Parameterizing Munitions Mobility and Burial in Riverine Environments

MR21-1227

Dr. Carter DuVal

U.S. Naval Research Laboratory

In-Progress Review Meeting

12 Jan 2026

Project Team

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Other Performers:
Mr. Ed Braithwaithe, Engineer, NRL – materials / electronics design and fabrication
Mr. Grant Lockridge, Engineer, NRL – Smart surrogates
Mr. Samuel Griffith, Geologist, NRL – sediment processing
Ms. Sun Woo Park, Graduate Student, Udel – field data collection and analysis
Mr. Grant Otto, Field Technician, Udel – AUV surveying, vessel handling
Ms. Catherine Hughes, Graduate Student, Udel – field sampling, sediment processing

Bottom Line Up Front

Study to quantify and model mobility and burial of munitions and explosives of concern (MEC) in dynamic riverine environments using a Munitions Response Site (MRS).

Completed 2 successful field deployments, including a ~10 month deployment with 30 surrogate munitions tracked.

Calibrated numerical model and built site climatology of MRS

Remaining tasks:

- Parameterized models for UnMES

Technical Objective

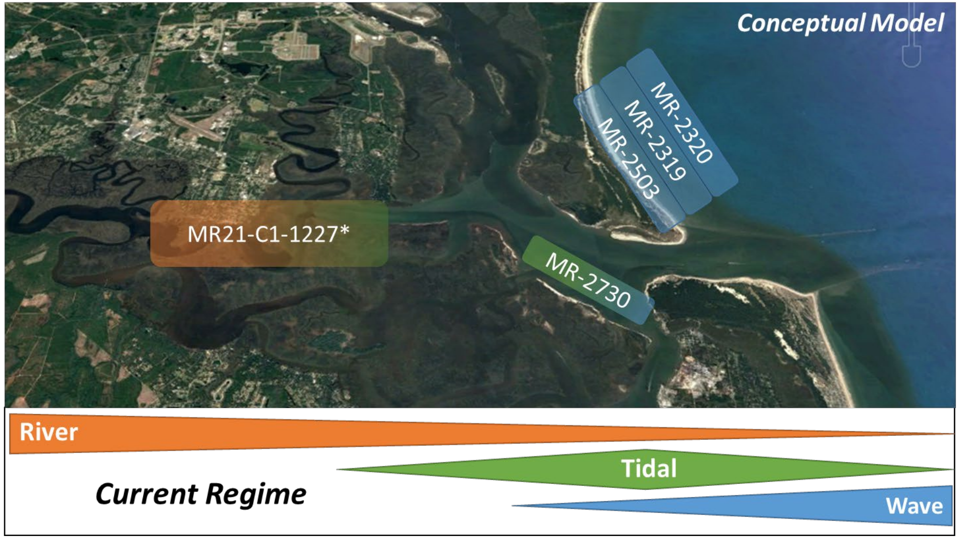
Our primary objectives are to:

1. Quantify mobility and burial of munitions and explosives of concern (MEC) in dynamic riverine environments using a Munitions Response Site (MRS)
2. Identify and reduce the parameters necessary to predict MEC mobility and burial in riverine sites for models such as the Underwater Munitions Expert System (UnMES) (MR-2227, MR-2645, and MR19-1126).

The long-term goal is to reduce the amount of independent field observations and model parameters required to effectively operate MEC mobility and burial predictive models for MRS site management.

Technical Background

- Existing Data / Data Gap
  - Recent SERDP munitions mobility studies focused on wave or tidally dominated environments
- At least 288 identified FUDS or MRS on / near river systems (USACE FUDS 2013 GIS data)
  - 48 fall on major river / streams
  - 11 or more fall in close proximity to public receptors (pers. comm Bryan Harre, NAVFAC)

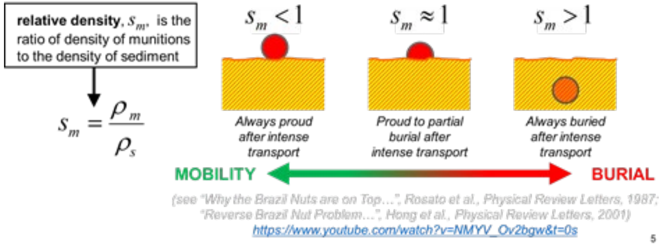


*current study

Technical Background

- Mobility & burial previously linked to:
  - MEC density
    - MEC denser than sediment bury, less dense mobilize
  - Sediment type (cohesive / non-cohesive)
    - Controls burial via scour / bed liquefaction / bearing capacity

- A new environment introduces new parameters that must be considered:
  - Channel gradient (i.e. slope & aspect)
    - Decreases critical threshold for mobility?
  - River flood / discharge
    - Greatly increase current forcing and sediment transport
  - Channel erosion / deposition
    - Exposure or burial of historic MEC?



Calantoni MR-2320

Potomac River at Great Falls, VA

Courtesy Sundance Institute

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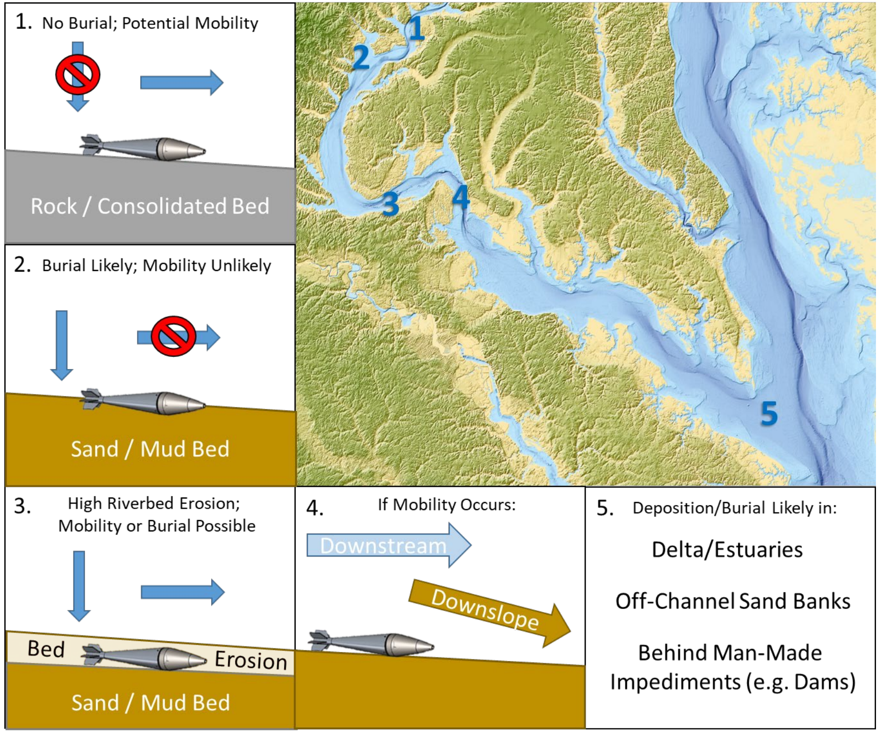
Technical Background



- The pronounced variability of rivers complicate direct translation of previously observed and modeled MEC mobility and burial
- Conceptual model combining the MEC research with expected conditions in riverine environments
  - Requires field observations to validate and modify existing / develop new parameterized relationships

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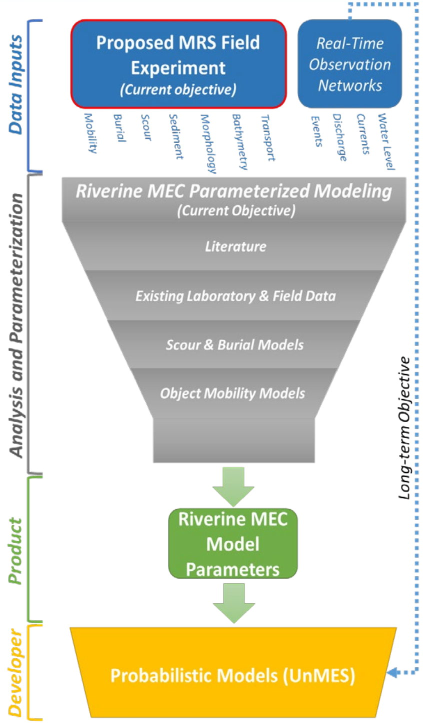
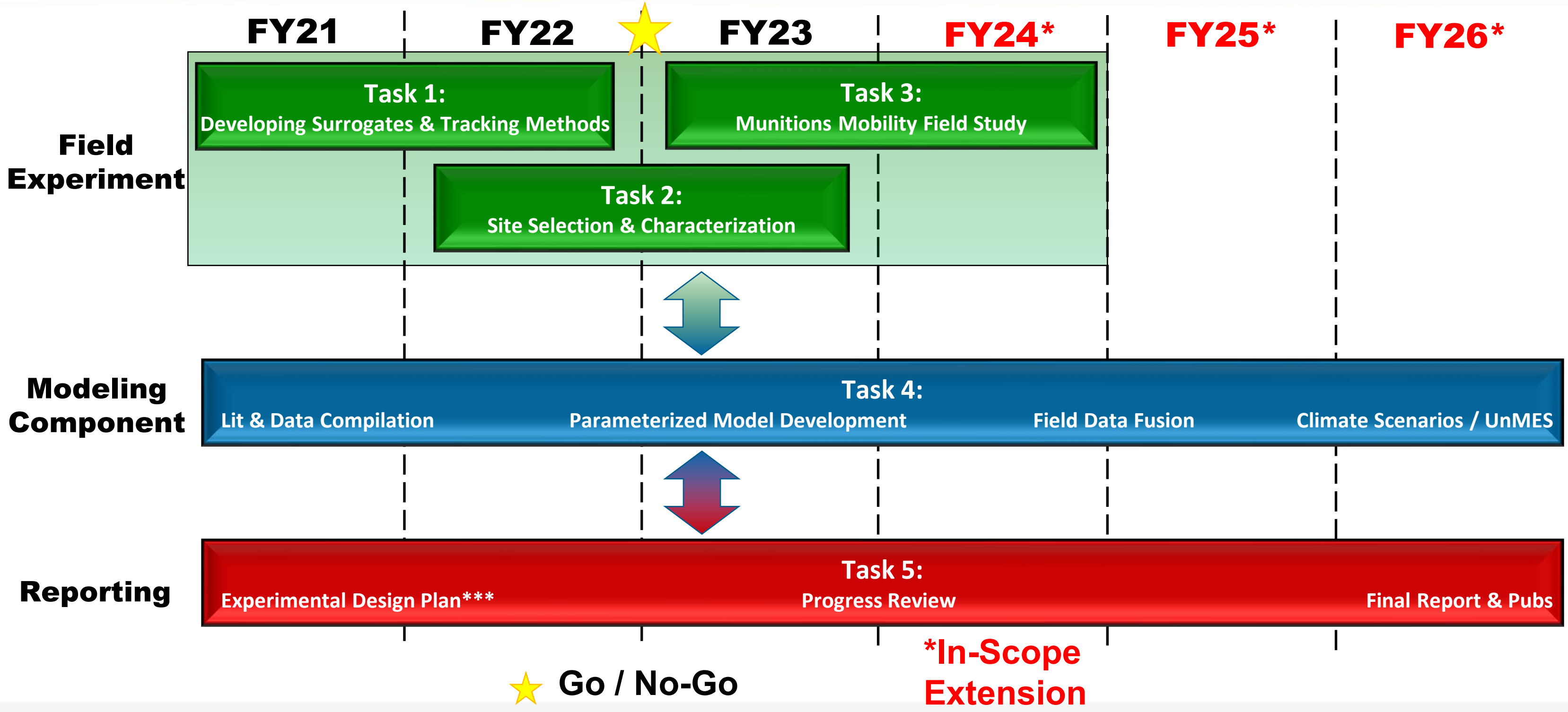
Technical Approach

- This study will use a two part approach:
  1. An *in situ* experiment at a riverine MRS (or proxy site)
     - Provide needed observations to develop / calibrate parameterized models
  2. Parameterized modeling of munitions mobility and burial in rivers
     - Leverage existing literature, real-time observation & operational hydrodynamic modeling
     - Provide bridge to leverage real-time observation and forecast models for MEC probabilistic modeling

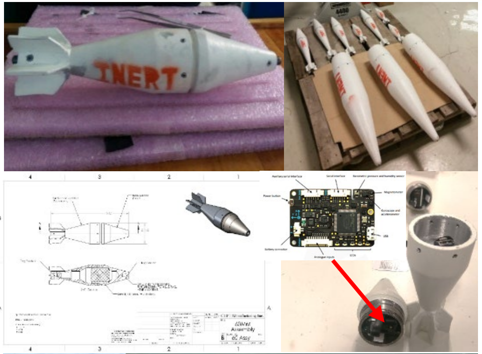


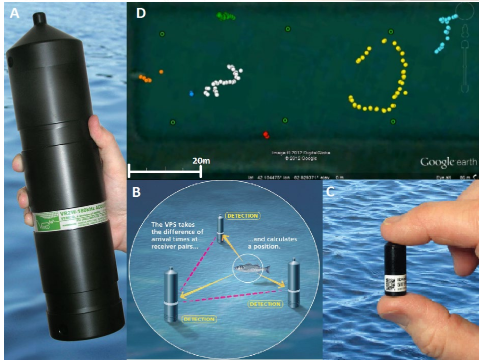
Technical Approach



Task 1: Development of MEC Surrogates and Tracking Methodology

- **Goal:** Provide quantitative and *statistically significant* observations of MEC mobility / burial
- **Subtask:** Construct a suite of instrumented and simple surrogates
  - Leverage existing instrumented surrogates (MR-2730)
  - Design and build >=20 simple, inexpensive surrogates
- **Goal:** Monitor surrogate mobility and burial *in situ*
- **Subtask:** Modify / refine Vemco VPS (acoustic tracking system) methods for riverine application
  - Incorporate Vemco Fathom Live monitoring





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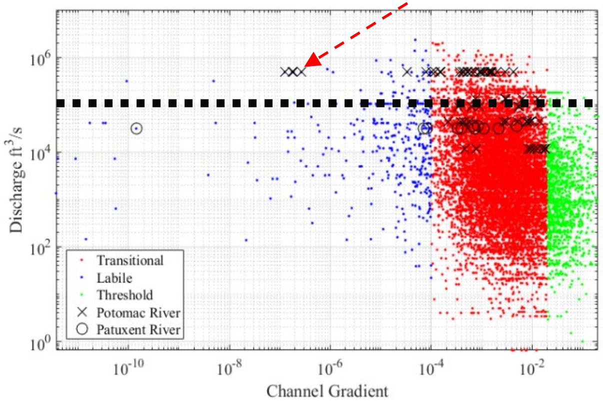
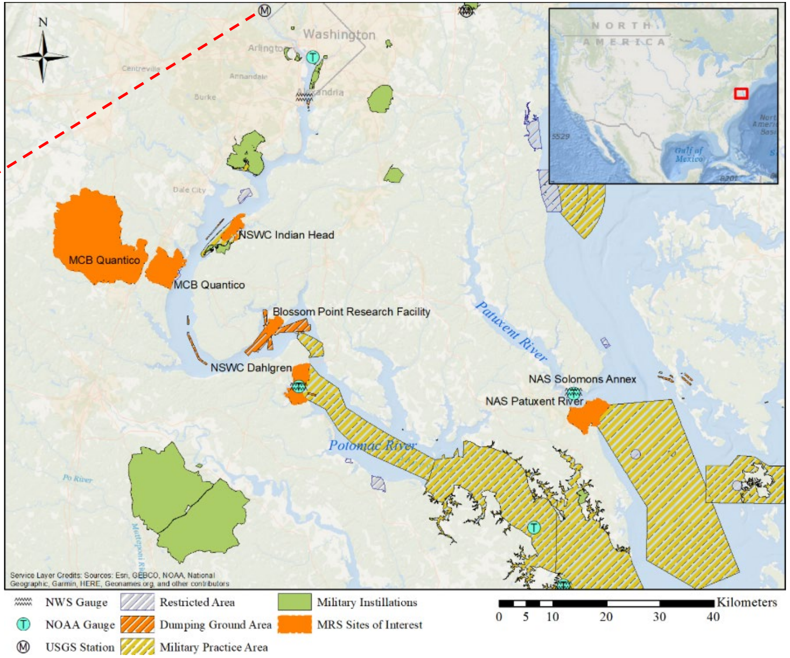
Task 2: Site Selection & Geophysical Site Characterization

- **Goal:** Identify field experiment site (MRS or proxy site)
- **Task:** Work with SERDP / MRS site managers to identify appropriate study location & permitting

♦ Potomac / Patuxent Rivers contain multiple MRS

♦ Short recurrence interval for high-discharge (re 100000 ft^3/s discharge)





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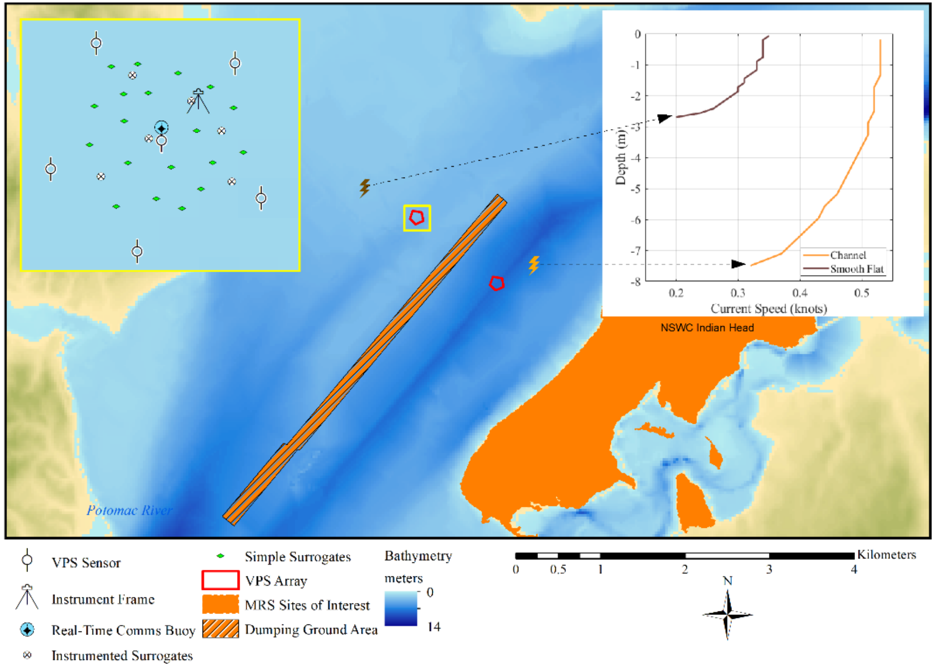
Task 3: Munitions Mobility Field Study

- **Goal:** *In situ* observations of munitions mobility / burial
- **Task:** Extensive field experiment at / near MRS
  - Maximize coverage of potential conditions / parameter space
    - Sediment type
    - Depth
    - Currents
  - Target seasonal window of increased discharge



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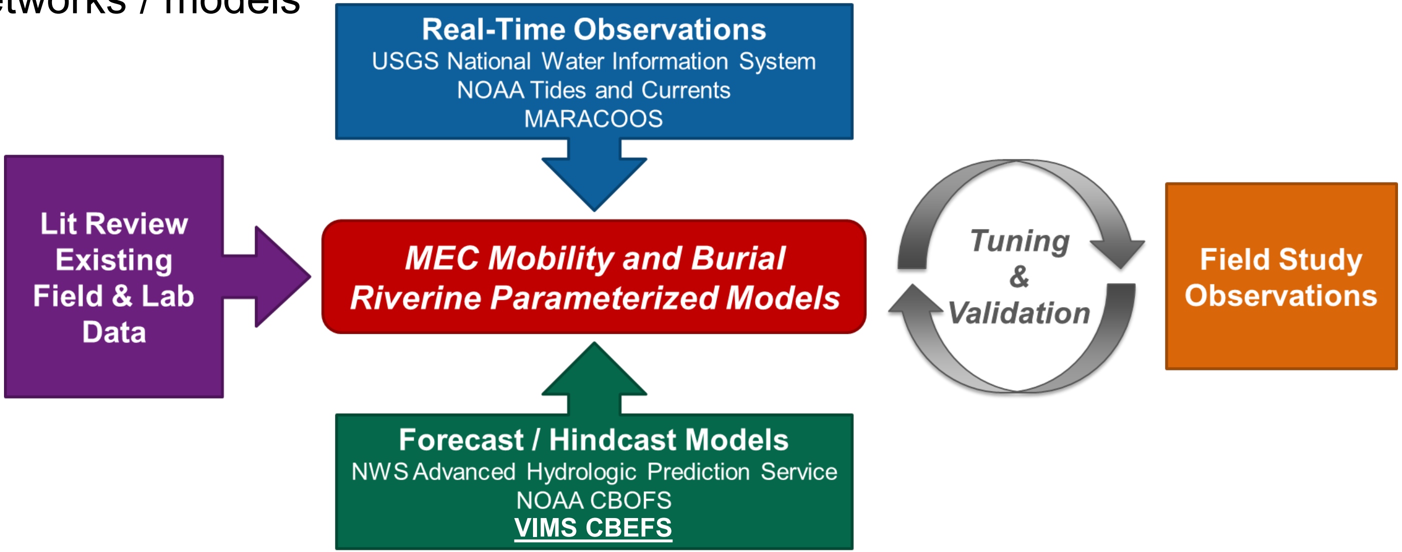
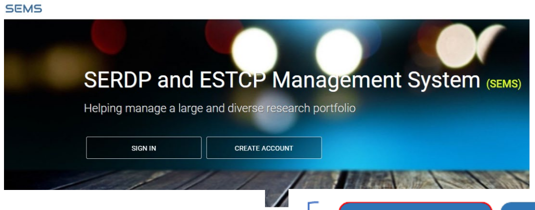
Task 4: Data Analysis and Model Integration

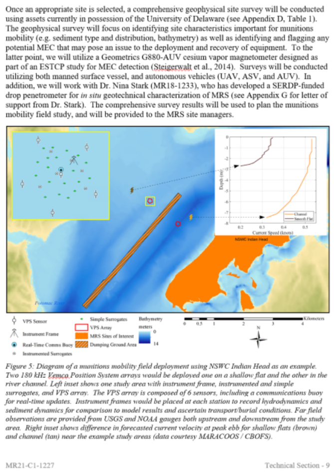
- **Goal**: Parameterized relationships for UXO mobility and burial in riverine environments
- **Task**: Data analysis and parametrized model development leveraging field experiment and observational networks / models



Task 5: Reporting

- Experimental Design Plan***
  - Go / No-Go Deliverable
- Data / Model Transfer
  - UnMES (Rennie MR19-1126)
  - MRS Site Manager(s)
- Project Reporting
  - Finances
  - Quarterly Reports
  - IPR
  - SERDP & ESTCP Symposium
  - Final Report



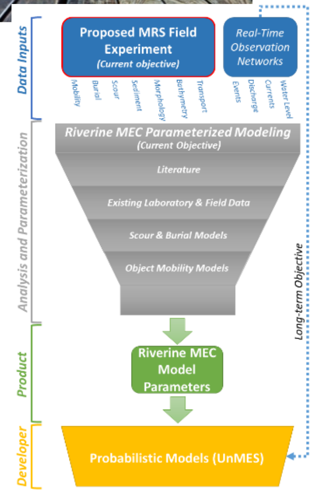


Once an appropriate site is selected, a comprehensive geophysical site survey will be conducted using assets currently in possession of the University of Delaware (see Appendix D, Table 1). The geophysical survey will focus on identifying site characteristics important for munitions mobility (e.g. sediment type and distribution, bathymetry) as well as identifying and flagging any potential MEC that may pose an issue to the deployment and recovery of equipment. To the latter point, we will utilize a Geometrics G880-AUV cesium vapor magnetometer designed as part of an ESTCP study for MEC detection (Steigerwalt et al., 2014). Surveys will be conducted utilizing both manned surface vessel, and autonomous vehicles (UAV, ASV, and AUV). In addition, we will work with Dr. Nina Stark (MR18-1233), who has developed a SERDP-funded drop penetrometer for *in situ* geotechnical characterization of MRS (see Appendix G for letter of support from Dr. Stark). The comprehensive survey results will be used to plan the munitions mobility field study, and will be provided to the MRS site managers.

VPS Sensor
Instrument Frame
Real-Time Comms Buoy
Instrumented Surrogates
Simple Surrogates
VPS Array
MRS Sites of Interest
Dumping Ground Area
Bathymetry meters 0 14
0 0.5 1 2 3 4 Kilometers
N

Figure 5: Diagram of a munitions mobility field deployment using NSWC Indian Head as an example. Two 180 kHz Vemco Position System arrays would be deployed one on a shallow flat and the other in the river channel. Left inset shows one study area with instrument frame, instrumented and simple surrogates, and VPS array. The VPS array is composed of 6 sensors, including a communications buoy for real-time updates. Instrument frames would be placed at each station to record hydrodynamics and sediment dynamics for comparison to model results and ascertain transport/burial conditions. Far field observations are provided from USGS and NOAA gauges both upstream and downstream from the study area. Right inset shows difference in forecasted current velocity at peak ebb for shallow flats (brown) and channel (tan) near the example study areas (data courtesy MARACOOS / CBOFS).

MR21-C1-1227 Technical Section - 9



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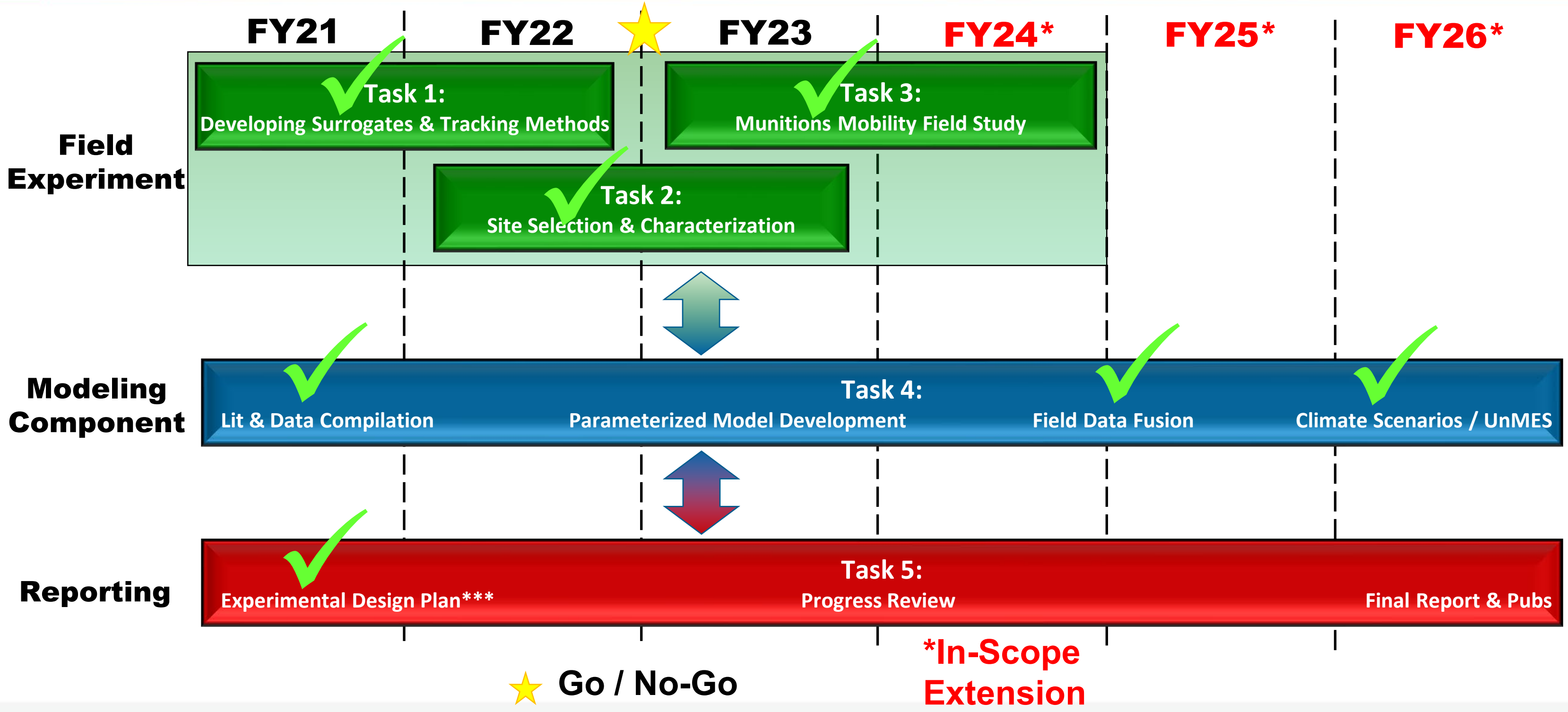
Results to Date



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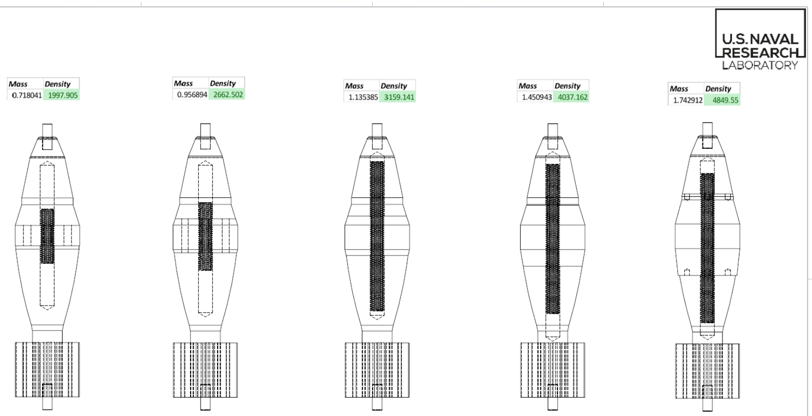
Task 1: Surrogate Fabrication

- Fabricated
  - ♦ 60mm mortar (5x)
  - ♦ 81mm mortar (5x)
  - ♦ 4” Projectile (5x)
  - ♦ 6” Projectile (5x)
- Densities from 2 g/cm^3 – 5 g/cm^3
- Materials
  - ♦ Steel
  - ♦ Nylon (3D Printed)
  - ♦ PVC / PET
- Cost per unit:
  ~ $175 - $500



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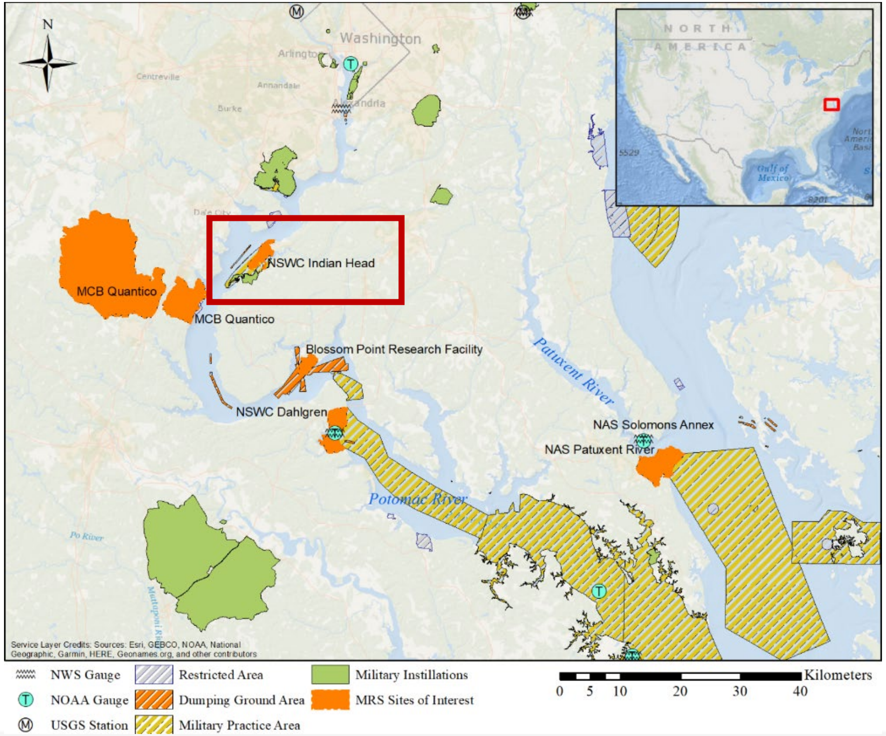
Task 2.1: Site Selection

- NSF Indian Head, MD
  - 12000 Acres
  - Sediments:
    - 36% Clay, 27% Silt, 37% Sand
    - Median grain size (0.01mm – Silt)
- Battleship Gun test 1891-1921
  - 1-in to 16-in AP & HE projectiles
- Rockets 1946-1947



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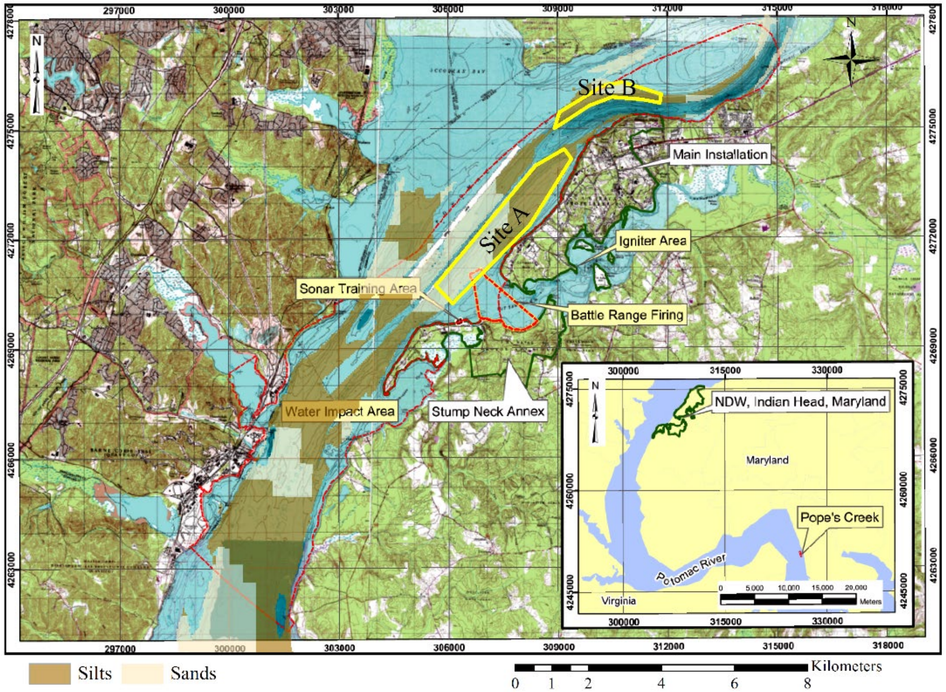
Task 2.1: Site Selection

NSF Indian Head

- Identified potential study areas on:
  - ♦ Depth
  - ♦ Channel Location
  - ♦ Sediment Type (usSEABED)
  - ♦ Underwater Hazards
- Identified 2 sites within Water Impact Area
- Geophysical Survey (10-12 Oct, 2022)
  - ♦ Multibeam bathymetry, side-scan sonar, magnetometry



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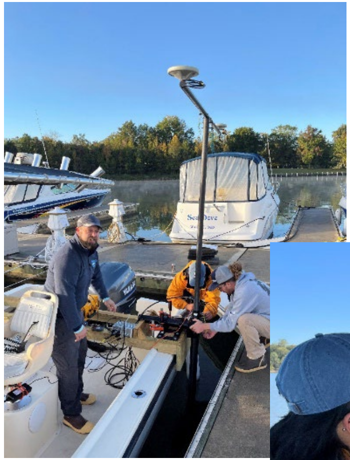
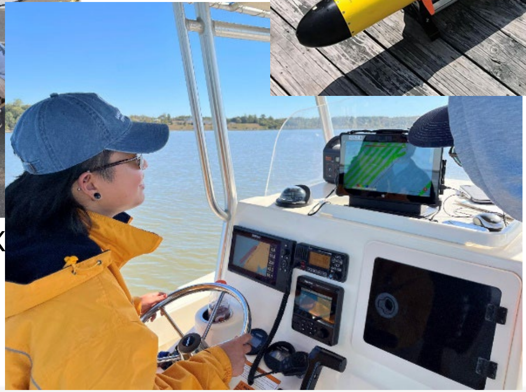
Geophysical Survey 10-12 Oct, 2022

1. Characterize site bathymetry and sediments
2. Anomaly detection and avoidance



NORBIT iWBMSh-STX
Mulitbeam sonar



L3Harris IVER3
with Edgetech 2205 PMES

Marine Magnetics Magnetometer

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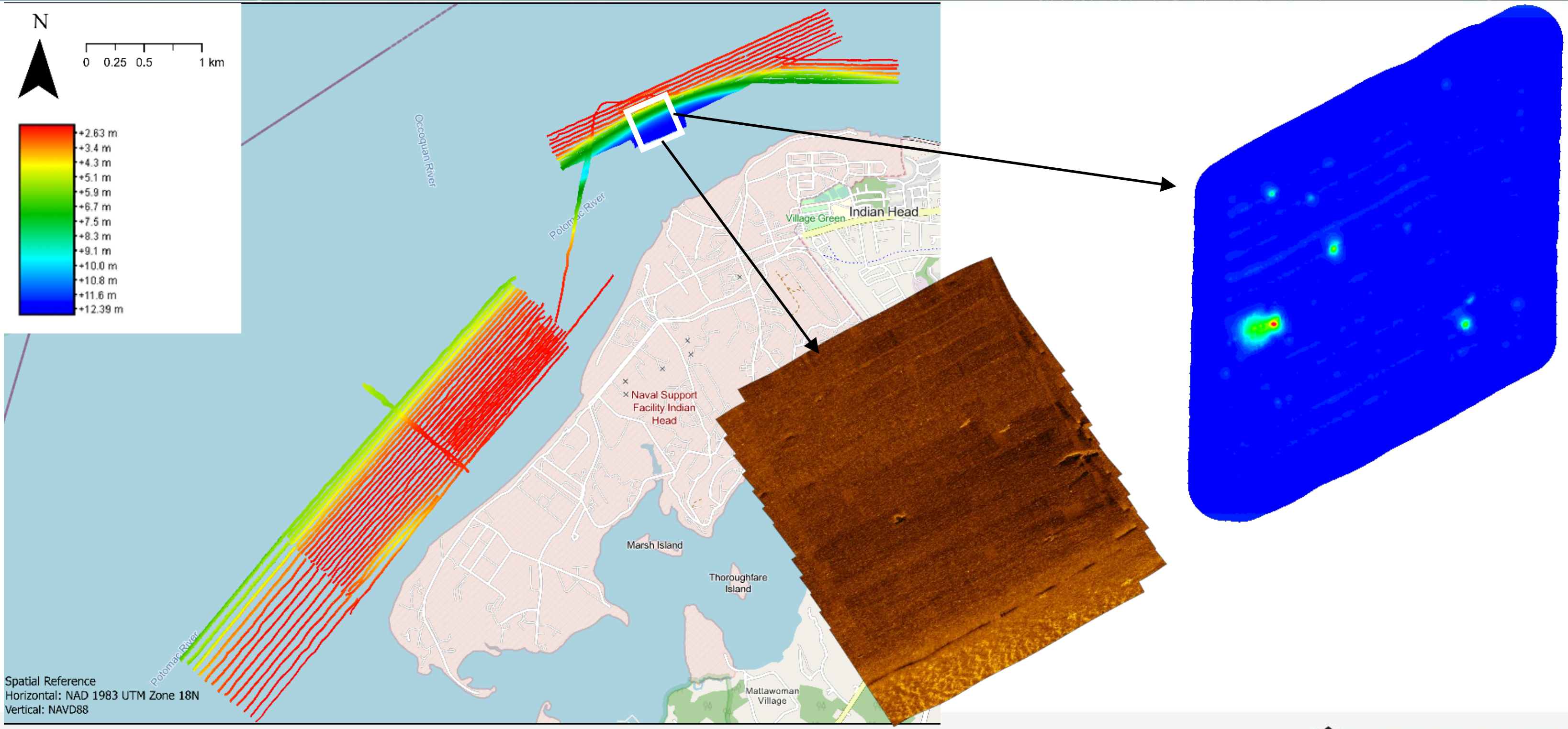
Task 2.2: Site Selection & Geophysical Site Characterization



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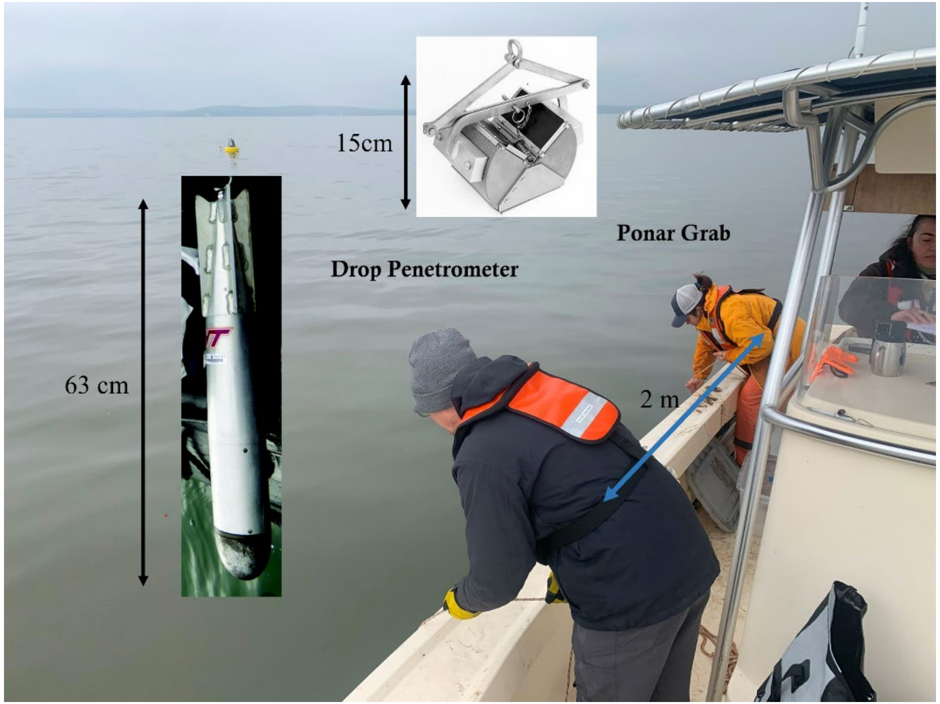
Task 2.3: Geotechnical Characterization



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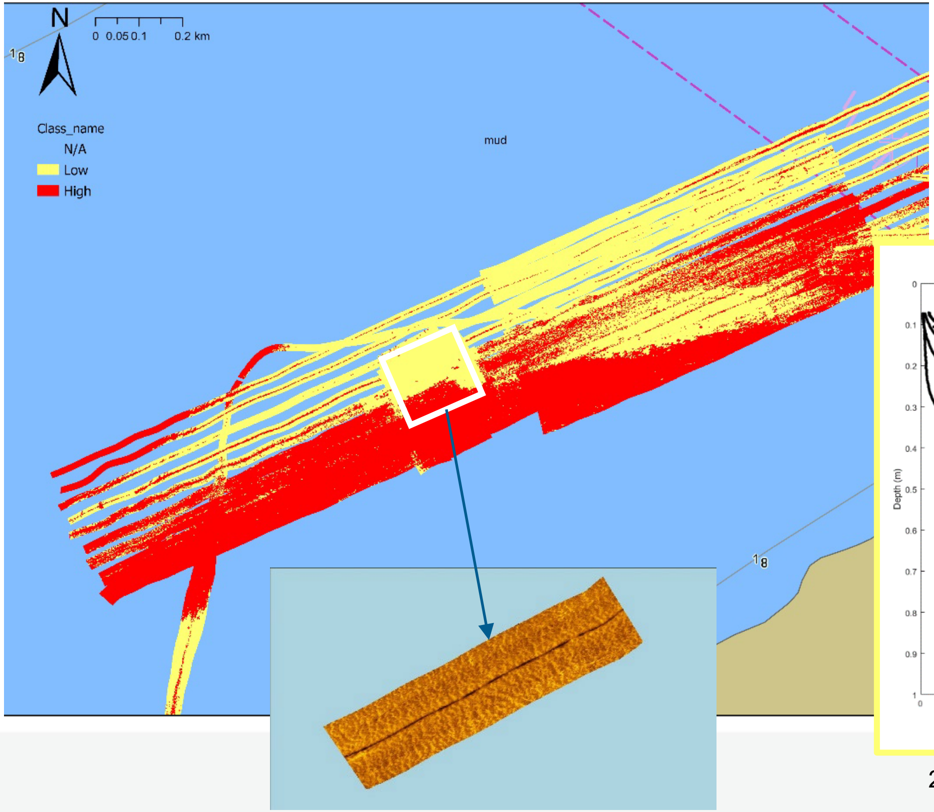
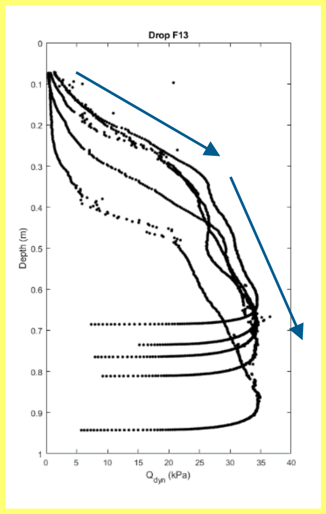
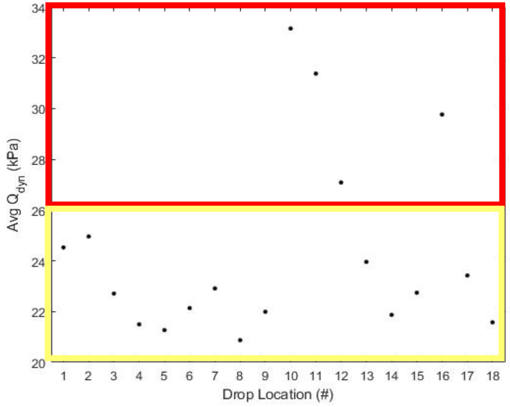
Task 2.3: Geotechnical Characterization





- Backscatter vs Penetrometer
  - Slopes (lower backscatter) showed lower avg Qdyn
  - Thalweg (higher backscatter) showed higher avg Qdy



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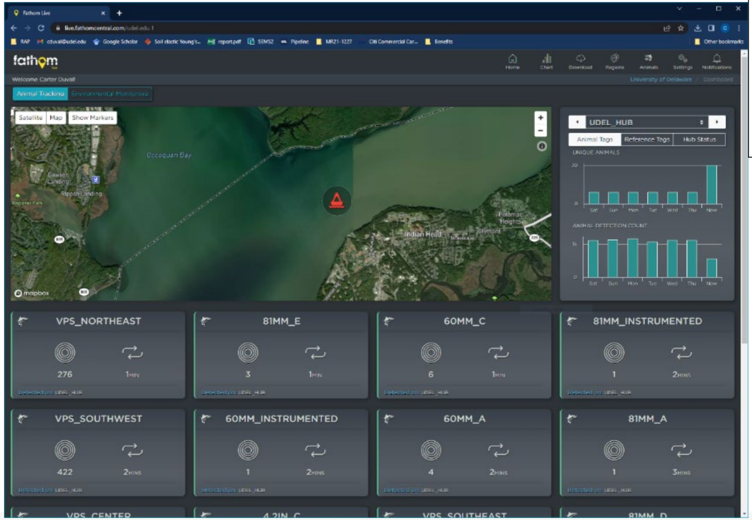
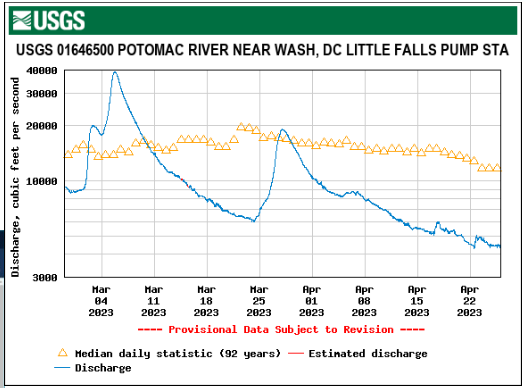
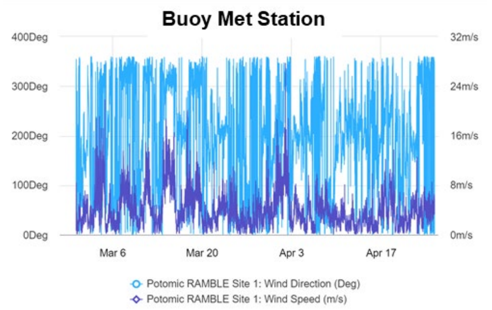
Task 3: Field Experiment 1

- 27 Feb – 28 Apr 2023
  - Deployed 20 surrogates (16 simple, 4 instrumented)
  - Continuous monitoring via Innovasea Fathom Live, Sofar spotter buoy, and USGS gauges
  - Below average discharge
    - 2 weather events







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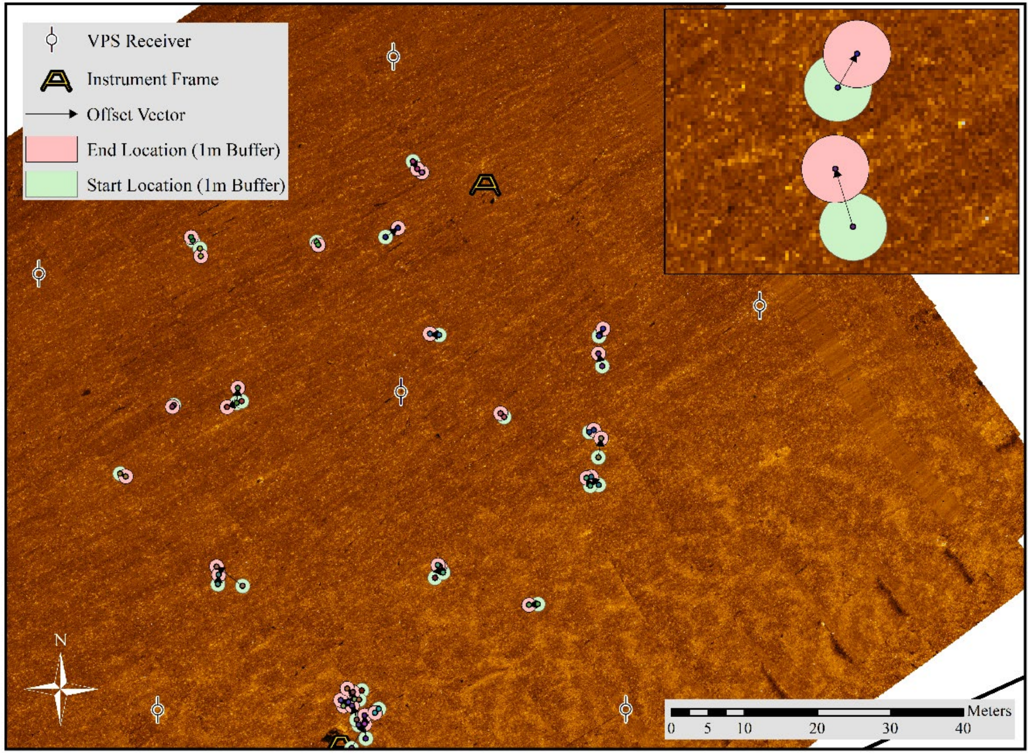
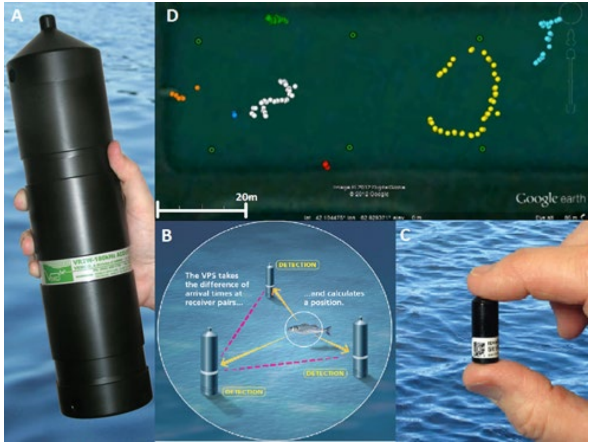
Results: Field Experiment 1



- Little to no detectable mobility from acoustic tracking



Offsets in start and end position within positional error

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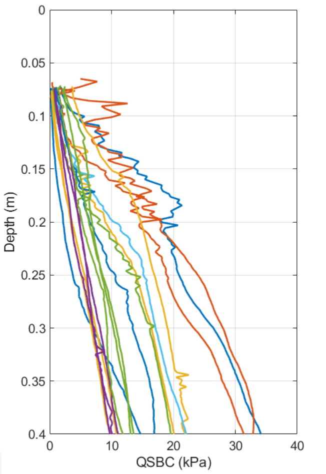
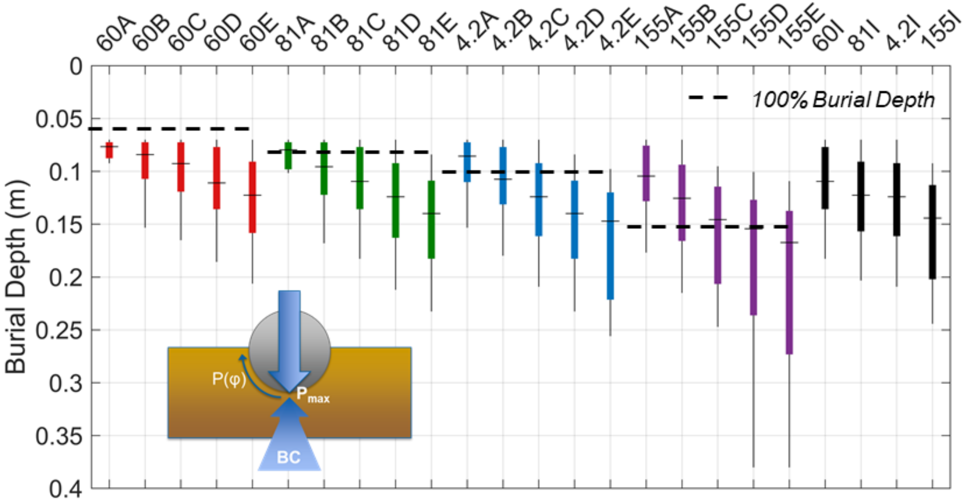
Results: Field Experiment 1

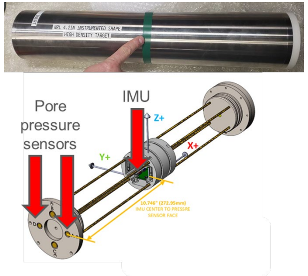
- Divers reported general burial trends:
  - Less dense mortars tipped nose down, ~ 50 – 75 % buried (tail exposed)
  - Less dense shells ~ 50 – 100% buried
  - More dense were >100% buried, with densest up to 15cm below surface
- Using geotechnical measurements, ran settling model from MR20-1480 to compare predicted burial depth to diver observations

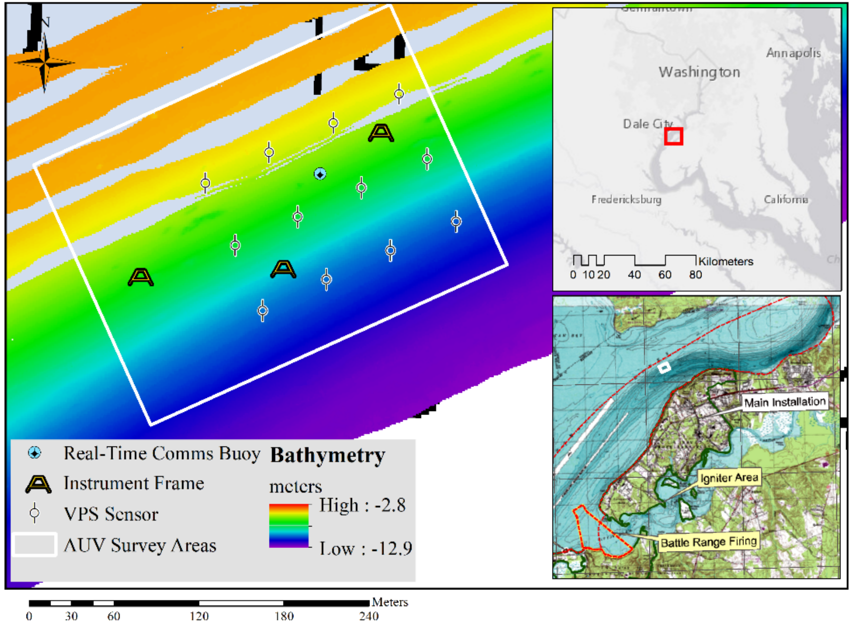




Task 3: Field Experiment 2

- Improvements from Experiment 1
  - Grid pattern array to increase detections and coverage
    - 12 receivers
    - 3 instrument platforms
    - 1 data buoy
  - More surrogates = more observations
    - 20 simple surrogates
    - 10 instrumented
      - 6 pressure surrogates (MR19-1317)





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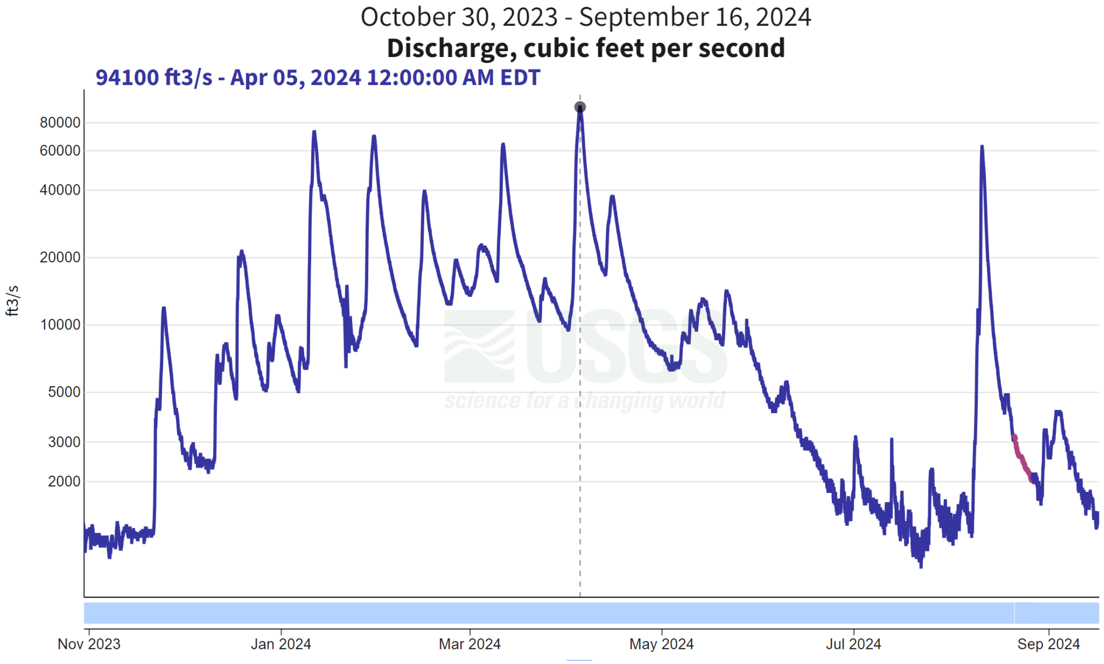
Results: Field Experiment 2

- Oct. 30, 2023 – Sep 11, 2024
  - Peak discharge – 94,100 cu. ft / sec (nor'easter)
  - Rapid discharge event August
    - Importance of dHs/dt in wave environments -> dUc/dt ?



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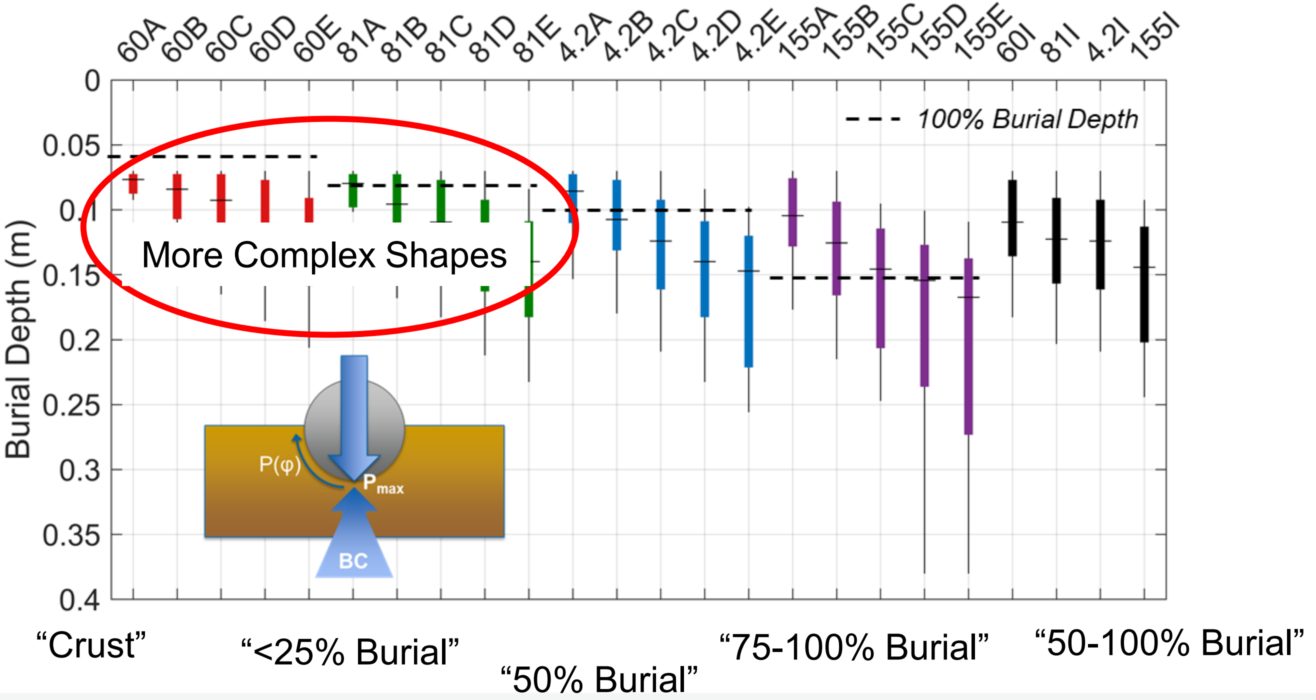
ver Observations



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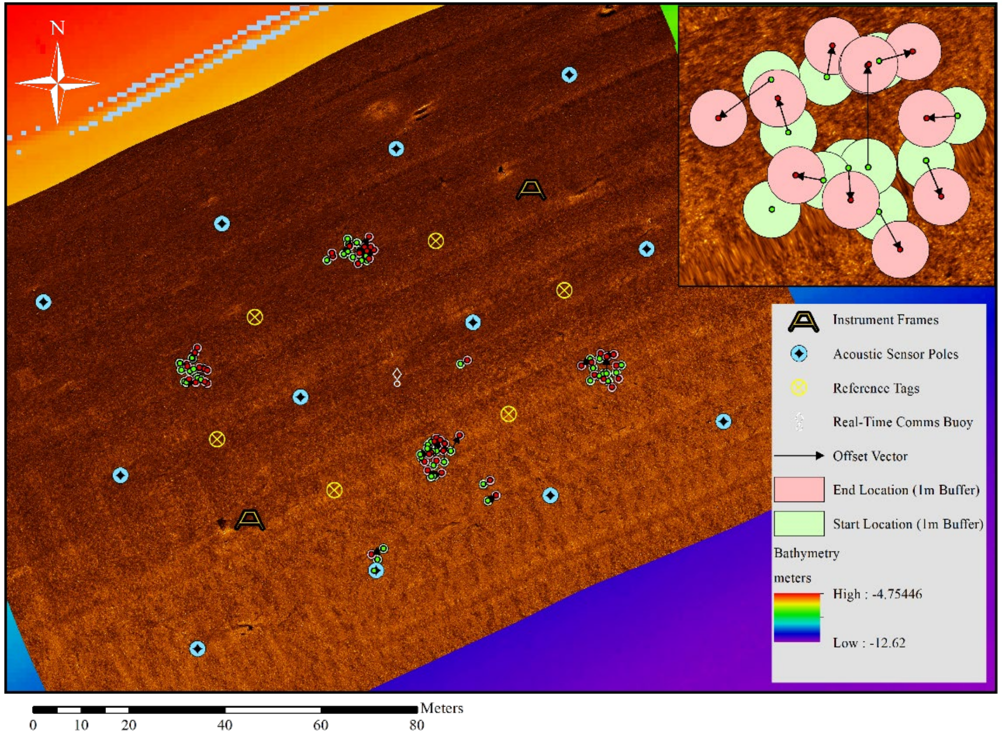
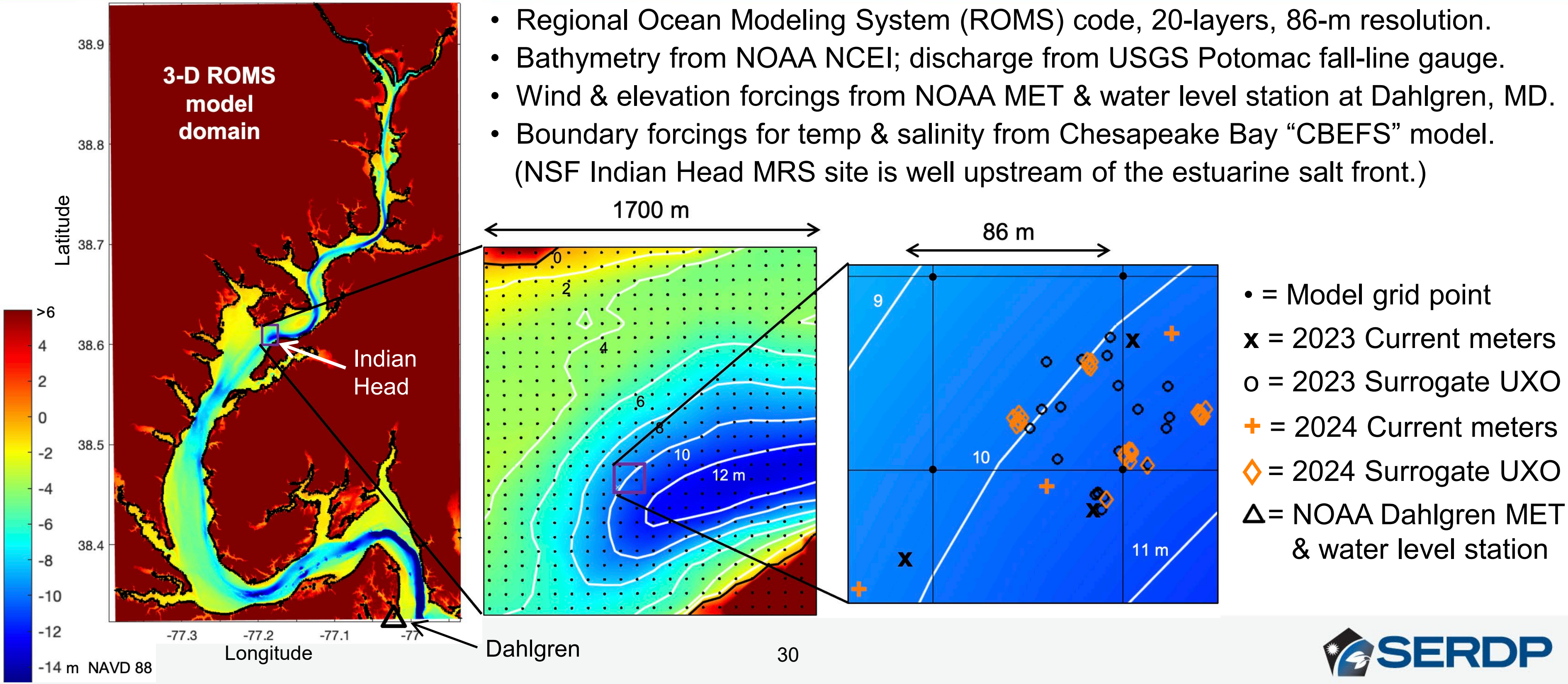
Results: Field Experiment 2

- All surrogates successfully tracked and recovered
  - Including 5 surrogates not recovered following Experiment 1
- Tracking for full deployment (Oct ‘23 – Sep ‘24)
  - Limited to no lateral mobility across entire deployment
  - Burial dominant mode

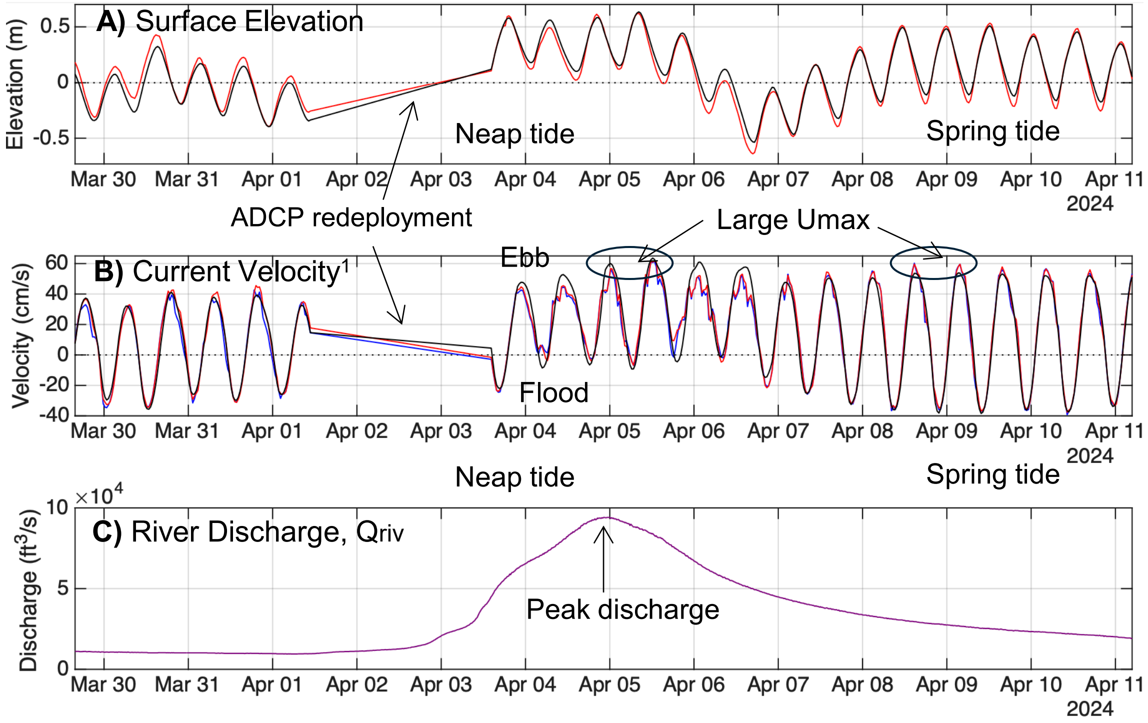


Results to Date: Hydrodynamic Model

- Regional Ocean Modeling System (ROMS) code, 20-layers, 86-m resolution.
- Bathymetry from NOAA NCEI; discharge from USGS Potomac fall-line gauge.
- Wind & elevation forcings from NOAA MET & water level station at Dahlgren, MD.
- Boundary forcings for temp & salinity from Chesapeake Bay “CBEFS” model. (NSF Indian Head MRS site is well upstream of the estuarine salt front.)



Results to Date: Hydrodynamic Model



- **Panels A & B**: Modeling (black lines) reproduces ADCP surface elevations (red) and velocities (red and blue) well (MAE 4.9 cm, 3.6 cm/s).

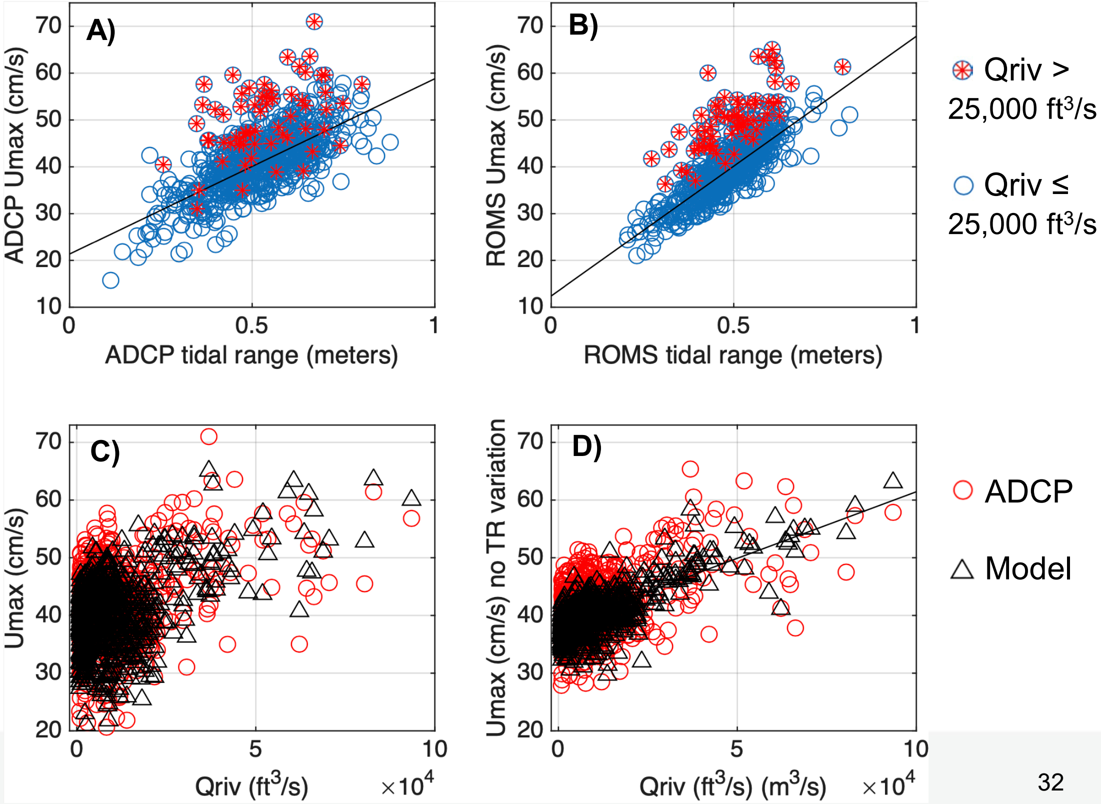
- **Panel B**: Different ADCP sites (red and blue lines) are highly consistent (MAE 1.8 cm/s). Ebb is stronger than flood, and ebb is more relevant for potential munitions motion.

- Maximum ebb velocities (U_{max}) in **Panel B** are only slightly greater at the peak of the field experiment's largest river discharge event (in **Panel C**) compared to several days after.

- Peak discharge (**Panel C**) was just after neap tide. U_{max} is a function of both river discharge (Q_{riv}) and tidal range.

[1]All velocities are depth-averaged.

Results to Date: Hydrodynamic Model



- **Panels A & B**: Umax is (unsurprisingly) dependent on tidal range. Umax visually shifts higher for Qriv > ~ 25,000 ft^3/s.

- **Panel C**: Dependence of Umax on Qriv is also apparent, but noisy. Similar trends for ADCP data and model results.

- **Panel D**: Best-fit relations from **A & B** used to remove effect of variation in tidal range (TR).

- **Panel D**: ADCP & model results pooled to derive best-fit relation between Umax (in cm/s) and Qriv (in ft^3/s):

$$U_{max} \approx 38 + 2.4 \times Q_{riv} / (10{,}000 \text{ ft}^3/\text{s})$$

(in cm/s) (in ft^3/s)

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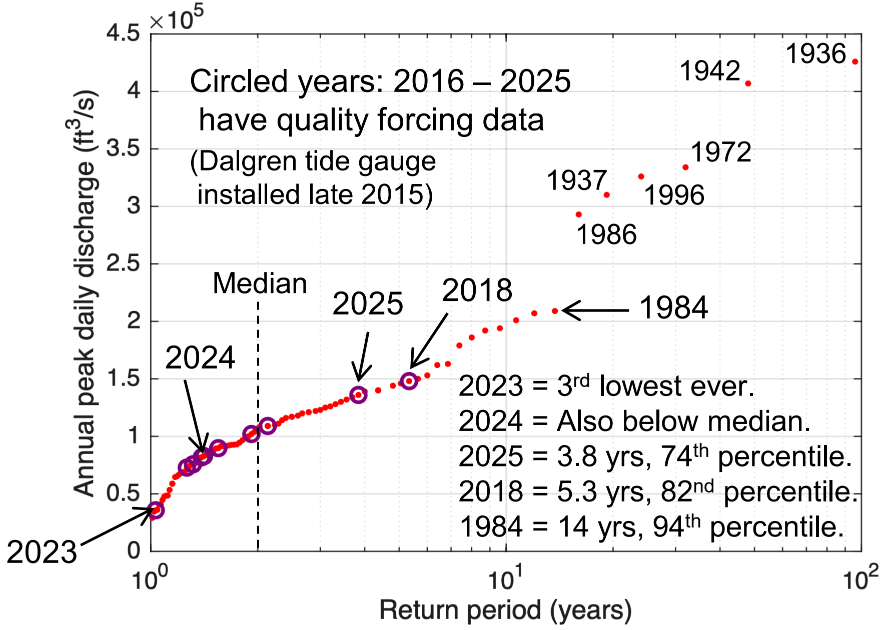
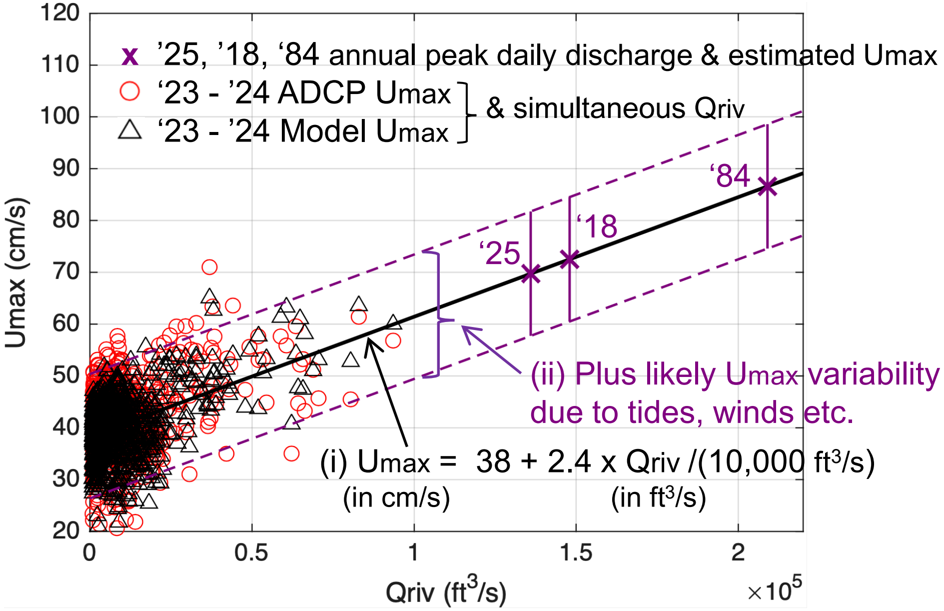
Results to Date: Hydrodynamics





Additional modeling can investigate recent higher flow years with high quality forcing available, namely 2025 & 2018.

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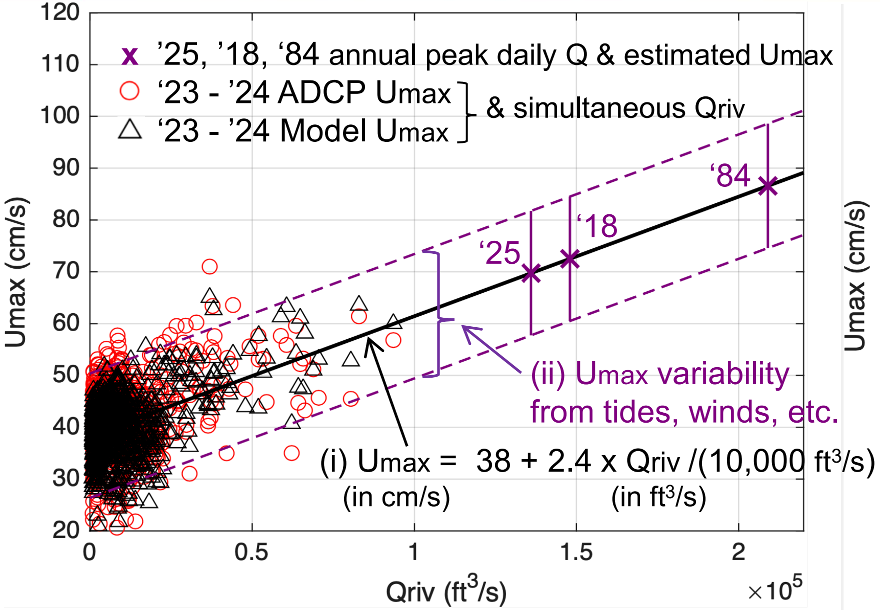
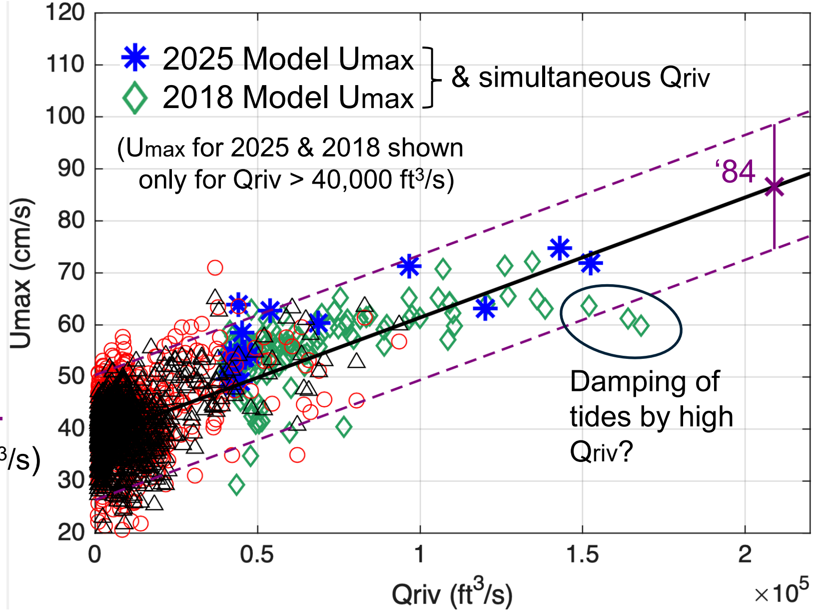
Results to Date: Hydrodynamics





- Umax is unlikely to have exceeded 80 cm/s in the last 10 years and not exceeded 100 cm/s since the mid '80s.
- The contribution of tides to Umax may decrease due to frictional damping as Qriv increases ([1]Cai et al., 2014).
- Observed near-bed currents will be used to constrain forces on munitions as function of Umax.

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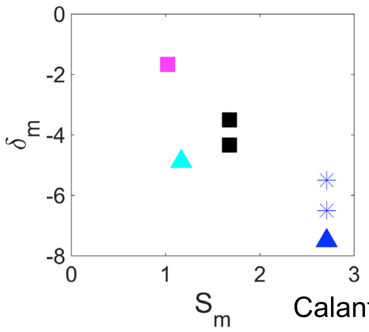
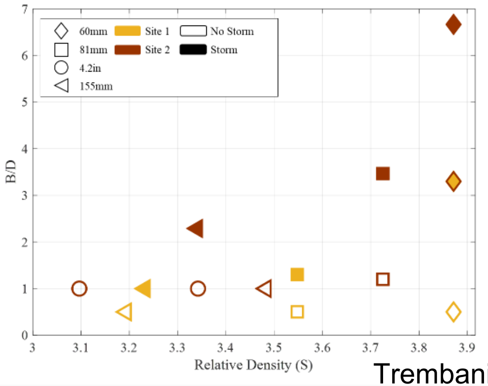
Planned Work: Simple UXO Sinking Models

- UXO in the present study (MR21-1227) sank into the bed and were not transported.
- Sinking of UXO more deeply into the bed without horizontal transport has been observed at other at other SERDP field sites:
  - At Duck, NC (Calantoni MR-2320) due to momentary liquefaction of sand by waves.
  - At Delaware Bay (Trembanis and DuVal MR-2730) due to fluidization of mud by waves.
- Together, these three data sets provide an opportunity to synthesize simple parameterized models which explain the dominant factors leading to deep seabed burial of UXO in place.



$$S_m = \frac{\rho_m}{\rho_s}$$

Calantoni MR-2320



Trembanis MR-2730

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Planned Work: Simple UXO Sinking Models

- Questions to be addressed with simple parameterized modeling:
  1. In all three studies, why did UXOs sink without horizontal motion? Builds on previous modeling of Friedrichs (MR-2224).
  2. At Duck, NC, why did UXOs sink to systematically different depths in sand as a function of their size & density at a given site? Builds on previous modeling of Friedrichs (MR-2647).
  3. At Delaware Bay, why did UXOs of different sizes & densities sink to approximately the same depth at a given site? Builds on previous modeling of Trembanis & DuVal (MR20-1480)

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Planned Work: Simple UXO Sinking Models

- A UXO sinks if its weight minus buoyancy = submerged weight (SW) > the sediment's bearing capacity (BC), and stops sinking when SW ≤ BC (Trembanis & Duval MR20-1480; [1]Shrestha et al. 2024).
- Some shallow sinking in mud is common because of low BC at the muddy bed surface.
- Relatively deep sinking can be triggered by bed fluidization or liquefaction by waves.
- Sinking can be arrested by:

  (i) a decrease in UXO SW with depth (buoyancy ↑ as partial burial increases);

  (ii) an increase in sediment BC with depth or time.
- Similar or contrasting total sinking depths for UXO depend on (for example):

  (i) Rate of sediment BC increase with depth relative to differences in UXO properties;

  (ii) Duration of fluidization / liquefaction events relative to the UXO sinking time scale.

[1]https://doi.org/10.1016/j.apor.2024.103948

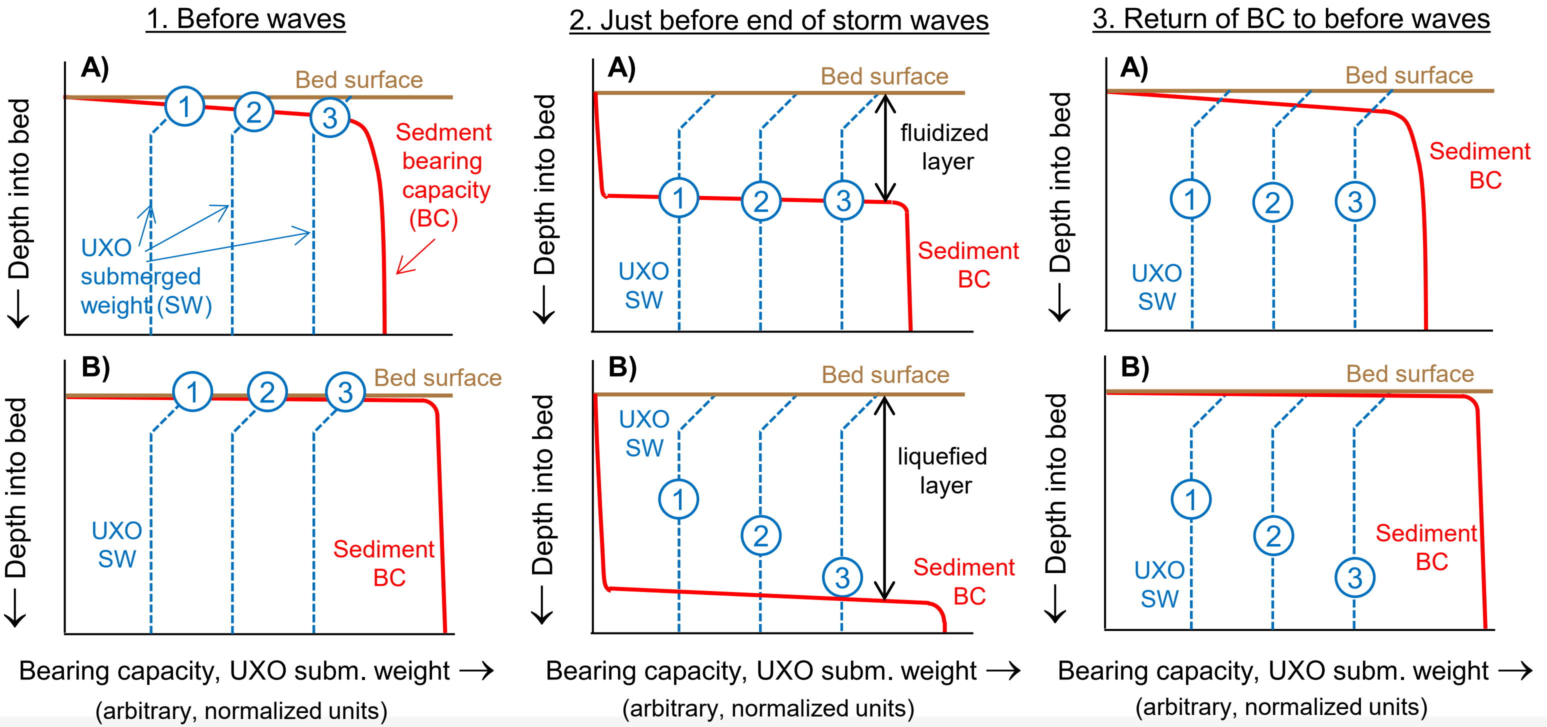
Planned Work: Simple UXO Sinking Models

UXO depths = ① ② ③

UXO weights ③ > ② > ①

A. Mud fluidization at Delaware: Duration of fluidization > Time scale for sinking. All UXO sink to depth of rapid strength increase.

B. Sand liquefaction at Duck: Duration of fluidization < Time scale for sinking. Heavier UXO sink more quickly and thus deeper.



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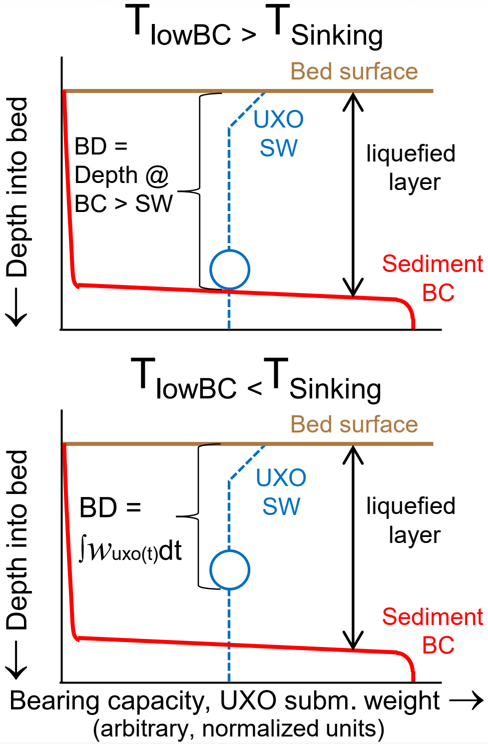
Planned Work: Simple UXO Sinking Models

- For fluidized muddy beds or liquefied sandy beds, the time-varying thickness of the very low BC sediment layer can be predicted from bed sediment properties and storm wave time series (building on [1]Soltanpour et al. 2009; [2]Qi & Gao 2015) .
- If the duration time for the very low BC layer (T_{lowBC}) is longer than the time scale for UXO sinking ($T_{Sinking}$), the sinking depth is given by the maximum depth of liquefaction or fluidization.
- If T_{lowBC} is shorter than $T_{Sinking}$, a force balance still exists between (i) UXO submerged weight and (ii) a velocity-dependent frictional resistance. Utilizing an effective sediment viscosity or UXO drag coefficient, the UXO's sinking velocity can be derived (building on Friedrichs MR-2647).
- Depth of sinking then follows from integrating the UXO's sinking velocity in time during the brief duration of the very low BC bed.



[1]https://doi.org/10.2112/07-094.1
[2]https://doi.org/10.1016/j.taml.2015.01.004.

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Next Steps

- Timeline
  - Task 4
    - Complete parameterized UXO sinking model
    - Incorporate into UnMES
  - Task 5
    - Final reporting

Technology Transfer

- Introduce simplified framework for leveraging real-time observations and models to predict MEC mobility and burial in riverine environments.
  - We are working to incorporate the field and parameterized mobility model results into the SERDP UnMES expert system.
  - All results from the field experiment and model parameterization will be made available for existing MEC mobility and burial models and studies.
- Characterization of site conditions, both historical and present, for the NSF Indian Head MRS site in and around study area
  - All results will be formally presented to relevant MRS site managers to aid in future MEC monitoring and management.

BACKUP MATERIAL

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

MR21-1227: Parameterizing Munitions Mobility and Burial in Riverine Environments

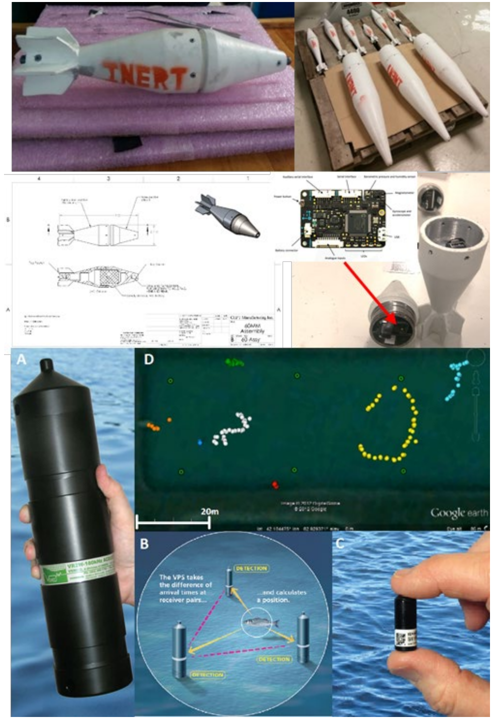
Performers:
- Dr. Carter DuVal (US Naval Research Lab)
- Dr. Art Trembanis (University of Delaware
- Dr. Carl Friedrichs (Virginia Institute of Marine Science)

Technology Focus
- Parameterized modeling of munitions mobility and burial in rivers leveraging in situ observations of acoustically-tracked surrogates

Research Objectives
- Quantify mobility and burial of MEC in dynamic riverine environments at an MRS
- Identify and reduce the parameters necessary to predict MEC mobility and burial in riverine sites for models such UnMES

Project Progress and Results
- Fabricating suite of surrogates
- Identified field site (NSF Indian Head) and conducted geophysical surveys of field site
- Conducted 2 field experiments (Spring 2023, Oct 2023 – Sep 2024)

Technology Transition
- Introduce simplified framework for real-time observations and models to predict MEC mobility and burial in riverine environments.
- Incorporate parameterized models into UnMES
- All results will be formally presented to relevant MRS site managers to aid in future MEC monitoring and management.



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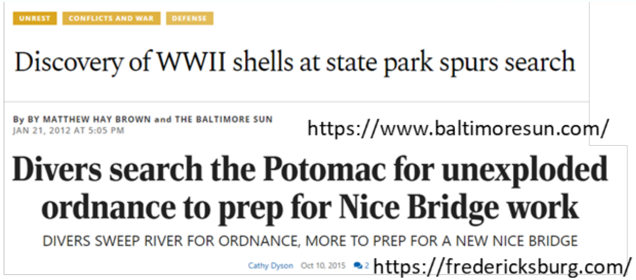
Plain Language Summary

- Munitions are found in underwater environments from conflict, live-fire training, exercises, and disposal.
- The fate of munitions in the underwater environment remains a topic of concern.
- We are conducting experiments to characterize how legacy munitions move or bury underwater and develop models to predict this behavior, focusing on dynamic riverine environments.
- The models were are developing will assist in the management of underwater munitions at formerly-used defense site to reduce the risk of military, government, commercial, or public interaction in the future.

Impact to DoD Mission

- A thorough understanding of the fate of Munitions and Explosives of Concern (MEC) is required for the detection, classification, modeling, monitoring, and mitigation of MEC at Munitions Response Sites (MRS).
- Probabilistic models for munitions mobility and burial (e.g. UnMES) require data for training and validation
    - Data gap identified in both:
        1. the number of observations of munitions mobility and burial
        2. environmental types studied (e.g. riverine, lacustrine, and coralline)
- Lacking much needed observations at underwater munitions sites (MRSON-21-C1)


UNREST CONFLICTS AND WAR DEFENSE

Discovery of WWII shells at state park spurs search

By BY MATTHEW HAY BROWN and THE BALTIMORE SUN
JAN 21, 2012 AT 5:05 PM

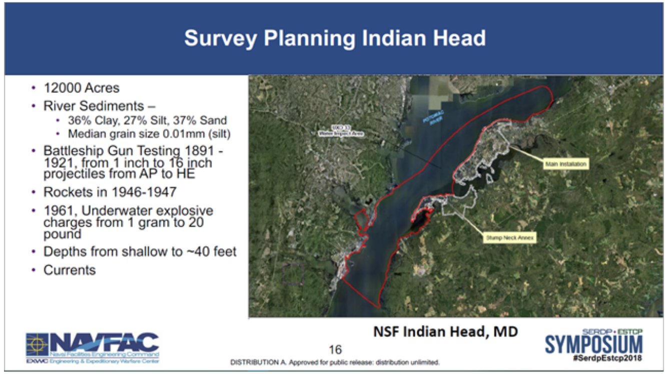
https://www.baltimoresun.com/

Divers search the Potomac for unexploded ordnance to prep for Nice Bridge work

DIVERS SWEEP RIVER FOR ORDNANCE, MORE TO PREP FOR A NEW NICE BRIDGE

Cathy Dyson Oct 10, 2015

https://fredericksburg.com/



Courtesy Brian Harre, NAVFAC

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Action Items

- No outstanding items – all 2024 IPR comments addressed

We have added a Technology Transition task to your project plan to more explicitly delineate Technology Transition products and activities. Under this task, we've added subtask 6.1: Critical Findings Sheet. The Critical Findings Fact Sheet should be no more than 1 - 2 pages long and should contain the following sections: Technology Overview; Research Approach; Critical Findings; Point of Contact; One or more images. An example fact sheet has been uploaded to your Miscellaneous Documents. Please note, the Program Office will format the final fact sheet; please focus on the content

Closed Assigned: 10/28/2024 Due Date: 11/13/2025 Subtask: Critical Findings Sheet

Acknowledgment Only

1 Comment SUBMIT

The Final Report is currently due in October 2025. In the comment box below, please confirm this submittal date is accurate given that there is substantial funding remaining to be sent. In addition, review all subtasks and confirm the accuracy of current completion dates; propose new due dates as needed.

2024 MR October In Progress Review

Submitted Assigned: 10/30/2024 Due Date: 2/5/2025

1 Comment SUBMIT

The actual amount invoiced on this project is substantially different than what is being reported through the Monthly Financial Report(s) for fiscal years 2021, 2022, and 2023. Check the status of invoicing with your organization and provide an update in the comment section of this action item explaining the discrepancy and when invoicing will be up to date.

Overcome by Events Assigned: 10/29/2024 Due Date: 1/24/2025

2 Comment SUBMIT

An action has been assigned to you in SEMS to update your FY23 and FY24 Expenditure Plan(s) to better estimate when these funds will be completely expended. Also, in the response to this action item, provide an amount needed, if any, to continue the project without interruption through January 2026. Once this information is provided, you will receive an action in SEMS to enter your FY25 Expenditure Plan. 2024 MR October In Progress Review

Submitted Assigned: 10/30/2024 Due Date: 1/24/2025

1 Comment SUBMIT

The Final Project Summary presentation is currently scheduled for October 2025. The presentation will be conducted via teleconference. Additional meeting information will be provided 2-3 months in advance of the meeting. The Final Report should be submitted prior to the presentation date; we will reschedule the final presentation if additional time is needed to submit the Final Report. 2024 MR October In Progress Review

Closed Assigned: 10/30/2024 Due Date: 1/24/2025

Acknowledgment Only

1 Comment SUBMIT

1 | 25 items per page | 1 - 5 of 5 items

Publications

- Provide a list of all publications, patents, awards, etc., resulting from this work.

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Literature Cited

- Provide a list of all the published work you cited in the presentation.

Additional Slide(s) for High-Quality Photos

Acronym List

- BC: Bearing Capacity
- DOD: Department of Defense
- FUDS: Formerly-Used Defense Site
- GPS: Global Position Systems
- IMU: Inertial Motion Unit
- MEC: Munitions and Explosives of Concern
- MR: Munitions Response
- MRS: Munitions Response Site
- QSBC: Quasi-Static Bearing Capacity
- RTK: Real-Time Kinematic
- SCUBA: Self-Contained Underwater Breathing Apparatus
- SERDP: Strategic Environmental Research and Development Program
- SW: Submerged Weight
- UD: University of Delaware
- UnMES: Underwater Munitions Expert System
- UXO: UneXploded Ordnance
- VIMS: Virginia Institute of Marine Science
- VPS: Vemco Positioning System

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Deliverables

- Quantify the influence of conditions unique to river systems on munitions mobility and burial (e.g. discharge, channel gradient, riverbed composition)
- Parameterized models for munitions mobility and burial in riverine environments
  - Incorporate into UnMES
- Framework to incorporate real-time monitoring and forecast / hindcast modeling into parameterized models
- MRS geophysical / geotechnical site characterization
- Report / Presentation to MRS site managers

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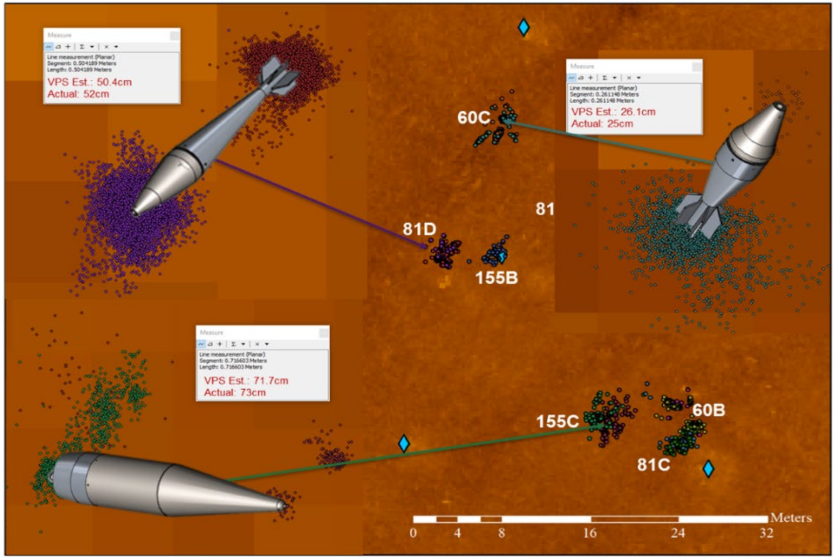
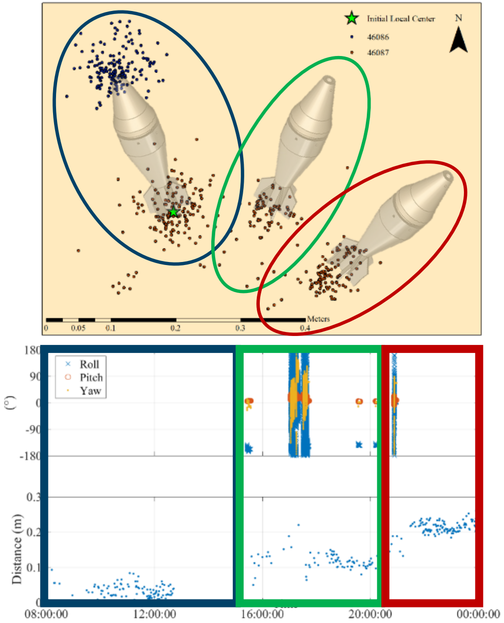
Task 1: Development of MEC Surrogates and Tracking Methodology

MR-2730





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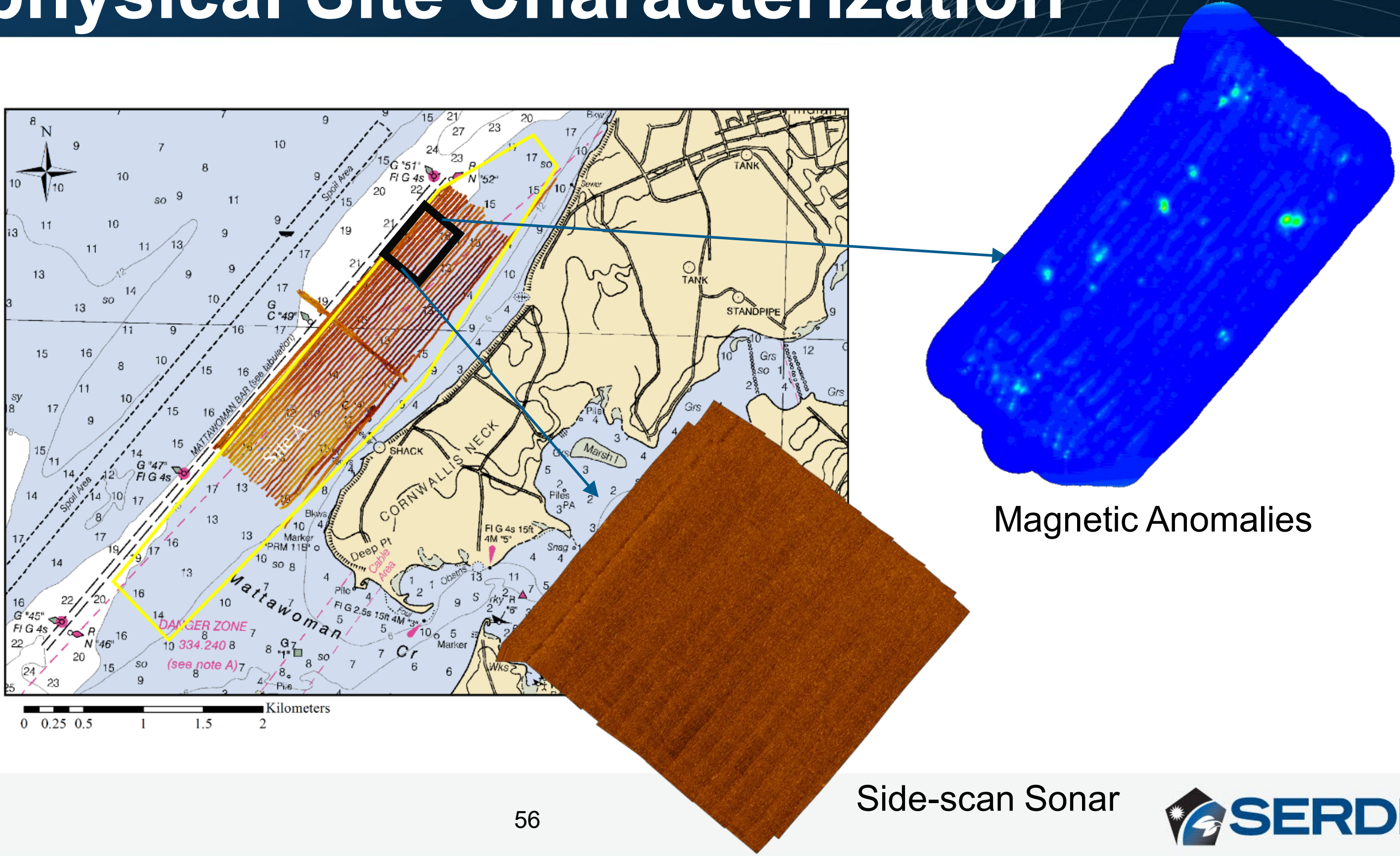
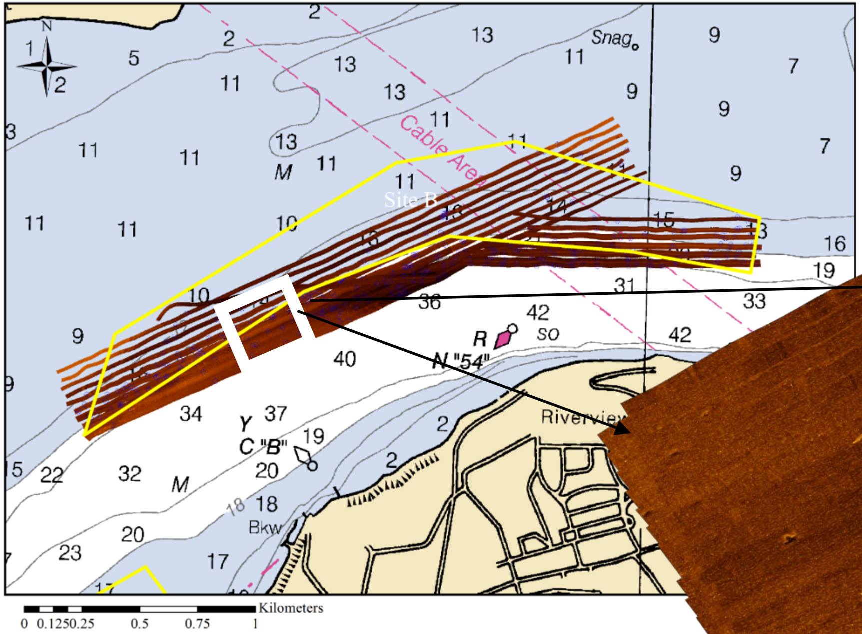
Task 2.2: Site Selection & Geophysical Site Characterization

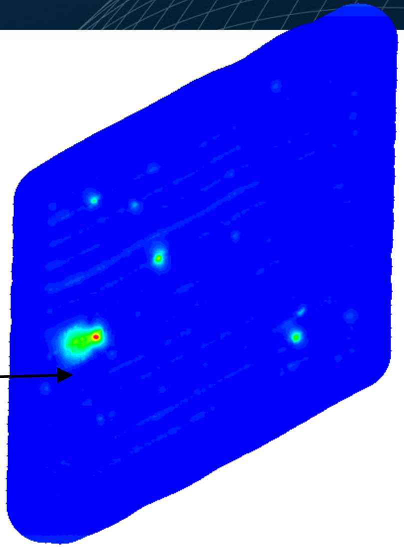


Magnetic Anomalies

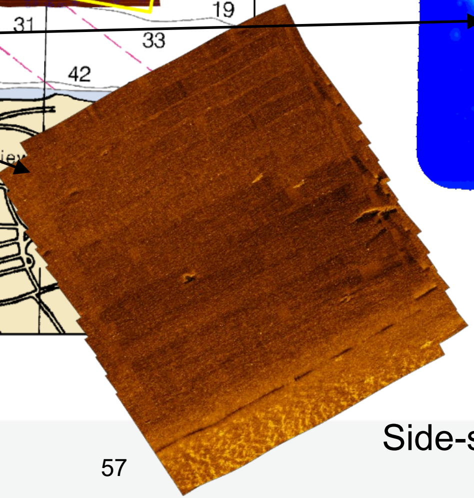
Side-scan Sonar

Task 2.2: Site Selection & Geophysical Site Characterization





Magnetic Anomalies



Side-scan Sonar

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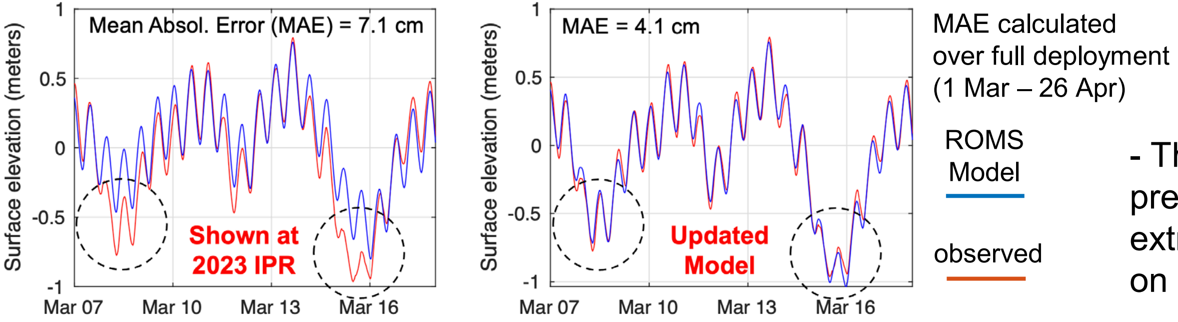
Social Media Content

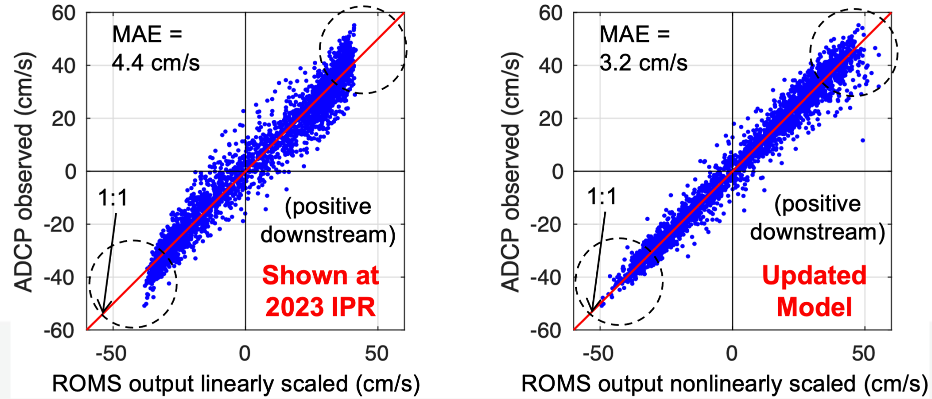
- **Project outreach through multiple social media platforms**
    - *Twitter, Facebook, and Google+*
- **Outreach highlights:**
    - *Project development and field highlights shared through Facebook Teampage- UDel Team Habitat Mappings*
    - *Twitter feeds- @USNRL &@PapaZissou*
    - *Public Google Photo Page https://photos.app.goo.gl/HYdZ69ManvZHuzB96*

Results to Date: Hydrodynamic Model

Example surface elevations at Spring 2023 deployment site



Depth-averaged currents at deployment site, 1 Mar - 26 Apr 2023



- The ROMS hydrodynamic model version presented at 2023 IPR underestimated extremes in observations. (See dashed circles on left-hand plots).

- Improved hydrodynamic forcing plus improved current scaling in updated ROMS model captures observed extremes better. (See dashed circles on right-hand plots.)

(Scaling adjusts for inconsistencies in tidal current magnitude and phase likely caused by errors in the model's fine-scale bathymetry.)

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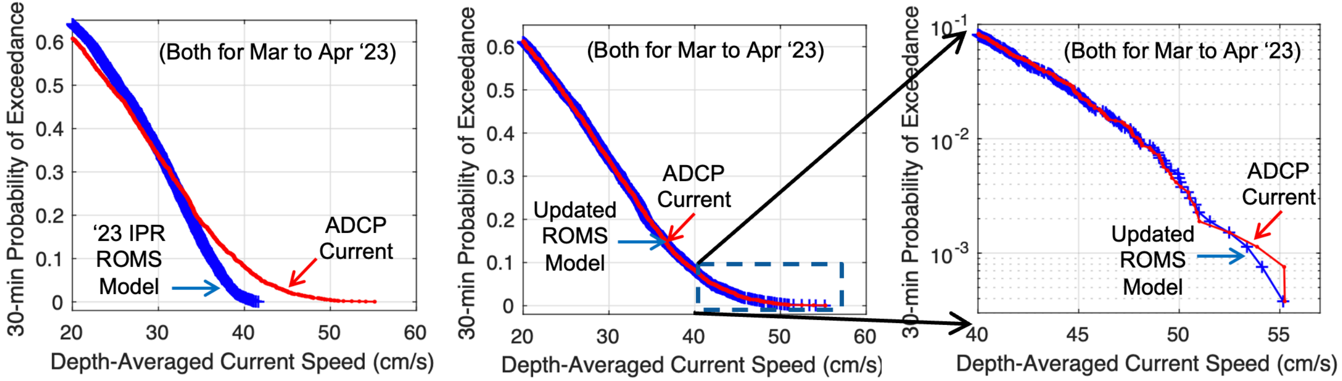
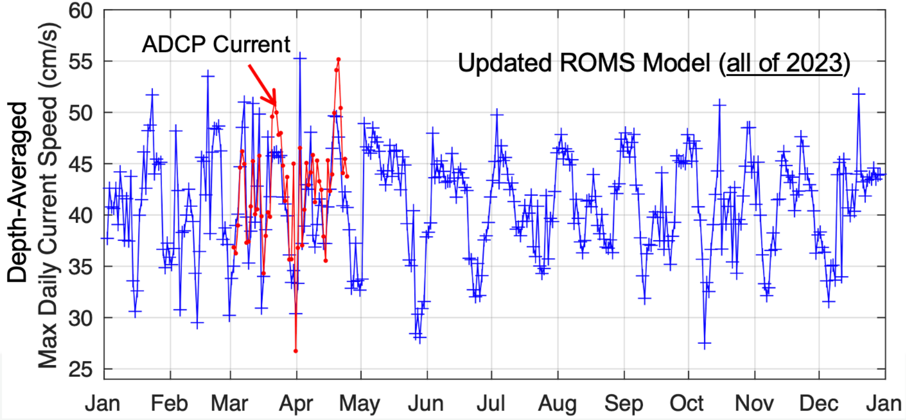
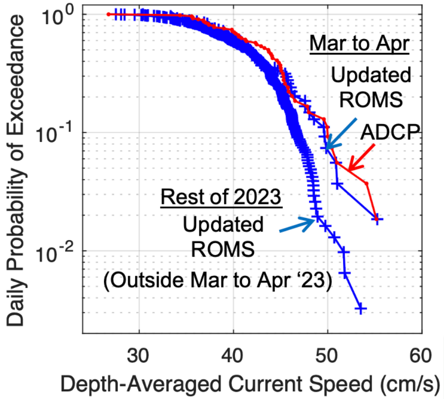
Results to Date: Hydrodynamic Model



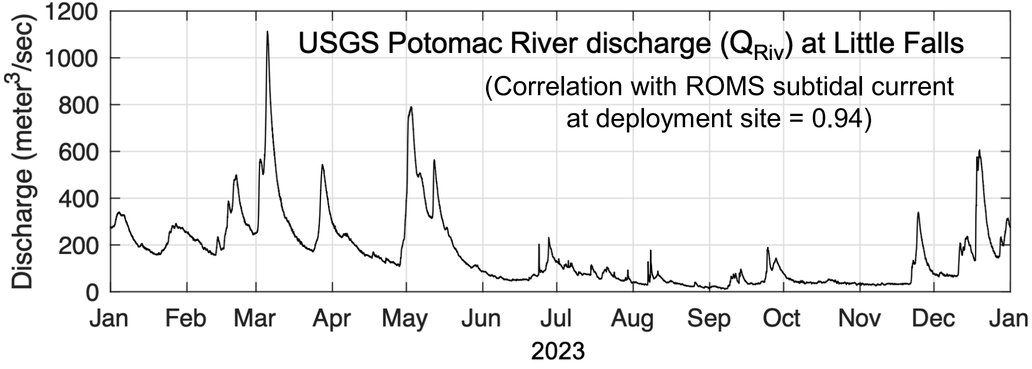
- Statistics for improved ROMS model (e.g., Prob. of Exceedance) match Mar to April ‘23 ADCP currents well.

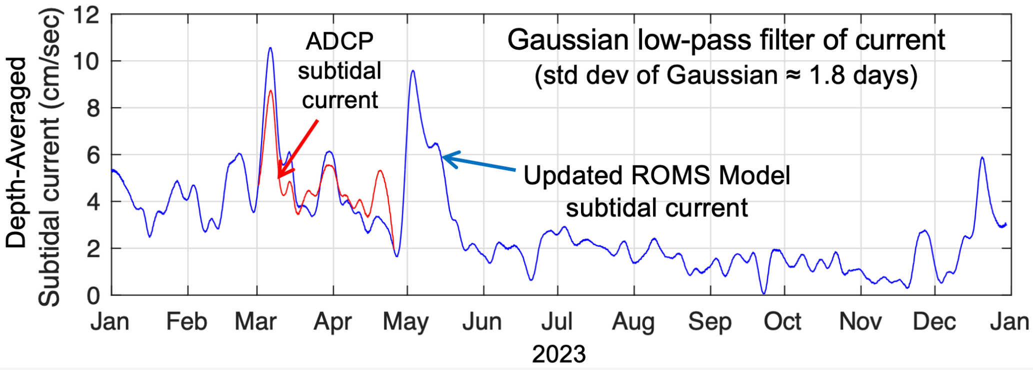




- Improved model shows max daily currents tended to be lower during rest of 2023 (lower Prob. of Exceedance).

Results to Date: Hydrodynamic Model





- Model logically suggests 2023 subtidal current ($U_{SubTidal}$) was dominated by river discharge.

- Model $U_{SubTidal}$ (in cm/s) ≈ Q_{Riv} (m^3/s) / 100

- 25-year return flood ≈ 10,000 m^3/s
→ Potential $U_{SubTidal}$ up to ~ 100 cm/s

- Max 2024 discharge ≈ 2,500 m^3/s
→ 2024 $U_{SubTidal}$ up to ~ 25 cm/s

- Plus ~ 45 cm/s spring tidal current in absence of notable discharge suggests U_{Max} in 2024 ~ 70 cm/s.

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Planned Work: Simple UXO Sinking Models

- Why do UXOs placed on unconsolidated mud or sand usually sink or bury without notable horizontal mobility?
- *Answer: Most UXOs have densities greater than bed the sediment (Calantoni MR-2320).*
- Therefore, initial UXO sinking and/or scour-driven burial typically occurs faster than increasing waves or currents can initiate horizontal transport of the UXO (building on Traykovski MR-2729).
- Partial sinking or burial (i) decreases the exposure of the UXO to near-bed flow and (ii) increases the physical resistance to UXO motion, both of which reduce the likelihood of horizontal UXO mobility (building on Friedrichs MR-2224).
- Mobility is more likely for objects with density lower than bed sediment, especially in combination with steeply sloping flat beds found in wave breaker and swash zones ([1]Cristaudo & Puleo 2020).

[1]https://doi.org/10.1016/j.oceaneng.2020.107322

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