

Model roundup and extension for the current- and wave-induced burial, re-exposure, mobilization and migration of UXO and DMM

MR21-1081

Peter Menzel

Corvus Works GmbH

In-Progress Review Meeting

01/13/2025

Project Team

Corvus Works



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Bottom Line Up Front

- A Simulation tool for burial and mobilization of UXO was developed.
- The site-manager requirements were defined in two site-manager meetings.
- The final Simulations for Fort Pierce are nearly finalized.
- The Lattice Boltzman Method was substituted by the established TELEMAC Model.
- UnMES was not available for Implementation and comparison.
- No further support needed.

Technical Objective

- We will provide tools that can directly be used by site managers to monitor and predict
 - if objects are mobilized by certain weather conditions,
 - in which direction they may be mobilized and
 - if they may be buried or re-exposed.
- The tools will be software to generate GIS-compatible maps.

Technical Approach

Task 1

Applying the existing model.

- Selecting the Area of Interest (site).
- Collecting Data.
- Adapting the UXOmob to the site.
- Stakeholder Dialog.
- Final Reporting and Site Manager Report.
- Final reporting still in progress.

Technical Approach

Task 1

Applying the existing model.

Task 2

Waves, currents and morphodynamics simulation.

- Developing and running Simulations (LBM was planned).
- TELEMAC was applied as it delivers more robust data.
- Spatial and temporal data of waves, currents and morphodynamics.
- Finalized.

Technical Approach

Task 1

Applying the existing model.

Task 2

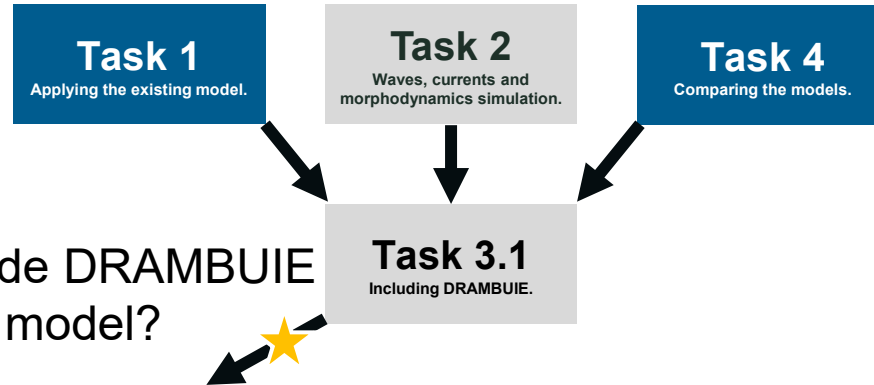
Waves, currents and morphodynamics simulation.

Task 4

Comparing the models.

- Analyzing the existing models.
- Cross-comparison of the models.
- Improving DRAMBUIE.
- Preparing methods for objects migration and treatment of different sediment classes.
- Still in progress. Ending before 01/31/2025.

Technical Approach

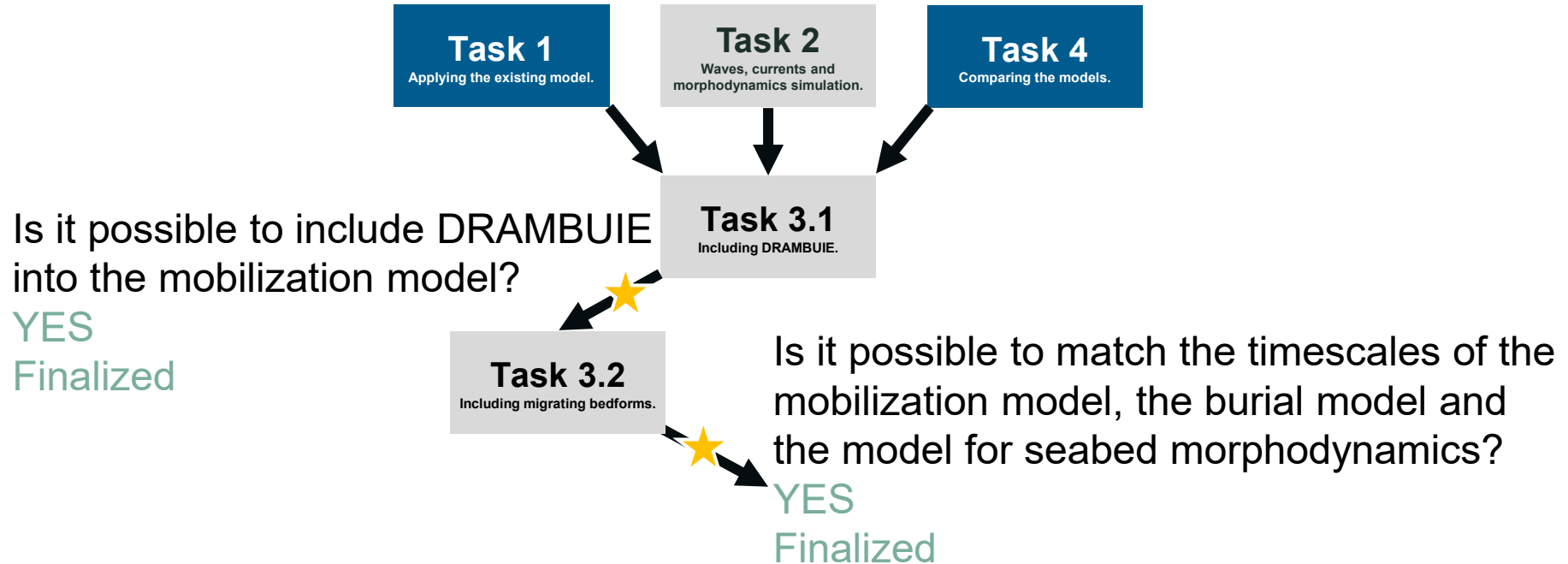


Is it possible to include DRAMBUIE
into the mobilization model?

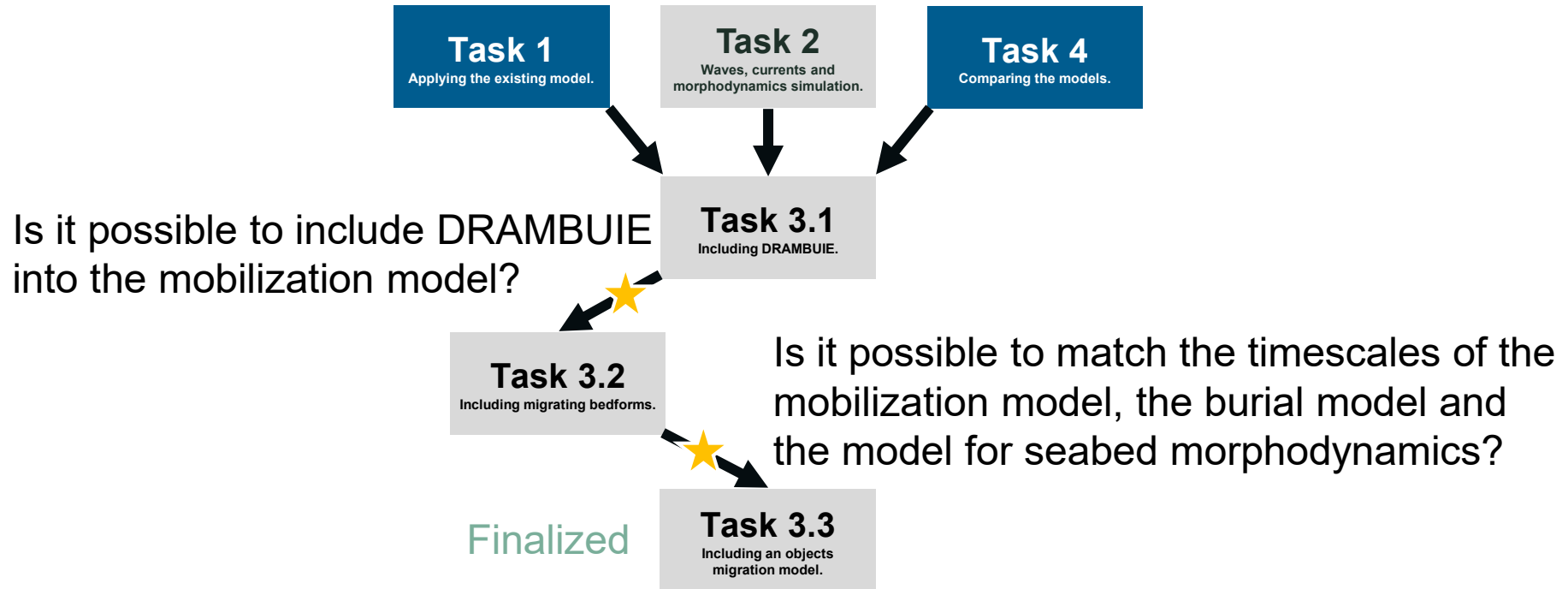
YES

Finalized

Technical Approach

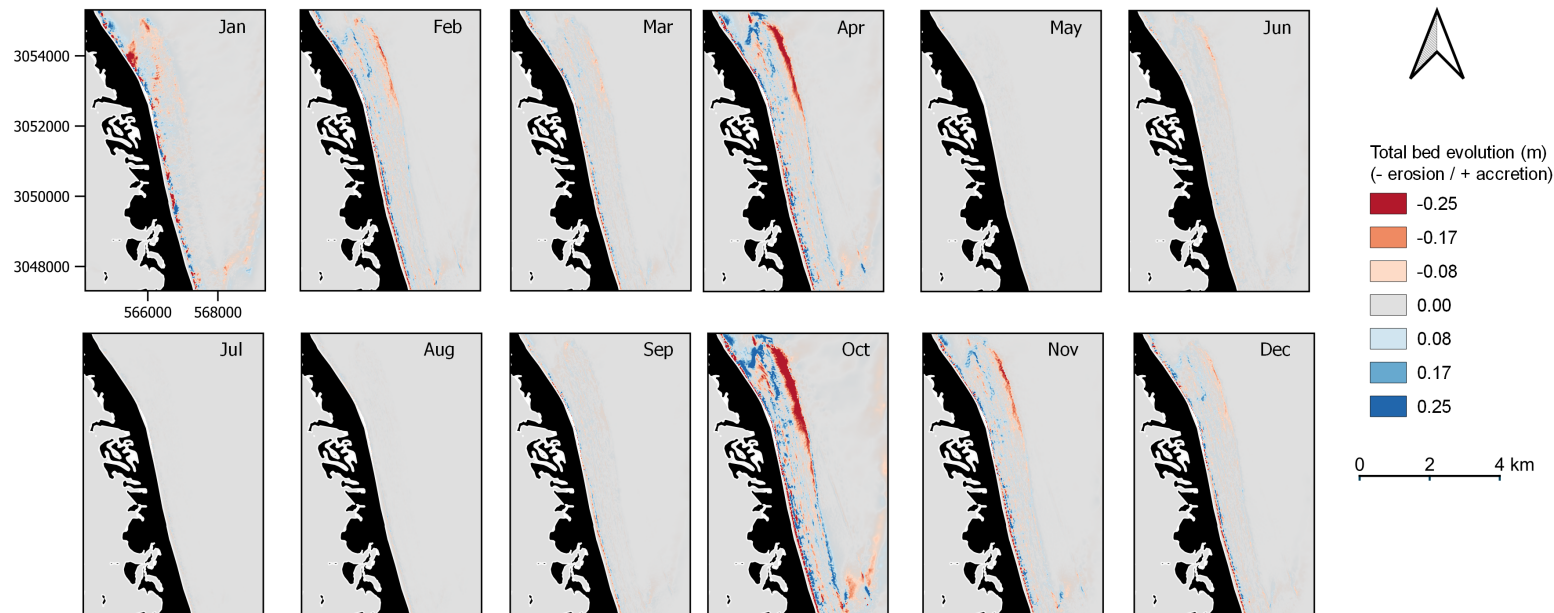


Technical Approach



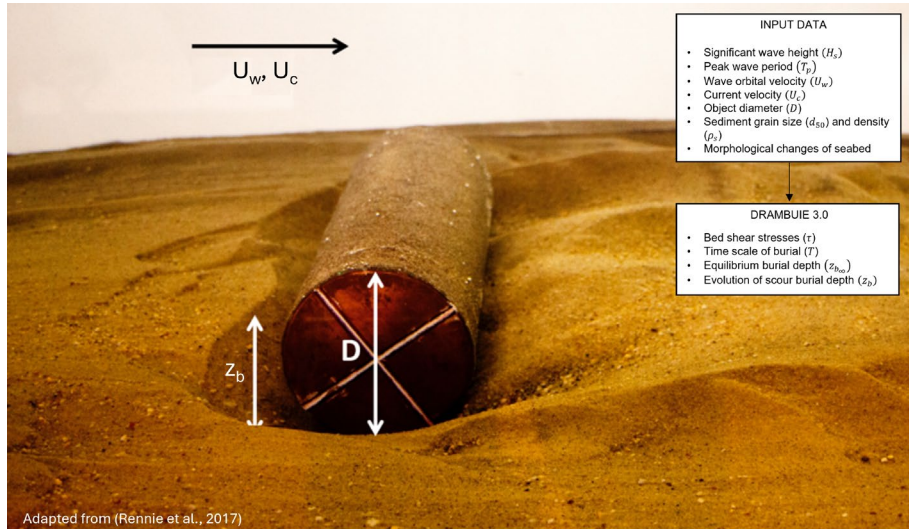
Results to Date

- TELEMAC Simulations (waves and Morphodynamics) for 2016 incl. Hurricane Matthew



Results to Date

- An improved burial prediction approach has been implemented, combining an equilibrium burial model (Friedrichs et al., 2018) and a time evolution model (Whitehouse, 1998).



Friedrichs, C., Rennie, S. E. and Brandt, A., 2018. *Simple Parameterized Models for Predicting Mobility, Burial and re-exposure of underwater munitions*. SERDP Final Report MR-2224, Virginia Institute of Marine, Science, William & Mary.

Rennie, S., Brandt, A. and Friedrichs, C., 2017. *Initiation of motion and scour burial of objects underwater*. *Ocean Engineering*, 131, 282-294.

Whitehouse, R., 1998. *Scour at marine structures - A manual for practical applications*. London: Thomas Telford.

Results to Date

- Modern C++ Standard: C++20

- Modern Build System: bazel

Codebase Size:

- 336 Files
- 35311 code lines
- 9491 comment lines
- 12 Interfaces

Testing:

- Fully automated static and dynamic code quality assurance
- 525 Unit and Integration Tests
- 14298 code lines

Dependencies:

- Fully integrated external dependencies
- Fully automated deployment of external dependencies



UXOmob

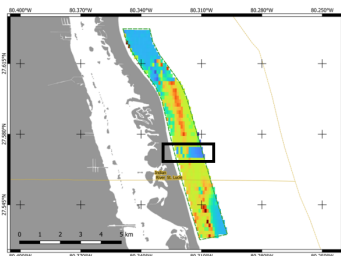
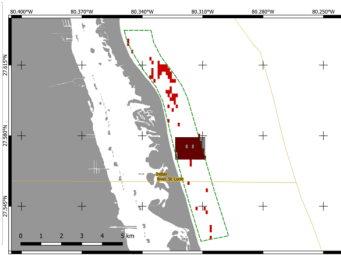


- Several Interfaces possible: (App, Shell, Webbrowser,...)

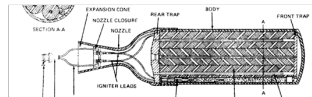
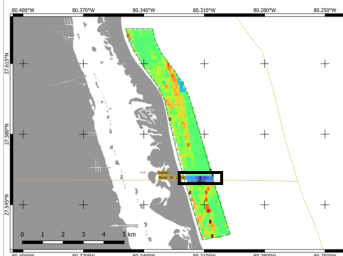
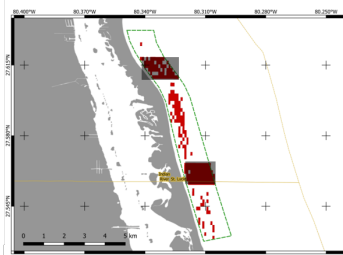
Results to Date



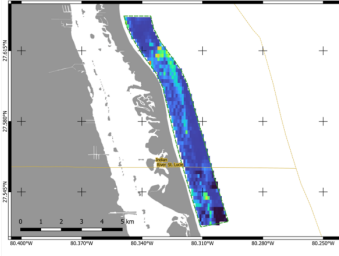
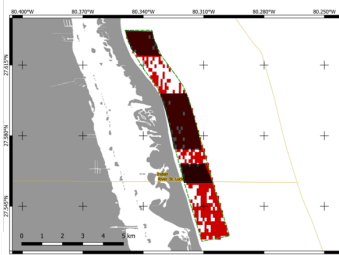
1000 lbs
General Purpose Bomb



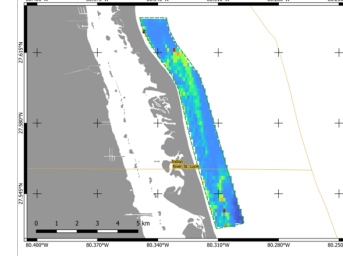
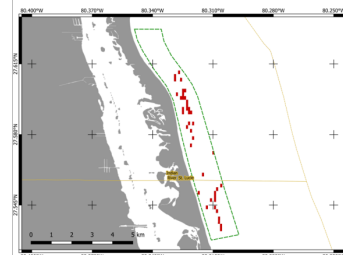
500 lbs
General Purpose Bomb



Rocket Motor M3A2



155 mm HE 107

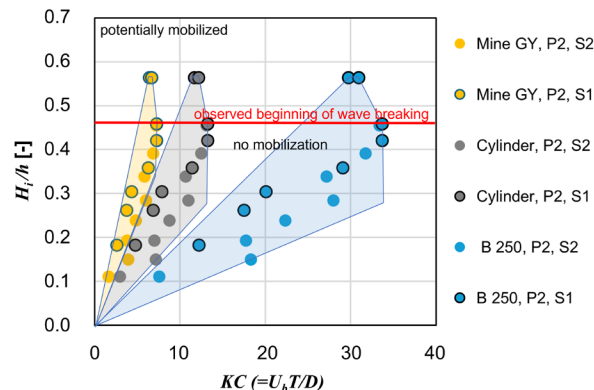
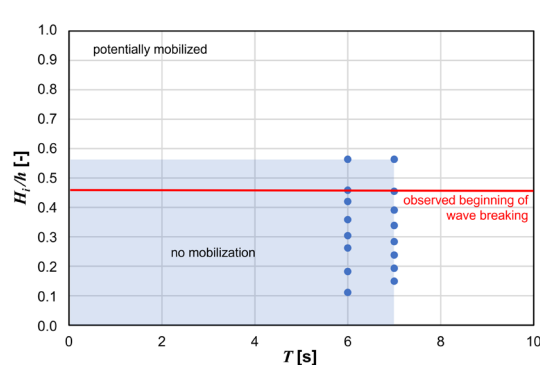


Legend
 Area of Interest
 County
 Land
 Potential Mobilisation

Legend
 Area of Interest
 County
 Land
 Burial Depth in [m]
 1
 0

Results to Date

■ Verification



Menzel, P.; Wolters, G.; Drews, A.; Real scale experiments on the wave-induced burial and mobilization of Unexploded Ordnance on the seafloor; Applied Ocean Research; Volume 154; 2025; 104342; ISSN 0141-1187; <https://doi.org/10.1016/j.apor.2024.104342>.



Real scale experiments on the wave-induced burial and mobilization of Unexploded Ordnance on the seafloor

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Burial
Mobilization

ABSTRACT

As a result of armed conflicts, large amounts of Unexploded Ordnance (UXO) and Discarded Munition Material (DMM) are expected to be located on the seafloor, especially in coastal regions. During Offshore Construction, strategic site monitoring and systematic remediation activities, the behavior of such objects in waves and currents is of huge interest as potential mobilization of objects after a survey or clearance activity could change the situational picture again. From findings and reports it is assumed that UXO and DMM tend to migrate over the seafloor for long distances. Here, anthropogenic effects like fishing or dredging activities are underestimated, these scientific approaches clearly show that mobilization and migration of UXO over long distances does not occur. However, theoretical analysis remain theories until they are proven by experiments. For this reason, three large representative objects were investigated under real scale wave conditions in the Delta Flume at DLR. The objects represent real scale models of UXO found in the North Sea as well as realistically shaped objects. All objects as well as the flume tank were instrumented to measure the full environmental conditions as well as the behavior of the objects. The sediment represents typical sand found in the North Sea and the seabed morphology and soil conditions were closely monitored during the experiments. The experiments support the theoretical models that predict burial but no mobilization also under extreme wave conditions.

1. Introduction

As a result of warfare actions, huge amounts of Unexploded Ordnance (UXO) and Discarded Munition Material (DMM) are expected to rest on the floor of the seas. In German waters of the North and Baltic Sea, 1.6 million tons of UXO and DMM are expected to be located on and in the seabed (Günther et al., 2011). Although DMM are expected to be not found and most of the UXO are expected to be not active anymore due to aging processes such as corrosion, they present a potential risk to humans in different ways. Due to corrosion, the toxic compound becomes more and more exposed to the water and thus can find its path into the marine food chain (Herr and Fischer (2013)). In preparation of ground penetrating offshore construction works, such as cable laying activities, the potential risk of an explosion due to direct intense contact needs to be assessed. As a result of these aspects, the regions of direct impact of ground penetrating machinery, including a certain safety region, are usually closed from critical objects (Wolters and Frey, 2022). After such clearance activities, the area usually is declared as free from UXO for a certain time frame. The given expiration time of the certificate is often based on caution rather than physical process knowledge. The main driver for this is the assumption that UXO and DMM could migrate over larger distances than have been cleared due to wave and current actions. During the last years, much progress in understanding of the physical processes was achieved. The burial process of objects is mainly investigated by the authors. Here, different effects need to be considered. The process of soil burial or burial by scour is caused by a local increase of the shear stresses due to the flow around the objects. Due to this, the local sediment transport budget is disturbed and erosion is found, which leads to a failure of the supporting sediment below the object. The object changes its position mainly in vertical direction (downward) (Menzel et al., 2018; Jansen and Jansen, 1996; Reineke et al., 2017; Chu et al., 2023). This vertical displacement

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URL: <http://www.fraunhofer.de>, <https://www.fraunhofer.de/en>, <https://www.fraunhofer.de/en> (P. Menzel), <https://www.fraunhofer.de/en> (G. Wolters), <https://www.fraunhofer.de/en> (A. Drews).

<https://doi.org/10.1016/j.apor.2024.104342>
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Next Steps

- Final Reporting
- Executive Summary
- Voluntary Site Manager Report
- Proposed additional deliverables
 - Webinar
 - Stakeholder Presentation
- Final Invoicing: 02/15/2025

Technology Transfer

- Webinar
- Stakeholder Presentation
- Voluntary Site Manager Report
- Further Transfer through ESTCP was not supported.

Issues

- No Issues.

BACKUP MATERIAL

These charts are required, but will only be briefed if questions arise.

MR21-1081: Model roundup and extension for the current- and wave-induced burial, re-exposure, mobilization and migration of UXO and DMM

Performers: Peter Menzel, Tommaso Attili, Karsten Breddermann, Sebastian Escobar, Daniel Klembt, Michiel Knaapen, Helen Morrison, Mirko Rummelhagen, Nick Tavouktsoglou, Richard Whitehouse

Technology Focus

- *Simulation model, based on analytical approaches for complex processes*

Research Objectives

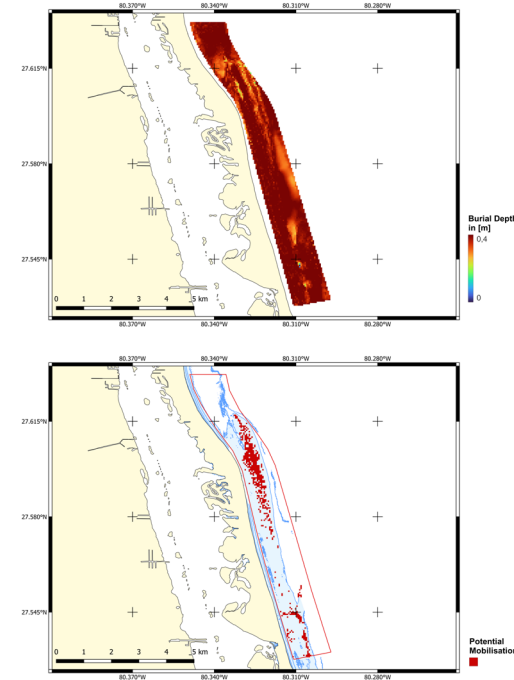
- *Combining different models and applying them on a FUDS.*

Project Progress and Results

- *UXOmob combines the mobilization model with the new DRAMBUIE 3.0 and reproduces scour burial, morphodynamics and mobilization.*
- *A Drift Model is running separately.*
- *A close stakeholder dialog was introduced and the requirements of the site manager are addressed.*

Technology Transition

- *Handover of all results and a full documentation to SERDP.*



Plain Language Summary

- During the 2nd World War, Bombs and Rocket were lost in the Ocean close to our Beaches. They can be very dangerous.
- We answer the following questions:
 - Are they covered with sand today? If yes, how much sand?
 - Could it be possible that the sand will be removed by currents and waves so that the Bombs are not covered anymore?
 - Can waves or currents push the Bombs so that they roll maybe in direction of the beach?
- We are doing this by running a very complex computer program. For this, we also investigate, what happens on the seafloor.
- There is a computer program and a report for the people who have to search and recover the Bombs. With the program we predicted, where to look for the Bombs.

Impact to DoD Mission

- Two Stakeholder Meeting with the Site Manager were held.
- A common Proposal with CENHC was submitted. (rejected)
- In general, the Site Manager and CEHNC directly could use the results for planning and risk assessments.
- In general, the software could be used by CEHNC to produce the results by themselves.

Action Items

- No open Action Items.

Publications

- Published:

- Escobar, S., Whitehouse, R. J. S., Benson, T., & Knaapen, M. A. (2023). Hydro-morphodynamics modelling for the mobilization assessment of UXOs and DMMs. Proceedings of the 29th TELEMAC-MASCARET Users Conference 2023.
- Klemmt, D.; Menzel, P.; Breddermann, K.; Wranik, H.; Miethe, T.; Determination of the drag, lift and added mass coefficients of special unexploded ordnance (UXO) as a function of the Reynolds number and the burial depth. Applied Ocean Research, 146 (2024) 103946, <https://doi.org/10.1016/j.apor.2024.103946>
- Menzel, P.; Wolters, G.; Drews, A.; Real scale experiments on the wave-induced burial and mobilization of Unexploded Ordnance on the seafloor; Applied Ocean Research; Volume 154; 2025; 104342; ISSN 0141-1187; <https://doi.org/10.1016/j.apor.2024.104342>.

- Submitted:

- Escobar, S., Attili, T., Whitehouse, R. J. S., Benson, T., & Knaapen, M. A. (2024). Hindcast modeling of morphodynamic changes and UXO burial caused by Hurricane Matthew 2016, Fort Pierce, Florida.

Literature Cited

- Escobar, S., Whitehouse, R., Benson, T., & Knaapen, M. (2023). Hydro-morphodynamics modelling for the mobilization assessment of UXOs and DMMs. In Proceedings of the 29th telemac-mascaret users conference 2023. Karlsruhe, Germany.
- Friedrichs, C., Rennie, S. E. and Brandt, A., 2018. Simple Parameterized Models for Predicting Mobility, Burial and re-exposure of underwater munitions. SERDP Final Report MR-2224, Virginia Institute of Marine, Science, William & Mary.
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Additional Slide(s) for High-Quality Photos

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hwrwallingford CORVUS WORKS

UXOmob

Fort Pierce

MAIN NETCDF DATA ENVIRONMENT OBJECTS WAVE CHART

Main Settings
Theme: light
Dark

Simulation Data
ENVIRONMENT FILE: .\UXOmobData\env.nc
OBJECT FILE: ...UXOmobData\obj.csv
WAVE FILE: .\UXOmobData\wave.nc
MORPHOLOGY FILE: .\Tom_F1_ords4_out.nc

Wave Model
Stokes 3rd

Wave Breaking Model
Goda et al.

Wave Spectrum
JONSWAP

Burial Model
DRAMBUE 3.0

Simulation Configuration
Reference system
WGS 84 80.4 W 27.5 N 80.2 W 27.7 N

Simulation Time
0 12/2/2018

Simulation Setup Overview
Preview 1: Burial Depth
Preview 2: Mobilization

Special Wave Data
Special Coefficients
TELEMAC Settings
dbSEABED Settings

Simulation Parameters
☐ Immobilize Object
☒ Double Precision
☒ Stone Forces
☒ Save Intermediate Steps
☐ Use Wave Profiles
☐ Simulate Seabed Morphology

Export to QGIS

START SIMULATION
Calculating... 80%
Simulation is Running

Recycle Bin

Search

05:00 PM
12/03/2024

Additional Slide(s) for High-Quality Photos



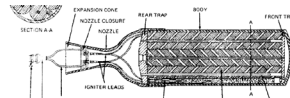
Additional Slide(s) for High-Quality Photos



1000 lbs
General Purpose Bomb



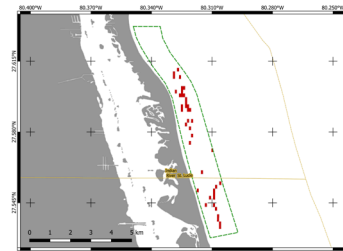
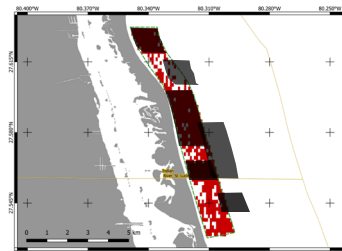
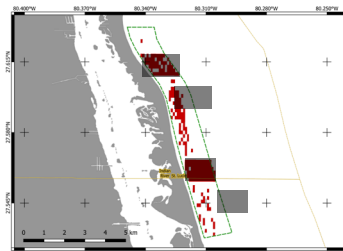
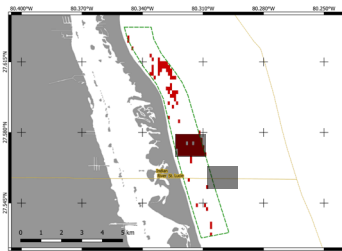
500 lbs
General Purpose Bomb



Rocket Motor M3A2

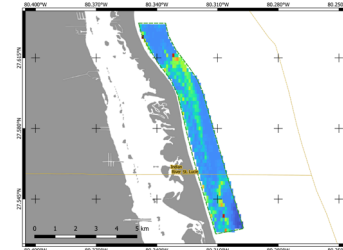
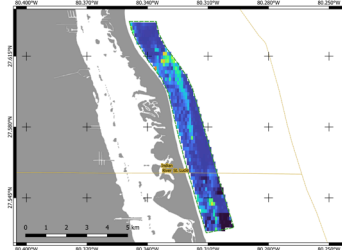
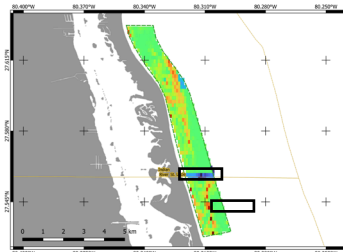
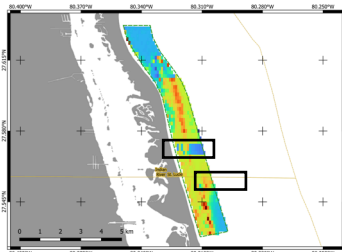


155 mm HE 107



Legend

- Area of Interest
- County
- Land
- Potential Mobilisation



Legend

- Area of Interest
- County
- Land
- Burial Depth in [m]

1

0

Acronym List

CEHNC	U.S. Army Engineering and Support Center, Huntsville
DMM	Discarded Military Munitions
DRAMBUIE	Defense Research Agency Mine Burial Environment
UXO	Unexploded Ordnance Devices