MUNITIONS MOBILITY AND BURIAL IN A MICRO-TIDAL ESTUARY

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The MINELAB project, funded by the Strategic Environmental Research and Development Program (SERDP), aims at investigating the fate of underwater unexploded ordnances (UXOs) displaced over or buried into the heterogenous sedimentary bed of a micro-tidal estuarine site, subjected to both fluvial and marine forcing. Our objectives are: 1) to observe directly the combined effect of river flow, water waves and tide on the mobility and burial of UXOs; 2) to improve the models for the prediction of the UXOs behavior.
Field observations of surrogate mobility and burial will be carried out and used to validate specifically tailored numerical models, which could be exploited to understand the UXO behavior in estuarine environments characterized by multiple forcing actions and mixed sediments (from gravel and sand to silt and clay), but also to predict UXO fate due to different environmental conditions.
While studies have largely focused on UXO surrogate fate in underwater sandy environments (Calantoni et al., 2014; Traykovski & Austin, 2017; Puleo & Cristaudo, 2020), less knowledge exists on sites characterized by cohesive sediments or mixtures of cohesive and non-cohesive materials (Trembanis & DuVal, 2020). Furthermore, to the authors' knowledge, no studies exist on UXO mobility and burial in estuarine environments, where riverine and marine forcing interact over a heterogeneous bottom.

THE STUDY AREA

The study area is the estuary of the Misa River (Senigallia, Italy), which can be regarded as a field-scale laboratory, the final reach of the river being bounded by masonry-wall embankments and the whole estuarine area being monitored by an existing, integrated system of sensors (Brocchini et al., 2015, 2017). The monitoring infrastructure is characterized by two remote sensor systems, i.e. the video-monitoring station SGS, equipped with five cameras recording the final MR reach, the estuary and the nearshore area (white pin in Figure 1), and an X-band radar, which collects data for the reconstruction of wave field and bathymetry (up to 6 km from the shore; yellow pin). Onsite sensors are also installed: an offshore ADCP, which collects the offshore wave characteristics (red pin); a tide gauge, which gather the water surface elevation in the Senigallia harbor (cyan pin); a USGS-style gauge, collecting the water surface level and velocities in the river, about 1 km upriver of the mouth (green pin). Such instruments will be used to characterize the hydrodynamic forcings of the estuarine flows during the field experiments. Moreover, the data collected by the integrated monitoring system has already been used as input and benchmark for numerical models. Two-dimensional (2D) depth-averaged numerical simulations were run by means of the Delft3D software suite to study specific physical processes evolving at the mouth of the Misa River after some preliminary calibrations (Baldoni et al., 2021, 2022).
Some preliminary modeling of the study area was used to characterize the hydrodynamics of the site and to consequently properly design the field experiment and choose the optimal locations for the UXO deployment (Figure 2).

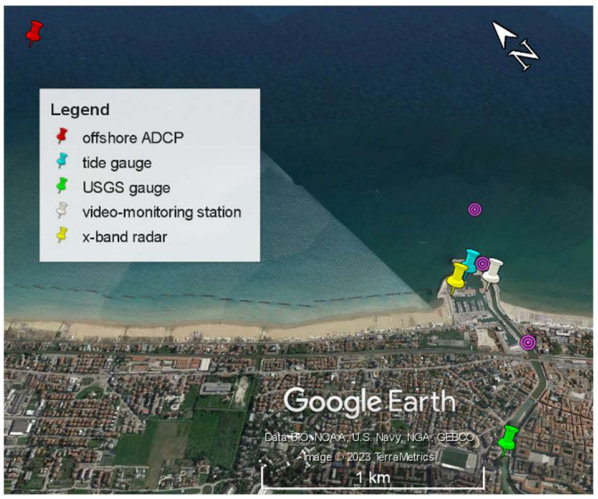

Figure 1 – View of the Misa River monitoring system. The magenta circles indicate the three locations where UXOs are planned to be deployed.

FIELD EXPERIMENTS

The design of the field experiments was done in collaboration with institutions and companies involved in the project and based on some preliminary numerical modeling. The UXOs used in the experiments will be both 1) inerted (empty) ordnances provided by a dedicated service of the Italian Army located in Noceto (Parma, Italy) and 2) steel cylinders built from a local blacksmith (Figure 3).
Field experiments are planned for the period October 2023-

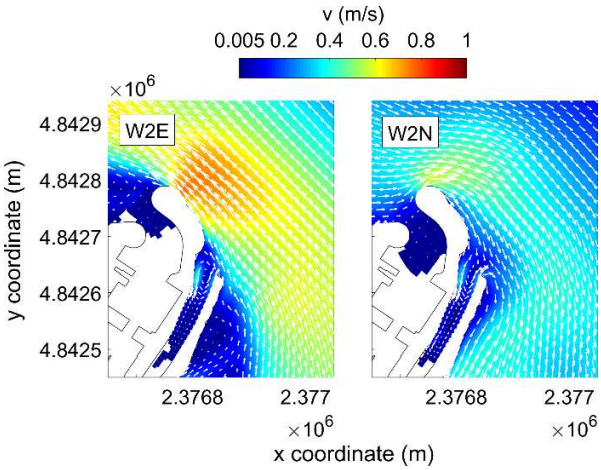

Figure 2 – Current velocities triggered by wave storms characterized by maximum significant wave height of 2 m, coming from E (left panel) and NNE (right panel).

January 2024 at three different locations to observe different sea-river interactions: river dominance; strong sea-river interaction; sea prevalence.
At each location, five objects are planned to be deployed.
UXOs and mock-up ordnances having the same caliber and density, but different shapes will be deployed together to compare their behavior. In fact, state-of-the-art research has shown that the munitions caliber and relative bulk density have the most important effect on the UXO maximum burial depth (Klammler et al., 2020).
Deployments will be performed in relation to expected events of significant wave forcing (sea storms), river discharges (intense or long-lasting rainfalls) and mixed sea-river forced events.
For the first 6 hours of the experiment, when most of the motion is expected, using a pinger-receiver system, divers will follow the signal emitted by a pinger tied to the UXOs. Moreover, we will also tie to the biggest UXO an intelligent tracking system (ITS) made of both a GPS and an AHRS modules to: 1) record data for estimating the UXO position; 2) be able to follow the UXO even if divers cannot get into the water due to adverse meteorological conditions.
For the longer timescale, we plan to follow the biggest UXO through the ITS system and retrieve the position of all the objects from high resolution MultiBeam surveys and a metal detector.

Figure 3 – Left panel: UXOs retrieved from Noceto. Right panel: cylinders built from the blacksmith.

Field data could be used to improve and validate some models to predict UXO mobility and burial (Menzel et al., 2018; Palmsten et al., 2020). Such models require the ambient flow forcing, which can be provided by Delft3D hydro-morphodynamics simulations, together with the object properties and the sediment characteristics.

Results of experimental tests will be presented at the conference.

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