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ASSESSING SHORELINE CHANGE TRENDS ALONG U.S. PACIFIC NORTHWEST BEACHES

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INTRODUCDTION

Sandy ocean beaches represent some of the most popular tourist and recreational destinations in the United States, and also constitute some of the most valuable real estate in the country. These changing and ephemeral interfaces between water and land are the sites of intense residential and commercial development even though they are frequently subjected to a range of natural hazards that can include flooding, storm impacts, coastal erosion and tsunami inundation. Because population and economic trends have made the coasts so valuable, the U.S. Geological Survey (USGS) is conducting a National Assessment of Coastal Change Hazards. One component of this effort, the National Assessment of Shoreline Change, documents changes in shoreline position as a proxy for coastal change. Shoreline position is one of the most commonly monitored indicators of environmental change (Morton, 1996), and it is easily understood by those who are interested in historical movement of beaches.

A principal purpose of the USGS shoreline change research is to develop a repeatable surveying methodology so that shorelines for the continental U.S., and portions of Hawaii and Alaska, can be periodically and systematically updated in an internally consistent manner. In addition, new methods for developing datum-based shorelines and assessing coastal change can provide the opportunity to achieve more comprehensive assessments of error and uncertainty in the future. Historical shoreline changes have previously been determined for the coasts of California (Hapke et al., 2006), the Gulf of Mexico (Morton et al., 2004), and the Southeast U.S. coasts (Morton et al., 2005). Current research is now focused on the U.S Pacific Northwest (PNW) coastline.

We have initiated the analysis of the sandy open-coast shorelines for much of Oregon and Washington, extending 100s of kilometers alongshore. Along several stretches of PNW coastline this new effort will complement previous efforts at quantifying shoreline change performed at smaller spatial scale (Kaminsky et al., 1999, Allan et al., 2003). These complementary efforts allow for the testing of the methodologies developed by the USGS as well as provide a mechanism for the direct integration of results of this study into state level efforts of coastal management.

METHODS

Methodologies developed for quantifying shoreline change along the U.S. east- and gulf coasts are applied to the PNW coast, and involve obtaining and geo-referencing historical NOS topographic maps (t-sheets) from the late 1800s, 1930s, and 1950s-1970s. The modern shoreline for the project is derived from lidar data that was collected as part of a USGS/NOAA/NASA survey of much of the west coast in 2002. Long-term shoreline change rates are computed via linear regression uses each of the four shorelines while short-term shoreline change rates are computed using the end-point method on the 1950s-1970s era and modern 2002 lidar shoreline.

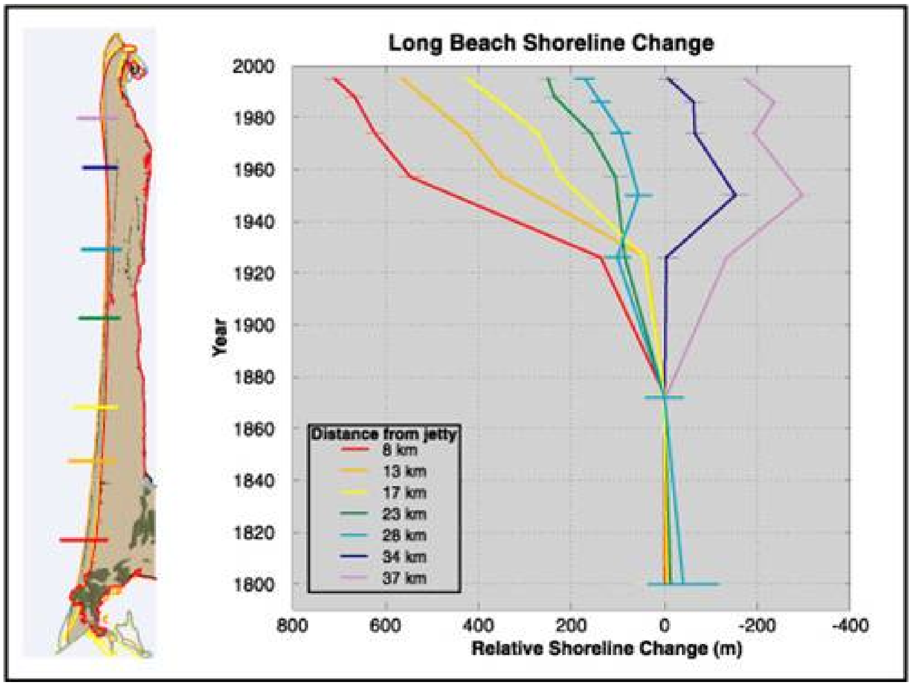
The three historical shorelines in the analysis are proxy-based shorelines that represent the high water line (HWL), traditionally, the most commonly used proxy for shoreline position (e.g., Anders and Byrnes, 1991; Crowell et al, 1991). The HWL is typically assumed to represent the landward extent of the last high tide and is recognized as a tonal contrast between the wet intertidal beach and the dry supratidal beach. This feature has been considered especially useful in shoreline change studies because the HWL was the preferred boundary for separating land and sea on NOS t-sheets. The lidar shoreline is an elevation contour (datum-based shoreline) on the sub-aerial beach extracted from the data at an elevation representing the Mean High Water (MHW) tidal datum.

In virtually all real world situations the proxy-based HWL is located landward of the MWH datum-based shoreline. Therefore changing the shoreline definition from a proxy-based horizontal location (t-sheet shorelines) to a datum-based elevation contour (lidar shorelines) has important implications with regard to inferred changes in shoreline position and calculated rates of change, particularly along the high energy low sloping beaches of the PNW (Ruggiero et al., 2003, Moore et al., 2006). Here we use the methodology presented in Moore et al., 2006 and Hapke et al., 2006 for estimating the HWL (proxy)-MWH (datum) bias on a regional basis.

RESULTS

Initial results suggest significantly different historical shoreline change trends for beaches still deriving their sediment from the Columbia River, Southwest Washington and Northwest Oregon, and beaches elsewhere in the PNW. It has been well documented that the beaches within the Columbia River littoral cell (CRLC) are still evolving from anthropogenic perturbations to the natural system some of which occurred over a century ago (Kaminsky et al, 1999). The construction of jetties at both the mouth of the Columbia River and at Grays Harbor, Washington as well as the development of the extensive flow control systems of the Columbia River (dams and irrigation) have severely altered the natural sediment supply to the CRLC. The majority of the beaches in this PNW sub-region have responded to these human impacts by experiencing dramatic beach progradation over the last century with rates significantly higher than inferred pre-historic rates (Figure 1). While the CRLC is still responding to these human impacts, in several locations beaches that had been rapidly prograding are now either prograding at a slower rate or actually eroding (Figure 1).

While the Columbia River certainly delivered sediments to other PNW beaches at lower stands of sea level, it is generally agreed that at present the Columbia River only provides sediment to the CRLC. These other PNW beaches, particular those within the many individual littoral cells comprising the rest of the Oregon coast, have relatively simple sediment budgets and are not influenced by the human impacts to the Columbia system. Recent findings suggest that Oregon shorelines typically have not experienced the century-scale trends apparent in the CRLC but instead respond episodically to major storms that produce large waves coincident with high water levels (Allan et al., 2003). In general shoreline changes along the Oregon coast are highly variable both spatially and temporally with beaches undergoing periods of rapid erosion (often associated with El Niños) followed by intervening periods of beach recovery and dune growth.



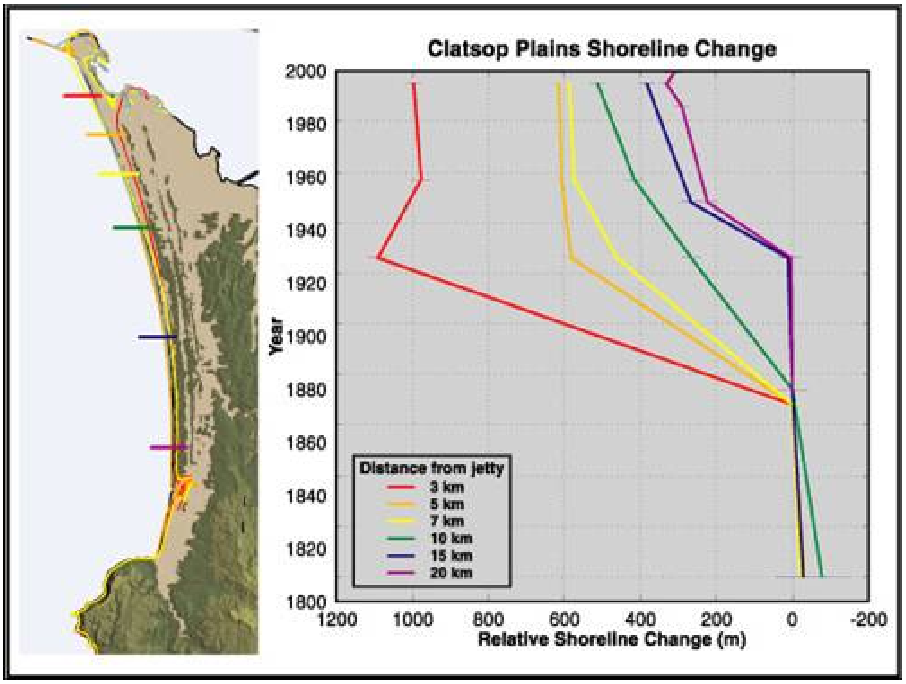


Figure 1. Historical shoreline changes along both the Long Beach Peninsula (Washington side of the Columbia River) and the Clatsop Plains (Oregon side of the Columbia River).

For both the CRLC and other PNW littoral cells accurate estimates of shoreline change rates must consider the impact of the proxy-datum bias. The high-energy offshore wave climate as well as the relatively mild foreshore beach slopes in the region conspire to make the bias higher in the PNW than most other U.S. coastlines. Hapke et al., 2006 report that for the average bias calculated for the entire state of California is approximately 18 m. Recent work in the PWN has demonstrated that the bias can be as high as 50 m in some locations (Ruggiero et al., 2003), a value that can significantly impact both short-term and long-term shoreline change rate calculations.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Shoreline change analyses performed along the PNW suggest very different historical shoreline change behavior for the beaches adjacent to the Columbia River and for those out of the modern day river's influence. Most shorelines within the CRLC have experienced readily quantifiable decadal- to century- scale trends. Along these coastlines, knowledge of sediment budgets along with the measured trends can be used to make initial estimates of erosion hazard zones (Kaminsky et al., 1999). Along many stretches of the rest of the Oregon coast no such measurable shoreline change trends exist. These shorelines are still very dynamic but instead respond more to individual storm events than to large-scale changes in the sediment budget. Along these shorelines the application of long-term trend rates are not meaningful for the establishment of coastal setbacks in foredunes or atop sea cliffs (Allan et al., 2003). Setbacks along much of the Oregon coast therefore must be developed based upon a quantified understanding of the impact of individual storms or a series of storms during relatively intense winters. Regardless of the existence or non-existence of long-term shoreline change trends, the proxy-datum bias must be considered in order to derive any meaningful information from shoreline change studies in the PNW.

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