NUMERICAL INVESTIGATION OF SEDIMENT BYPASSING AT SHINNECOCK INLET, NEW YORK

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ABSTRACT

Tidal inlets on open ocean coasts are valuable commercial, recreational, and ecological entities. As such, interest in guaranteeing their form and function is high. Maintaining tidal inlet form and function, however, come at a high cost. As littoral sediments approach a tidal inlet, they are either deposited in the vicinity of the inlet, or naturally bypassed around the inlet to continue alongshore (Brunn & Gerritsen, 1961). Sediment deposition in the vicinity of tidal inlets reduces the amount of sediment available to longshore flow, which may enhance downdrift shoreline erosion. Dean (1988a) estimates that as much as 80% of coastal erosion in Florida is due to the presence of inlets. Mitigation of downdrift erosion commonly occurs via dredging and/or the installation of artificial sediment bypassing systems at the inlet. As calls for mitigation of erosion continue to increase, an understanding of the processes that control natural sediment bypassing becomes more important.

Natural sediment bypassing at tidal inlets is accomplished through both continuous and discontinuous transport mechanisms. Continuous bypassing mechanisms involve the persistent transport of sediments along the outer edge of the ebb tidal delta by waves and tidal currents (Dean, 1988b), whereas discontinuous bypassing mechanisms involve the downdrift and onshore migration of discrete bar complexes (Fitzgerald, 1988; 1982). The mechanism by which inlets bypass sediments (continuously or discontinuously) determines erosion and accretion patterns on downdrift beaches.

Shinnecock Inlet is the easternmost of six permanent inlets located on Long Island's south shore. This inlet provides a conduit for tidal exchange between Shinnecock Bay and the Atlantic Ocean. Since the inlet's opening by the Great New England Hurricane of 1938, its location has migrated until its position was stabilized in 1956 by the construction of two stone jetties. Because more than $8.5 * 10^6$ yd^3 of sediment has gone to feed the developing ebb tidal delta (Morang, 1999), significant interruption of longshore drift and chronic erosion of downdrift shorelines has occurred. The installation of an artificial bypassing system may alleviate this erosion; however, considering the cost of such system, it is imperative to first understand the rates and pathways by which natural bypassing occurs at this site.

Numerical simulation provides the most reasonable method of assessing the rates and pathways by which natural sediment bypassing occurs at Shinnecock Inlet. This study employs the modification and application of a numerical model for bathymetric evolution under the influence of both waves and currents. For this study we have obtained SHORECIRC, which is a quasi-3D nearshore circulation model developed at the University of Delaware (Putrevu & Svendsen, 1999; Svendsen & Putrevu, 1994). SHORECIRC will provide us with a full 3D depiction of nearshore circulation in the vicinity of Shinnecock Inlet.

Quasi-3D models are based on depth-integrated, time-averaged governing equations of motion, which calculate nearshore current velocities in a two-step process. SHORECIRC first calculates horizontal gradients in hydrodynamic entities such as radiation stress and mass flux. These gradients drive currents and infragravity wave motions in the 2D horizontal plane. This calculation gives u(x,y) and v(x,y), where u and v are the x-directed and y-directed velocity components respectively , and x and y denote location on a rectangular grid. SHORECIRC then calculates the 1D vertical variation in velocity at each grid point to give u(x,y,z). A depth-integrated wave-averaged model is used for this calculation. The use of SHORECIRC in our simulations provides us with a full 3D depiction of nearshore circulation that is needed to ascertain sediment transport patterns in our study area.

We have successfully run SHORECIRC on several test cases involving various bathymetries representative of an inlet bathymetry. Because SHORECIRC, by itself, does not include sediment transport or a mechanism for updating bathymetry, part of the major goal of this research is to modify the present version of SHORECIRC by attaching Buonaiuto's (1999) sediment transport model into SHORECIRC. In this model, sediment transport is determined by integrating over depth the product of local fluid velocity and sediment concentration. The 1D model for sediment concentration is a standard advection-diffusion profile for sediment in which the upward turbulent diffusion of sediment is balanced by the downward flux due to gravitational settling. The bottom boundary condition for this model is set by a reference concentration, $C_{A,}$ which is dependent on wave-current shear stress, bed turbulence, and gravitational settling of sand grains (Briand, 1990). C_A is given in (1) where K_v and K_t are calibration constants in units of concentration (submerged kilograms of sediment per cubic meter of fluid), g is the acceleration of gravity , D is dissipation, T is wave period, W_f is sediment fall velocity, and τ_{xy} is the magnitude of the shear stress vector. These constants indicate the relative importance of wave breaking and wave-current shear stress on sediment mobilization, respectively (Buonaiuto, 1999).

$$C_A = \frac{K_v\left(\frac{gD}{8T}\right)^{1/3} + K_t\left(\frac{\tau_{xy}}{\rho}\right)^{1/2}}{W_f} \qquad \textbf{(1)}$$

Once transport has been calculated, changes in bathymetry will be determined by applying conservation of sediment given by (2) where I is the immersed weight transport rate, $\psi = (1 - p)(\rho_s - \rho)$, which transforms immersed weight to sediment volume, h is the elevation of the sediment bed, and p is the porosity (Buonaiuto, 1999). The modified model will thus consist of a 2D depth-averaged horizontal circulation model linked to 1D models of vertical fluid velocity and sediment concentration. The individual model results will then be used to update bathymetry.

$$\Psi \frac{\partial h}{\partial t} = \frac{\partial I_x}{\partial x} + \frac{\partial I_y}{\partial y} \qquad \textbf{(2)}$$

Our simulations will run on a fixed spatial grid with a 10 m spacing that spans 3 km alongshore and 1.5 km acrossshore. This domain includes all wave-affected regions of the inlet, including the ebb tidal delta where continuous bypassing processes would dominate. We will obtain bathymetry with which to carry out model simulations from periodic, high resolution, shallow-water mulitbeam SWATH surveys. Three surveys will be conducted, and the resulting bathymetries will represent 1) conditions following a long period of mild wave climate, 2) conditions following a season of energetic wave climate, and 3) conditions following a storm event. These bathymetries will serve as initial bathymetric conditions in the simulations.

Simulations will then proceed with model forcing, which consists of conditions (wave climate and inlet tidal currents) observed prior to, during and following the bathymetry surveys. At specific times during the simulations, model bathymetry will be saved for comparison with earlier bathymetry (Buonaiuto, 1999). Comparison between successive simulated bathymetries will allow us to determine zones of erosion and deposition as well as identify bedform movements. Comparison of simulated model bathymetries with measured multibeam SWATH bathymetries will provide validation for the model results. From these observations we will obtain an understanding of the predominant sediment bypassing rates and pathways at Shinnecock Inlet.

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