

MIGRATION AND BURIAL TENDENCIES OF VARIABLE DENSITY MUNITIONS: INITIAL RESULTS FROM A LARGE-SCALE STUDY

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INTRODUCTION

Past military activity close to the coast has discarded numerous ordnances in the nearshore environment. These ordnances (some of them unexploded; also called UXOs or munitions) are transported by waves and currents and may become exposed on beaches. The increased intensity of storm events may lead to a subsequent increase in UXO exposure and migration. Prolonged exposure of UXOs to ocean conditions leads to surface growth that alters their bulk density. Hence, it is essential to understand the influence of bulk density on mobility characteristics. This study, funded by the Strategic Environment Research and Development Program (SERDP), aims to quantify the processes that affect the mobility and burial of variable density munitions in the surf and swash zones during scaled extreme forcing.

EXPERIMENT

The experiments were performed at the multifunctional large-scale wave flume managed by the Environmental Hydraulics Laboratory at the *Institut National de la Recherche Scientifique* (INRS), Quebec, Canada. The facility is one of the largest in North America, with dimensions of 120 m x 5 m x 5 m. The piston-type wave maker with active absorption has a maximum stroke length of 4 m and can generate regular and irregular waves reaching a maximum velocity of 4 m/s. The generated wave amplitude can reach the top of the flume walls with operational water depths ranging from 2.0 - 3.5 m and wave periods of 3 - 12 s.

The beach profile used in the study was modeled from Mantoloking in Ocean County, New Jersey, USA. The wave conditions used in the study were scaled from the onset of hurricane Sandy off the coast of New Jersey between 27-29 October 2012. Water level data was obtained from the National Oceanic and Atmospheric Administration (NOAA) buoy 8534720 near Atlantic City, New Jersey.

The Froude scaling methodology (Van Rijn et al., 2011) was used to scale the prototype conditions. Five test cases were formulated to address the following scientific objectives.

1. Evaluate the response of variable density munitions under the same forcing conditions.
2. Compare the response of munition and canonical shaped items under the same forcing conditions.
3. Identify the importance of storm onset, the temporal increase in forcing conditions, in variable density munitions mobility, burial, and exhumation.
4. Determine the net migration of munitions over the duration of a scaled storm event and identify

conditions that lead to onshore migration of munitions.

Traykovski and Austin (2017) identified mobility and burial characteristics of munitions as related to dU_{wave}/dt , the temporal variability in fluid velocity adjacent to the munitions. This parameter has a nearly 1:1 relationship to dH_s/dt . Hence, we used dH_s/dt to create five different rapid storm onset conditions (Figure 1) to provide the best opportunity for munitions migration.

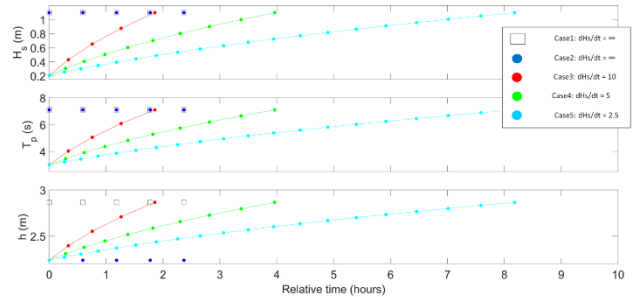


Figure 1 - Hydrodynamics and water level conditions used for the experiment.

A Preliminary modeling study was carried out using XBeach (Deltares, 2018) in the surf beat mode to identify the regions of interest within the test domain. The simulations showed a net offshore migration of the berm and extensive erosion in the swash zone (Figure 2) when subjected to similar test conditions.

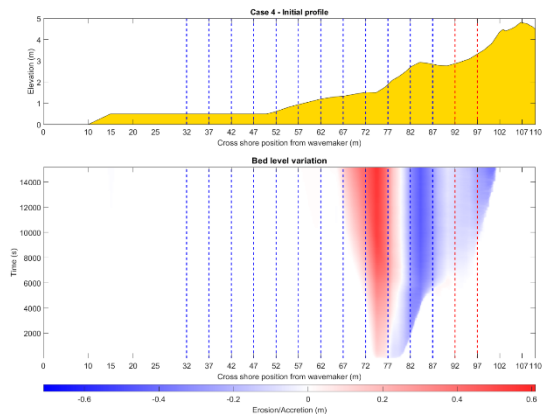


Figure 2 - Results from X Beach simulation corresponding to the case 04 tests H_s increasing from 0.21 m to 1.1 m, T_p from 3.01 s to 7.1 s, and h from 2.23 m to 2.87 m over ten trials ($(dH_s)/dt=5$).

Sixteen stations were identified along the length of the flume (Figure 3) to deploy an array of sensors: Acoustic Doppler Profiling Velocimeters (ADPV), Electromagnetic Current Meters (EMCM), and Acoustic Doppler Velocimeters (ADV) to measure velocity, Pressure transducers (PT) to estimate pore pressure, Moisture Sensor (MS) to estimate volumetric moisture content, Optical Backscatter Sensor (OBS) to measure sediment concentration and turbidity and Conductivity Concentration Profiler (CCP) to measure sheet flow conditions. A 3D scanning LIDAR, GPS survey, and camera were used to measure bed profile evolution and wave runup. The MS and PTs were deployed in stacked pairs to investigate the relationship between moisture content, pore pressures, and the net changes to the dune and the berm.

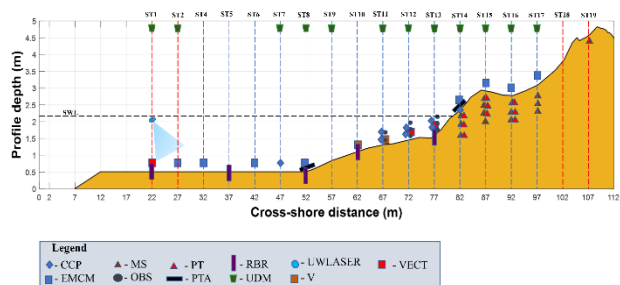


Figure 3 - The location of sensors used in the study in relation to the initial profile.

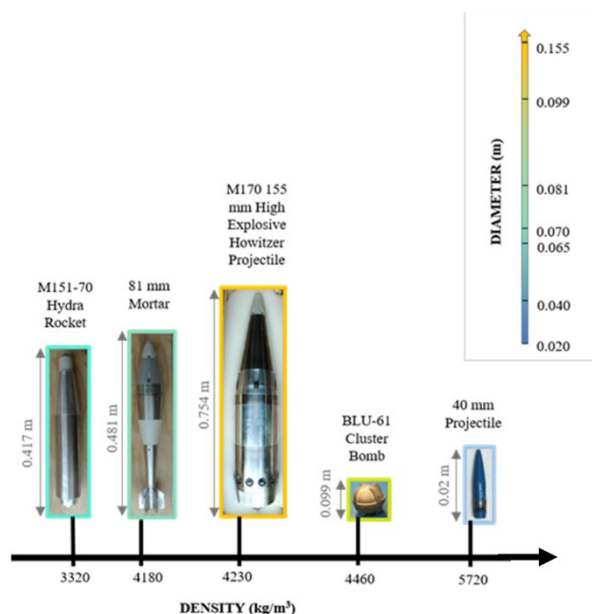


Figure 4 - Standard surrogate munitions and densities

Alongside the standard surrogates (Figure 4), canonical shapes (cylinders and spheres) of various bulk densities were created. The UXOs were deployed in two classes of clusters, one with the same shape and different bulk

densities and the second with the same external shape and different bulk densities. Some of these inert UXOs were equipped with IMU and PT to record the mobility and pressure data in real-time. These clusters were deployed at eighteen stations. After every two runs, the wave flume was drained to survey the munition positions.

A lidar scan of the bed shows the presence of evenly spaced sediment ripples and scour holes from ST1 to ST 11 (refer to Figure 3). The ripples and scour holes have influenced the mobility characteristics of both light and dense UXOs. Around the larger UXOs, such as 155s, sediment transport created scour holes 8-9 times the diameter of munitions (for 155s). These holes trap the munitions affecting their mobility (Figure 5).

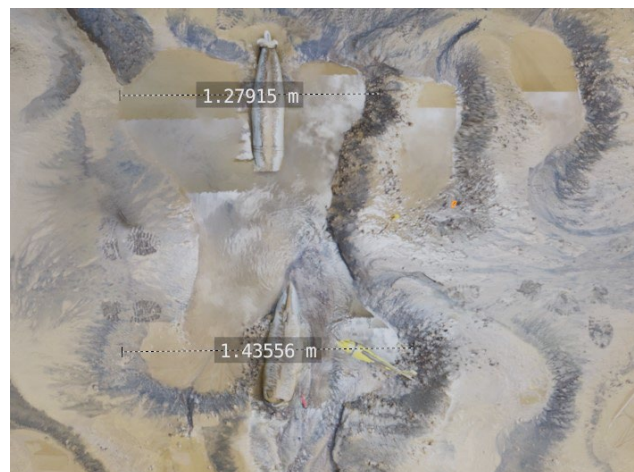


Figure 5 - High-resolution lidar scan of the bed after case 03 trial 05 showing a pair of 155s and associated scour. The overlaid measurements show the size of the scour.

Bed elevation measurements also showed minor deviations when compared to the results from the initial XBeach simulations. The deviations may be related to grain size variability. The initial sediment size distribution indicated well-graded sediments. Subsequently, wave breaking, turbulence, and undertow resulted in cross-shore sediment sorting, thus affecting the predictions. The findings from the large-scale study will be discussed.

REFERENCES

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