Bridging Lab and Field Scales to Enhance Understanding of Munitions Mobility in Underwater Environments

Unexploded ordnances (UXOs) can be found at the bottom of coastal areas as the residue of military wartime activities, training, or accidents. These underwater objects are hazards increasing the need for addressing the knowledge gaps regarding the initiation of motion, fate and transport of UXOs in underwater environments (e.g., coastal ocean, estuaries, lakes, and rivers). The fundamental work of laboratory and field efforts provides critical data for the development of new, and advancement of existing, field scale models for the mobility of munitions.

Extensive large-scale laboratory experiments were conducted for the initiation of motion of UXOs under various rigid bed roughness conditions (smooth PVC, pitted steel, marbles, gravels and bed of spherical particles) for both unidirectional and oscillatory flows. Particle image velocimetry measurements were conducted under both flow conditions to resolve the flow structure estimate the critical flow conditions for initiation of motion of UXOs. Analysis of the experimental observations shows that the geometrical characteristics of the UXOs, their properties (i.e., volume, mass) and their orientation with respect to the mean flow play an important role on the reorientation and mobility of the examined objects. A unified initiation of motion diagram is presented using an effective/unified hydrodynamic roughness and a new length scale which includes the effect of the projected area and the bed-UXO contact area. Both unidirectional and oscillatory critical flow conditions collapsed into a single dimensionless diagram highlighting the importance and practical applicability of the experimental work.

In addition to the rigid bed experiments, the burial dynamics of proud UXOs on a mobile sand bed were also examined and compared to field observations. The complex flow-bedform-UXOs interactions were evaluated which highlighted the effect of munition density on burial rate and final burial depth. Burial dynamics and mechanisms for motion were examined for various UXOs types, and results show that, for the case of the low density UXOs under energetic conditions, lateral transport coexists with burial. Prior to burial, UXO re-orientation was also observed depending on the geometric characteristics of the objects.