals the amount of maintenance required on the existing SPS system.

Applying the above formula to Table 5 shows the present value range of total economic costs associated with the 20-year scenario ranged from \$14.2M to \$22.1M for a 3% discount rate and \$8.5M to \$13.2M for a 7% discount rate. The present value range of total economic costs associated with the 50-year scenario ranged from \$37.9M to \$54.8M for a 3% discount rate and \$14.6M to \$23.7M for a 7% discount rate.

Protect Option Costs						
Type	SPS- New Construction[a,d]	SPS Maintenance[b,d]	Lost Expenditure Costs ($25/day)[c]	Lost Expenditure Costs ($48/day)[c]	Total Protection Costs @ $25/day	Total Protection Costs @ $48/day
Expenditures	N/A	N/A	(52,893,425)	(101,555,376)	N/A	N/A
Cost/ft	$200	$100	N/A	N/A	N/A	N/A
Year 5	(800,000)	0	(1,322,336)	(2,538,884)	(2,122,336)	(3,338,884)
Year 10	(800,000)	(2,415,200)	(2,644,671)	(5,077,769)	(5,859,871)	(8,292,969)
Year 15	(800,000)	0	(3,967,007)	(7,616,653)	(4,767,007)	(8,416,653)
Year 20	(800,000)	(2,815,200)	(5,289,343)	(10,155,538)	(8,904,543)	(13,770,738)
Year 25	(800,000)	0	(6,611,678)	(12,694,422)	(7,411,678)	(13,494,422)
Year 30	(800,000)	(3,215,200)	(7,934,014)	(15,233,306)	(11,949,214)	(19,248,506)
Year 35	(800,000)	0	(9,256,349)	(17,772,191)	(10,056,349)	(18,572,191)
Year 40	(800,000)	(3,615,200)	(10,578,685)	(20,311,075)	(14,993,885)	(24,726,275)
Year 45	(333,800)	0	(11,901,021)	(22,849,960)	(12,234,821)	(23,183,760)
Year 50	0	(3,698,650)	(13,223,356)	(25,388,844)	(16,922,006)	(29,087,494)
Totals	**(6,733,800)**	**(15,759,450)**	**(72,728,459)**	**(139,638,642)**	**($95,221,709)**	**($162,131,892)**

[a] SPS construction rate of 800 feet/year

[b] 50% of existing SPSs need maintenance/10-year period

[c] Tourism Revenue lost at 0.5% per year

[d] SPS Contractor estimates/OPRD

Discount Rate	20-Year NPV @ $25/day	20-Year NPV @ $48/day	50-Year NPV @ $25/day	50-Year NPV @ $48/day
3%	($14,181,030)	($22,077,751)	($37,909,533)	($54,816,890)
7%	($8,520,943)	($13,205,506)	($14,556,484)	($23,702,534)

Table 5: Protect option cost streams and PV scenarios

Option #2: Protect-Beach Nourishment

General Discussion

Soft stabilization measures involve beach nourishment in which sand is brought in from either offshore or other locations and used to replace the eroded and displaced sand. Soft measures can also involve the rebuilding and revegetation of previously eroded sand dunes. Beach nourishment projects are partially funded by the Federal government. For the initial nourishment costs, the Federal share is 65% and the State share is 35%. After that, the maintenance costs of nourishment are split 50/50 between the State and Federal governments (USACOE, 1995). The major issue will be in determining what quantity of sand will be necessary for nourishment purposes. It is assumed that there will be no change in beach width.

Under this option, it is assumed that the SPS construction rate will be the same as in Option 1, and that the maintenance costs for SPSs will involve 25% of existing structures every 10 year period. This is less then in Option 1, because it is assumed that the nourishment added to the beach will improve the buffering capacity of the shoreline, thereby inflicting less damage to the hardened shoreline. Therefore, the costs associated with this option include new SPS construction, SPS maintenance, and nourishment costs.

Costs of Beach Nourishment

Assessment of the economic feasibility of this option involves every step from Option #1, and also includes the costs associated with beach nourishment. These involve the initial beach nourishment effort, as well as a maintenance program to be utilized on an as-needed basis. Data from historical beach nourishment projects were collected from all over the country, including numerous beaches along the East and Gulf coasts, and several beaches in California. See Appendix D for the collection of 40 different beach nourishment projects selected for use in this study. These projects occurred between 1985 and 2003 and all dollar amounts were converted to 2004 dollars. Nourishment projects were not selected if they were classified as for emergency situations, as these are typically more expensive.

A review was also conducted on the Army Corps of Engineer (Corps) data related to beach nourishment projects. The Corps is the primary Federal agency responsible in dealing with coastal erosion and flooding. The Corps have been performing beach nourishment projects since the 1950's and a summary of these data are included at the bottom of Appendix D. The historical average for the Corps projects is just slightly higher then the 40 projects selected for this study, which provides support to the high end range used here. The information collected for each project includes the name of the beach and its location, total project cost, the length of beach nourished, and the volume of sand used in the nourishment process. The average cost of nourishment is $592/ft of linear beach utilizing 104 cubic yards/ft of beach.

In addition to these studies, several contractors were contacted to determine costs to nourish the amounts of sand calculated in Tables 6 and 7. The cost for each 10-ton truckload of sand would be $22.50 so to nourish the beach at 100 cubic yards/ft would cost $225 (Morris, 2004). Installation costs (50% extra) added on to the cost of beach sand brings the total cost to approximately $350 per linear foot. It is unknown if there is sufficient sand from these contractors to meet the requirements for nourishment, but it helped establish the low end range. Therefore, it was decided that the $/ft cost to nourish the beaches would be between $350/ft and $600/ft.

The next step is to determine how much sand to use for the nourishment process and when to do it. The procedure behind this process involved calculating the historic sand supply that has been blocked by SPSs since 1967. By using the average rate of erosion, the average bluff or dune height, and the average length of SPSs in place for a certain time period (Figure 11), it is possible to calculate the volume of sand that has been blocked since 1967. The time periods were segmented to obtain better accuracy. See Table 6 for details. The total sand blocked since 1967 was 977,387 cubic yards, and this will be the total initial nourishment.

As for the maintenance nourishment volumes, these were calculated in a similar manner. Table 7 shows the initial nourishment volume and costs at year 0, as well as for every 5-year period. The nourishment costs ranged from $350/ft to $600/ft. With the average nourishment project using 100 cubic yards/linear foot, if the amount of nourishment used in a certain time period is divided by 100 cubic yards, the length of beach nourished can be calculated. For example, in year 10, 218, 658 cubic yards of sand are needed for nourishment purposes. Dividing 218,658 by 100 cubic yards, determines that 2,187 linear feet of shoreline can be nourished at a cost ranging from $765,000 to $1.3M.

Table 6: Calculations of loss of historic sand supply due to SPS installation.

Historic Sand Supply Blocked by SPSs						
Years	# of Years	Average Rate of Erosion Per Year (ft)[1]	Average Height (Bluff, Dune) (ft)[2]	Average Length of SPSs (ft)[2]	Amount of Sand Blocked by SPSs (ft^3)	Amount of Sand Blocked by SPSs (yd^3)
1967-1971	4	0.5	51	11,880	1,211,760	44,880
1971-1973	2	0.5	51	15,840	807,840	29,920
1973-1976	3	0.5	51	21,120	1,615,680	59,840
1976-1978	2	0.5	51	22,440	1,144,440	42,387
1978-1982	4	0.5	51	23,760	2,423,520	89,760
1982-1988	6	0.5	51	31,680	4,847,040	179,520
1988-1991	3	0.5	51	34,320	2,625,480	97,240
1991-2003	12	0.5	51	38,280	11,713,680	433,840
Totals	**36**	**N/A**	**N/A**	**N/A**	**26,389,440**	**977,387**

[1] DOGAMI Open-File Report O-97-11

[2] Good, 1992.

Table 7: Future sand supply blocked by SPSs and maintenance nourishment costs

Future Sand Supply Blocked by SPSs									
Future	# of Years	Average Rate of Erosion Per Year (ft)[1]	Average Height (Bluff, Dune) (ft)[2]	Avg. Length of SPSs (ft)[2]	Amount of Sand Blocked by SPSs (ft^3)	Amount of Sand Blocked by SPSs (yd^3)	Length of Beach Nourished	Maintenance Nourishment @$350	Maintenance Nourishment @$600
Year 0	N/A	0.5	51	N/A	26,389,440	977,387	9,774	3,420,853	5,864,320
Year 5	5	0.5	51	42,304	5,393,760	199,769	1,998	699,191	1,198,613
Year 10	5	0.5	51	46,304	5,903,760	218,658	2,187	765,302	1,311,947
Year 15	5	0.5	51	50,304	6,413,760	237,547	2,375	831,413	1,425,280
Year 20	5	0.5	51	54,304	6,923,760	256,436	2,564	897,524	1,538,613
Year 25	5	0.5	51	58,304	7,433,760	275,324	2,753	963,636	1,651,947
Year 30	5	0.5	51	62,304	7,943,760	294,213	2,942	1,029,747	1,765,280
Year 35	5	0.5	51	66,304	8,453,760	313,102	3,131	1,095,858	1,878,613
Year 40	5	0.5	51	70,304	8,963,760	331,991	3,320	1,161,969	1,991,947
Year 45	5	0.5	51	73,452	9,365,130	346,857	3,469	1,213,998	2,081,140
Year 50	5	0.5	51	73,973	9,431,558	349,317	3,493	1,222,609	2,095,902

[1] DOGAMI Open-File Report O-97-11

[2] Good, 1992.

Aggregate Economic Costs of Protect-Beach Nourishment Option

Appendix C lists the complete economic costs associated with this option. The formula for calculating the present value of these costs is:

$$PV(costs) = [(BN)n + (C)n + (M)n]/(1+r)n$$

where n is for the time periods 5 through 50 (every 5-year period); BN equals the sand nourishment costs; C equals the amount of new SPS construction; and M equals the amount of maintenance required on the existing SPS system.

The present value range of total economic costs associated with the 20-year scenario ranged from \$9.5M to \$13.6M for a 3% discount rate and \$7.3M to \$10.8M for a 7% discount rate. The present value range of total economic costs associated with the 50-year scenario ranged from \$14.7M to \$20.4M for a 3% discount rate and \$8.7M to \$12.6M for a 7% discount rate.

Option #3: Gradual Retreat

General Discussion

The third option involves the decision to retreat. Retreat for this project will be a gradual process that will occur on an "as needed" basis. This means that when a coastal property is threatened by erosion, the structure will either be relocated towards the back area of its lot or it will be demolished to allow for the natural landward migration of the shoreline. If a property has a SPS in place, then maintenance will no longer be allowed and the SPS will be removed once it is deemed a safety hazard. When the SPS is removed, the previous decision tree will be adhered to the next time the property is threatened by erosion. The "as-needed" basis of retreat is assumed to equal the range of SPS construction, since it figures that these are the properties threatened annually by erosion events. From the previous section, it was determined that the SPS construction rates have ranged from 400 to 1000 linear feet per year. Thus, the assumption is that 400 to 1000 linear feet per year of shoreline will be required to retreat.

The case study methodology previously discussed, is now utilized to determine the economic impact of this option. Costs will need to be determined for the following items: SPS removal, structure demolition, structure relocation, average property value, average tax revenue. To determine these, the 1-mile sample population previously mentioned is utilized. It is assumed that all inland properties are residential structures.

Asset Inventory-Property Value Information

A common misconception is that the value being lost under this option is the expensive oceanfront properties. In reality, the land being lost is the inland properties because there will always be properties adjacent to the oceanfront. Essentially, these oceanfront values are being transferred to the adjacent inland properties. What will be lost is the tax revenues collected from these oceanfront properties, but only for the short-term. Eventually, once the property values have been mostly transferred, the tax revenues will adjust accordingly.

The first information need is the average property value of the inland properties. Appendix A lists both the oceanfront and inland properties for the 1 mile sample population that was selected. It is located in the Lincoln City area of the Siletz littoral cell. This table also lists the average property values, square footage, and annual tax revenues for each type of property (Lincoln County, 2004). For example, the average inland property value is approximately $120,000 and the tax revenue is about $1,400 per year. Figure 17 shows an example of some of the interior properties in the case study.

Figure 17: Examples of interior lots in the case study (~33rd Street).

In this same stretch of shoreline, the oceanfront properties had an average property value of $357,000 for residential properties and $1.4M for commercial properties. As mentioned earlier, 75% of the oceanfront properties are residential, with the other 25% being commercial properties. The average annual tax revenue for oceanfront property came out to $6,028 per property.

SPS Status and Retreat Costs

As mentioned in the general discussion, it is assumed that the range of retreat would be the same as the range of SPS construction. To determine the costs associated with this option, several calculations must be made. Earlier, it was shown that 54.5% of the cell already has SPSs, so it is assumed that 54.5% of 400 and 1000 feet, respectively, will incur costs to remove existing SPSs. Therefore, 218 and 545 feet, respectively, multiplied by the cost of $75/ft to remove the SPSs, yields $16,350 and $40,875 in annual costs for SPS removal.

The next decision pertains to the properties requiring retreat and whether a property has to be demolished or relocated. It was determined that approximately 58% of the existing buildup can be relocated further back at their current location (Good, 1992). Therefore, with a retreat of 400 feet, 232 feet (58%) can be relocated. Dividing this number by the average frontage (50 feet) for oceanfront property, provides the quantity of properties that need to be relocated. These 4.64 properties multiplied by the average cost to relocate a property ($18,750) determine that the annual cost to relocate properties will be $87,000. The remaining 168 feet is the length of shoreline requiring demolition. Dividing 168 feet by 50 feet yields the number of properties that will have to be abandoned annually. Taking these 3.36 properties and multiplying it by the average cost to demolish a property, provides an annual cost of $52,500. For both the relocation and demolition costs, the calculation was an average cost prorated at the percentage of residential versus commercial property. See Table 8 for these calculations and for the complete cost figures.

Aggregate Economic Costs of Gradual Retreat Option

The formula for calculating the present value of these costs is:

PV(costs)= (TARC)n/(1+r)n

where n is for the time periods 1 through 50; TARC equals the total annual retreat costs which includes the SPS removal, relocation of structures, demolish of structures, lost inland property values, and lost tax revenues.

The present value range of total economic costs with the 50-year scenario is $30.1M to $75.3M for a 3% discount rate and $16.1M to $40.4M for a 7% discount rate. The present value range of total economic costs with the 20-year scenario is $17.4M to $43.5M for a 3% discount rate and $12.4M to $31.0M for a 7% discount rate.

Table 8: Retreat costs for Siletz littoral cell

Rate of Retreat @400 ft/year				
Type	Length(ft)	Lot Width[6]	Cost/ft	Annual Cost
SPS Removal (54.5% of cell is hardened)[2,3]	218	50	$75	(16,350)
Demolition Cost-Residential/Commercial[1,7] (42% of lots)	168	50	$15,625	(52,500)
Cost to Relocate-Residential/Commercial[4,8] (58% of lots)	232	50	$18,750	(87,000)
Average cost of Inland Property[5]	400	50	$120,767	(966,136)
Tax Revenues Lost from Oceanfront Properties[5]	8	N/A	$6,028	(48,224)
			Total	**($1,170,210)**
			Total: Years 1-50	**($58,510,500)**

Rate of Retreat @1000 ft/year				
Type	Length(ft)	Lot Width[6]	Cost/ft	Annual Cost
SPS Removal (54.5% of cell is hardened)[2,3]	545	50	$75	(40,875)
Demolition Cost-Residential/Commercial[1,7] (42% of lots)	420	50	$15,625	(131,250)
Cost to Relocate-Residential/Commercial[4,8] (58% of lots)	580	50	$18,750	(217,500)
Average cost of Inland Property[5]	1000	50	$120,767	(2,415,340)
Tax Revenues Lost from Oceanfront Properties[5]	20	N/A	$6,028	(120,560)
			Total	**($2,925,525)**
			Total: Years 1-50	**($146,276,250)**

[1] (DeSpain, 2004)
[2] (Morris, 2004)
[3] (Good, 1992)
[4] (Griggs, 1986)
[5] Lincoln County Assessor's Office (Property Information: Appendix A)
Tax Revenues: 75%-Residential @$4,232/property+ 25%-Commercial @$11,415/property
[6] Average oceanfront lot has 50 feet of frontage
[7] 75%-Residential @$7,500/structure+25%-Commercial @$40,000/structure (Demolition)
[8] 75%-Residential @$10,000/structure+25%-Commercial @$45,000/structure (Relocation)

Discount Rate	20-Year Retreat PV @400 feet/year	20-Year Retreat PV @1000 feet/year	50-Year Retreat PV @400 feet/year	50-Year Retreat PV @1000 feet/year
3%	($17,409,770)	($43,524,425)	($30,109,227)	($75,273,068)
7%	($12,397,221)	($30,993,054)	($16,149,771)	($40,374,428)

Conclusions and Recommendations

Tables 9 and 10 summarize the present value findings for both the 20-year and 50-year cost scenarios for all three options. The tables compare the costs of each option at a 3% and 7% discount rate. They are displayed from the least costly option to the most costly option. The question then becomes: what do these tables tell us? What it shows is that in the 20-year scenario, the 'protect' option is clearly the least costly option due to the existing high levels of development. In the short term (20-years), it makes economic sense to protect the existing infrastructure. However, it also shows that protecting the shoreline with nourishment will be the least costly option. By using beach nourishment as a management tool, the beach can be preserved and recreation quality maintained, thereby minimizing the decline in beach visitation rates.

What happens when we look further out into the future? The 50-year scenarios still show that the 'protect' and 'protect with beach nourishment' are still the two lowest cost options due to the continued preservation of the beach and visitation rates to the beach. However, an interesting cost shift occurs between two of the options. The low range of the 'retreat' option is now more favorable economically then the low end of the 'protect' only option. Over a longer time frame, it simply becomes costlier in losing more beach visitors than it is to continue protecting the existing infrastructure.

The assumptions used in this analysis were meant to cover most scenarios given a range of historical and current conditions. Many events could change that would shift the preference of options. For example, increased storm and wave activity could dramatically alter the rates of erosion. Difficulties in the nourishment process and in locating adequate amounts of the right kind of sand could add to its cost structure. If either or both of these events happen, than the preference might shift toward a gradual retreat.

Another possible scenario is that the management of the beach could involve a hybrid of the three policy options discussed. The rolling easement scenario is a good example. A rolling easement policy allows construction near the shore, but requires the property owner to recognize nature's "right of way" to advance inland as sea level rises (Titus, 1998). SPSs would not be allowed in this option, but it is assumed that in the interim, soft shore protection measures such as nourishment, sand berms, and vegetation might be allowed and utilized until it becomes economically unfeasible to do so. This would combine the gradual retreat option with beach nourishment to delay the rate at which retreat would take place. Once a property becomes threatened, then if relocation is not an option, abandonment would occur and it would allow for the natural progression of the shoreline.

Whatever policy option is selected, it should be noted that this paper only assessed the cost side of this problem. There are many types of values that will need to eventually be accounted for to determine the total economic impact of sea level rise. These values are known as non-use values and share three important features- *irreversibility*, *uncertainty*, and *uniqueness*. One example is bequest value which captures the desire to endow a resource to future generations (Pearce and Turner, 1990). Further research is needed to determine these types of values for Oregon's beaches to give a more complete accounting.

The coast is a popular area to recreate for millions of people. However, in the face of climate change and rising sea levels, many unforeseen consequences are on the horizon. Hopefully, this paper will alert and inform local communities and government agencies who manage the beach and oceanfront development, and provide additional rationale to take a precautionary approach in the face of chronic coastal hazards. To efficiently and successfully deal with sea level rise and chronic coastal hazards, it is going to take the unified effort of local, state, and federal officials, and a well-informed public to preserve the priceless amenity of Oregon beach recreation.

Table 9: Comparison of present values: 20-year scenario

Comparison of Present Value 20-Year Scenarios						
Discount Rate	Protect: Nourishment @$350/ft	Protect: Nourishment @$600/ft	Protect @ $25/day	Retreat @400 feet/year	Protect @ $48/day	Retreat @1000 feet/year
3%	($9,543,743)	($13,560,906)	($14,181,030)	($17,409,770)	($22,077,751)	($43,524,425)
7%	($7,293,082)	($10,751,430)	($8,520,943)	($12,397,221)	($13,205,506)	($30,993,054)

Table 10: Comparison of present values: 50-year scenario

Comparison of Present Value 50-Year Scenarios						
Discount Rate	Protect: Nourishment @$350/ft	Protect: Nourishment @$600/ft	Retreat @400 feet/year	Protect @ $25/day	Protect @ $48/day	Retreat @1000 feet/year
3%	($14,741,578)	($20,351,636)	($30,109,227)	($37,909,533)	($54,816,890)	($75,273,068)
7%	($8,676,870)	($12,558,340)	($16,149,771)	($14,556,484)	($23,702,534)	($40,374,428)

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Appendix A: Lincoln County Assessors' Office Property Information

Property Information					
Total Value-Commercial Oceanfront	**Taxes**	**Total Value-Residential Oceanfront**	**Taxes**	**Total Value for Inland Property**	**Taxes**
$2,195,160	$28,738	$347,350	$3,600	$243,480	$3,634
$782,460	$10,115	$311,870	$3,392	$56,740	$792
$725,940	$8,347	$360,280	$4,085	$176,220	$2,446
$2,082,460	$26,056	$551,590	$6,707	$94,930	$1,342
$588,290	$8,156	$422,350	$4,902	$88,630	$1,181
$1,335,290	$16,359	$499,430	$6,122	$106,410	$1,235
$1,367,110	$16,644	$360,130	$4,107	$156,570	$2,058
$1,286,120	$15,190	$398,820	$4,591	$122,120	$1,612
$1,429,220	$16,241	$391,500	$5,079	$137,220	$1,885
$3,077,050	$36,801	$309,290	$3,441	$129,340	$1,743
$1,198,500	$14,145	$319,510	$3,258	$136,570	$1,842
$1,028,200	$15,903	$495,860	$5,449	$106,560	$1,440
$1,463,690	$21,961	$295,180	$3,015	$76,380	$973
$1,960,000	$25,360	$319,220	$3,801	$75,240	$943
$1,176,540	$15,036	$401,880	$4,390	$87,350	$1,040
$1,189,330	$16,189	$319,470	$3,338	$165,340	$1,998
$22,885,360	**$182,647**	$325,850	$3,328	$117,890	$1,709
$1,430,335	**$11,415**	$328,670	$3,437	$110,570	$1,471
		$301,310	$3,184	$85,910	$1,233
		$339,960	$3,924	$117,690	$1,738
		$365,200	$4,215	$94,860	$1,360
		$328,150	$3,871	$120,950	$1,661
		$583,700	$7,669	$84,620	$1,205
		$292,350	$3,401	$257,440	$3,949
		$279,300	$3,485	$135,930	$2,001
		$350,100	$4,612	$96,590	$1,407
		$392,410	$5,348	$124,150	$1,860
		$308,130	$3,726	$113,540	$1,693
		$282,640	$3,564	$95,080	$1,282
		$370,150	$4,842	$98,210	$1,343
		$259,790	$4,018	$79,700	$1,051
		$468,030	$5,235	$98,260	$1,335
		$327,170	$4,430	$171,020	$2,437
		$458,250	$5,806	$76,740	$1,029
		$307,700	$3,784	$127,280	$1,836
		$289,040	$3,486	$169,910	$1,894
		$261,310	$3,043	$158,120	$2,199
		$376,160	$4,691	$95,570	$1,317
		$315,380	$3,646	**$4,589,130**	**$63,174**
		$260,770	$3,052	**$120,767**	**$1,404**
		$383,650	$4,437		
		$14,658,900	**$173,511**		
		$357,534	**$4,232**		

Appendix B: Beach Inundation Scenarios for Siletz littoral cell

Beach Inundation Scenarios															
Siletz littoral cell	*Sea Level Change Scenarios[1]*			*Vertical Land Movement[2]*		*Relative Sea Level Change*						Beach Slope[3]	*Shoreline Change[4]*		
	@ 2.0 mm/yr	@ 5.0 mm/yr	@ 8.6 mm/yr			Scenario I		Scenario II		Scenario III			Scenario I	Scenario II	Scenario III
Locations	cm/c	cm/c	cm/c	mm/yr	cm/c	mm/yr	cm/c	mm/yr	cm/c	mm/yr	cm/c	m	cm/yr	cm/yr	cm/yr
Siletz Spit	20.0	50.0	86.0	0.2	2.0	1.0	18.0	4.8	48.0	8.4	84.0	1:14	2.5	6.7	11.8
Roads End	20.0	50.0	86.0	0.2	2.0	1.0	18.0	4.8	48.0	8.4	84.0	1:28	5.0	13.4	23.5
Lincoln City	20.0	50.0	86.0	0.2	2.0	1.0	18.0	4.8	48.0	8.4	84.0	1:25	4.5	12.0	21.0

cm/c= centimeters per century; mm/yr= millimeters per year

1 (IPCC, 2001)

2 (Komar, 1997)

3 (Shih, 1992)

4 (Bruun, 1962)

Appendix C: Beach Nourishment Costs for $350/ft and $600/ft Scenarios

Siletz littoral cell Beach Nourishment Costs @ $350/ft

Type	Cost/ft	Year 0*	Year 5	Year 10	Year 15	Year 20	Year 25
Initial Nourishment (35%) State	$350	(1,197,299)	0	0	0	0	0
Initial Nourishment (65%) Federal	$350	(2,223,555)	0	0	0	0	0
Maintenance Nourishment (50%) State	$350	0	(349,596)	(382,651)	(415,707)	(448,762)	(481,818)
Maintenance Nourishment (50%) Federal	$350	0	(349,596)	(382,651)	(415,707)	(448,762)	(481,818)
New SPS Construction[1]	$200	0	(800,000)	(800,000)	(800,000)	(800,000)	(800,000)
SPS Maintenance[2]	$100	0	0	(1,207,600)	0	(1,407,600)	0
	5-Year Totals	($3,426,853)	($1,499,192)	($2,772,902)	($1,631,414)	($3,105,124)	($1,763,636)

Year 30	Year 35	Year 40	Year 45	Year 50
0	0	0	0	0
0	0	0	0	0
(514,873)	(547,929)	(580,984)	(606,999)	(611,305)
(514,873)	(547,929)	(580,984)	(606,999)	(611,305)
(800,000)	(800,000)	(800,000)	(333,800)	0
(1,607,600)	0	(1,807,600)	0	(1,849,325)
($3,437,346)	($1,895,858)	($3,769,568)	($1,547,798)	($3,071,935)
			Total	($27,915,626)

*Used 977,387 yd^3 for initial nourishment

[1] Built at the rate of 800 linear feet/year

[2] 25% of existing SPS every 10 years

Discount Rate	20-Year PV @ $300	50-Year PV @ $300
3%	($9,543,743)	($14,741,578)
7%	($7,293,082)	($8,676,870)

Siletz littoral cell Beach Nourishment Costs @ $600/ft

Type	Cost/ft	Year 0*	Year 5	Year 10	Year 15	Year 20	Year 25
Initial Nourishment (35%) State	$600	(2,052,512)	0	0	0	0	0
Initial Nourishment (65%) Federal	$600	(3,811,808)	0	0	0	0	0
Maintenance Nourishment (50%) State	$600	0	(599,307)	(655,973)	(712,640)	(769,307)	(825,973)
Maintenance Nourishment (50%) Federal	$600	0	(599,307)	(655,973)	(712,640)	(769,307)	(825,973)
New SPS Construction[1]	$200	0	(800,000)	(800,000)	(800,000)	(800,000)	(800,000)
SPS Maintenance[2]	$100	0	0	(1,207,600)	0	(1,407,600)	0
	5-Year Totals	**($5,864,320)**	**($1,998,614)**	**($3,319,546)**	**($2,225,280)**	**($3,746,214)**	**($2,451,946)**

Year 30	Year 35	Year 40	Year 45	Year 50
0	0	0	0	0
0	0	0	0	0
(882,640)	(939,307)	(995,973)	(1,040,570)	(1,047,951)
(882,640)	(939,307)	(995,973)	(1,040,570)	(1,047,951)
(800,000)	(800,000)	(800,000)	(333,800)	0
(1,607,600)	0	(1,807,600)	0	(1,849,325)
($4,172,880)	**($2,678,614)**	**($4,599,546)**	**($2,414,940)**	**($3,945,227)**
			Total	**($37,417,127)**

*Used 977,387 yd^3 for initial nourishment

[1]Built at the rate of 800 linear feet/year

[2]25% of existing SPS every 10 years

Discount Rate	20-Year PV @ $600	50-Year PV @ $600
3%	($13,560,906)	($20,351,636)
7%	($10,751,430)	($12,558,340)

Beach Nourishment Project Costs

Name of Beach	State	Year	Cost	Volume $(yd)^3$	Length (ft)	Volume/ft	$/ft	Sand Source
Virginia Beach	Virginia	1996	$1,100,000	300,000	18,480	16	$60	Not Available
Pawleys Island	South Carolina	1999	$1,300,000	250,000	13,200	19	$98	Intertidal sand deposit
Ocean City	New Jersey	1995	$1,269,546	360,000	10,560	34	$120	Not Available
Edisto Beach	South Carolina	1995	$1,500,000	150,000	10,560	14	$142	Offshore
South Brevard County	Florida	2002	$2,960,000	1,100,000	15,840	69	$187	Not Available
Debidue Beach	South Carolina	1998	$1,500,000	250,000	7,920	32	$189	Inland Sand Pit
Hilton Head Island	South Carolina	1997	$9,000,000	2,500,000	42,240	59	$213	Offshore
Sandy Point	Rhode Island	1996	$444,444	60,000	2,000	30	$222	Not Available
Ocean City	New Jersey	1995	$5,922,269	1,411,000	24,816	57	$239	Not Available
Tybee Island	Georgia	1987	$3,700,000	1,360,000	14,500	94	$255	Offshore
Carolina Beach	North Carolina	1995	$3,185,642	1,157,742	11,600	100	$275	Not Available
Grand Isle	Louisiana	1985	$10,500,000	2,970,000	36,400	82	$288	Not Available
St. Augustine Beach	Florida	2002	$4,100,000	Not Available	13,200	Not Available	$311	Not Available
Dewey Beach	Delaware	1998	$1,948,000	453,500	6,095	74	$320	Not Available
Daufuskie Island	South Carolina	1998	$6,000,000	1,400,000	18,480	76	$325	Offshore
Panama City Beach	Florida	1999	$30,000,000	7,500,000	89,760	84	$334	Not Available
Redington Beach	Florida	1988	$2,900,000	700,000	8,184	86	$354	Tidal inlet
Ocean Ridge	Florida	1998	$3,169,000	939,886	8,448	111	$375	Not Available
Dewey Beach	Delaware	1994	$2,342,230	578,874	6,000	96	$390	Not Available
Rehoboth Beach	Delaware	1998	$1,087,750	274,300	2,750	100	**$396**	Not Available
Jupiter/Carlin Beach	Florida	1995	$2,274,400	603,000	5,702	106	$399	Not Available
Ocean City	Maryland	1991	$15,003,269	3,800,000	36,960	103	$406	Not Available
Dam Neck Naval Base	Virginia	1996	$3,800,000	808,000	9,200	88	$413	Not Available
Fire Island Pines	New York	N/A	$3,000,000	500,000	7,000	71	$429	Not Available
Martin County	Florida	1996	$8,625,000	1,269,000	19,800	64	$436	Not Available
South Amelia Island	Florida	2002	$8,000,000	177,000	17,424	10	$459	Not Available
Assateague Island	Maryland	2003	$12,200,000	1,800,000	22,966	78	$531	Sand Bypass System
San Diego Beaches	California	2001	$17,500,000	2,000,000	31,680	63	$552	Offshore
Cape May	New Jersey	1995	$2,683,150	330,000	4,800	69	$559	Not Available
Rockaway Beach	New York	1996	$2,400,000	340,000	4,000	85	$600	Navigation Disposal

Beach Nourishment Project Costs (Continued)

Name of Beach	State	Year	Cost	Volume $(yd)^3$	Length (ft)	Volume/ft	$/ft	Sand Source
Indian Shores Beach	Florida	1992	$10,000,000	900,000	16,368	55	$611	Ebb delta
Greater Myrtle Beach	South Carolina	1997	$22,360,000	1,965,000	32,736	60	$683	Offshore
Shinnecock Inlet	New York	N/A	$2,950,000	405,000	3,500	116	$843	Not Available
Ft. Pierce Beach	Florida	1999	$6,200,000	908,000	6,864	132	$903	Not Available
Indian Rocks Beach	Florida	1990	$14,500,000	Not Available	14,731	Not Available	$984	Ebb tidal delta
Hempstead Beach	New York	1995	$3,060,750	459,000	3,000	153	$1,020	Navigation Disposal
Sandy Hook	New Jersey	1995	$19,673,000	4,400,000	16,368	269	$1,202	Not Available
Sandy Hook	New Jersey	1996	$16,300,000	4,100,000	12,672	324	$1,286	Not Available
West Hampton Beach	New York	1996	$30,700,000	4,000,000	12,000	333	$2,558	Not Available
Surfside-Sunset Beaches	California	1997	$13,000,000	1,600,000	3,500	457	$3,714	Offshore
		Total	$308,158,450		**Average**	**102**	**$592**	
ACOE (1950-1993)			$670,200,000	N/A	1,108,800	N/A	**$604**	

Sources: [3,4,5]