VORTEX LATTICE MODEL FOR MINE SCOUR AND BURIAL

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LONG-TERM GOALS

We seek to understand the leading order processes and develop quantitative modeling skill for the problem of scour and burial of solid objects on a sedimentary bed in geophysical flows.

OBJECTIVES

1) Identify leading order processes; 2) formulate the model and write the computer code; 3) initialize and calibrate the model using archival data; 4) validate the model in a contemporary field experiment with modern mines of various shapes; 5) conduct numerical experiments with the model to determine the relative strength of various scour and burial mechanisms, and the sensitivity of those mechanisms to the fluid forcing history and sediment characteristics; and, 6) exploit the results of the field and numerical experiments to pose potential mine countermeasures.

APPROACH

Analysis of an archival data set of field measurements, photos and diver observations from a 1953-55 Mark 36 mine scour and burial experiment off Scripps Beach resulted in a model formulation with two distinct sets of burial mechanics. Separation of the model architecture into *far-field* and *near-field* burial mechanics permit the model to be adaptable to real coastal settings. The *far-field* mechanics (Figure 1) are associated

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with burial due to seasonal changes in the shorerise (outer) and bar-berm (inner) bottom profiles in response to variations in the wave climate and littoral sediment supply. Seasonal bottom profile changes may cause mines to bury or become exposed, depending upon the seasonal wave climate. This is the only mechanism which can account for deep burials where the top of the mine is well beneath the ambient elevation of the bed surface, (Figure 2). The seasonal profile changes are based on the second law of thermodynamics, whereby the shorerise and bar-berm profiles adjust to a change in wave climate such that they maximize the dissipation of incident wave energy. The leading order dissipation mechanism differs between the shorerise and the bar-berm profile. In the shorerise profile, the dissipation is controlled by the rate of working due to the bottom friction exerted by the bottom wind. In the bar-berm profile, the dissipation is the result of mean stresses arising from shoaling wave asymmetries.

The second set of burial mechanics are referred to as *near-field* and involve vortex scour using the vortex lattice method. In any arbitrary cross-wake plane, trailing vortex filaments produce scour by two distinct transport processes, i.e., bed-load transport and suspended-load transport. The down-washing induced by the trailing vortex filaments produces a flow convergence on the seabed, which elevates the bottom stress above the threshold of motion for the ambient sediments. The tangential velocity induced by the trailing vortex filaments causes bed-load induced scour transversely across the wake proportional to the cube of the circulation generated by the bluff-body shape of the mine. Finally, the up-wash induced along the wake perimeter by the trailing vortex filaments gives rise to scour resulting from the flux of seabed material into suspended load, a mechanism that is proportional to the fourth power of the bluff-body circulation.

WORK COMPLETED

Progress has been made on all six objectives during FY-97 or in the antecedent period of funding for this two year effort. Two peer-reviewed papers and four conference proceedings papers resulted from the FY-97 research..

RESULTS

The action of *near-field* scour processes results in the scour holes which lead to a burial sequence with two distinct degrees of freedom depending upon the mine shape and the nature of incipient mine motion. The first degree of freedom for burial is the scour-and-roll sequence discussed in our earlier paper, Inman & Jenkins, 1996. The scour-and-roll burial sequence is specific to cylindrical and spheroidal mine shapes like the Soviet MDM series or the U. S. Destructor Series. For flat bottom mines, like the Italian MANTA or Swedish F-80 BUNNY, a second degree of freedom for burial predominates, which we refer to as the shear- failure sequence. In this sequence the vortex scour produces undercutting that reduces the contact area under the mine, increasing the dispersive pressure associated with the immersed weight of the mine. When the pressure exceeds the shear strength of the granular material under the mine, failure occurs, causing

slumping of the material under the mine and an accompanying downward displacement of the mine. These *near-field* scour and burial physics are treated in our most recent paper, Jenkins & Inman (in preparation).

Our 1997 MANTA mine field experiment revealed that *near-field* vortex scour alone may only account for a portion of the observed burial (Figure 2). The *far-field* burial mechanics associated with seasonal profile transitions between winter and summer equilibria (Figure 1), may be the controlling burial mechanism, particularly with the uncharacteristic departures from typical conditions during ENSO cycles. The ENSO induced effects on the wave forcing and sediment yield are addressed in our two conference papers (Inman, et al. 1996; Inman & Jenkins, in press, 1997). Inclusion of the mechanism of bottom profile changes accounts for both rapid and deep burial, consistent with the observations obtained during the 1997 El Niño (Figure 2).

A collateral result of the *far-field* burial mechanics has been the discovery of a new class of homogeneous non-linear differential equation having an exact solution. The second law of thermodynamics gives a governing equation for the shorerise profile of the form:

$$\frac{x^2}{2h}\frac{d^2h}{dx^2}\left(\frac{dh}{dx}\right) - \frac{x}{5}\frac{d^2h}{dx^2} - \frac{3x^2}{2h^2}\left(\frac{dh}{dx}\right)^3 + \frac{3x}{2h}\left(\frac{dh}{dx}\right)^2 - \frac{9}{25}\frac{dh}{dx} = 0$$

where h is the local depth of water and x is the cross-shore position. This new class of non-linear equation admits to the rather simple solution

$$h = Ax^m$$

where $m = 2/5$, and A is a factor independent of x resolved from the shorerise boundary conditions. This result was found to be in agreement with the field data and is treated in our paper, Jenkins & Inman, in press.

IMPACT/APPLICATIONS:

Experiments with the model have revealed a potential mine countermeasure, involving seeding a mine field with coarse binary aggregate to arrest the burial sequence and enhance the detectable footprint of the mine. Study and evaluation of this technique is proceeding under this continuing ONR grant.

The *near-field* scour and burial components of the model are applicable to a number of ocean engineering problems involving sea floor scour of structures, footings and foundations, as well as interpreting observations of scour made by the recent Mars Rover. The *far-field* components of the model are applicable to a number of beach erosion and nourishment problems in coastal engineering and have demonstrated yet another application for thermodynamics to equilibrium states of natural systems.

TRANSITIONS:

The vortex lattice scour and burial model has not yet been adapted to a graphical user interface (GUI) and therefore remains in the category of a research model. However, installation of a GUI would allow the model to be quickly exportable to other NAVY uses. Meanwhile, additional validation of the model is expected once data from a NATO mine burial exercise conducted in the North Sea area, summer of 1997, has been released to us.

RELATED PROJECTS:

We have had a number of exchanges of technical reports, letters, and conversations with Dr. Michael D. Richardson, who heads the Mine Burial Processes Program at the Naval Research Laboratory, Stennis Space Center, MS. Concepts for a joint experiment have been considered. In addition, we have interacted with the Naval Research and Development Laboratory, CODE 352, San Diego, and the Mobile Mine Assembly Group, Unit One, Seal Beach, who have provided us with inert mines for our field experiments.

REFERENCES

Inman, D. L. & S. A. Jenkins, 1996, "A chronology of ground mine studies and scour modeling in the vicinity of La Jolla," University of California, San Diego, Scripps Institution of Oceanography, SIO Reference Series 96-13, 26 pp.

Inman, D. L., S. A. Jenkins & M. H. S. Elwany, 1996, "Wave climate cycles and coastal engineering practice," Coastal Eng., 1996, Proc. 25th Int. Conf., (Orlando), Amer. Soc. Civil Eng., New York, v. 1, Ch 25, p. 314-327.

Inman, D. L. & S. A. Jenkins, in press, 1997, "Changing wave climate and littoral drift along the California coast," California and the World Ocean '97, San Diego, CA. 12 pp.

Jenkins, S. A. & D. L. Inman, in press, "Analytic solutions for equilibrium profiles on ocean beaches, Jour. Geophys. Res.

Jenkins, S. A. & D. L. Inman, in preparation, "Scour mechanics for simple and complex forms," Jour. Sedimentary Res.
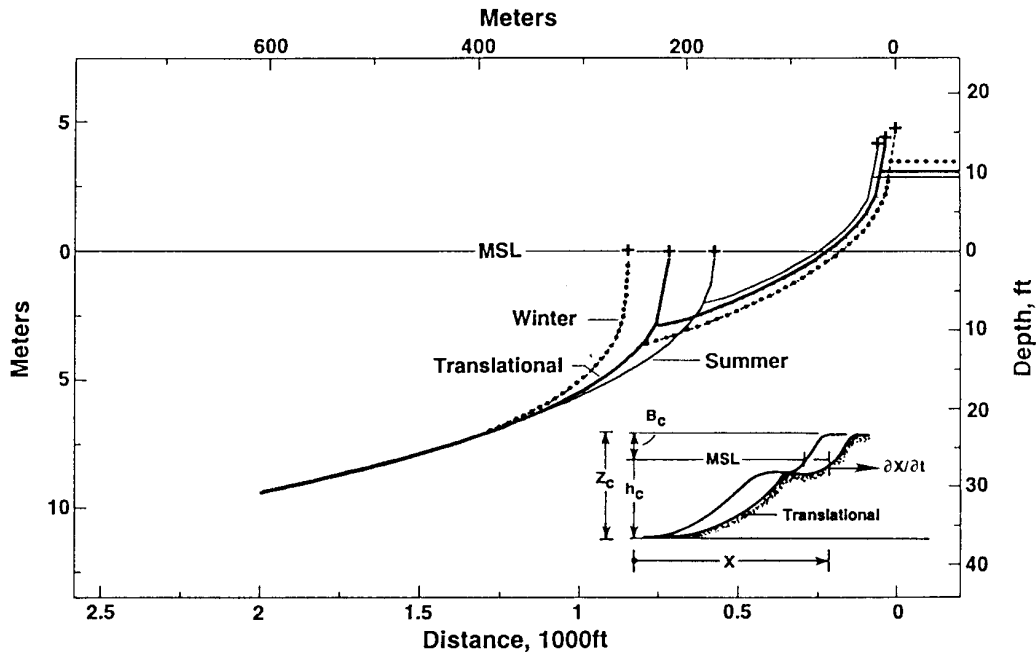
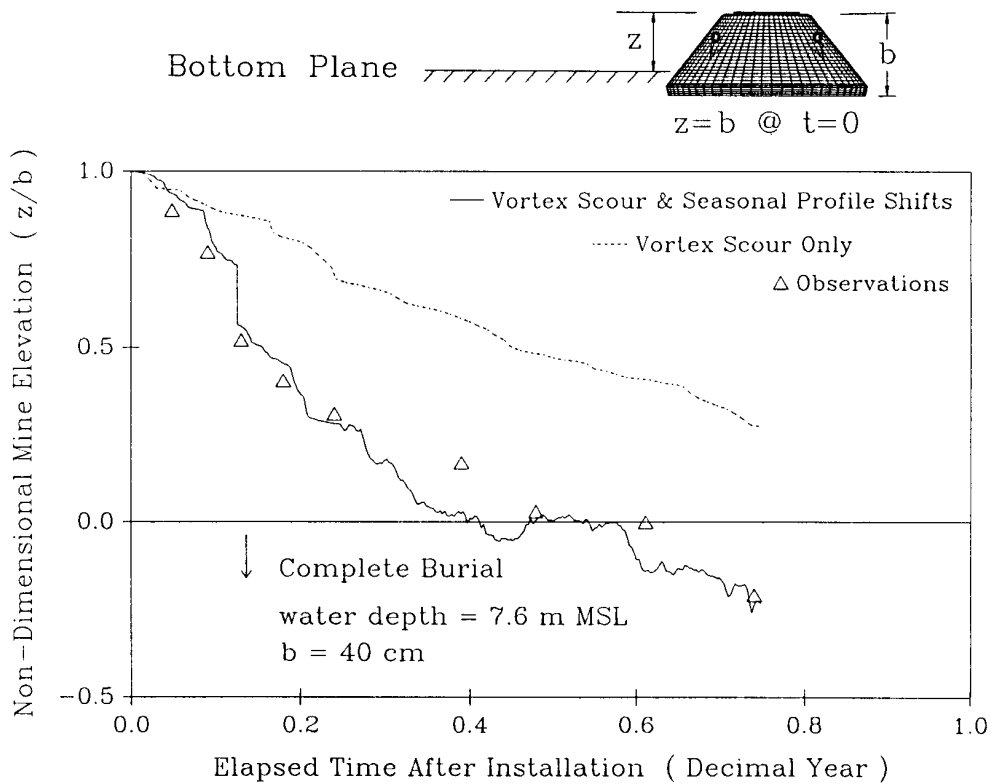Figure 1: Burial mechanisms due to seasonal profile changes.

Figure 2: Dependence of burial rate on near-field (scour) and far-field (profile changes) mechanisms for 1997 wave climate.