STATE OF OREGON
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OPEN FILE REPORT 0-94-2

CASCADIA BEACH-SHORELINE DATA BASE, PACIFIC NORTHWEST REGION, USA

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1994

Financial support for this work was provided by National Coastal Resources, Research and Development Institute, Portland, Oregon, under grants No. 2-5632-03 (1988-1989) and CZ17.90-5635-01 (1990-1991). This work was also partially supported by the Oregon Sea Grant College Program, grant number NA36RG0451 (Project number R/CP-28).

CONTENTS

Summary

The information contained in this report provides the first regional data base of physical shoreline resources of ocean beaches in Washington, Oregon and northernmost California. This report contains aerial photogrammetry data taken from about 2,000 reference points, spaced at one half kilometer intervals, along the 1,000 km long study area, and (2) profile data taken from 127 across-shore profile sites in 18 representative littoral cells of the Pacific Northwest (PNW) coastal zone. These selected littoral cells represent a total of 500 km in coastal distance or about 75% of the beach-fronted study area.

The data base has been loaded into three separate data files in Excel version 4.0 Spread-Sheet format for either the Apple or DOS operating systems. The data base files include (1) PNW Beach Physiography File (DOS; pnwphysi:xls), (2) PNW Beach Survey File (DOS; pnwsurve.xls) and (3) PNW Beach Deposit File (DOS; psnwdepos.xls). The data files can be used in compatible spread-sheet programs and/or graphing programs. Alternatively the data can be loaded into relational data base programs or geographic information systems (GIS). The aerial photogrammetry data contain cartametric variables documenting shoreline type, orientation, length, width, and adjacent geomorphic features. The beach survey and beach deposit data contain variables establishing beach sediment grain size, wave runup elevations, foredune heights, wave-cut platform elevations, across-shore profile gradients, and beach sand cross-sectional areas, among others.

The information presented in this report can be used to map and analyze the regional distributions of different types of shorelines including rocky headlands, sandy beaches, tidal inlets, dune fields and coastal terraces. Specific shoreline variables and beach parameters can be used to help predict regional shoreline susceptibility to (1) chronic and catastrophic hazards, (2) impacts from shoreline protection structures, (3) shoreline instability from sand mining or dredge spoil disposal, and (4) contamination from pollutants. Finally, this shoreline data base can be integrated with other spatially related data bases of wildlife habitats, recreational-economic interests, and jurisdictional boundaries for a wide variety of coastal inventory and planning uses.

Introduction

Several factors are now focusing the attention of scientists, planners, and the general public on shoreline dynamics and beach resource management in the Pacific Northwest Coastal Zone (PNWCZ) from Cape Flattery, Washington -to- Cape Mendocino, California (Figure 1). These include (1) increasing coastal development and associated shoreline impacts, (2) dramatic shoreline changes following the 1982-83 El Niño climatic event, and (3) predictions of coseismic coastal subsidence and associated shoreline erosion along the Cascadia margin (Peterson and Priest, 1991). The latter two factors represent infrequent, but regionally catastrophic hazards. By comparison, annual cycles of storm-wave erosion, sea cliff slumping or eolian dune migration represent chronic hazards along some PNWCZ shorelines (Komar, 1992). Finally, the regional impacts of increasing coastal development on natural shoreline resources, such as littoral sand supply, beach access, natural view shed and wildlife habitat have generally not been addressed by coastal planners and managers in the PNWCZ. This has been due, in part, to a lack of accessible information on the distributions of physical shoreline resources in the region.

A study of regional sediment dynamics and shoreline instability in littoral cells of the Pacific Northwest was initiated in 1989 with support from the Coastal Zone Management 309 Program, administered by the National Coastal Resources, Research and Development Institute (NCRI) Portland, Oregon. Some of the data collected in that study are presented in this report, including (1) aerial photogrammetry data taken from reference points, spaced at one half kilometer intervals, along the 1,000 km long study area, and (2) beach sediment and profile data taken from 127 across-shore profile sites in 18 representative littoral cells of the PNWCZ. The sources of the data are discussed below under the report headings Data Sources and Field Methods. The aerial photogrammetry data contain cartametric variables documenting shoreline type, orientation, length, width, and adjacent geomorphic features. The beach survey and beach deposit data contain variables establishing beach sediment grain size, wave runup elevations, foredune heights, wave-cut platform elevations, across-shore profile gradients, and beach sand cross-sectional areas, among others. These variables are discussed in detail below under the report heading Data Base Components.

Interested parties can use this data base to map and analyze the regional distributions of different types of shoreline including rocky headlands, sandy beaches, tidal inlets, dune fields and coastal terraces. More detailed information is also available on beach sediment sizes, across-shore profiles and beach sand abundance in defined littoral cells. The data can be plotted (graphed) on a personal computer-printer or used in sophisticated Geographic Information System (GIS) programs. Specific shoreline variables and beach parameters can be used to help predict regional shoreline susceptibility to (1) natural climatic or tectonic hazards, (2) impacts from shoreline protection structures, (3) shoreline instability from sand mining or dredge spoil disposal, and (4) contamination from oil spills or other pollutants. Finally, this shoreline data base can be integrated with other spatially related data bases of wildlife habitats, social-economic interests, and jurisdictional boundaries for a wide variety of coastal inventory and planning uses.

To maximize the accessibility of this regional shoreline data to users with very different interests the data base has been loaded into three separate data files in Excel Spread-Sheet format for Apple and DOS operating systems. The Pacific Northwest (PNW) data base files include (1) PNW Beach Physiography File (DOS; pnwphysi:xls), (2) PNW Beach Survey File (DOS; pnwsurve.xls) and (3) PNW Beach Deposit File (DOS; psnwdepos.xls) The data files can be printed-out directly in spread sheet format, or translated into data base or graphing programs that can read the Excel Spread-Sheet format, as discussed below under Data Base Access. Reference sites are listed from north to south (from file top to file bottom) in the data base files, and can be located from corresponding Universal Transverse Mecator (UTM) map coordinates. The UTM coordinates are taken from U.S. Geological Survey 7.5 minute topographic maps, and they represent northing (N/S) and easting (E/W) distances (in meters) relative to established grids. Shoreline and beach parameter variables can be plotted (graphed or mapped) against corresponding UTM N/S coordinates for analyses of spatial (longshore) variability. Alternatively, the variables can be plotted against one another for analyses of correlation between different beach conditions. Finally, the user can add new variables to the data base for comparisons of new variables to the corresponding physical shoreline data.

Data Sources

To establish a baseline survey of beaches, dune fields, sea cliffs and associated shoreline conditions in the study area we have analyzed stereo aerial photographs (1:12,000 or 1:24,000 scale) and corresponding topographic maps (U.S. Geological Survey 7.5 minute quads, 1: 24,000 scale). The baseline aerial photographs were taken between the years 1974 and 1981 (Peterson et al., 1991a), which predate the anomalous erosion period following the 1982-83 El Niño Southern Oscillation (ENSO) event. While continuous aerial photography of northernmost California was flown in May of 1978, no single year provides continuous shoreline coverage in either Oregon or Washington. However, about 70 percent of the total PNW study area coverage is accommodated in aerial photographs from two years 1977 and 1978 (Appendix). Many of the PNW beaches affected by 1982-83 ENSO eventually returned to pre-1983 conditions by the late 1980's (Peterson et al., 1990). This suggests that the 1974-1981 baseline period does represent modern 'equilibrium' conditions of beach sand distribution in the PNWCZ. Updated shoreline coverage by vertical photography and videography was flown for selected littoral cells in 1989 and 1991, as described see below.

The aerial photographs used in the baseline survey were selected on the bases of (1) season, i.e., either summer or fall with a few exceptions, and (2) complete or nearly complete sequence coverage of continuous beach segments i.e., littoral cells or subcells, between major headlands. Most of the flight sequences, representing some 88 percent of total coastline distance, fall into a tidal range of ± 1 m MTL (see Appendix). Tide level change is considered to be negligible during in-flight periods over individual beach segments, which are generally less than 100 km in length. Approximately 2,000 reference sites for the 1,000 km long study area were established at approximately 0.5 km intervals longshore directly on aerial photographs and and corresponding U.S.G.S. topographic maps. The reference sites are located by UTM coordinates, rounded off to the nearest 50 meters, for each of the 0.5 km longshore intervals (see Beach Physiography File). Each reference site was analyzed for a variety of cartametric variables including (1) longshore distance from north-bounding headland, (2) presence of sea cliff, terrace or dune field termination of the backshore, (3) shoreline orientation, (4) apparent beach width, and (5) dune field width, among others (see discussion of Beach Physiography File below).

One of the most important variables is the apparent width of the active beach deposit, taken from landward termination of the beach backshore to the swash zone. This variable discriminates between beach and rocky shorelines, and is used to define continuous beach deposits, e.g., proxies for littoral cells. While the landward termination of the backshore can be identified at the base of a sea cliff or the crest of a vegetated foredune, the position of the swash zone is more difficult to identify. For the analysis of beach width at each reference site the swash zone is identified in aerial photographs by the zone of dark wetted-sand that contrasts with lighter colored dry-sand landward of the swash zone, and with patchy light and dark colored water in the choppy foam-laden surf zone seaward of the swash zone. The relative and absolute accuracy of this approach is discussed under the section on Field Methods, below. Coastline types and width of dune fields were also identified and or measured directly off the scaled aerial photographs. Shoreline orientation and terrace height at each reference point were established from the base topographic maps and checked against corresponding aerial photographs. About one half of the study area was recently flown for high-resolution photography/videography. Across-shore beach profiles were surveyed at representative localities, in part, to ground-truth the photogrammetry data. The high-resolution videography served to calibrate the profile data between widely-spaced profile locations (Rosenfeld et al., 1991).

Field Methods

We have flown vertical aerial photography and high-resolution color video over 16 representative littoral cells during the summer seasons of 1989 and 1991

(Rosenfeld et al., 1991). Together with two additional pocket beaches in northern Washington these selected littoral cells represent a total of 500 km in coastal distance or about 75% of the beach fronted study area (see Beach Physiography File). The recent aerial photography and videography was performed during local mean tide-level (± 20 minutes) at each of the study clittoral ells. The high-resolution aerial videography was used to measure current beach widths at the established reference sites (0.5 km longshore spacing) under conditions of known tidal level relative to Mean Tidal Level (0 m MTL) and wave energy, i.e., mid-summer (fair-weather) conditions. Color infrared aerial photographs were taken to better discriminate between the episodically exposed swash zone and the shallow surf zone. However, the high-resolution color videography best documented the transitions between (1) the swash zone, (2) the dry sand of the upper-foreshore, and (3) the shallow surf zone of the lowermost foreshore, during the period of mean tidal level.

A total of 246 beach profiles were surveyed by Electronic Distance Measuring (EDM) instrumentation at 127 locations in the 18 selected littoral cells between Cape Flattery, Washington and Cape Mendocino, California. The across-shore traverses were surveyed by surface and subsurface profiling during the summers of 1989 and 1991. The locations of the across-shore profiles were selected on the basis of (1) representative spacing of longshore intervals, e.g., ranging between 1 and 10 km in length, depending on total cell lengths, which range from 5 to 165 km, and (2) on representative beach morphology, established from the aerial photogrammetry analysis (above).

On-site inspections were used to further constrain master profile positions that minimized anomalous effects from local ephemeral features. These features include foredune blowouts, backshore channels, beach cusps, beach toe runnels, and offshore bars, etc., that typically extend tens of meters to several hundred meters distance longshore. These various features represent irregularities in the surface, and therefore thickness, of the beach deposits. One or two companion profiles were surveyed at each of 50 representative master-profile locations to establish the small-scale variability of beach sand volume associate□d with these ephemeral features. The adjacent profiles were taken at longshore spacing of 100-300 m on either side of the 50 representative master profiles (about one third of the 127 master profile localities). The size and position of the ephemeral features were found to vary significantly between some adjacent profiles (Pettit, 1991) but, did not significantly influence gross measures of beach deposit sand volume. For example, estimated cross-sectional areas of beach sand deposit above MLLW, generally varied by less than 15 percent between the 50 paired (adjacent) profiles.

Due to the gross similarities of the representative paired profiles, only the master profile survey data is presented here (see Beach Survey File). By comparison, the larger-scale coastal irregularities that occur over multi-kilometer distances do produce substantial differences in beach width and in corresponding sand volume between the 127 profile locations. Such large-scale irregulaities are associated with headlands, embayments, tidal inlets, and river mouths among others. A means is neccessary to account for the significant variability in beach width between some master profile locations. To this end, profile cross-sectional areas are calibrated with beach width data from the 0.5 km longshore reference sites between profile localities. This semi-quantitative approach is used to address the larger-scale coastal irregularities in some littoral cell segments (see Beach Deposit File).

Beach profile surveying was completed with a Lietz Set 4 EDM total station and reflecting prism. The profile surveying was conducted during periods of low tide and calm ocean conditions. Beach profiles were measured from sea cliffs or foredune crests to at least the beach toe, i.e., approximately the mean lower low water (MLLW) position (Peterson et al., 1991b). All surveyed distances and elevations were measured to within centimeters. Profile elevations relative to mean sea level (MSL) are established from timed swash-zone measures of local tidal-level and predicted tidal-elevations (National Oceanic Atmospheric Administration, 1974-1991).

At least one profile per littoral cell was also surveyed into registered bench marks to verify profile elevations relative to established MSL datum, and to compare timed tidal level datums with established MSL datums. Estimates of local mean sea-level, based on the swash zone tidal-levels were found to be within ± 0.5 m of established MSL datums from the surveyed bench marks. The error associated with estimating the position of mean tidal level (± 0.5 m) could yield up to a 20 meter error of beach width relative to absolute MTL, assuming a typical mid-beach slope of 2.5 percent. Field surveying results demonstrated that a point located at about one third of the distance across the wetted swash zone, from the surf zone, most closely represented the predicted tide level relative to established bench marks on low sloping beaches, e.g., mid-beach slopes less than two percent grade. On more steeply sloping beaches the mid-swash zone position most closely represented the elevation of the predicted tide level. Repeated surveys of the swash zone at many of the profile sites showed less than ± 5 m variability of mid-swash zone position during the perios of tidal level surveys, generally lasting 3-5 minutes at each profile. Therefore tidal level was monitored for 5-15 minutes at each profile locality, depending on the number of profiles (1-3) surveyed at each locality.

Subsurface profiling by seismic refraction was performed at selected across-shore sites along the master profile traverse at appropriate survey locations. A seismic refraction system (12 channel-analog) was used to establish subsurface depth to the wave cut platform where field observations suggested sand thicknesses between 1.5 and 10 m depth subsurface (Peterson et al., 1991b). Minimum depth detection with the 12 geophone system (24 or 48 meter longshore array) is on the order of 1.5 meters, which is sufficient to estimate typical beach sand thicknesses of 1.5 to 10 m. Test pits dug to depths of about 1.5 m subsurface were used to confirm very shallow beach sand stratigraphy and to establish the lithology of high-velocity refraction horizons. In Washington and northern Oregon the wave cut platform is generally composed of either semi-consolidated Pleistocene deposits or older Tertiary mudstones or sandstones. In southern Oregon and northern California the wave cut platform is generally cut into either Pleistocene deposits or pre-Tertiary meta-sedimentary rocks.

Intermediate velocity horizons such as mixed sand and gravel or cobble layers (0.5-1.5 m thick) typically occur above the wave cut platform, as observed in some shallow test pits. These layers might have been picked as the platform surface, if their seismic velocities approached those of the underlying platform materials. The beach sand thickness could be underestimated in those traverses that contain substantial layers of gravel above the platform contact. For this reason, the beach deposit cross-sectional areas calculated from the surface and subsurface profiling are considered to represent conservative values (minimum) of total beach sediment. Furthermore, signal attenuation in loosely packed sands or gravels of several profiles limited refraction results to subsurface depths of less than 5 m. Finally, beach sand depths greater than 10 m below MSL, e.g., very-thick sand deposits under sand spits or locally prograded shorelines, are not included in this analysis of beach sand cross-sections. The subsurface cut-off depth of 10 m below mean sea-level is both the practical limit of our seismic refraction system, and it also represents the maximum erosional depth expected under interannual conditions of beach erosion. For example, maximum depths of six to eight meters, respectively, of beach sand erosion were observed locally between 1984 and 1986 in central Oregon (Peterson et al., 1990) and northernmost California (Tuttle, 1987; D.C., Tuttle, unpublished data, 1986). These extreem erosional effects resulted from anomalous wave-climate conditions and associated beach sand displacement that was associated with the 1982-83 El Niño-Southern Oscillation (ENSO) (Peterson et al., 1990).

Beach sands were collected from mid-beach faces at beach profile sites and other selected sites for grain size analysis during the summers of 1989 and 1991. Gravel beaches and backshore gravel berms in otherwise sandy beaches were not sampled for grain size analysis. Accessibility to wilderness beaches restricted sampling in some areas, but sample spacing generally averaged at least one sample site per 10 km distance longshore throughout the 1000 km long study area. At least one kilogram of sediment was scraped from a 10 cm depth interval at each mid-beach site to provide sediment samples representative of fair-weather (summer) beach deposits. Test pits dug to depths of 1.5 m in some beaches generally showed an increase in sediment grain size with depth in the foreshore and backshore deposits. Thus, conditions of offshore transport and beach face excavation are expected to yield sediment grain sizes that are somewhat coarser than summer samples at corresponding sites. Analyses of sample mean grain-size and standard deviation of sediment grain size were performed by standard sieving techniques (Folk, 1980).

Data Base Access

The shoreline data base is provided in three separate files in Excel version 4.0 Spread-Sheet format for either Apple or DOS operating systems. These files can also be read by various word processing or database programs. In the Apple compatible format the files are named: PNW Beach Physiography File, PNW Beach Survey File, and PNW Beach Deposit File. In the DOS compatible format the three file names are abreviated to PNWPHYSI.XLS, PNWSURVE.XLS, and PNWDEPOS.XLS.

All file column formats are ten characters in width. The number of variables, i.e., total number of columns in each of the files, are as follows: PNW Beach Physiography File, 17 columns, including the geographic feature name (1st column on left); PNW Beach Survey File, four columns for each profile, two side-by-side, to total eight columns for the file; PNW Beach Deposit File, 23 columns including one column for littoral cell name (1st column on left). The length of each file, i.e., total number of rows (records), is as follows: PNW Beach Physiography File, 2025 rows, including variable headers (top two rows of file); PNW Beach Survey File,1078 rows, including one variable header row each for the 18 littoral cells; PNW Beach Deposit File, 147 rows, including variable headers (two top rows of file) and 18 rows for littoral cell names.

The littoral cells selected for beach surveying have been named here on the basis of a corresponding population center, geographic feature, or beach name from USGS 7.5 minute Topographic Maps. These littoral cells from Washington (WA), Oregon (OR) and northernmost California (CA) include from north to south: Hobuck, WA; Shi-Shi, WA; La Push, WA; Kalaloch, WA; Columbia River, WA-OR; Cannon Beach, OR; Lincoln City, OR; Otter Rock, OR; Newport, OR; Waldport, OR; Winchester, OR; Bullard, OR; Bandon, OR; Garrison Lake, OR; Gold Beach, OR; Brookings, OR-CA; Crescent City, CA; and Eureka, CA.

The easiest way to access and plot the data is via spread sheet programs that can read the Excel format. Excel version 4.0 or compatible spread sheet programs such as Lotus 123 (DOS) can be used to read and print out the data base files. Alternatively, the files can be loaded into data base or geographical information system (GIS) programs to manipulate the relational data. The spreadsheet format allows the user to (1) quickly scroll through the data columns and rows, (2) perform simple mathematical computations, and (3) plot the data in various types of graphs. For convenience, the user might divide each of the data base files into smaller files that cover shoreline areas of particular interest. In any case, backup files should be made of the original data base on hard drives and/or diskettes prior to file manipulation.

Data Base Components

The variables listed in each of the three files are discussed below. The name of the variable in each data file is shown in parentheses, with the corresponding unit of measure, for purposes of identification in the data base. The different variables are discussed in their order of presentation in the data files, i.e., columns from left to right. Terminology of beach morphology generally follows that of Komar (1976). A standard cross-section of a hypothetical beach profile is shown in Figure 2. A quick reference guide to the data base variables (shoreline parameters) is provided in Table 1.

PNW Beach Physiography File

A total of 2,023 reference sites have been established at longshore intervals, i.e., approximately 0.5 km longshore, along the length of the 1000 km study area. The reference sites are located by geomorphic feature name (Feature Name), by county name (County Name), and by UTM Northing (UTM N/S, m) and Easting (UTM E/W, m) coordinates. Note that the 0.5 km spacing between the reference sites is based on longshore distance. The differences between adjacent reference site UTM N/S coordinates deviate from 0.5 km values when the coastal orientation deviates from a true north bearing.

Steep, rocky coastlines, steep boulder beaches and tidal inlets are identified here as shorelines with zero beach sand width. Shorelines with continuous beaches, i.e., at least 10 m in width and at least 2 km in length, are identified as continuous beach segments. These beach segments serve as proxies for littoral cells (Terich and Schwartz, 1981; Peterson et al., 1991a). The continuous beach segments are bounded by headlands of various sizes (see below). Tidal inlets are not considered to represent termination's of continuous beach segments in this study, as the shallow inlets are generally floored and flanked by beach sands. However, this does not preclude the potential for the largest inlets to serve as effective boundaries to longshore transport. Harbor jetties constructed at many of the larger tidal inlets (Grays Harbor, Columbia, Tillamook, Yaquina, Siuslaw, Umpqua, Coos, and Humboldt Bays) might presently serve as modern cell boundaries, but such artificial structures are not addressed in this report.

Longshore terminations of continuous beach segments by major headlands are defined where active beach widths consistently fall below a 10 m width cutoff over a distance of least one kilometer. Minor headlands bounding the smallest pocket beaches, e.g., 1-2 km beach lengths, are not identified in this study. The seaward projections of the major headlands (Headland Proj., km) are measured at right angles from shore-parallel lines drawn across the base of each headland (Peterson et al., 1991a).

The positions of beach reference sites, within continuous beach segments, i.e., proxies for littoral cells, are measured in longshore distance (Cell Position, km) from the north-bounding headland of each corresponding littoral cell. Therefore, the cell position at the greatest distance south of the bounding headland represents the approximate total length of the continuous beach segment or cell. Although some sand is likely mixed over time between the littoral cells that are separated by the smaller headlands, the majority of the larger littoral cells appear to represent discrete sand bodies (Peterson et al., 1991a). These littoral cells provide natural planning boundaries with respect to concerns over modern supply and loss of beach sand.

The orientation or bearing of beach reference sites (Bearing, °TN) as measured in degrees clockwise from true north (TN) are estimated from tangent lines drawn parallel to the beach at the water line. Shoreline orientation relative to prevailing wave direction is an important variable in predicting longshore transport (Komar, 1976).

The landward margins of the shoreline reference sites are characterized on the basis of coastline physiography or type. The coastline type (Coastline Type) for each reference site is identified as one of the following: high sea cliff with no broad terraces (U), lowest apparent coastal terrace (T), eolian dune field (D), coastal terrace in back of a narrow dune field (TD) and tidal or river inlets (I). Estimates of terrace heights and dune field widths are discussed below.

The coastal terrace heights (Terrace Height, m MSL) as measured in meters of elevation above Mean Sea Level (MSL) are provided for reference sites that are backed by relatively low terraces, e.g., generally less than +100 m MSL. The terrace surface heights are estimated near the edge of the present sea cliff, from the first landward deflection in slope, as observed in the aerial photographs and/or USGS 7.5 minute topographic maps. The first (lowest) terrace height is taken from the first topographic map contour above the first apparent break in slope. Therefore the estimated terrace heights at each reference site represent maximum terrace-surface heights. The USGS topographic map contours are shown at roughly 6 m contour intervals, yielding a terrace height error of at least ± 3 m. However, some sections of the coast are currently mapped at a resolution of only 12 m contour intervals.

Terrace surface elevations of selected reference sites throughout the study area, about 50 in number, were field checked with an altimeter (accuracy ± 3 m) to verify mapped elevations, and to estimate terrace deposit thickness. Field-checked terrace heights were found to be within ± 5 m of estimated lower-terrace heights (under 30 m height). Somewhat larger errors (± 10 m) were found in a few of the highest terraces, that were associated with dense tree cover. For this report all terrace heights are rounded off to the nearest 10 m interval. Due to the over-estimation of terrace height from the topographic maps, as noted above, we assume that actual terrace heights should be of similar or less elevation than the rounded-off terrace heights reported here. For example reference sites reported to have estimated terrace heights of 10 m are likely to have actual terrace-surface heights of between five and ten meters above MSL at the sea cliff edge.

Finally, longshore variability of terrace surface height results from local dune field and colluvium cover, erosional gullying and slumping, and tectonic warping of terrace platforms. Therefore estimated terrace heights at the reference points only approximate the actual range of terrace surface heights over the corresponding 0.5 km intervals. We emphasize that the lowest terrace surface picked from the aerial photograph and topographic map analyses do not necessarily represent the same age terrace from site to site due to tectonic warping. The lowest terraces measured here are thought to range from 80 to 120 ka in age (Peterson et al., 1991a). Wave-cut platforms underlie the terrace deposits that form the terrace surfaces. The marine terrace deposits include near shore and/or lagoonal sediments, that range from 1 to 20 m in thickness, above the wave-cut platform. Accumulations of eolian dunes and colluvium (landslide debris) generally 1-10 m thickness, locally overlie the marine terrace deposits. The elevations of the terrace surfaces provide regional information on beach access, sea-cliff landslide hazard, tsunami runup hazard, and coastal neotectonic deformation.

The flight dates (Flight Date, month/day/year) of the aerial photography or videography are shown with corresponding shoreline variables of beach and dune widths. The ranges of tidal levels for the 1974-1981 flights are shown in the Appendix of this report. Tidal elevations for the 1989 and 1991 flights generally fall within ± 0.1 m Mean Sea Level (MSL). The active beach width (Beach W. 1974-81, m; or Beach W. 1989-91, m) at the reference sites are estimated from vertical aerial photographs or vertical videography. The beach width is taken from the measured shore-normal (across-shore) distance of the active beach deposit from the mid-swash zone to the base of a sea cliff or to an established vegetation line. The discrimination of the swash zone is discussed under Data Sources and Field Methods (above). The regional beach-width data can be used to (1) define different types of shorelines, e.g., beaches, rocky coasts and tidal inlets and (2) evaluate the regional variability in sand supply to the PNW coastline. Note that tidal inlets (I) are identified under coastline type (see above). Furthermore, the regional beach-width data can be used for evaluating shorelines in terms of recreational use, wildlife habitat, and impacts from oil spills, etc.

The beach widths measured during the 1974-81 period are likely to vary by as much as ± 40 m due to variable tidal level (Appendix) assuming an average beach gradient of 0.025 in the study area (Pettit, 1990). However, an analysis of the longshore variability of these beach widths shows that changes in beach width over multi-kilometer length scales generally occur on either side of cell bounding headlands (Peterson et al., 1991a) rather than between different flight dates or tidal level. The large-scale changes in beach width appear to reflect regional sand supply rather than varying tidal level during the different flight periods. However, the variable tidal-levels and different flight seasons/years limit the 1974-81 beach data to only semi-quantitative comparisons of beach segments flown under different conditions. For beaches that were flow within a single flight period and tidal level (Appendix) the precision of beach width measurement is much better, e.g., less than ± 10 m error for most beaches. Beach width measurements taken from the 1974-81 flight dates are given to the nearest 10 meter interval for comparison of beaches flown within the same flight period.

By comparison, the 1989-91 beach widths are referenced to a single season (summer) and single tidal level, i.e., mean tidal level (MTL) putting the mid-swash zone at approximately 0 m MTL. These measurements allow beach width comparisons within the littoral cells, as well as between the littoral cells that were flown during this time period. Furthermore, use of a restricted tidal-level period for flights in future years will permit long-term monitoring of regional beach-width change. Several factors led us to select the MTL position as the seaward termination of the measured beach width. From a practical standpoint, this tidal level occurs more frequently than extreme tidal levels such as mean higher high water (MHHW) or mean lower low water (MLLW) during mid-day (high sun angle) flight periods. This is not a trivial matter in the Pacific Northwest where fog and storm clouds frequently obscure the coast throughout the year. In addition, the mean tidal level (MTL) position typically represents a relatively steeper part of the beach profile than does the MLLW position. Therefore beach widths measured to the estimated MTL position are less sensitive to small changes in sea level relative to the absolute MTL position.

To further reduce beach width bias from either storm surges or variable swash runup the 1989-91 aerial videography was flown during middle to late summer conditions of minimum wave height. The only exception was a small littoral cell in northern Oregon (Cannon Beach cell). Surveys of mid-swash zone positions for many of the study area beaches showed less than ± 5 m variability for the several minute period of swash zone survey (see Field Methods). Beach width measurements taken from the 1974-81 flight dates are given to the nearest 10 meter interval in this report. The MTL beach width data is important in (1) analysis of the longshore variability of beach sand abundance, and (2) initiating a base line survey for future monitoring of beach width changes.

The base of the sea cliff, used for the landward boundary of the active beach deposit, is taken at the point where beach sand contacts the foot of the bluff. Where beaches have prograded beyond sea cliffs the landward boundary of the active beach deposit is taken at the point of established vegetation. The established vegetation line is defined by the most seaward position of bushes or dense grass cover, typically located at the foredune crest throughout the study area. Generally speaking, large beach widths correspond to excess beach sand supply, which helps buffer the backshore areas from annual storm-wave erosion. However, the introduction of non-native beach grass in the Pacific Northwest has resulted in the temporary stabilization of many backshore environments by vegetated dunes. The growth of these dunes has likely narrowed the active beaches, thereby concentrating erosion at the foredune during severe storm periods. For this reason, the part of the foredune seaward of the dune crest, is included in the active beach deposit.

The dune width (Dune W. 1974-81, m) at each corresponding reference site is measured from the seaward line of established vegetation to the landward termination of the vegetated dune field or to a maximum shore-normal distance of 500 meters. The resolution of measurement from the aerial photographs (1:24,000 scale) is on the order of a couple of meters. However, the interpretation of the seaward termination of the larger dune fields probably doubles this error, e.g., ± 5 m, due to the irregular nature of the vegetated foredune crest. The dune width estimates reported here are rounded off to the nearest 10 m interval.

The direct communication between the beaches and the largest dune fields (up to several km in width) in terms of modern sand supply, are not well known in the PNWCZ. Most of the larger dune fields are vegetated by trees, indicating some degree of stabilization. Some of the largest dune fields are thought to be of late Pleistocene age (Cooper, 1958). The arbitrary cutoff width of the modern dunes, at 0.5 km from the beach, likely underestimates the width of some active dune fields, and so, is considered to represent a conservative estimate of recent dune development. The width of the modern dune fields are thought to generally represent the abundance of net sand supply to corresponding beaches. The distribution, width, and continuity of dune fields are important factors in assessing wildlife habitat, beach access and recreational resources.

Two variables of beach deposit grain-size are included for sampled reference sites in this PNW Beach Physiography file for comparison to the cartametric variables. The two grain-size variables include mean grain-size of intermediate diameter (Grain Size, Diam. mm) and one standard unit of deviation from the mean size (Size Std. Dev., mm), which is a measure of relative grain sorting or grading. These variables are also included in the PNW Beach Deposit File. However, that file only includes grain-size data for corresponding beach profile sites , which are fewer in number than the total number of analyzed samples shown in the PNW Beach Physiography file. The sand grain-size data is important in predicting beach slope, and beach susceptibility to erosion. Foreshore slope generally increases with increasing grain-size in the study area (Pettit, 1990). The grain size data is also helpful in (1) defining littoral cell boundaries (Peterson et al., 1991a), (2) describing beach habitat conditions, and (3) rating beaches in terms of recreational use.

PNW Beach Survey File

For this regional data base only the survey data for the master profiles are provided for each of the 127 profile locations. The profiles are grouped under the corresponding 18 littoral cells that were surveyed. The cell names are listed on the left side of the file, from north (file top) to south (file bottom), with intervening profile data sets stacked vertically under variable headers (X,Y and Y'). The northing UTM location of each profile (seven digit number) is shown at the top of the right hand column of each profile data set. Two profile data sets are shown side by side, to allow for single page-width printing of the PNW Beach Survey File.

The survey results from each profile include (1) the across-shore distance (X, m) from the total station position, typically located in the backshore or on the foredune crest, (2) the corresponding vertical elevation (Y) of each survey point in meters (m) relative to estimated, mean tidal level (MTL) and (3) the elevation of the subsurface wave-cut platform or basal gravel layer (Y') also in meters relative to MTL. Note that estimated MTL for each profile is assumed to be within 0.5 m of actual MTL. For the purposes of this regional study the elevation reference to MTL also serves as an approximate reference to mean sea level (MSL).

Under the profile locator (UTM coordinate) i.e., the right hand column of each profile data set, some abbreviated field notes on the backshore morphology are listed at corresponding survey points. These abbreviations include Base of Sea Cliff (BSC), Crest of Foredune (CFD), Base of Foredune (BFD), Crest of Cobble Beach Ridge (CBR) and Base of Cobble Beach Ridge (BBR). The landward edge of the active beach is generally taken to be either the crest of the foredune (CFD) or the base of the sea cliff (BSC), if no dunes are present. Several of these morphological features establish positions and elevations of interannual wave runup, e.g., base of the sea cliff (BSC), base of the foredune (BFD) or base of the cobble beach ridge (BBR). These proxies for modern storm-wave runup heights are summarized for each profile in the PNW Beach Deposit File, as are the measured heights of the foredunes, and the elevations of the wave-cut platforms at the mid-beach face.

PNW Beach Deposit File

This file summarizes the beach profile data from each of the 127 master profiles. In addition, some cartametric beach-width data has been summarized here to address the longshore variation of beach morphology between master profile sites. The variables in this PNW Beach Deposit file are listed below in file format order, i.e., from left to right in the file. As with the discussions of the previous files (above) all variable names, i.e.., column headers, are shown in this text in parentheses with the corresponding unit of measurement. Each group of profiles is listed under the corresponding cell (Cell Name). The profile itself is identified by its UTM northing coordinate (UTM N/S). One sediment sample was taken at the estimated MTL position (mid-beach face) for each profile site (see Field Methods). The mean grain size of the sample (Grain Size, Diam. mm) is given in millimeters. The corresponding standard deviation of grain size (Size Std. Dev., mm) is also given for one unit of deviation about the mean.

The width of the surveyed beach profile (Beach Prof. W., m) is given in meters to the nearest 10 m interval. The profile width is measured from the landward termination of the backshore to the intersection of the foreshore with the estimated elevation of mean tide level (MTL). The landward termination of the active beach deposit is taken to be at the sea cliff if no vegetated dunes are present. Where vegetated dunes are present the active beach deposit is taken to the line of established vegetation, typically located at the dune crest or slightly seaward of the dune crest. This beach profile width roughly corresponds to the 1989-91 beach widths estimated from aerial videography at the 0.5 km interval reference points (see PNW Beach Physiography File). However, the profile sites might be as much as a quarter kilometer away (longshore) from the nearest cartametric reference site.

The slope of the surface profile is provided in percent grade (rise over run X 100) for the mid-beach face (Mid-Slope, %) that is the foreshore slope roughly between the MHHW and MTL. The slope of the entire length of the profile (Ave. Slope, %) is also provided for each profile site in the Beach Deposit File. Profiles were generally extended from the termination of the backshore to the beach toe. The beach toe, or the transition between the foreshore and the surf zone, typically occurs where the profile intersects the MLLW elevation. Where the backshore is terminated by a foredune the foredune height (Foredune Ht, m MTL) is given to the nearest 0.5 meters.

The maximum backshore height (Backshore Ht., m MTL) is also rounded off to the nearest 0.5 m. The maximum backshore height is taken at the base of the sea cliff (BSC) or base of foredune (BFD) in this study area (see Beach Survey File). These maximum backshore elevations serve as proxies for minimum runup heights for seasonal storm waves. That is to say that storm waves, possibly in combination with storm surges and high tides, reach these elevations at least on an interannual basis, precluding the establishment of perennial vegetation. The maximum backshore heights also indicate the relative abundance of beach sand available to the beaches. For example, the transition between erosional sea cliff and progradational dune field generally occurs at maximum backshore heights of about +5 m MTL (see Beach Survey File).

The elevation of the Holocene wave-cut platform or the basal gravel layer (Platform Depth, m MTL) is given to the nearest 0.5 m relative to MTL. The elevation of the wave cut platform is taken at the mid-beach face position, i.e., at the surface profile intersection with 0 m MTL. This point typically represents the average platform elevation between the beach toe and the backshore area. The elevation of the wave-cut platform provides regional information about the thickness of unconsolidated beach deposits, and the potential depth of wave scour during erosional events. For example, some PNW beaches represent only thin sand veneers supported on wave-cut platforms of shallow depth, e.g., platform elevations above -3 m MTL. This information can be useful in (1) predicting shoreline response to beach sand loss, and (2) designing or permitting shoreline protection structures.

The cross-sectional areas of the active beach deposits are estimated for the profile sites on the basis of the surface and wave-cut platform profiles. These two profiles are taken to extend from the landward termination of the active beach deposit to the seaward terminations at arbitrary tidal datums, either MHHW or MLLW. The cross-sectional areas of sand between the surface and bottom profiles or the arbitrary tidal datums are calculated for several accumulation zones. These zones include (1) sand cross-sectional area above mean higher high water (Cs MHHW, m^2), (2) sand cross-sectional area above mean lower low water or the wave-cut platform where it is shallower than MLLW (Cs MLLW, m^2), and (3) total sand cross-sectional area (Cs TOTAL, m^2) measured across-shore out to the MLLW datum, and down to a maximum possible depth of -10 m MTL or the wave-cut platform, which ever is shallower (Figure 2). These cross-sectional areas are rounded off to the nearest 10 square meter interval.

The cross-sectional area of sand above MHHW represents the backshore deposits above normal tidal range. This parameter indicates the relative abundance of surplus sand supply to the beach. The cross-sectional area above the MLLW datum represents beach sand deposits within and above the normal tidal range. This parameter indicates the relative amount of sand buffer available to the beach during storm events. Note that very shallow wave-cut platforms, e.g., above the MLLW tidal datum, significantly decrease the amount of beach sand above this tidal datum. Finally, the total cross-sectional area of beach sand represents all of the available sand that can be scoured from a beach to the limiting depths of either the wave-cut platform or to a maximum cutoff depth of -10 m MTL.

As previously noted, the longshore distributions of the beach profile locations were established to reflect representative shoreline conditions within the surveyed littoral cells. That is to say that the mid-points between master profile locations were positioned to correspond to changes between beach segments of different morphology. The term beach segment is used here to represent the longshore intervals of apparently similar morphology. For example, mid-points between segments were positioned where (1) sea cliffs give way barrier spits, (2) where wide beaches change to narrow beaches, (3) where shoreline orientations change, or (4) where wave-cut platform depths are likey to vary from tectonic warping or lithologic changes. Therefore, each profile locality should represent its corresponding shoreline segment in terms of general beach morphology.

Nevertheless, the aerial videography results do show significant differences in apparent beach width within multi-kilometer distances, e.g., within the beach segments between profile localities. The differences in beach width are associated with a variety of features including, distance from cell bounding headlands, small coastal promontories, variable shoreline orientations, river mouths, and harbor jetties, among others. In many PNWCZ littoral cells the cross-sectional areas of sand in the relatively thin beach deposits are primarily controlled by beach width. The problem then becomes one of accounting for the significant variability of beach width and associated sand abundance between the limited number of profile locations. Even a doubling or a quadrupling of the number of beach profiles would still fail to address much of longshore variability in beach width, as observed along many irregular shorelines of this active margin.

Profile calibration by aerial videography is used here to semi-quantitatively address the longshore variability of beach width observed between some profile locations. First, the apparent beach width (Ap. Width, m) of the profile site is taken from the nearest reference point (see Beach Physiography File). Then the apparent beach widths from all of the reference points in the beach segment represented by the corresponding profile location are averaged to find the apparent mean beach width (Ap. Mean W., m). Both the apparent beach width (reference site nearest the master profile) and the apparent mean beach width (average for corresponding segment) are taken to the nearest meter for purposes of computation.

The standard deviation of the apparent beach width (Ap. W. S.D., m) indicates the variability of beach width within the beach segment. As might be expected the variability of beach width increases with proximity to cell bounding headlands, river mouths, and other anomalous features within the cell. This parameter is useful in characterizing beach uniformity within a cell. A mean normalized deviation of apparent beach width (Ap W. S.D/M.) is also shown. That is to say that the standard deviation of beach width for a segment is divided by the corresponding mean beach width for the segment. Mean-normalized standard deviations of segment beach widths can be used for comparisons of longshore variability of beach width between beach segments of widely-different average widths.

The apparent beach width nearest the profile site is divided by the mean apparent beach width for the corresponding beach segment to yield a correction factor (Ap. Cor. Fac.) for each profile location. For example, a correction factor that is greater than one (> 1.0) indicates that the average beach width in the segment is greater than the apparent beach width at the corresponding profile site. Conversely, correction factors less than one indicate averaged beach widths that are less than the apparent width at the profile site. The correction factor is multiplied by the profile cross-sectional areas to produce the adjusted cross-sectional areas (Adj. Cs MHHW, m^2), (Adj. Cs MLLW, m^2), and (Adj. Cs TOTAL, m^2), representative of the average beach deposit size within the corresponding beach segment. This calibration yields beach cross-sectional areas that better reflect the conditions of the entire beach segment.

Finally, the adjusted cross-sectional areas are multiplied by the corresponding segment lengths (Segm. Length, m) to compute sand volumes (Vol. MHHW, m^3), (Vol. MLLW, m^3) and (Vol. TOTAL, m^3) for the beach segments within the surveyed littoral cells. The segment lengths are given to the nearest 10 m interval. The segment volume estimates are rounded off to the nearest 1000 cubic meter interval. Regional beach sand volumes are needed to evaluate cumulative effects on beach sand reservoirs from various management practices including shoreline protection, dune stabilization, beach sand mining, and dredge spoil dumping, among others.

CONCLUSIONS

This beach-shoreline data base represents the first compilation of regional data on shoreline conditions to be presented in a digital (electonic) file format. Users are encouraged to send recommendations to the authors for improvement of the file data or file formats. Additional work is underway to complete the beach profiling in the remaining littoral cells not yet surveyed, and to map regional impacts from potential chronic and catastrophic hazards. It is hoped that information from other sources on wildlife habitat, coastal development, recreational interests, and other landuse planning factors will be added to this data base in the years ahead.

ACKNOWLEDGMENTS

Many individuals have contributed to the data compilation, field survey work, laboratory analyses, and data reduction necessary to produce this regional data base on ocean shoreline conditions in the Pacific Northwest region. We thank Daniella Assail, Ben Booth, Mike Boyer, Bob Carson, Greg Briggs, Charles Clough, Mike Hammond, Mark Hansen, Terra Karnes, Ingmar Saul, Margot Truini, Greg White, and Honyung Zhang for their participation in this study. Coastal aerial photographs were loaned to us from the Oregon Department of Transportation, the US. Army Corps of Engineers (Portland District), the California Coastal Commission, and the Washington Department of Natural Resources. Financial support for this work was provided by the NOAA CZM 309 Program, administered by the National Coastal Resources, Research and Development Institute, Portland, Oregon, under grants No. 2-5632-03 (1988-1989) and CZ17.90-5635-01 (1990-1991). Support for the final data-base compilation was provided under grant number NA36RG0451 (Project number R/CP-28) from the National Oceanic and Atmospheric Administration to the Oregon State University Sea Grant College Program and by appropriations made by the Oregon State Legislature. We thank James B. Phipps and Richard A. Crucchiola for their reviews of this report.

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TABLE 1 REFERENCE GUIDE TO DATA BASE VARIABLES

PNW BEACH PHYSIOGRAPHY FILE:

VARIABLE NAME	UNIT	Notes
Feature Name		Reference site locality (feature)
County Name		Reference site locality (County)
UTM N/S	m	Univer. Trans. Mercator, Northing
UTM E/W	m	Univer. Trans. Mercator, Easting
Headland Proj.	km	Headland seaward projection
Cell Position	km	Distance from northern headland
Bearing	°TN	Shoreline orientation
Coastline Type		High sea cliff (U) Low coastal terrace (T) Eolian dune field (D) Dune fronted terrace (TD) Tidal/river inlet (I)
Terrace Height	m MSL	Approx. elevation of lowest marine terrace
Flight Date	month/day/year	
Beach W. 1974-81	m	Width of beach (variable tides)
Beach W. 1989-91	m	Width of beach (during MTL)
Dune W. 1974-81	m	Dune field width (up to a 0.5 km cutoff width)
Grain Size, Diam.	mm	Mean size of sediment grain diameters.
Size Std. Dev.	mm	Grain-size stand. devi. (1$_{Sig.}$)

PNW BEACH SURVEY FILE:

VARIABLE NAME	UNIT	Notes
Littoral Cell		Name
Profile Number		Profile UTM-Northing Location
X	m	Across-shore distance
Y	m MTL	Vertical elevation relative to MTL
Y'	m MTL	Elevation of wave-cut platform
Field Notes		Base of Sea Cliff (BSC) Crest of Foredune (CFD) Base of Foredune (BFD) Crest of Cobble Beach Ridge (CBR) Base of Cobble Beach Ridge (BBR)

PNW BEACH DEPOSIT FILE:

VARIABLE NAME	UNIT	Notes
Cell Name		Name of littoral cell

UTM N/S		Profile location (UTM-Northing)
Grain Size, Diam.	mm	Sediment mean grain size (D_i)
Size Std. Dev.	mm	Grain-size std. deviation ($1_{Sig.}$)
Beach Prof. W.	m	Profile beach width (during MTL)
Mid-Slope	%	Slope of mid-beach face
Ave. Slope	%	Slope of entire beach profile (backshore to beach toe)
Foredune Ht.	m MTL	Elevation of foredune crest
Backshore Ht.	m MTL	Maximum backshore elevation
Platform Depth	m MTL	Elevation of wave-cut platform
Cs MHHW	m^2	Deposit cross-sectional area above MHHW
Cs MLLW	m^2	Deposit cross-sectional area above MLLW
Cs TOTAL	m^2	Total cross-sectional area above wave cut platform or - 10 m MTL depth cutoff
Ap. Width	m	Apparent beach width at profile
Ap. Mean W.	m	Apparent mean beach width for profile segment
Ap. W. S.D.	m	Apparent beach width std. deviation for segment
Ap W. S.D/M.		Apparent width std. deviation normalized by mean width
Ap. Cor. Fac.		Apparent beach width correction factor
Adj. Cs MHHW	m^2	Adjusted cross-sectional area above MHHW
Adj. Cs MLLW	m^2	Adjusted cross-sectional area above MLLW
Adj. Cs TOTAL	m^2	Adjusted cross-sectional area above wave-cut platform or -10 m MTL depth cutoff
Vol. MHHW	m^3	Volume of deposit above MHH
Vol. MLLW	m^3	Volume of deposit above ML
Vol. TOTAL	m^3	Volume of deposit above wave cut Platform or -10 m MTL depth

APPENDIX AERIAL PHOTOGRAPHY FLIGHT DATA: 1974-81

UTM Location	Date	Time	Estimated Tidal Level (m) MTL*
Washington			
5360450-5359150	09/11/77	12:48-13:38	+0.4
5358750-5310050	07/18/77	10:05-12:00	-0.4
5309100-5305500	09/11/77	12:48-13:38	+0.3
5305400-5295950	07/18/77	10:05-12:00	-0.8
5295500-5271650	07/22/77	11:00-12:05	-1.0
5271200-5221000	06/06/77	10:07-12:54	-1.4
5220500-5218500	08/06/81	11:00	-1.0
5218000-5216000	06/06/77	10:07-12:54	-1.4
5215650-5215250	08/06/81	11:00	-1.0
5214550-5211100	06/06/77	10:07-12:54	-1.4
5210750-5209750	05/28/81	10:10	-0.1
5209300-5192650	06/06/77	10:07-12:54	-1.5
5192350-5180200	07/19/77	10:43-10:45	-0.8
5179800-5154300	06/12/74	12:50-12:55	-0.8
5153700-5124150	06/17/74	13:40	-0.2
Oregon			
5119200-5110900	10/06/78	11:16-11:20	+0.0
5110350-5091700	10/12/78	12:34-13:55	-0.3
5091600-5062500	10/02/78	13:11-13:30	+1.5
5061900-5043900	10/25/78	10:07-11:12	+0.2
5043300-5002700	10/12/78	12:34-13:55	-0.1
5002150-4923100	10/25/78	10:07-11:12	+0.2
4922550-4899600	10/31/78	11:33-11:53	+1.2
4899400-4837550	09/28/79	11:31-14:09	+0.2
4837000-4799450	11/06/79	10:35-11:18	+0.9
4799300-4797050	09/28/79	11:31-14:09	+0.1
4796550-4791800	07/17/80	10:35-11:18	-0.9
4791600-4747400	04/11/80	13:20-13:56	-0.9
4746800-4732550	04/02/80	11:16-13:36	+0.7
4732350-4724000	04/11/80	13:20-13:56	-1.0
4723650-4695500	04/02/80	11:16-13:36	+0.5
4694900-4669150	12/08/79	11:36-12:11	+0.5
4664350-4651600	01/23/80	11:16-13:36	0.0
California			
4650900-4477000	05/05/78	10:36-12:58	+0.4

*Estimated from Tide Tables (NOAA, 1974-1981)

Figure Captions

Figure 1. Location of study area from Cape Flattery, Washington to Cape Mendocino, California. This study area encompasses the Pacific Northwest Coastal Zone (PNWCZ) of the contiguous United States. Reference Northing UTM coordinates at 100 km spacing ($^{54}00$-$^{45}00$) are shown for the study area, about 1,000 km in total length. This study area corresponds to the United States portion of the Cascadia margin, an active subduction zone (Peterson et al., 1991) and is nearly equally distributed (north and south) about the mean landfall of the winter-storm-track at about 45° latitude in central Oregon (Peterson et al., 1990).

Figure 2. Across-shore beach profile showing cross-section areas of beach deposit (stippled pattern) above (1) Mean Higher High Water (MHHW), (2) Mean Lower Low Water (MLLW) and (3) the wave-cut platform (solid line in figure) or a 10 m cutoff depth below Mean Tidal Level (MTL). All cross sectional areas are bounded landward by the base of a sea cliff or crest of the foredune, and are bounded ocean ward by the intersection of the beach face with the predicted elevation of Mean Lower Low Water (MLLW).