Research Performance Progress Report (RPPR)

Award

Federal Agency: Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy (EERE)
Water Power Technologies Office (WPTO)

Award Number: DE-EE0009450

Project Title: An Atlantic Marine Energy Center (AMEC) for Advancing the Marine Renewable Energy Industry and Powering the Blue Economy

Project Period: Budget Period 1: 08/01/2021 to 9/30/2023 (incl 6-month NCE)
Budget Period 2: 10/01/2023 to 7/31/2027

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Report

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Signature of Submitting Official:

X
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Major Project Goals and Objectives – Overall Project

The University of New Hampshire (UNH-lead), Stony Brook University (SBU), Lehigh University (LU) and the Coastal Studies Institute (CSI; managed by East Carolina University, North Carolina) will establish and operate the Atlantic Marine Energy Center (AMEC) as a university-led consortium to address the ongoing needs for research and development (R&D) and testing to advance Marine Energy (ME) technologies towards commercialization, and to develop Powering the Blue Economy (PBE) solutions. The consortium is well-positioned to support ME utility-scale development for wave, tidal, and ocean current energy for Technology Readiness Level (TRL) 1-6, including analytical, numerical, and laboratory work and deployments at well-understood open-water test sites. AMEC is also well-positioned to support PBE applications for TRL 1-8, including power at sea for ocean sensing, aquaculture, resilient coastal communities, and marine microgrids.

AMEC will collaborate with DOE federally funded research and development centers (FFRDCs) that include the National Renewable Energy Laboratory (NREL), Sandia National Laboratories (SNL), and Pacific Northwest National Laboratory (PNNL). To complete the partnership and provide access to full-scale test sites, we have also teamed with the European Marine Energy Center (EMEC) and Old Dominion University (ODU) on specific tasks.

The AMEC project (DE-EE0009450) has three main objectives:

(1) Establish the Atlantic Marine Energy Center: Develop the organizational structure of the center and AMEC Strategy, establish R&D partnerships with industry, develop testing programs, and achieve accreditation of scaled open water tidal (UNH) and wave energy (CSI) test sites under ISO/IEC 17025 for testing in accordance with TC 114 (IEC 62600) marine energy standards. Coordinate with the University Marine Energy Research Coordinator (UMERC, formerly Foundational Research Network Facilitator (FRNF) and existing National Marine Renewable Energy Centers (NMRECs).

(2) Operate Modern Test Facilities: Upgrade existing infrastructure to improve and expand current capabilities, develop new testing and analytical capabilities and skills, including numerical modeling and digital twinning capabilities, with the goal of improving alignment with industry needs and enhancing our testing capability under the Testing Expertise and Access for Marine Energy Research (TEAMER) program.

The UNH-SBU-LU-CSI consortium has developed and operated significant infrastructure and capabilities for ME and PBE research over the past 10+ years, and under AMEC will be an effective partner for industry. Infrastructure upgrades and capability development were selected to meet our goal of supporting ME utility (TRL 1-6) and PBE (TRL 1-8) development, including cross-cutting research.

(3) Conduct research in ME utility, PBE and on cross-cutting topics such as storage integration, microgrids, supply chain analysis and stakeholder engagement-systems analysis. Research projects were identified based on an analysis of challenge areas, in collaboration with our partners at the FFRDCs, and EMEC, and to complement our existing ongoing research portfolios.

In addition to R&D, AMEC will play a role in ME workforce development. We will develop an MRE-specific curriculum, and we will organize short courses, conferences, workshops, and online programs to train and mentor the next generation of scientists and engineers in MRE.

Note: Since the AMEC project will stand up a new National Marine Renewable Energy Center (NMREC) and has multiple distinct tasks, each Task will be reported on separately below.

The project tasks for Budget Period 1 are:

Task 1.0 Establish AMEC

Task 2.0 Establish Stakeholder Outreach and Engagement Planning

Task 3.0 Education and Workforce Development Planning

Task 4.0 Infrastructures Upgrade and Capabilities Development - BP1

Task 5.0 Accreditation Planning

Task 6.0 Integrating waterway and tidal induced turbulence into MRE design by digital twinning at laboratory and field scales

Task 7.0 Assessing hydrodynamic impacts of single and multiple hydrokinetic units and tidal farms on the marine environment using laboratory, field, and numerical studies

Task 8.0 Physics-based data-driven reduced-order models for site-specific optimization of MHK device arrays in tidal farms

Task 9.0 Power at Sea - Wave Energy Powered Water Pump

The project tasks for Budget Period 2 are:

Task 10.0 Operate AMEC

Task 11.0 MRE Stakeholders Engagement

Task 12.0 Education and Workforce Development Activities

Task 13.0 Infrastructures Upgrade and Capabilities Development, BP2

Task 14.0 Accreditation

Task 15.0 Integrating waterway and tidal induced turbulence into MRE design by digital twinning at laboratory and field scales

Task 16.0 Assessing hydrodynamic impacts of single and multiple hydrokinetic units and tidal farms on the marine environment using laboratory, field, and numerical studies

Task 17.0: Power at Sea - Wave Energy Powered Water Pump

Task 18.0 (MRE) Physics-based data-driven reduced-order models for site-specific optimization of MHK device arrays in tidal farms

Task 19: Decision Support Platform for Coastal Communities' Power Infrastructure Resilience

Task 20.0 Performance and design of foundations supporting marine energy devices

Task 21.0 Supply Chain Optimization

Task 22.0 Storage Integration across MRE – from Power Grid to Blue Economy Markets

General Instructions for AMEC team:

Add new text for the quarter, highlight the new part in YELLOW. Un-highlight previous parts.

When you add Figures, please number them by Task and Subtask, then sequentially. For example, see the Figure for the AMEC logo in Task 1.1 --- it becomes Figure 1.1.1

Also update "Plans for next Quarter" – this is also a good place to check whether what we set out to do was accomplished in the last quarter. (previous "plans" that are completed can be deleted)

It is o.k. to update previous text passages to make the report consistent and read better, as long as you highlight in yellow what was changed, to alert us and the DOE WPTO team.

Don't forget to update the "Participants and Collaborators" section at the end.

GOAL: by adding content quarterly, the result should be a growing report for the overall project, which can then be used as an interim and final report (or at least as a reasonable basis for these).

Note: tasks below can be collapsed/expanded as needed. For BP2 reporting we collapsed all Tasks from BP1 for ease of reading (added carry-over infrastructure Tasks 4.X to BP2).

Budget Period 1 tasks

Note: Due to file upload size limits for EERE Project Management Center (PMC) of 50 MB, Budget Period 1 Tasks were taken out of the RPPR1. Please see previously submitted RPPR1 for BP1 Tasks.

Major Project Goals and Objectives

This task will leverage an existing stand-alone, float-spar point absorber wave energy converter (WEC) and integrate it with a hydraulic/pump PTO in order to pump cooler, nutrient rich near-bottom water up to offshore aquaculture kelp or fish farms.

Project Activities Completed

Subtask 9.1 Review of prior work, initiate analytical and computer modeling

Literature review has been completed, utilizing various research databases (including Engineering Village). Eleven relevant papers have been reviewed on various wave energy pump designs and theory. UNH design of a two-body wave pump system with separate inlet and outlet appears to be studied less frequently compared to other systems. One relevant paper, by White et al. in 2010 had a wave powered pump design consisting of a float, vertical hose, and one-way valve system. Though simple, the system had structural issues in ocean deployment. Additionally, papers studying the optimal conditions for kelp growth were reviewed to begin identifying key design characteristics to enhance kelp growth. The literature review has been reviewed by UNH project advisors, and other UNH researchers working on similar projects.

WEC-Sim is being considered as a potential simulator/numerical model. NREL/Sandia Labs Reference Model 3 (two body point-absorber) in WEC-Sim is used as a starting point for modeling the UNH WPWP. Capytaine, a Boundary Element Modeling (BEM) software, was used to analyze the hydrodynamic parameters of the wave pump design.

Evaluated a simplified geometry of the WPWP in Capytaine to determine hydrodynamic properties of the system. Applied the Capytaine results to WEC-Sim RM3. Modified the Hydraulic PTO-Sim Simulink model for the RM3 to represent the single piston pump of the WPWP. These modifications included eliminating the rectifying check valve, and adding in a reduced version that includes two, one-way check valves instead of four. Another alteration included the check valves both connecting to the bottom half of the piston pump, where one is positive (for the inlet) and one is negative (for the outlet). The top half of the piston pump was altered so that its pressure stays constant with the atmosphere, and does not drive hydraulic fluid motion, as reflective of the WPWP design.

Properties of the check valves were also confirmed with the manufacturer, with some elements, such as discharge coefficient, still requiring further refinement.

Preliminary results of the WEC-Sim simulation indicate reasonable flow rates at expected wave conditions for the deployment site. The simulated one-way check valves appear to be operating correctly with one valve admitting flow, while the other is closed. Further analysis is needed to determine whether the relative motion in the simulation is correct.

Current work for modeling the device in WEC-Sim was presented at the UNH School of Marine Science and Ocean Engineering Graduate Symposium on May 4th, 2022.

A separate numerical model of the device is being developed in parallel to the WEC-Sim model for additional validation. A linear and heave-only model is also being put together in Matlab.

Milestone 9.1 was completed, however additional work under task 9.1 may continue after data collection for numerical model validation.

Subtask 9.2 Tank testing of existing WEC device in UNH Engineering Tank.
Updates for Q2 FY2022 Quarterly Report

Comprehensive review of hardware replacement on the existing wave pump device has begun in preparation for tank testing. Instrumentation required for tank testing has been identified, and purchases will begin next quarter. A flow meter, Lidar, and data acquisition system with data relay capabilities will be purchased and installed onto the wave pump device.

Updates for Q3 FY2022 Quarterly Report

Bulk orders for approximately 80% of materials needed for tank and field testing have been completed. Drawings have been completed for machined parts, which will be machined by Paul Lavoie, UNH machine shop technician. The hours that will be required for machining parts are currently being quoted.

Underwater electronic connectors and cables are getting quoted by Electronic Sales of New England. These parts are required to transfer the flow meter data from underwater to the DAQ located at the top of the spar. The data will then be sent onshore for real-time data monitoring.

Discussions amongst the UNH team have identified the necessity of adding a GPS clock and an IMU (inertial measurement unit) to the data acquisition (DAQ) system. The GPS clock will be necessary to obtain highly accurate time series data and synchronize the other sensors' clocks. The IMU data will be used to validate the WEC-Sim numerical model.

Reassembly of the device and testing for watertightness is on track for August 2022 (M9.2.1).

The test plan for both the tank test and the field test has been created and is in the review process with the UNH team. The test plan is on track for meeting the August 2022 deliverable date (D9.4.1). The team used the Test Standard IEC 62600-103 to inform the test plan.

Updates for the Q4 FY2022 Quarterly Report

Corroded hardware on device has been comprehensively replaced, through disassembly and reassembly of most of the device. Friction of the piston within the spar was bench tested and found to be minimal. A new 26-pound ballast ring was added to the spar buoy to incorporate required ballast directly onto the structure. An underwater electrical connector and cable routing was added to the spar buoy to bring the flow meter data from subsurface to the DAQ located at the top of the spar. See Subtask 9.4 for more detail on device updates which prepare it for both the UNH Engineering Tank test and the field deployment.

The device test in the UNH Engineering Tank is scheduled for the week of October 31st, 2022.

Updates for Q1 FY2023 Quarterly Report

The tank testing for the existing WEC device in the UNH Engineering Tank (subtask 9.2) has been completed as of December 16th, 2022.

The first round of testing took place in October 2022, and revealed a severe leak within the spar buoy. The leak was substantial enough to impact the dynamics of the spar during an ocean field test, which would impact efficiency and survivability of the device. After the leak was discovered, the device was disassembled into subsections so that the various potential leak locations could be tested individually. There were several suspected leak locations, including the PVC junctions in the wave pump, the internal PVC coupling for the piston cylinder, and the pipe flanges. One test revealed a leak located along the radial face of the pipe flange. A marine grade epoxy was used to repair the seal at this location. The device was then reassembled and tested in the tank, resulting in no leaks from the device.

Additionally, the ballast ring added to the spar created the intended effect, where the spar's waterline was at the intended location. The float was also stable in its upright position. Five additional pounds of ballast may be necessary for deployment. While this task is now complete, there may be additional tank tests to capture some pseudo data of the instrumentation prior to a field deployment.

<u>Subtask 9.3 Permit review and NEPA consultation regarding temporary deployment at near-shore site at Shoals Marine Lab:</u>
A description of the project and project location has been completed. This description was submitted to DOE NEPA Specialist Roak Parker, who ruled that a Biological Assessment (BA) was necessary.
The engineering component of the BA was completed. Identified qualified persons for intertidal/subtidal biology and bird components and have reached out to request quotes for completing the respective BE parts.

Updates for Q2 FY2022 Quarterly Report

We contracted with Stephen Barrett of Barrett Energy Resources Group, LLC, MA to complete a Biological Assessment (BA) for Task 9.4, Deployment of the Wave-Powered Water Pump at Isles of Shoals. Steve Barrett sent a draft of the BA to the UNH project team on 30 March 2022, with additional questions regarding consultations we have had, i.e. communication with federal, state or local regulatory authorities about the project, and regarding specifics of the dimensions of the heave plate.

Updates for Q3 FY2022 Quarterly Report

Steve Barret and Dan Cahill (who has taken over for Roak Parker at DOE), consulted together on the BA and made edits to several iterations. Edits were completed on June 2nd, 2022. Dan Cahill sent the BA to the appropriate parties at NMFS and FWS. A request was made to change the light on the device to a flashing white light instead of a steady white light. With this change, parties at NMFS and FWS indicated approval of the BA. The EQ1 Questionnaire was also completed on July 18th, 2022. The NEPA consultation and permit review is on track with DOE to be completed by August of 2022 (M9.3.1).

Updates for Q4 FY2022 Quarterly Report

Approval of NEPA Biological Assessment is complete internally within DOE, and official notice is due to UNH in mid-October. This official notice marks the completion of this task.

<u>Subtask 9.4 Field testing of the Wave-powered pump off the UNH/Cornell Shoals Marine Lab on Appledore Island, Isles of Shoals.</u>

Updates for Q4 FY2022 Quarterly Report

The flow meter sensor has been purchased, and a water-tight housing for it has been manufactured. Mounting components for the housing have been added to the spar. The 1-½" NPT pipe fittings on the pump structure have been replaced with 2" NPT fittings. Hose and clamps have been purchased and cut to the correct size for installation to spar. A sensor calibration for the flow meter is planned prior to the field deployment.

The Lidar sensor has been purchased and extensively bench tested for accuracy. Lidar target has been manufactured and attached to the float's aluminum structure.

DAQ development is nearly complete. A new plate for the top of the spar was manufactured for mounting the DAQ box. Wiring and soldering for the DAQ is completed. Code for the flow meter and Lidar sensors have been completed and bench tested. The DAQ has capabilities to write data to a microSD card, as well as include the GPS driven time with the data. The data is collected at a rate of 20Hz. Flow meter data from the pump is presented in liters per minute, and Lidar data of the linear heave motion is presented in centimeters. The data share a time signal driven by the Arduino clock, corrected by GPS time. A 24-hour dry test of the DAQ using its final form of the code will be conducted prior to the field deployment.

DAQ power will be supplied by three Lithium phosphate battery packs, each with a capacity of 7500mAh. Power will also be supplied by three 12V, 1.7W solar panels, which will recharge the batteries throughout the field deployment. Materials have all been purchased and are in the process of assembly within the DAQ.

Cameras have been purchased to install onto the float's aluminum structure for passive environmental monitoring on the buoy.

A hydrophone has been selected for deployment approximately 50 feet away from the Wave Pump device. The hydrophone will listen for sound produced by the Wave Pump device, in addition to any marine mammal activity during the field deployment.

Three potential field deployment dates have been selected and confirmed with the R/V Gulf Challenger's captain. The first potential deployment date is November 7th, 2022. Mooring lines and equipment are in the process of being finalized for the field deployment. The Sofar spotter buoy used for gathering nearby wave condition data is in good condition and will be prepared for deployment.

Updates for Q1 FY2023 Quarterly Report

Due to the leak in the spar buoy found during the completion of Subtask 9.2 and field deployment weather windows, Subtask 9.4 has been delayed. New deployment dates have been selected with the R/V Gulf Challenger captain for late March 2023 into early April of 2023.

Preparations are underway for the deployment, including finalizing the DAQ and instrumentation. The power capabilities of the DAQ are being tested to ensure it can remain powered throughout its deployment. The time signal for the DAQ is based on a GPS signal, which has some lag in the data of a few seconds. A code was written to correct this timing lag using linear interpolation after the data is collected. The flow meter housing for the flow meter has been prototyped for the third time, due to water intrusion in the first two prototypes. Testing is underway to ensure the flow meter housing prevents all water ingress during a field deployment.

Polyurethane adhesive was added to the top of the spar to ensure backflow behind the piston would not drain into the main spar. The marine light for the field deployment was ordered new, and the bracket was adjusted to accommodate it.

Updates for Q2 FY2023 Quarterly Report

The wave pump device was tested in the UNH Chase OE Engineering Tank multiple times in Q2 in preparation for its field deployment test. One test was completed with all the instrumentation and sensors integrated and powered on. Waves were generated by rocking a surface float back and forth repeatedly. This pseudo data was used to begin writing code to process the field data and ensure the DAQ and sensors work as they are expected.

A buoyancy collar was added to the spar float to trim the equilibrium spar position in the water. Prior to the addition of the collar, the spar was riding too low. The collar added approximately 36 pounds of flotation and is made using 4-pound density flotation foam. The collar was produced in the lab using cardboard sonotube and PVC pipe as the molds. Its dimensions are 18" OD, 8.625"ID and 6" tall. The ballast for the field deployment is 13 pounds, attached to the heave plate. Logo banners were also added to the float buoy. These are outdoor-grade adhesive labels (1 ft x 4 ft) attached to thin aluminum sheets. The added weight due to the labels is approximately 3 pounds.

A secondary tank test was completed after adding the labels and buoyancy collar. This test re-configured the float into a 'fountain' effect, where the pump outlet was attached to the float buoy. A series of additional pipes and adapters were used to create this effect. In this configuration, the pumped water is seen moving above the tank's surface. Waves were generated using a surface float, and a video was recorded for demonstration purposes.

The DAQ power system was tested extensively prior to deployment to ensure adequate power supply throughout the field deployment. The DAQ was tested outside in temperatures as low as 19°F, in precipitating weather, for several days. Lithium batteries packs were exchanged for ones with a capacity of 13,600mAh, and an additional one was added for the Lidar circuit, due to its heavy current usage. The solar panels were also exchanged for 5W panels, to meet the energy demands. The system was projected to last a minimum of seven days in low light conditions, indicating that it would last the length of the deployment.

In preparation for the field deployment, the mooring plan and equipment were carefully considered. New mooring lines were purchased with an 11,000-pound tensile strength rating. These lines all have galvanized metal thimbles. These were attached to the float buoy using shackles. All shackles were secured with either mousing wire or cotter pins. New lifting lines were purchased of the same rating and style for safe lifting maneuvers during deployment. The mooring ball, swivels, and shackles were selected for attachment to the SML mooring.

The Sofar Spotter buoy mooring system was also devised. The overall length was approximately 50 feet of line, with trawls floats and weights interspersed to create an accordion effect in the waves. This type of surface mooring increases the accuracy of the Spotter measurements. Rubber coated chains, swivels, and shackles were all employed to increase the durability of the spotter mooring. The Spotter buoy data was purchased, and checked to make sure its satellite connection was working.

Additional equipment and tools were packed for the field deployment. The instrumentation were all disassembled from the device prior to moving the device. The device was loaded onto a flatbed trailer using a forklift and secured into place using tensioned straps. The equipment was loaded onto the truck, and driven from the Chase Engineering building in Durham, NH to New Castle, NH to the UNH pier. The device was lifted off the trailer using a crane. The instrumentation was all re-installed and tested briefly on the device. The Lidar was tested by moving an object over the light, and the flow meter was tested by blowing air through it before the hoses were installed. All sensors and DAQ were working prior to deployment.

On the morning of March 21st, the device was loaded onto the R/V Gulf Challenger using the pier crane. All equipment was also loaded onto the Challenger. The Spotter buoy was activated, and the DAQ batteries were installed. The device was deployed from the Challenger, and tied alongside the ship, while its mooring was prepared. The mooring ball was not sufficient flotation, so an additional fender from the Challenger was used to lift the mooring chain. The device mooring line was secured to the SML mooring, and the mooring was dropped using the Challenger's quick release system. The second SML mooring was pulled up using the Challenger winch, and two hydrophones were installed on its rope. The Spotter was installed and then re-released back to the ocean. The deployment took approximately four hours. Data was collected from the device prior to leaving the mooring site.

Monitoring of the devices during the deployment was conducted utilizing the web camera in the Appledore Radar Tower. Three additional trips were taken in a smaller vessel out to the site during the deployment to monitor the devices. Data was also collected during these trips. The device operated as expected. After five days at sea, a storm knocked the device onto its side where it remained stable. A trip in the small vessel allowed the team to right it again. Two days later, the mooring line shackle came undone, due to a missing cotter pin, and the device came ashore onto Appledore Island. The device was retrieved using the smaller vessel and towed back to the New Castle pier. The Spotter and hydrophones were retrieved a few days later using the Challenger. All the equipment was successfully recovered and stored back at Chase OE. The seven days of data collected from the deployment appear to be of good quality. More analysis and a full deployment report are forthcoming.

The power system on the DAQ was projected to last over fifty days during the deployment. This increase from the shore testing is likely due to the increased length of day on the water, as well as the increase in daylight hours and average air temperature due to the changing season. This task is now mostly complete pending the full deployment report deliverable.

Updates for Q3 FY2023 Quarterly Report

Post-deployment calibrations of both the lidar and flow meter have been repeated for data quality control. The lidar calibration was additionally completed using a video and image tracking software (Kinovea), to verify the result with a large positive correlation between each data set.

The data from the field deployment have been extensively reviewed and processed. Using Matlab the Spotter wave condition data has been broken into twenty-minute segments to match the DAQ data segments. This is done for a better one-to-one comparison. The flow meter data and lidar data have been processed and averaged. Additionally, correlations between the Spotter, lidar, and flow meter data have been calculated. These correlations revealed that the data with the highest accuracy occurred during the timeframe between March 21st 13:18 and March 26th at 12:45PM ET.

To confirm the processing methods of the lidar data, image tracking software (Kinovea) is applied to the videos taken in the field from the Appledore Radar Tower. These revealed that the processing is on the same order of magnitude as the image tracked data.

Spotter data is organized such that files of wave elevation data can be isolated for a particular time set. This will be used to aid in the WEC-Sim numerical model validation (more details next section).

Heave RAO plots for the device have been calculated for various wave states. Using the lidar and Spotter data, spectral analysis was determined to calculate RAO. These plots indicate the frequencies at which the device responds with the highest relative motion. The plots appeared to match the expected form and confirm the processing method chosen for the lidar data.

Device performance characteristics were calculated, to show flow rates in various wave states. This indicates the capabilities of the device and provides insight into redesign and future applications.

The hydrophone and video monitoring of the device during the field deployment were also reviewed. The hydrophone data requires significant further analysis to determine whether any noise attributed to the device was detected. Additional analysis of hydrophone data could include marine mammal detection. The video monitoring review was extensive and revealed a few interactions with gull species. No adverse effects to the gull species involved were observed.

The draft of the field report (AMEC Deliverable 9.4.2.) is complete, with internal reviews pending. The team is prepared to send the field report with supporting data.

Updates for Q4 FY2023 Quarterly Report

AMEC Deliverable 9.4.2. Field Report is completed and has been uploaded to the MHKDR website. All the previous deliverables and applicable milestone reports have been included with this submission. This data is now publicly available on the MHKDR. The DOI is: https://dx.doi.org/10.15473/2000556.

Validation of the WEC-Sim model was performed using the field data to simulate sixteen, twenty-minute trials. The results yielded an approximate 20% difference between simulated and field data values for output flow rate, relative stroke height, and stroke period. The heave RAO analyses were also conducted comparing the WEC-Sim relative position values to the Lidar field data in the frequency domain. These results indicated a close match between the WEC-Sim model and field data. A comprehensive thesis compiling the work on the project was successfully defended and published via ProQuest.

<u>Subtask 9.5 System redesign using lessons learned from the Subtask 9.1-9.4 observations</u>

Updates for the Q1 FY2023 Quarterly Report

A list of lessons learned from work on tasks thus far has been compiled.

Updates for Q2 FY2023 Quarterly Report

Lessons learned from the deployment were added to the current compilation. Additional work on the WEC-Sim numerical model is being completed, to complement the system redesign.

Updates for the Q3 FY2023 Quarterly Report

An outline of the redesign report is in progress. It includes four categories for improvement: performance, durability, maintenance, and deployment procedure. The first two categories will include analysis, and the second two include ideas for future re-design from lessons learned. The performance category will rely upon a validated WEC-Sim model to determine what effects piston size, float size, hose depth, and hose size will have on device performance.

The WEC-Sim model is in the process of being validated using the field data. Simulations are currently being run on the UNH high performance computing cluster, Premise. These simulations will determine the similarity between the field data and the simulated WEC-Sim model.

The second category for the re-design report will include a hydrostatic analysis to ensure a righting moment in all sea state conditions, and analysis of the heave plate.

The outline will be submitted July 18th and completed by the end of August (AMEC deliverable 9.5.1.).

Updates for the Q4 FY2023 Quarterly Report

AMEC Deliverable 9.5.2. Redesign Report is completed. This report outlines a redesign concept which improves performance and survivability. In a WEC-Sim simulation of the redesign concept, the device pumped water at a rate of 140gpm (compared to the field-tested device which produced 16.5gpm in similar wave conditions). Survivability of the redesign concept was evaluated for whether it maintained a positive righting moment throughout ninety degrees of rotation. Additional recommendations were made for improving manufacturability and deployment procedures for future endeavors.

Reflection on Progress

Subtasks 9.1 through 9.5 are now complete. Task 9 is now complete in its entirety.

Challenges, Risks, Mitigation, and Requests

Nothing to report on Tasks 9.1 – 9.4.

NEPA review and the Biological Evaluation constitutes a risk in that it has the potential to delay or prevent open-water testing (Task 9.4).

Plans for Next Quarter

Subtask 9.4 Field Test of WEC device at Shoals Marine Lab completed at the end of Q2 FY2023. Data analysis and report deliverable is complete as of end of Q3 2023, pending internal review.

Subtask 9.5 System redesign using lessons learned from the Subtask 9.1-9.4 observations will be completed by mid Q4 FY2023.

Future work for this project will continue in AMEC BP2, Task 17.

Outputs

Milestone M9.1.1, Review of prior work and literature search, was completed, but there was no Deliverable associated with it. D.9.4.1 Test Plan has been completed.

Completed Deliverables:

Post-Test Report and Data from deployment (D9.4.2) is complete and available on MHKDR (https://dx.doi.org/10.15473/2000556.).

Report on re-design and modifications of WEC, along with associated performance improvements (D9.5.1) is completed and is available via email.

Impact

A wave-powered water pump that can pump cooler, nutrient rich near-bottom water towards the surface has the potential to significantly increase biomass production in kelp farms.

Carry-over tasks from BP1

Task 4.2 UNH Memorial Bridge turbine testing infrastructure

Major Project Goals and Objectives

Upgrade turbine testing infrastructure at the UNH Memorial Bridge Tidal Energy Test Site. Upgrades would include the installation and integration of an imaging sonar, turbine deployment platform height sensors, vertical guide post strain gages, and upgrades to the onboard DAQ system.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

A Biological Assessment covering Memorial Bridge Tidal Energy Test Site infrastructure upgrades was revised by DOE and submitted to the NMFS.

Updates for Q2 FY2024 (January 1st – March 31st)

Received a letter from US Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service that concurred with our conclusions that activities covered under Subtask 4.2 are not likely to adversely affect any NMFS ESA-listed species or designated critical habitats. This should result in lifting any "NEPA holds" against Subtask 4.2. As such, work can begin in earnest on this subtask. UNH will continue to finalize equipment procurement and installation plans and resume work on this subtask.

Updates for Q3 FY2024 (April 1st – June 30th)

Reinitializing discussions with subcontractors who will be responsible for installation of equipment (strain gauges, platform elevation sensors). Discussing equipment selections, integration, installation plans.

Researching acoustic imaging cameras and associated hardware and software for final selection and purchasing.

Updates for Q4 FY2024 (July 1st – September 30th)

Vertical Guide Post load-sensing:

Received updated quotes from subcontractors for the installation of strain gages to the vertical guideposts. These quotes are more expensive than previously expected, partially due to the complexity of the field-install nature of the project. The life expectancy of the sensors was not ideal. The data type (measurement of strain, rather than a calibrated measurement of applied force) is somewhat unwieldy.

As a result, we are investigating the use of load cells installed within the load path between the turbine deployment platform and the vertical guide posts. This may be less expensive, easier to install, would provide more meaningful measurements, and would apply more directly to the satisfaction of IEC standard 62600-202: mooring loads.

In the process of identifying off-the-shelf load cell solutions, as well as load cells that are custom-designed to suit the application. Some off-the-shelf solutions have been identified, and we are in discussions with Sensing Systems, a company that has provided high quality load cells for UNH projects in the past.

Working with OSTEC project team to integrate these signals into the MODAQ system, as opposed to sending the signals to a standalone DAQ system as originally intended. The ability to integrate these signals into MODAQ is yet another advantage of this approach.

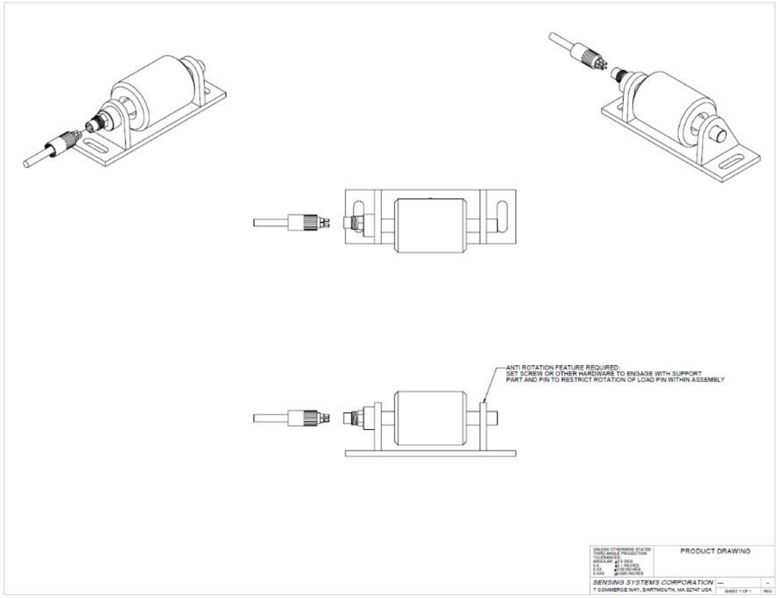


Figure 1.1.1 - Preliminary concept sketch of custom load "pin" for VGP load sensing. This configuration would measure forces exerted onto the VGPs by the turbine deployment platform at the point of contact between the guide rollers and VGP itself.

Platform Elevation Sensors

Researching off-the-shelf elevation sensors that could be installed onto the TDP and integrated into MODAQ. Sensors will be selected with prioritization on ease of installation into the MODAQ system. Because available channels within the MODAQ system are relatively limited, the selection of elevation sensors will be made specifically with MODAQ communication preferences in mind. It is likely that these sensors will be purchased and installed by UNH/AMEC staff. NREL staff will be on site to assist with MODAQ instrument integration, so they will be consulted at that time to assist with selecting the ideal instruments.

Acoustic Imaging Sonar

Considerable research on acoustic imaging sonar devices has been performed. This includes discussions with product manufacturers & vendors, acoustic experts at UNH, and those with significant experience in the field of acoustic imaging sonars for use in marine energy-related applications. Sufficient research has been performed to make a decision based on "paper" research, however vendors have offered free loans of their acoustic imaging sonars. This provides an excellent opportunity to test equipment firsthand prior to making a selection. UNH has likely missed the opportunity to test these devices in the fair weather season of 2024, so a selection may be pushed to 2025, once the devices can be tested. We may make the determination that field testing is not required, in which case we can make a decision based on paper research.

Updates for Q1 FY2025 (October 1st – December 31st)

Significant progress on sensor design and selection. Selection and purchase of most sensors is imminent:

Vertical Guide Post load-sensing:

A strong concept for a load-sensing pin is being developed by AMEC/Sensing Systems. While this sensor solution concept has merit, the load sensing capacity of these devices must be considered carefully. Close review of a 2016 report that discusses the structural design of UNH's turbine deployment platform, including evaluation of anticipated input forces, indicated that the original sensing capacity was arguably under-specified. UNH intends to continue to develop the load pin sensing solution, albeit with a revised load capacity specification. A balance between sensor accuracy and sensor strength must be considered as these parameters tend to work against one another in this application. The devices must be strong enough to withstand the application while being accurate enough to produce useful information. Once the load sensing capacity is specified, final pricing can be considered and components purchased for integration.

Platform Elevation Sensors:

A platform elevation sensor system is largely specified and priced out, ready to order. Waiting to order instrumentation until each of the components (load cells, elevation sensors, acoustic imager) of this subtasks are priced out.

Acoustic Imaging Sonar:

Fair weather testing opportunity for 2024 was missed. Several suitable options for acoustic imaging sonars have been identified and short listed. Final selection is imminent.

Updates for Q2 FY2025 (January 1st – March 31st)

Vertical Guide Post load-sensing

AMEC/UNH refined load sensing capacity requirements and worked with Sensing Systems to develop an updated load-sensing pin design.

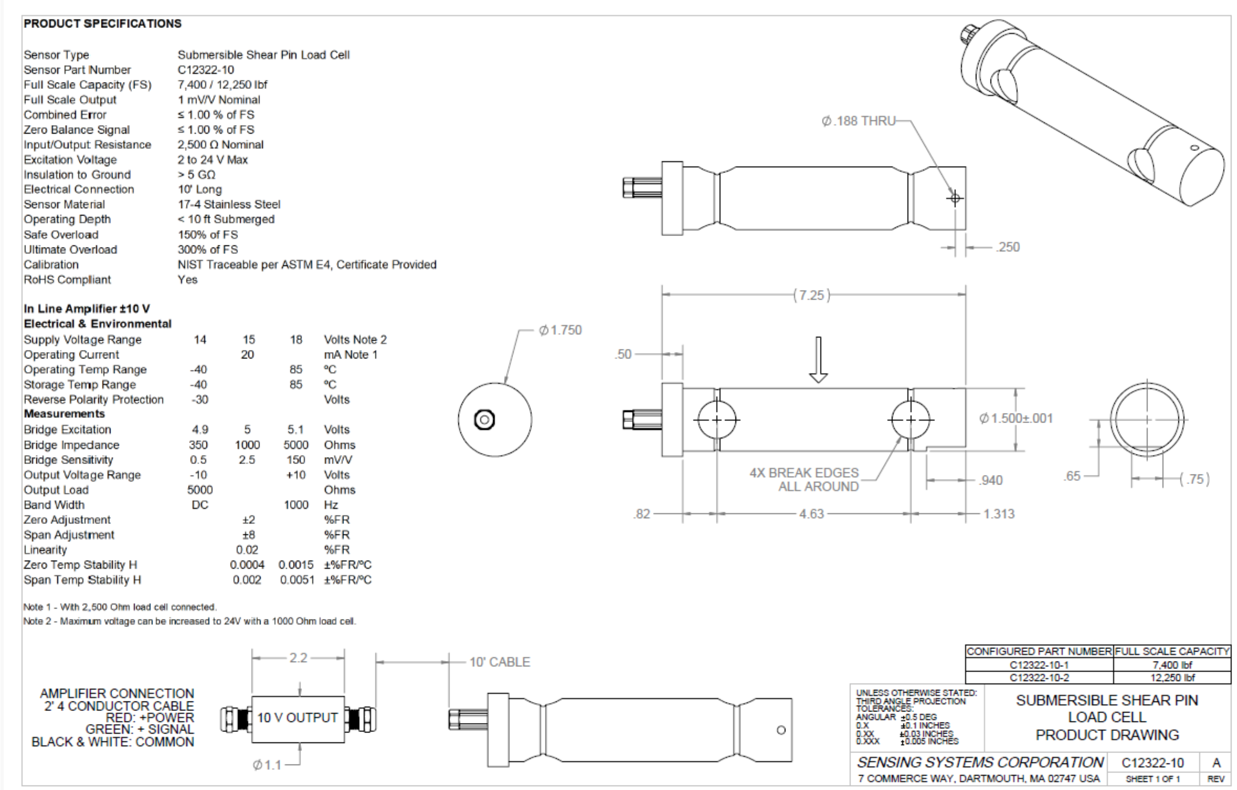


Figure 4.1.2 – Specification summary sheet for submersible load pin for use at UNH/AMEC TDP.

The updated sensing ranges are based partly on the review of a 2016 structural assessment of the Turbine Deployment Platform and Vertical Guide Post assemblies. The estimated input forces include additional impact loading caused by waves at the test site, in addition to the expected turbine-related input forces such as rotor thrust and structure drag.

The "load pins" would be rated for full-scale capacities of 7,400 lbf and 12,250 lbf for cross-stream and streamwise load sensing load pins, respectively. They include a safe overload of 150% of full-scale capacity. They would include integral amplifiers for convenient integration into NREL's MODAQ data acquisition system.

The load pins have been designed to physically integrate into the TDP's pile guide assemblies as readily as possible. The pins and their brackets are generally interchangeable with existing, off-the-shelf guide rollers, such that the instrumented load pins can be substituted with conventional guide rollers in the event that the load pins require service or recalibration.

Platform Elevation Sensors:

Platform elevation sensor systems are largely specified and priced out. The sensors, including marine rated weatherproof enclosures, have been designed into new, upgraded pile guide assemblies for installation at the UNH/AMEC TDP.

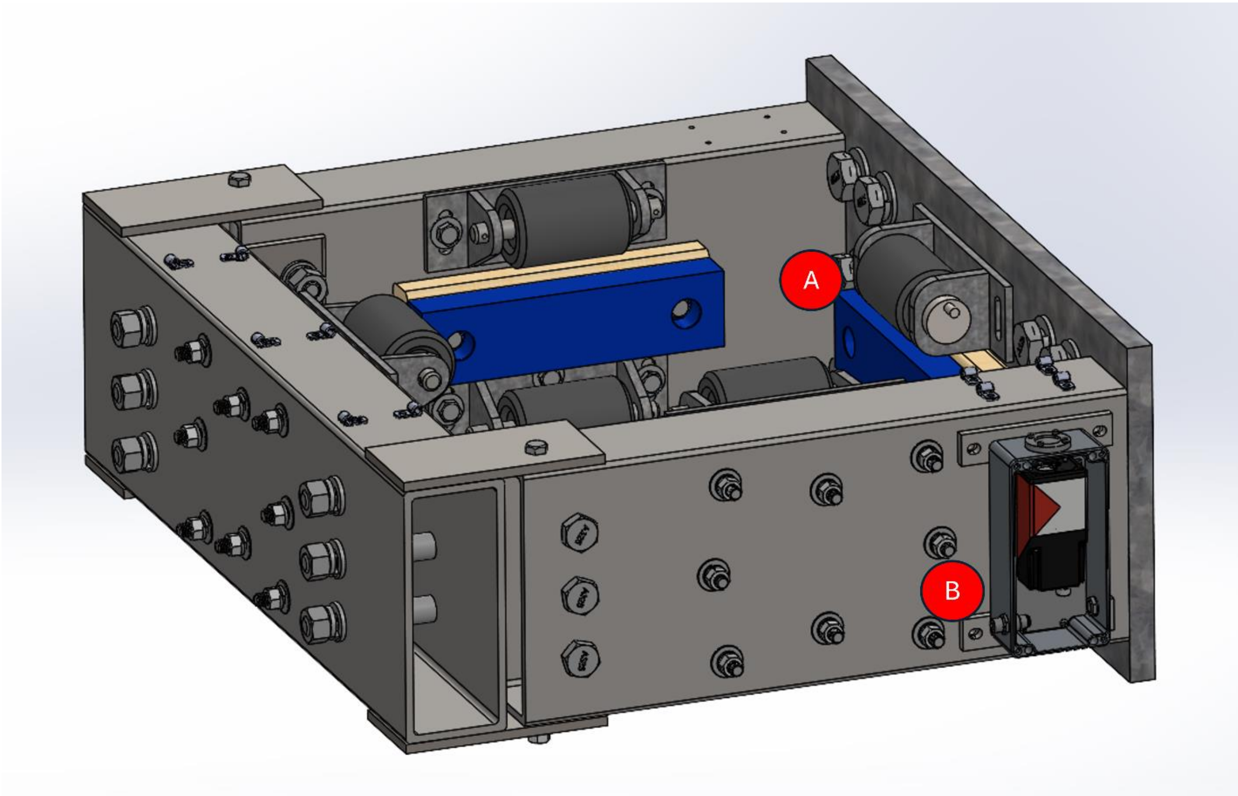


Figure 4.1.3 – Upgraded pile guide assemblies for UNH Turbine Deployment Platform. New pile guide assemblies will withstand increased forcing resulting from a 6-ft platform extension. They will also include provisions for new load-sensing roller pins (A) and platform elevation sensors (B).

Acoustic Imaging Sonar:

Several suitable options for acoustic imaging sonars have been identified and short listed. Final selection is imminent. Procurement of all instruments under subtask 4.2 will be procured concurrently as they will be included within the same UNH Fabricated Equipment project number.

Updates for Q3 FY2025 (April 1st – June 30th)

Vertical Guide Post load-sensing:

Load pin sensing range and capacities were finalized, along with wiring details and physical design parameters. Importantly, after finalizing all sensor information, an order was placed through Sensing Systems. Estimated delivery date 4-8 weeks after receipt of order.

Platform Elevation Sensors:

Based on final sensor pricing and capabilities, an order for elevation sensors was placed through Laser-View Technologies. Estimated delivery date is 3-4 weeks after receipt of order.

Acoustic Imaging Sonar:

Final selection of acoustic imaging sonar was confirmed; a Tritech Gemini 1200 IKD imaging sonar was purchased, along with critical add-on parts and accessories. Estimated delivery date is 4-6 weeks after receipt of order.

Pile Guide Assemblies:

The load pins and elevation sensors are to be installed locally to the UNH/AMEC TDP's pile guide assemblies (PGA). These are structural assemblies that moor the floating TDP to a Vertical Guide Post (VGP) structure, constraining the TDP to the bridge while allowing it to rise and fall with the tides. These assemblies are comparable to commercial- or industrial-duty floating dock pile guides used conventionally at docks, piers, or marinas.

The existing PGAs were corroded and worn from extended use and lacked convenient fixturing features to be used to integrate these new sensors. Because of this, new, upgraded PGAs were designed and ordered. Architecturally, the new PGAs are very similar to the originals. They will be stronger than the original assemblies, by using larger steel stock, thicker gauge steel, heavier welds, reinforced structural tubing webbing, larger fasteners, and more fasteners. Further, they incorporate mounting features specifically for the incoming load pins and elevation sensors.

New assemblies were designed, and an order placed through Ace Welding Co. in Merrimack, NH.

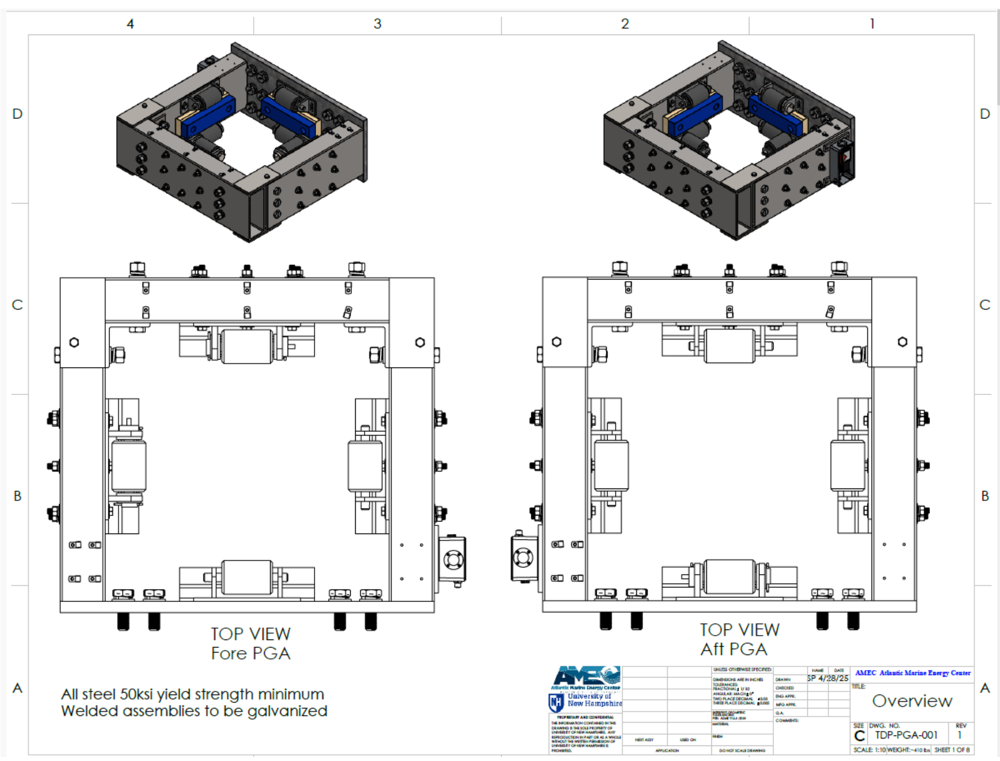


Figure 4.1.4 – Cover page of preliminary drawing package for new, upgraded Pile Guide Assemblies (PGAs). These upgraded assemblies use heavier duty materials and fasteners to increase assembly strength, and incorporate features to mount the new elevation and load sensors.

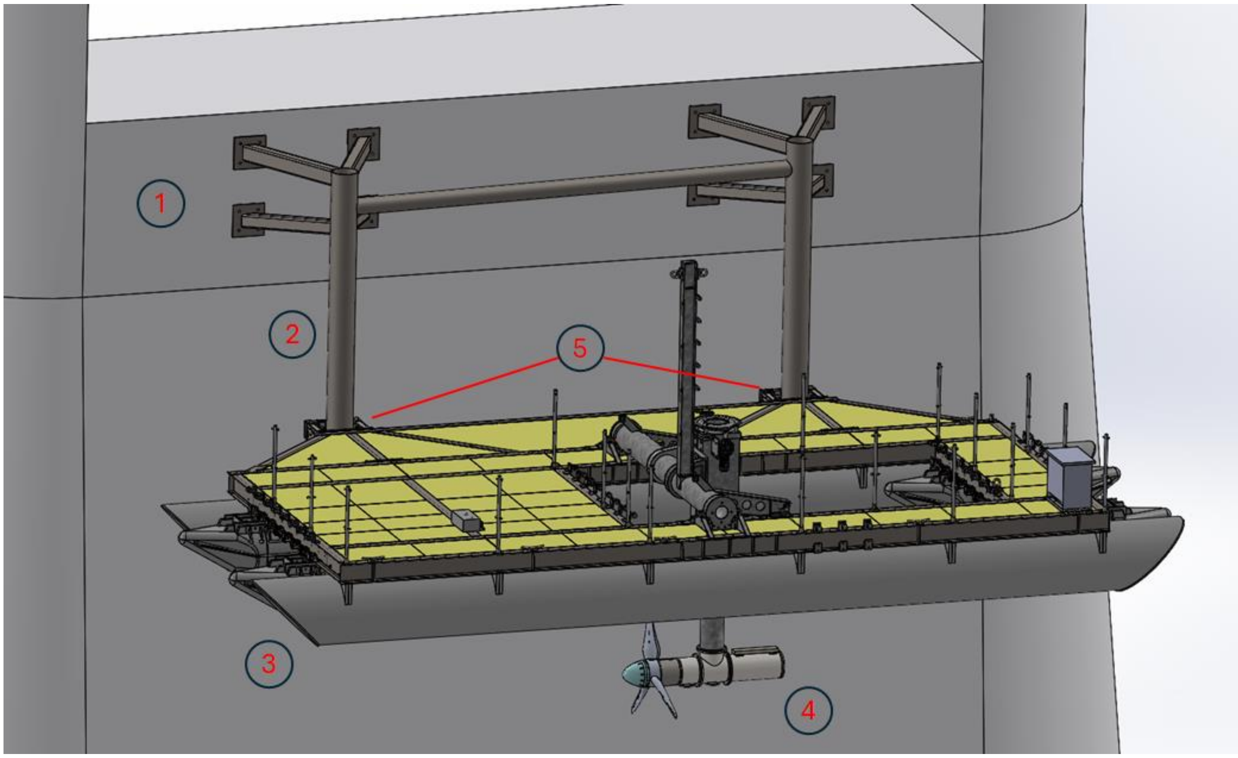


Figure 4.1.5 – Overview of the AMEC/UNH Tidal Energy Test Site, 1) Memorial Bridge Pier II, 2) Vertical Guidepost (VGP) mooring assembly 3) Turbine Deployment Platform (TDP) 4) OSTEC Turbine 5) Pile Guide Assemblies (PGAs)

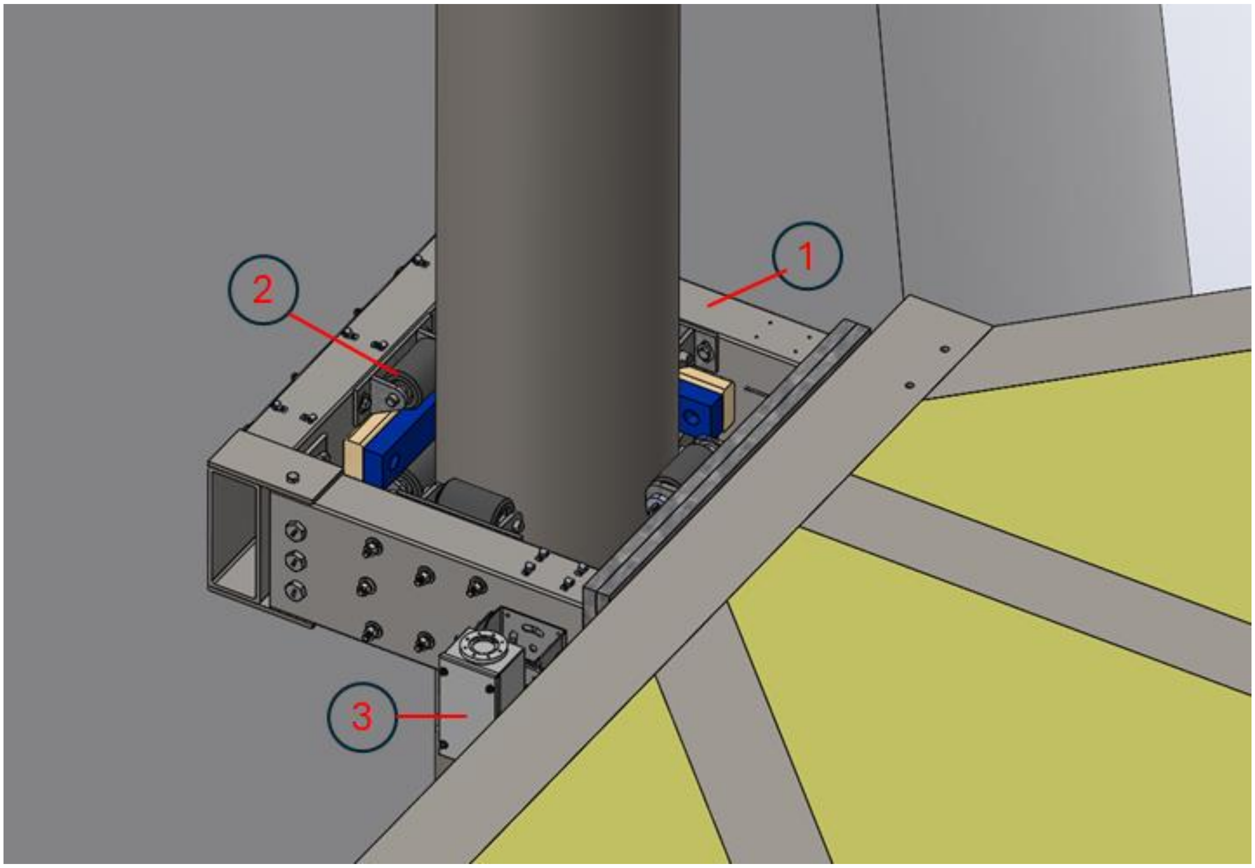


Figure 4.1.6 - Detail view of new instrumented pile guide assembly, installed onto TDP. 1) PGA structural framework 2) Pile guide roller, with instrumented load pin axle 3) Platform elevation sensor

TEAMER

UNH/AMEC collaborated with NREL to submit a TEAMER request for technical support. In the proposal, UNH/AMEC personnel request training from NREL on the software integration of sensors into the MODAQ data acquisition system. UNH/AMEC's Tidal Energy Test Site already uses a MODAQ system to capture data from a suite of sensors, so it is sensible to integrate the new elevation sensors and load pins into this acquisition system. The project structure would allow NREL to use their unique understanding of the MODAQ system, and train UNH/AMEC personnel on the software-side integration of these sensors.

The proposal was awarded, allocating funds to NREL to provide hands-on training to UNH/AMEC. UNH/AMEC personnel will use the skills gained from this training to perform the software integration of the sensors within subtask 4.2.

Updates for Q4 FY2025 (July 1st – September 30th)

Vertical Guide Post (VGP) load-sensing, mooring load measurement:

A complete order of 8 load pins was received by UNH from custom load cell manufacturer Sensing Systems Corp. in Dartmouth, MA, USA. Each marine environment-rated load pin comes with a unique calibration certificate, good for three years from date of manufacture, an integral power & signal cable approximately 30ft in length, and an integral signal amplifier for transmission of signal into MODAQ's National Instruments 9205 analog input module. A wiring diagram was developed for integration of these sensors into the greater UNH-MODAQ system for the Turbine Deployment Platform (TDP). This wiring diagram was prototyped and bench tested to verify its effectiveness and to verify the function of each sensor and their response to applied load; test results were positive.

Figure 4.1.7 - 1 of 8 custom, marine-rated, instrumented load pins (manufactured by Sensing Systems) mounted within a custom load pin bracket (fabricated). These devices will be outside within the TDP's pile guide assemblies.

The integral amplifiers are relatively small, but fairly heavy due to their stainless steel, waterproof enclosures. They are marine-rated, but will be stored inside the turbine deployment platform's instrumentation shed. To keep the weight of the amplifiers off of the instrument cables, a series of cradles were fabricated to keep the amplifiers neatly organized and to reduce risk of tangling or damaging the cable and/or amplifier.

The load pins will be integrated into the upgraded pile guide assemblies, documented below, and installed onto the TDP (as part of TDP modifications for OSTEC turbine).

Platform Elevation Sensors

A complete order of 2 elevation sensors was received by UNH from Laser-View Solutions. Each marine environment-rated elevation sensor is computer-configurable by the end user to tailor parameters such as sample rate, calibrated range, averaging period, etc. for a given application. A wiring diagram was developed for integration of these sensors into the greater MODAQ system. After the elevation sensors were configured using the OEM configuration software, the wiring diagram was prototyped and bench tested to verify its effectiveness and to verify the function of each sensor and their response to applied load; test results were positive.

Because the load pins and elevation sensors will be integrated into the UNH/AMEC Turbine Deployment Platform's (TDP) MODAQ system, but were added to the suite of sensors fairly late in the development of said system, the power and signal cables from each load pin and elevation sensor will be merged within a dedicated Pile Guide Assembly (PGA) Instrument Subpanel. The subpanel will combine each individual power and signal cable into one relatively large multi-conductor cable, which terminates in one male plug. This plug will connect to the MODAQ acquisition panel by way of one of the standard plug receptacles, and the power and signal cables routed as required to NI acquisition modules and power supplies.

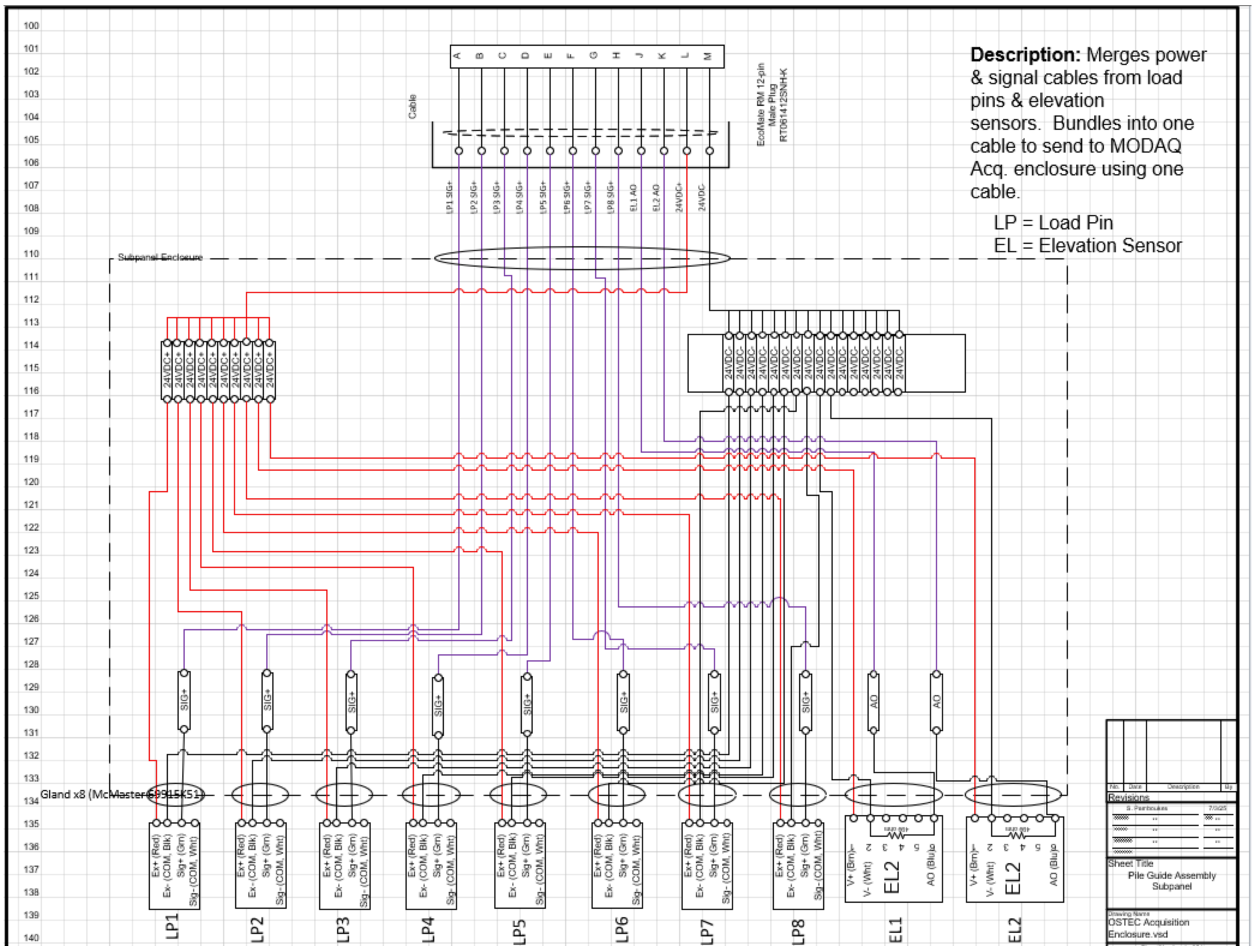


Figure 4.1.8 - Excerpt of PGA Instrument Subpanel wiring diagram.

Acoustic Imaging Sonar:

A TriTech Gemini 1200ikd acoustic imaging sonar was received, complete with travel carrying case, required cabling, and instrument clamp and pole mount. Preliminary investigations of this equipment have been performed; installing OEM software, testing device connectivity, and planning mounting & fixturing equipment for use at UNH's Engineering Tank, Tow Tank, and Turbine Deployment Platform. An accessory mount was devised to integrate UNH/AMEC's existing optical camera into the acoustic camera's mount. These devices can be used in tandem with one another within the imaging sonar's OEM software, allowing for easy comparison between optical and acoustic imagery.

Pile Guide Assemblies:

Upgraded pile guide assemblies have been completed and installed onto the TDP. These pile guide assemblies house the TDP's pile guide rollers, and effectively moor the TDP to the Memorial Bridge's vertical guidepost structure. All forces exerted upon the TDP are transmitted to the vertical guideposts via these PGAs, making them an ideal location for installation of instrumented load pins. They will also be used to mount the platform elevation sensors.

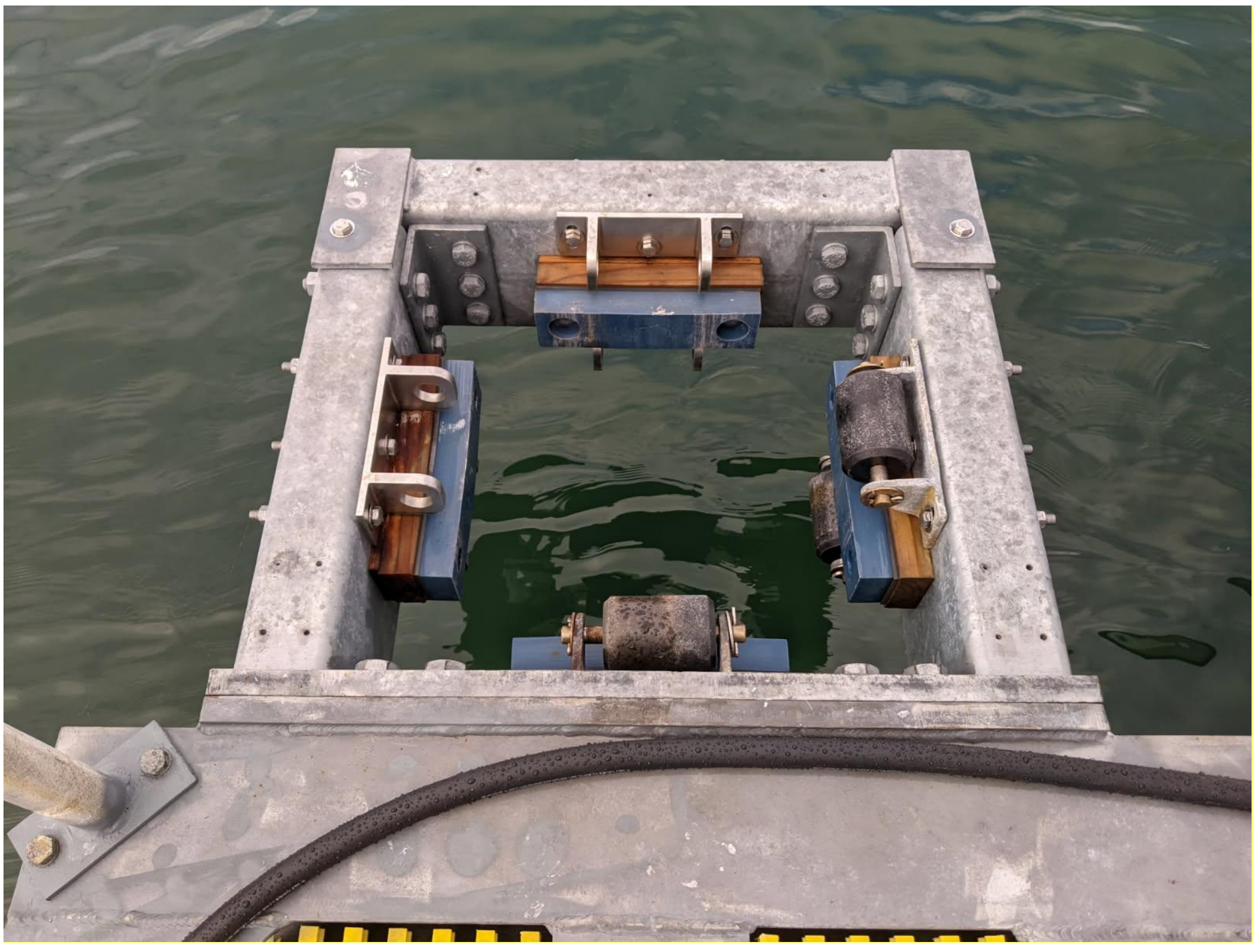


Figure 4.1.9 Upgraded pile guide assemblies (PGAs). These are constructed of heavier gauge steel, larger members, and heavier duty fasteners compared to the original PGAs. They also include bespoke mounting provisions for the custom load pins and elevation sensors (left and top). Shown partially assembled, the PGAs still require some mechanical components (shims, spacers, washers, brackets, etc.) before the load pins and elevation sensors can be installed.

TEAMER

UNH/AMEC and NREL are awaiting reviewer comments on their TEAMER project test plan. Once reviewer comments are provided, UNH & NREL can begin work on this TEAMER collaboration. The major goal of this project is for NREL to provide training to UNH on integrating additional sensors into the MODAQ system. The load pins and elevation sensors will be used as real-life case study examples for how a new sensor may be integrated into MODAQ.

Please note that soliciting TEAMER support from NREL can be categorized as an activity under Subtask 10.7 Partnerships in Marine Energy.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Progress relating to the actual infrastructure upgrades cannot actually be made until NEPA holds are lifted. However, progress has been made on drafting and submitting the required Biological Assessments. With the BA for this task submitted to DOE and NMFS, we can correspond with all parties until a determination is made.

Updates for Q2 FY2024 (January 1st – March 31st)

The letter of concurrence from NMFS is a significant milestone. With this letter, UNH can commence procurement of parts and work on this subtask.

Updates for Q3 FY2024 (April 1st – June 30th)

Revisiting prior quotes and contractor discussions that are sometimes years old. Good to continue these discussions and make progress toward final decisions and installation.

Discussions with acoustic camera expert users (e.g. Garrett Staines, Rob Cavagnaro, PNNL)

Updates for Q4 FY2024 (July 1st – September 30th)

Pivoting from subcontractor-installed VGP strain gages and level sensors to UNH-installed load cells and level sensors does represent a change from original plans, however this change should result in an overall significant benefit to the outcome of the subtask.

The new opportunity to test acoustic imaging equipment at little to no cost has provided an opportunity to test products firsthand before making a product selection. The value of a firsthand test is significant, however will require some time and planning and cannot happen until late winter/spring 2025.

Updates for Q1 FY2025 (October 1st – December 31st)

Steady progress has been made. The team is eager to finalize instrument selections, purchase, and integrate into test site infrastructure.

Updates for Q2 FY2025 (January 1st – March 31st)

Steady progress towards finalizing selection of each instrument. Selection and procurement is expected to be carried out in Q3 FY2025, with installation and integration into data acquisition system following immediately after.

Updates for Q3 FY2025 (April 1st – June 30th)

UNH/AMEC is pleased to have made significant progress on this subtask this quarter. All instruments have been selected and ordered. The upgraded pile guide assemblies themselves, to which the instruments will be fastened, have also been designed and ordered. A TEAMER proposal submission was successful, with funds awarded to NREL to provide training to UNH/AMEC staff.

Updates for Q4 FY2025 (July 1st – September 30th)
UNH/AMEC is pleased to have made significant progress on this subtask this quarter. All instruments have been received and mostly bench tested. Plans and provisions are being made to integrate the sensors at the hardware and software levels into the TDP and MODAQ. UNH & NREL await information from TEAMER prior to proceeding on their TEAMER collaboration.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
The NEPA holds on this project have been a persistent challenge on this subtask.

Updates for Q2 FY2024 (January 1st – March 31st)
Some equipment and contracted services relating to Subtask 4.2 may involve long lead time items. UNH intends to begin work immediately such that the upgrades may be performed within the most forgiving portions of the season. Spring, summer, and early fall are ideal for work on the turbine deployment platform (TDP).

A separate project that utilizes the TDP will require the TDP to be removed for equipment installation and refit purposes. UNH will need to coordinate with this project team to ensure that project schedules do not conflict with one another.

Updates for Q3 FY2024 (April 1st – June 30th)
Final equipment acquisition and installation timelines will be largely dependent on vendor and subcontractor schedules. We are hopeful to have this work complete during the favorable field work season (prior to winter '24), but this may be outside of our control.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Review of 2016 structural design study relating to UNH tidal energy test site suggests that original load cell capacities were underspecified. Need to evaluate the methods used to perform loading estimates in said study, decide if they are suitably accurate or if they should be revised.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Some sensors, components, and accessories will be subject to tariffs, as the products originate with international vendors. Product lead times, in some cases, are somewhat long, but instruments are expected to arrive in time for a deployment this year.

Updates for Q4 FY2025 (July 1st – September 30th)
None reported

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Ideally, UNH, DOE, and NMFS will conclude discussions relating to the BA for subtask 4.2, and the NEPA hold would be lifted. Once that is done, the project team can continue along with final selection and sourcing of hardware components and planning and executing installation.

Updates for Q2 FY2024 (January 1st – March 31st)
Contact vendors and contractors to review product pricing, quotes, and scopes of work. Fine-tune equipment selection decisions and proceed with purchase and subcontract initiation. Converge on a subtask timeline based on lead time and availability of products and subcontractors.

Updates for Q3 FY2024 (April 1st – June 30th)
Continue discussion with vendors and contractors to review product pricing, quotes, and scopes of work. Fine-tune equipment selection decisions and proceed with purchase and subcontract initiation. Converge on a subtask timeline based on lead time and availability of products and subcontractors.

Updates for Q4 FY2024 (July 1st – September 30th)
Continue to design and/or select load cells for VGP load sensing.

Continue to research and select a platform elevation sensor.

Determine whether or not a field test will be required for selection of acoustic imaging sonar, or if a selection can be made based on paper research.

Updates for Q1 FY2025 (October 1st – December 31st)
Finalize selection of instruments, purchase, and continue to plan and execute integration activities.

Updates for Q2 FY2025 (January 1st – March 31st)
While final selection was expected for Q2 2025, final specifications for load pins were received in very late Q2. With instrument specifications and pricing now acquired, we move into Q3 FY2025 with increased confidence that procurement can take place in Q3, immediately following on to installation and integration.

Updates for Q3 FY2025 (April 1st – June 30th)
While awaiting the receipt of ordered instruments, UNH/AMEC will plan the electrical integration of these sensors into MODAQ, including wiring diagrams, cable and connector planning, and subpanel planning. They will make plans to test, verify calibrations, and install the hardware once it arrives. They will work with NREL to begin software training. Ideally, sensors will be prototyped, tested, and fully integrated within Q4.

Updates for Q4 FY2025 (July 1st – September 30th)
With all instruments in AMEC/UNH's possession, AMEC/UNH can continue to physically integrate these sensors into the TDP's various subassemblies, and integrate their signals into the greater MODAQ system.

Some components will need to be fabricated or modified in order to install the load pins; plastic guide rollers must be bored out, shims cut, and final installation performed. Provisions for cable routing must be made to convey the instruments' cables from the PGAs to their respective DAQ cabinets.

Elevation sensors must be configured using the OEM-supplied software, then installed. A reflective target must be installed for the elevation sensors to reference against.

The acoustic imaging sonar will be tested at UNH's engineering tank, tow tank, and ultimately at the TDP.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
None reported.

Updates for Q4 FY2024 (July 1st – September 30th)
None reported.

Updates for Q1 FY2025 (October 1st – December 31st)
None reported.

Updates for Q2 FY2025 (January 1st – March 31st)
None reported.

Updates for Q3 FY2025 (April 1st – June 30th)
None reported.

Updates for Q4 FY2025 (July 1st – September 30th)
Outputs for this period would include the physical instruments, devices, and associated hardware. A wiring diagram for the load pins and elevation sensors has also been produced. CAD models of the PGAs and respective instruments have been produced.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
None reported.

Updates for Q4 FY2024 (July 1st – September 30th)
None reported.

Updates for Q1 FY2025 (October 1st – December 31st)
None reported.

Updates for Q2 FY2025 (January 1st – March 31st)
None reported.

Updates for Q3 FY2025 (April 1st – June 30th)
[Enter "Impact" text. This section should be a concise narrative describing the impact this project has on industry, technology, and society. This is an opportunity for recipients to explain the value of using taxpayer money to fund the project.]

Updates for Q4 FY2025 (July 1st – September 30th)
None reported.

Task 4.3 SBU Digital Twinning via Computational Fluid Dynamics (CFD)

Major Project Goals and Objectives

This subtask aims to upgrade the VFS code to enable coupled high-fidelity simulations of tidal flow, morphodynamics, marine hydrokinetic turbine (MHK) (blades, nacelle, and tower), and water free-surface. We also seek to increase the memory space of our computing cluster at SBU to enable data storage for the field scale high-fidelity simulations in BP2. VFS code currently includes modules to model various aspects of the tidal farms separately. Our over-arching objective is to fine-tune the existing modules and integrate them to enable fully coupled simulations of MHK, sediment, water, and air phases.

Task 4.3 was 100% completed in June 2024.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

The team at SBU has completed most (90%) of the remaining activities of this subtask. The remaining activities include integrating the sediment transport and morphodynamics module of the VFS code with the rest of the package, i.e., actuator models, geometry resolving model, free-surface tracking module, control modules of turbine blades, hydroelastic module of the code, etc.

The sediment transport module was incorporated into the suite of VFS code, and we are currently performing the final verification tests to ensure the robustness of the entire code to conduct BP2's tasks. For example, in Figure 4.3, we plot the code's simulation results for a utility-scale MHK turbine in a large-scale channel with a mobile bed. As seen, the model computed the bed deformation of the channel's mobile bed induced by the operation of the horizontal axis turbine.

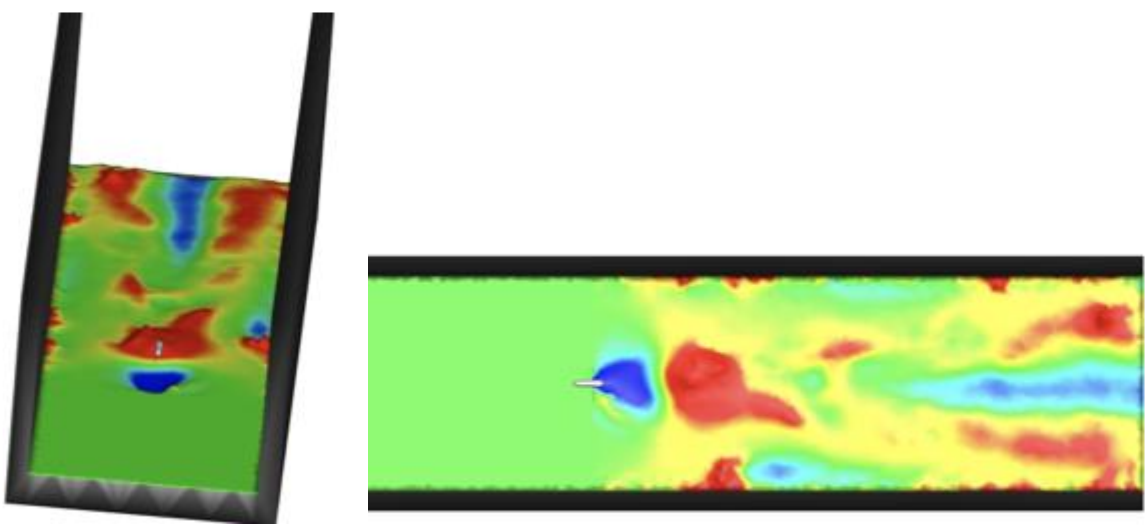


Figure 4.3.5: LES of flow, NHK turbine, and bed morphodynamics interactions. The turbine is 5 m in diameter and the flow has a bulk velocity of 2 m/s. The operation of the turbine has induced complex bed deformation downstream of the tower. Red and blue regions show deposition and scour zones.

Updates for Q2 FY2024 (January 1st – March 31st)

No update.

Updates for Q3 FY2024 (April 1st – June 30th)
The team has completed the integration, and the code has been successfully validated. This subtask is 100% completed.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
The progress of the subtask is as planned, and we think that the VFS code upgrade will end in March 2024. The blockage of funding after GNG is slightly hurting the team's activities as we have not been able to make planned purchases for software and supplies, among others.

Updates for Q2 FY2024 (January 1st – March 31st)
No update.

Updates for Q3 FY2024 (April 1st – June 30th)
This subtask is 100% completed.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Our main challenge during this quarter included the blockage of funding (after GNG) for software purchase, travel, and supply. Hopefully, this will soon be resolved, and we can complete this subtask.

Updates for Q2 FY2024 (January 1st – March 31st)
No update.

Updates for Q3 FY2024 (April 1st – June 30th)
This subtask is 100% completed.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
We will finalize the upgrade of the VFS and prepare it for the tasks of BP2 by March 2024. We are working to finalize a detailed instruction manual of the VFS code and will finalize it by March 2024. This comprehensive instruction manual -- along with the code and input files for sample modeling practices -- will be shared with the public on PRIMRE.

Updates for Q2 FY2024 (January 1st – March 31st)
No update.

Updates for Q3 FY2024 (April 1st – June 30th)
This subtask is 100% completed.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)

The outputs of the research team in this period include (1) the publication of 2 research articles in peer-reviewed journals and (2) graduating as a Master student in Marine Renewable Energy.

Updates for Q2 FY2024 (January 1st – March 31st)

No update.

Updates for Q3 FY2024 (April 1st – June 30th)

This subtask is 100% completed. The outputs of the team in this period include: (a) publication of 5 research articles in peer-reviewed journals and (b) graduating a PhD student (Zexia Zhang) and a Master student (Jonthan Craig) in the field of marine renewable energy.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

This research task's impact can be seen in the outputs of its research work, as mentioned above. The outputs of the research team in this period include (1) the publication of 2 research articles in peer-reviewed journals and (2) graduating as a Master student in Marine Renewable Energy. Updates for Q2 FY2024 (January 1st – March 31st)

Updates for Q2 FY2024 (January 1st – March 31st)

No update.

Updates for Q3 FY2024 (April 1st – June 30th)

This research task's impact can be seen in the outputs of its research work, i.e., (a) publication of 5 research articles in peer-reviewed journals and (b) graduating a PhD student (Zexia Zhang) and a Master student (Jonthan Craig) in the field of marine renewable energy.

Task 4.4 SBU Smart Mobile Grids and Power Conversion

Major Project Goals and Objectives

This sub-task targets the gaps in power electronics conversions and plans to develop a power converter platform for both hardware co-design/co-optimization, and converter hardware and control software validation. The objective of the projects is to deliver a scalable modular framework for high-performance power electronics converter design/optimization in MRE applications with co-design considerations from different application-oriented specifications.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

To attain the goals specified in BP1 and accomplish the project milestones and deliverables, the initial phase of hardware prototype development is underway. The focus is on designing an h-bridge prototype to enhance hardware scalability and modularity (Figure 4.4 (a.4.1)). This approach aims to enable system reconfigurability through the incorporation of cascaded h-bridge power stages. Wide Band Gap (WBG) devices were employed to enhance system efficiency and power density. Along with the power stage development, the advantages of using the hybrid two-fold enclosure were investigated (Figure 4.4 (a.4.2)).

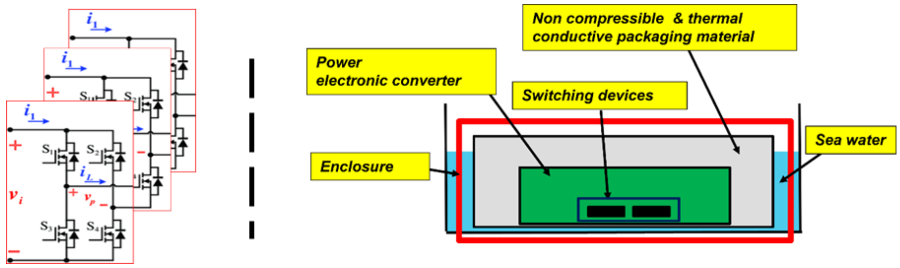


Figure 4.4 (a.4). (a.4.1) Schematic diagram of H-bridge cascading for reconfigurable power stage. (a.4.2) two-fold hybrid enclosure.

Following are the list of tasks accomplished during the Q1 FY2024:

Hardware Prototyping:

- ❖ The literature survey was conducted to identify a suitable converter topology for Marine Renewable Energy (MRE) applications, and Back-to-Back (BTB) converter topology was selected.
- ❖ Furthermore, the literature study was conducted to find the best modular solution. To enhance the scalability of the power stage and modular H-bridge solution was selected for the initial prototyping phase.
- ❖ The integration of WBG devices was done to enhance the power efficiency and power density of the system. Hence, Silicon Carbide (SiC) devices were employed for initial prototyping.

Packaging/ Enclosure Design:

- ❖ The preliminary study was conducted to determine the material type and establish the initial structure of the enclosure.
- ❖ A two-fold hybrid design has been chosen to minimize the weight and volume of the enclosure's thick walls. The inner enclosure will incorporate thermal coolant and insulation material, while the outer enclosure will encapsulate a water-repellent, non-compressible material. The entire system is then enclosed in a larger enclosure with thinner walls, resulting in reduced overall weight.

Updates for Q2 FY2024 (January 1st – March 31st)

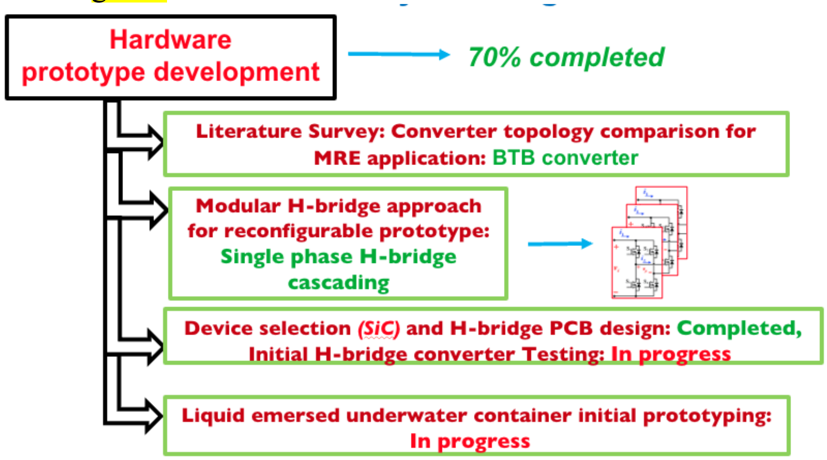
[Enter update here. This section should be a concise narrative explaining completed project activities and findings. Best practice is to section by SOPO task and subtask numbers (with their respective titles).]

Updates for Q3 FY2024 (April 1st – June 30th)

- ❖ Significant progress has been made in the hardware prototype development and associated software and control systems. The literature survey, focused on comparing converter topologies for Marine Renewable Energy (MRE) applications, specifically the Back-to-

Back (BTB) converter, has been successfully completed. The development of the modular H-bridge approach for the reconfigurable prototype, which involved single-phase H-bridge cascading, has also been completed. Additionally, the selection of Silicon Carbide (SiC) devices and the design of the H-bridge Printed Circuit Board (PCB) have been finalized.

- ❖ In terms of software and control systems, the development of software for design and optimization (M4.4.1) has been completed, along with the validation and posting of the software platform on PRIMRE (D4.4.1). The control system has been validated using Control Hardware-in-the-Loop (CHIL) methods, and the results have been posted on PRIMRE. Furthermore, a comprehensive instruction manual and report on the operation and maintenance strategy (D4.4.2) have been developed and completed.
- ❖ Overall, the project has achieved 80% completion, with the hardware prototype development set to continue into the next phase (BP2). These completed activities have laid a robust foundation for the upcoming stages, ensuring the project remains on track and aligned with its objectives.
- ❖ Two senior year projects were completed with the focus on developing self-coordinating robots for efficient onshore grid maintenance and building robotic arms for complex underwater maintenance in power substations. It further contributed to the overall project goals.



Updates for Q4 FY2024 (July 1st – September 30th)

Finalized and sent board designs to the manufacturer for production.

Completed comparison of two layouts for selecting the best configuration for H-bridges in the back-to-back converter.

A non-interleaving layout was selected due to significantly lower layer-to-layer capacitance (7x less than the interleaving layout).

Updates for Q1 FY2025 (October 1st – December 31st)

The H-Bridge hardware development has been successfully completed, and testing of the designed hardware is currently in progress. Overall, 90% of the work on hardware development has been accomplished.

- Overall, 90% of hardware development is completed.

- Testing is under progress which includes the characterization of the device losses.
- DPT tests are conducted to ensure the SiC device performance on the designed PCB
- The parasitic has been extracted for comparison in between the parasitic to choose the optimum layout for the SiC devices.
- A comparison has been made to select the gate driver IC for the designed H-Bridge.
- The optimum position has been selected to minimize the gate to source loop (direct placement of the gate driver board on the SiC gate to source pins)

Updates for Q2 FY2025 (January 1st – March 31st)

H-Bridge Hardware Development Update

The H-Bridge hardware development has now been fully completed, and initial testing is underway. Key accomplishments include:

- 100% of the hardware design has been completed and initial testing has been successfully conducted.
- Double Pulse Testing (DPT) results indicate strong performance, with a measured dv/dt of 49 V/ns and no signs of mis-triggering.
- The gate driver board has been fully designed and implemented.
- A direct connection has been ensured between the gate driver and the SiC device gate-source pins to minimize gate loop inductance.
- Parasitic extraction and comparison have been performed to identify and implement the optimal PCB layout for SiC device operation.
- Figure 4.4.1 shows the hardware DPT test setup along with the hard with direct gate pin connection.

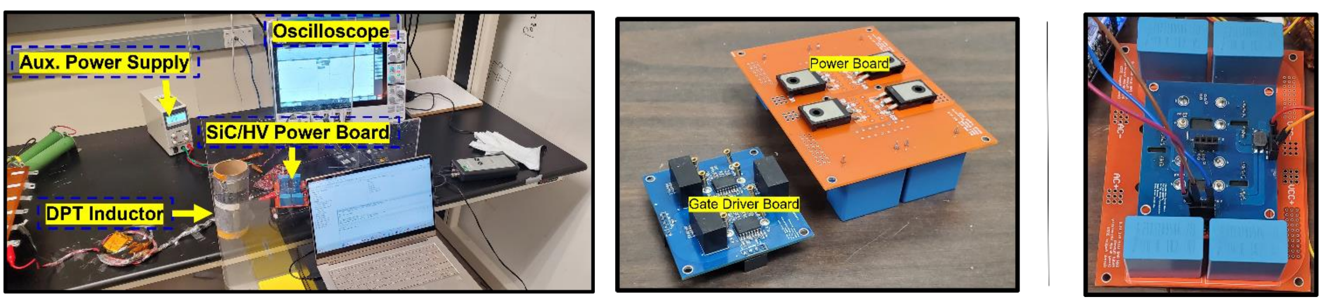


Figure 4.4.1 – (a) DPT test setup. (b) Designed H-Bridge with SiC devices (c) Direct gate to boar connection for reduced gate loop.

Updates for Q3 FY2025 (April 1st – June 30th)
This subtask is 100% completed.

Updates for Q4 FY2025 (July 1st – September 30th)
This subtask is 100% completed.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Hardware Prototyping: Selection of topology, device and Selection of Enclosure is done:

- ✓ Back-to-Back (BTB) converter topology chosen for Marine Renewable Energy (MRE) applications.
- ✓ Modular H-bridge solution selected for scalability in the power stage.
- ✓ Silicon Carbide (SiC) devices integrated for improved power efficiency and density.

Packaging/Enclosure Design:

- ✓ Hybrid design chosen for the enclosure to minimize weight and volume.
- ✓ Inner enclosure to include thermal coolant and insulation material.
- ✓ Outer enclosure to use water-repellent, non-compressible material.
- ✓ Overall system enclosed in a larger enclosure with thinner walls for reduced weight.

Updates for Q2 FY2024 (January 1st – March 31st)

The selection of components for the hardware prototype has been completed.

Updates for Q3 FY2024 (April 1st – June 30th)

Hardware Prototyping: Selection of topology, device and Enclosure is done:

- ✓ The design of the H-bridge Printed Circuit Board (PCB) was completed, ensuring reliable and efficient operation.
- ✓ Started initial testing for hardware prototype development.

Packaging/Enclosure Design:

- ✓ Initial prototyping of Liquid Emersed Underwater Container is started

The project has achieved 70% completion in the hardware prototype development phase. The design of the H-bridge Printed Circuit Board (PCB) was completed, ensuring reliable and efficient operation. The project continues in BP2, which will focus on continued hardware prototype development and integration.

Updates for Q4 FY2024 (July 1st – September 30th)

The project has reached 70% completion in the hardware prototype development phase.

The board designs were successfully finalized and sent for manufacturing, which was a critical milestone.

Testing will begin immediately after the population process is completed, showing steady progress towards deliverables.

Updates for Q1 FY2025 (October 1st – December 31st)

The H-Bridge hardware development has been successfully completed, with 90% of the work accomplished. Testing of the designed hardware is currently in progress, including the *characterization of device losses. Double Pulse Tests (DPT) have been conducted to verify the performance of SiC devices on the designed PCB. Additionally, parasitics have been extracted and analyzed to compare different layouts, ensuring the selection of the most optimal design for the SiC devices. A comparison has also been performed to identify the most suitable gate driver IC for the H-Bridge. Furthermore, the gate driver board has been optimally positioned directly on the SiC gate-to-source pins to minimize the gate-to-source loop for enhanced performance.*

Updates for Q2 FY2025 (January 1st – March 31st)
Hardware Prototyping: H-bridge design is 100% completed.

- ✓ *DPT testing has been conducted and one stage for single phase Back-to-Back (BTB) converter topology is completed.*

Updates for Q3 FY2025 (April 1st – June 30th)
This subtask is 100% completed.

Updates for Q4 FY2025 (July 1st – September 30th)
This subtask is 100% completed.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
The BP2 pending approval caused some delays in monthly updates for critical feedback. However, even with those delays the initial hardware prototyping was started and will be discussed in an upcoming monthly meeting under BP2.

Updates for Q2 FY2024 (January 1st – March 31st)
[Enter update here. This section should be a concise narrative explaining completed project activities and findings. Best practice is to section by SOPO task and subtask numbers (with their respective titles).]

Updates for Q3 FY2024 (April 1st – June 30th)
The testing phase of initial H-bridge converter involved multiple parameters and potential failure modes that needed to be thoroughly evaluated. Components failed under testing conditions and required replacements and redesigns.

Updates for Q4 FY2024 (July 1st – September 30th)
Challenges: No major issues identified at this stage.

Risk Mitigation: Preparations for component population and parallel development of testing protocols will help ensure a smooth transition into the testing phase.

Updates for Q1 FY2025 (October 1st – December 31st)
Challenges: At this point, no significant challenges have been encountered.

Risk Mitigation: Double Pulse Tests (DPT) are conducted prior to continuous testing to ensure that the devices perform as expected. This approach helps identify any design-level issues early, allowing them to be addressed and mitigated before proceeding to continuous testing. These preparations, along with the development of testing protocols, ensure the safe and reliable testing of the designed hardware.

Updates for Q2 FY2025 (January 1st – March 31st)
Challenges: At this point, no significant challenges have been encountered.

Updates for Q3 FY2025 (April 1st – June 30th)
This subtask is 100% completed.

Updates for Q4 FY2025 (July 1st – September 30th)
This subtask is 100% completed.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)

- **Hardware Prototype**
- After initial design validation the h-bridge power stage PCB will be sent out for the manufacturing process.
- Detailed electrical and thermal testing will be performed to check the electrical performance of the designed boards.
- To characterize the losses from the selected SiC devices, Double Pulse Test (DPT) will be conducted.
- The continuous operation will be done by putting the rated load across the h-bridge converter.
- The reconfigurable solution will be developed with the help of designed power stages.
- Final testing will be done with placing the converter in underwater enclosure placement.
- Optimization of the designed hardware will be done if needed to address the challenges.
- **Packaging/ Enclosure Design**
- The initial version of the two-fold enclosure will be tested for thermal and machinal validation.
- Different coolant materials will be compared and tested to compare and pick the best suited solution of underwater thermal environment.
- Final testing with the converter placed inside the enclosure will be done.

Updates for Q2 FY2024 (January 1st – March 31st)
[Enter update here. This section should be a concise narrative explaining completed project activities and findings. Best practice is to section by SOPO task and subtask numbers (with their respective titles).]

Updates for Q3 FY2024 (April 1st – June 30th)
Hardware Prototype Development

- Progressing with Initial H-Bridge Converter Testing:
  - ★ Finalize the ongoing testing phase for the initial H-bridge converter.
  - ★ Analyze test results and make necessary adjustments to ensure optimal performance.
- Advanced Prototyping of Liquid Emersed Underwater Container:
  - ★ Progress from initial prototyping to advanced stages.
  - ★ Incorporate feedback from initial tests to refine the design and functionality.

Updates for Q4 FY2024 (July 1st – September 30th)
Receive the manufactured boards and initiate the population process.

Begin the testing phase immediately after population.

Continue working on the validation of the software platform for high-performance power conversion systems, aiming for completion of the prototype by the next milestone.

Updates for Q1 FY2025 (October 1st – December 31st)
The preliminary testing is currently underway, including DPT testing. To achieve 100% completion of the preliminary hardware development, continuous testing will be carried out as part of the future work.

Updates for Q2 FY2025 (January 1st – March 31st)

The H-Bridge design has been successfully completed. The next steps in the prototyping phase include:

- Selection of a suitable heat sink for effective cooling.
- Thermal simulations determine the optimal heat sink configuration.
- Continuous testing.

Updates for Q3 FY2025 (April 1st – June 30th)
This subtask is 100% completed.

Updates for Q4 FY2025 (July 1st – September 30th)
This subtask is 100% completed.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
No reports were prepared in Q1 FY2024.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

- Two Papers titled "Enhancing Tidal Energy Integration: A Simulation-Based Comparative Study of Grid Following and Grid Forming Converters for Stability and Integration" and "Bridging the Seas: A Review on Integrating Energy Storage with MRE Sources" are presented in UMERC, 2024.
- Four senior design projects were completed, with two teams developing self-coordinating robots for onshore grid maintenance and two teams building robotic arms for underwater maintenance in power substations

Updates for Q4 FY2024 (July 1st – September 30th)
No reports were prepared in Q4 FY2024.

Updates for Q1 FY2025 (October 1st – December 31st)
No reports were prepared in Q1 FY2025.

Updates for Q2 FY2025 (January 1st – March 31st)
No reports were prepared in Q2 FY2025.

Updates for Q3 FY2025 (April 1st – June 30th)
No reports were prepared in Q3 FY2025.

Updates for Q4 FY2025 (July 1st – September 30th)
No reports were prepared in Q4 FY2025.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
The project will aid lead efforts in finding the gaps and advancing the state of the art in power conversions, investigating new converter topologies for MRE applications, and developing software/hardware platforms to design the high efficiency power conversion system which could

bring significant impacts on the existing MRE conversion structure, increases its resiliency, reliability, and conversion efficiency.

Updates for Q3 FY2024 (April 1st – June 30th)

The project will aid lead efforts in finding the gaps and advancing the state of the art in power conversions, investigating new converter topologies for MRE applications, and developing software/hardware platforms to design the high efficiency power conversion system which could bring significant impacts on the existing MRE conversion structure, increases its resiliency, reliability, and conversion efficiency.

Updates for Q4 FY2024 (July 1st – September 30th)

The selection of the non-interleaving layout will improve system performance by reducing layer-to-layer capacitance, enhancing the overall efficiency of the H-bridges in the converter.

The progress made so far lays the foundation for timely completion of the prototype, which will contribute to advancing smart mobile grid and power conversion technologies. This will ultimately support the development of high-performance, scalable power solutions for mobile grids.

Updates for Q1 FY2025 (October 1st – December 31st)

The designed H-bridge approach with SiC devices enables scalability and allows operation at higher frequencies, which contributes to increased power density. Through testing, both the performance and scalability feasibility will be validated, ensuring its effectiveness for future applications. This progress lays a strong foundation for advancing smart mobile grid and power conversion technologies, ultimately supporting high-performance, scalable power solutions for mobile grids.

Updates for Q2 FY2025 (January 1st – March 31st)

The H-Bridge design has been successfully completed, offering scalability and high-power density through SiC devices, with upcoming prototyping steps including heat sink selection, thermal simulation, and continuous operation testing to ensure reliable thermal performance.

Updates for Q3 FY2025 (April 1st – June 30th)

This subtask is 100% completed.

Updates for Q4 FY2025 (July 1st – September 30th)

This subtask is 100% completed.

Task 4.5 Lehigh Water Tunnel Speed Up

Major Project Goals and Objectives

Upgrade the pump at the Tidal Turbulence Test Facility at Lehigh University to increase flow velocity in the test section from 1.0 m/s to 1.9-2.0 m/s. The water tunnel can mimic inflow turbulence at tidal energy sites. This upgrade would allow for low TRL (<5) testing of MRE devices in the tunnel using open-water conditions as the majority of the tidal test sites have velocity in the range of 2-2.5m/s and Turbulence Intensity > 10%. Currently, this facility is the only laboratory facility that can mimic open water inflow turbulence in highly energetic tidal energy test sites and is listed in the DOE TEAMER network.

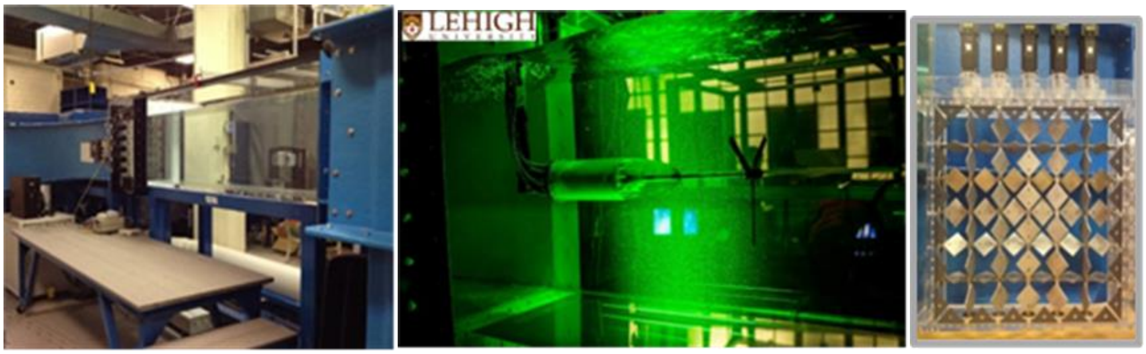


Figure 4.5.1. *Left: Lehigh Water Tunnel/Tidal Turbulence Test Facility to be upgraded. Middle: tidal turbine model, laser flow measurements, Right: active grid for turbulence generation in water tunnel.*

Facility Modifications: The following modifications will be incorporated into the existing facility:

- Replace existing 14" Axial Pump with 20" Axial Pump. The larger pump will allow the facility to attain a maximum test section velocity of approximately 2 m/s.
- Replace existing fiberglass distribution plenum with new fiberglass distribution plenum sized appropriately for the new, larger pump.
- Modify or replace the existing framework with a framework that accommodates the increased height of the pump assembly.
- Add a heat exchanger in the flow loop downstream of the fiberglass distribution plenum. The heat exchanger will be used to remove the energy of the larger motor driving the pump. This allows the test section water temperature to be maintained at a set value.

A magnetic flowmeter will be added to the return piping to measure the volume flow rate through the water tunnel.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

There are no updates. Chris Ruhl, Ph.D. student working on this project completed his Ph.D. and has commenced employment in industry. The PI is working with another graduate student Cong Han to take over the project and complete the measurements required after the upgrade is complete.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
There are no significant updates. We are working with ELD to finalize machine shops for the impellor and identifying a delivery time (see challenges, risk and mitigation). We have published two articles and working on submission of a third article based on experiments done with the tidal turbulence test facility.

Updates for Q2 FY2025 (January 1st – March 31st)
There are no significant updates. ELD has finalize a machine shop in the United Kingdom for the fabrication of the impeller. We are waiting to get estimates of a delivery time (see challenges, risk and mitigation).

We have been working on submission of two journal papers based on experiments done with the tidal turbulence test facility. A conference abstract based on the work done for this task has been submitted for UMERC 2025 in August 2025 in Oregon.

Updates for Q3 FY2025 (April 1st – June 30th)
There are no significant updates. We are waiting to get delivery estimates from ELD (see challenges, risk and mitigation). We submitted three journal papers based on experiments done with the tidal turbulence test facility. One paper has been accepted for publication in the journal Energy Conversion and Management. Another paper is currently under revision in Physical Review Fluids. A third manuscript has also been submitted and is under review.

Updates for Q4 FY2025 (July 1st – September 30th)
There are no significant updates. We are waiting to get delivery estimates from ELD (see challenges, risk and mitigation). One paper has been accepted for publication in Physical Review Fluids. A second manuscript on the tunnel characterization is being prepared for submission to the same journal.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Banerjee and ELD are both waiting for a machine shop quote to manufacture the impeller. A revised schedule will be provided once the price quote for machining is received.

Updates for Q1 FY2025 (October 1st – December 31st)
Banerjee and ELD are both waiting to finalize a machine shop quote to manufacture the impeller. A revised schedule will be provided once the price quote for machining is received. ELD has already started procuring other components for the tunnel upgrade.

Updates for Q2 FY2025 (January 1st – March 31st)
Banerjee now waiting for a revised schedule from ELD. Based on email communications, ELD has already started procuring other components for the tunnel upgrade.

Updates for Q3 FY2025 (April 1st – June 30th)
Banerjee waiting for a tunnel delivery estimate from ELD. Based on email communications, ELD has already started procuring other components for the tunnel upgrade.

Updates for Q4 FY2025 (July 1st – September 30th)
No significant updates. Banerjee waiting for a tunnel delivery estimate from ELD. Based on email communications, ELD has already started procuring other components for the tunnel upgrade and the machine shop in the UK have started work on the impeller.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
ELD has not updated Lehigh on a delivery estimate. Conversations are ongoing.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
ELD has delayed the delivery. The vendor that machined the 20 inch and 24 inch diameter impeller no longer available for the work. Banerjee reached out to folks at UNH and several other institutions and is currently working on leads obtained from those places. We have reached out to various machine shops in NY, NJ, PA, NH, RI, DE, LA, TX, MO, MN. Several shops have indicated willingness to do the work and the team is waiting for a price quote.

Updates for Q1 FY2025 (October 1st – December 31st)
Banerjee is working with ELD to finalize a quote for impellor machining.

Updates for Q2 FY2025 (January 1st – March 31st)
Banerjee is waiting for delivery estimates as the vendor for impeller machining has been identified.

Updates for Q3 FY2025 (April 1st – June 30th)
Banerjee is waiting for delivery estimates from ELD.

Updates for Q4 FY2025 (July 1st – September 30th)
Same supply chain challenges as before. Banerjee is waiting for delivery estimates from ELD.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)

Implement facility upgrade upon ELD delivery and installment. Once implemented, begin facility characterization at elevated flow speeds.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

To work with ELD on finding a machine shop. Continue tunnel calibration campaign at low speeds.

Updates for Q1 FY2025 (October 1st – December 31st)

To work with ELD on finding a machine shop. Continue tunnel calibration campaign at low speeds. Journal manuscript is being finalized for submission to Journal of Fluid Mechanics.

Updates for Q2 FY2025 (January 1st – March 31st)

To work with ELD on finalizing delivery estimates. Continue tunnel calibration campaign at low speeds based on data sets from UNH tidal test site. Two journal manuscripts are being finalized for submission.

Updates for Q3 FY2025 (April 1st – June 30th)

Continue tunnel calibration campaign at low speeds based on data sets from tidal test sites.

Updates for Q4 FY2025 (July 1st – September 30th)

No significant updates. Working on submitting manuscripts and also setting up the tunnel for twinning of UNH tidal site at Memorial Bridge.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)

No reports were prepared in Q1

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

One presentation at UMERC2024 at Duluth. In addition, a journal paper is currently under review in Renewable Energy as part of Special Issue for UMERC2023.

Updates for Q1 FY2025 (October 1st – December 31st)

A journal article was published in Special Issue of Renewable Energy for UMERC2023

- *Near wake evolution of a tidal stream turbine due to asymmetric sheared turbulent inflow with different integral length scales,* Cong Han and Arindam Banerjee, Renewable Energy, 237, 121833 (2024).

Another article was published in the journal Applied Energy.

- *Spectral behavior of a horizontal axis tidal turbine in elevated levels of homogeneous turbulence*, Mohd. Hanzla and Arindam Banerjee, Applied Energy, Volume 380, 124842, 2025.

Updates for Q2 FY2025 (January 1st – March 31st)

One abstract was submitted for UMERC 2025.

- *Generation and interaction of elevated shear inflow turbulence with scaled tidal turbine,* Mohd. Hanzla and Arindam Banerjee, UMERC 2025

Updates for Q3 FY2025 (April 1st – June 30th)

A journal article was published in Energy Conversion and Management

- *Performance and wake characteristics of a tidal turbine operating at different tip speed ratios in elevated free-stream turbulence,* Cong Han and Arindam Banerjee, Energy Conversion & Management, Volume 343 (1), 120214, 2025. (Published Open Access: https://doi.org/10.1016/j.enconman.2025.120214)

Updates for Q4 FY2025 (July 1st – September 30th)

A journal article was published in Physical Review Fluids

- *Wake momentum recovery of a horizontal axis tidal turbine under turbulence,* Cong Han and Arindam Banerjee, Physical Review Fluids, 10, 104601, 2025.
  DOI: https://doi.org/10.1103/mg6l-ch54

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

None to report for Q1

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)

Two journal manuscripts were published. The data sets can be used for Validation and Verification of wake models for tidal turbines.

Updates for Q2 FY2025 (January 1st – March 31st)

Nothing to report

Updates for Q3 FY2025 (April 1st – June 30th)
One journal manuscript was published. The data sets have been shared with SBU for Validation and Verification of their VFS code.

Updates for Q4 FY2025 (July 1st – September 30th)
Another journal manuscript was published. The data sets have been shared with SBU for Validation and Verification of their VFS code

New BP2 tasks

BP2 General Note:

The virtual 4-hour Go/No-Go conference between AMEC and WPTO at the end of Budget Period 1 took place on **8 August 2023**, with BP1 officially ending on 1 September 2023.

AMEC received the official "Go" for Budget Period 2 on **12 June 2024**.

With this delay in approval of BP2 many of the BP2 Tasks will not report any progress in Q1, Q2 and Q3 of FY 2024.

AMEC held a 2-hr technical kickoff-meeting for BP2 on Monday, July 1 2024, with refresher presentations on BP2 tasks.

Task 10.0 Operate AMEC

Major Project Goals and Objectives

The partner universities UNH, SBU, LU and CSI will operate the AMEC organization. During Budget Period 2, the partner universities will utilize and refine the organizational structure of the center, including meeting, communication, reporting structure. AMEC will manage continuing research projects and initiate new research projects as per SOPO. Information exchange with industry and R&D partnerships will be continued.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Subtask 10.1 AMEC Strategy:
Bi-weekly AMEC Co-Directors meetings were held on Mondays via Zoom (1130-1300 ET time slot).

An AMEC Advisory Board (AB) meeting was held with a hybrid in-person/virtual setting on October 3, 2023. Three of the AB members (Andrea Copping/PNNL, Vincent Neary/Sandia, Aidan Bharath/NREL) met in-person, and Nathan Tom/NREL and Thomas Boerner/CalWave connected virtually. AB members Craig Love/ANDRITZ, Montserrat Acosta-Morel/IFC and

Myles Heward/EMEC couldn't make it to the meeting and sent their regrets. The Board discussed AMEC responses from the comments of the previous meeting, accomplishments for BP1, plans for BP2, BIL funds proposal and the draft AMEC Charter.

An AMEC Quarterly Technical Meeting was held on November 13, 2023 during a longer BOD meeting to discuss the work scope for Budget Period 2. The meeting involved assigning Responsible, Accountable, Consulted, Supported, Informed (RASCI) parties/personnel. The meeting was participated in by the BoD only with the purpose of starting discussions and preparations for BP2 activities.

M. Wosnik, G. Bonner and M. Muglia attended the 10th International WaTERS workshop of leading marine energy test centers, held at EMEC in Orkney, Scotland, October 31 – November 3, 2023. AMEC participants provided an overview of recent deployments at their open-water tidal and wave energy test sites. Over the past 12 months, both tidal and wave energy devices were tested in open water at the University of New Hampshire, and wave devices were tested at CSI. The AMEC presentations, like those of other test centers, also included a forward look at the work planned for the next year and a discussion of challenges and opportunities for collaboration. The opportunity was also used for a meeting with our collaborators at EMEC to discuss the paths toward accredited testing of marine energy converters at AMEC's test sites.

M. Wosnik and A. Banerjee participated in the U.S. Technical Advisory Group (TAG) meeting of the IEC Technical Committee TC-114 on Marine Energy in Annapolis, MD, on November 15-16. This group of experts is active in writing technical specifications and best practices documents for the design and testing of marine energy converters.

AMEC researchers from the University of New Hampshire, Stony Brook University, and Lehigh University presented their work related to the fluid dynamics of marine energy at the 76th Annual Meeting of the Division of Fluid Dynamics of the American Physics Society (APS-DFD) November 19–21, 2023 in Washington, DC. APS-DFD 2023 is the largest fluid dynamics conference in the world and attracts about 3,000 researchers. Eight talks co-authored by AMEC researchers were presented. Here are the links to the abstracts:
1. Tidal Energy Resource and Turbulence Characterization at the Atlantic Marine Energy Center Tidal Energy Test Site at Memorial Bridge in Portsmouth, NH (link)
2. Dynamics of cross-flow turbines with varying blade materials and unsupported blade span (link)
3. Scaling up from the laboratory to open-water: Performance and Load Measurements for a Grid-Connected Tidal Energy Conversion System (link)
4. A parametric evaluation of the interplay between geometry and scale on cross-flow turbines (link)
5. Swell effects on the performance of a utility-scale offshore wind farm (link)
6. Dynamic strain measurement of a horizontal axis tidal turbine in elevated levels of freestream homogeneous turbulence (link)
7. Near-Wake Interaction of a Tidal Turbine with an Integrated Downstream Centrifugal Reverse Osmosis Module (link)
8. Revisiting the Den Hartog instability of a circular cylinder with surface protrusion: Effects of elevated inflow free-stream turbulence (link)

Subtask 10.2 Industry Partnership Development

We have been in discussions with an outreach/partnership generation specialist with significant experience in marine energy and blue economy application, but have held off on bringing her onto the AMEC team part time since the Operations DNFA funding is not in place yet. For the same reason we have also held off on participating in events that could generate additional industry partnerships.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

AMEC hosted the 2nd UMERC conference at the University of New Hampshire October 4-6, 2023. This year's conference focused on university-industry collaboration and will allow participants to meet researchers and industry leaders. The 2-day conference on October 5-6, 2023 was attended by 152 participants with two plenary talks, 60 oral presentations, 30 poster presentations, and 90 contributed papers. There were also several events co-located and side-events in the UMERC conference:

1. AMEC Advisory Board meeting
2. Tour of the Turbine Deployment Platform of DOE representatives and MECC participants
3. Marine Energy Collegiate Competition (MECC) in-person kick-off meeting on Tuesday October 3 organized by NREL
4. Tours of Olson Manufacturing Center and Chase Laboratory (with a reception)
5. Five technical workshops led by the national laboratories on October 4
6. Public workshop on Environmental Impacts of Marine Energy in the Portsmouth Public Library on Saturday, October 7 organized by PNNL in collaboration with AMEC.

Figure 10.3.1: photo collage from the UMERC conference at UNH: (from top left, counterclockwise), Bill Staby delivering one of the two Plenary talks, Shana Hirsch, PMEC co-director, Registration table with Sam Quinn/POET Director and Andressa Gutierrez/AMEC Program Manager, UMERC participants group photo, Ali Trueworthy/Oregon State University, (center) Jillian Eller/East Carolina University speaking to UMERC participants

There were 32 participants from AMEC contributing 29 oral presentations and 5 poster presentations.

With the 2nd UMERC conference, we have completed M.10.3.1, M10.3.4. and D 10.3.1.

M. Wosnik (UNH) stepped down from UMERC Board of Directors after two years of service in December 2023. A. Khosronejad (SBU) was elected to the UMERC Board of Directors.

Updates for Q2 FY2024 (January 1st – March 31st)

Subtask 10.1 AMEC Strategy

AMEC continued to work with DOE WPTO for processing additional funding for EE0009450 and new funding through BIL funds.

AMEC supported several proposal development efforts under FOA 3097 Marine Energy University Foundational R&D. A letter of collaboration was also prepared for 15 proposals submitted to this funding opportunity coming from AMEC universities.

We produced a professionally made, high-quality video for AMEC. The video aims to communicate the mission of AMEC and highlight the wave-powered water pump in time for the Water Power Week event that will take place from March 12 to 15, 2024, in Washington, DC. The main goal of this video is to introduce AMEC to a wider audience and communicate its mission and the value it brings in generating technologies that power the blue economy. We have posted the video on our website and LinkedIn account for general distribution. Additionally, our partners at the National Hydropower Association have included the video in their newsletter POWERHOUSE, and the Department of Energy (DOE) has posted a notification on the NMEC landing page to check out the new video for site visitors to view.

AMEC won first place in DOE EERE's Make a Splash competition in the Marine Energy category. The winning entry was from Stony Brook University's photo of a student working on power electronics at SBU.

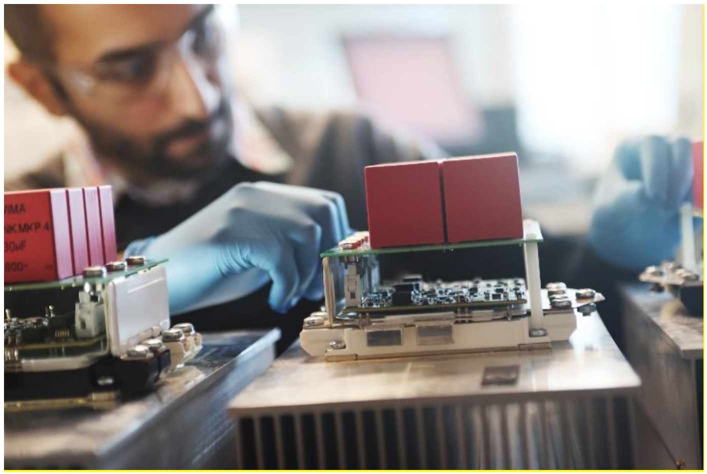


Photo 10.1.1 Make a Splash winning photo from AMEC

Entries from AMEC team members M. Wosnik/UNH, John McCord/CSI, and Nicole Marone/UNH also won prizes in other categories.

Subtask 10.2 Industry Partnership Development

M. Wosnik, A. Khosronejad, L. Dubbs and A. Gutierrez participated in the co-scheduled Blue Innovation Symposium and the Blue Venture Investment Summit held February 26 to 29, 2024 in Newport, RI. They generated # of new partnerships and maintained current ones. M. Wosnik gave a flash talk on AMEC and its capabilities.

M. Wosnik, L. Dubbs, and A. Gutierrez participated in the Water Power Week held March 12-15, 2024, in Washington DC. M. Wosnik was a panelist in the session ”Marine Energy: A Focus on Tidal.”

We have made connections to 12 private companies, educational institutions, and diplomatic staff.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

A. Khosronejad (SBU) is a director on the UMERC Board of Directors. They are planning the UMERC+METS 2024 conference for August 2024 in Duluth, MN.

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

No update.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

No update.

Updates for Q3 FY2024 (April 1st – June 30th)

Subtask 10.1 AMEC Strategy

AMEC continued to post updates to its LinkedIn account.

M. Wosnik was featured in a Physics World Weekly podcast where he discussed the potential of generating tidal energy using bridge infrastructure. He highlighted the UNH Living Bridge Project, which transforms a lift bridge into a living laboratory for researching various aspects, including tidal energy generation. The discussion also covered the work of AMEC, emphasizing their development of innovative methods for harnessing renewable energy from ocean movements.

Subtask 10.2 Industry Partnership Development

George Bonner, P.E., CSI Co-Director, participated in the 2024 State Energy Conference of North Carolina on April 23-24, 2024. This conference aims to provide actionable insights into the energy industry by connecting technical innovations, diverse resources, and industry opportunities. It also aims to drive North Carolina's regional energy economy forward, focusing on national impact.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

Ali Khosronejad attends regular monthly meetings as a member of the UMERC Board of Directors.

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

No update.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

No update.

Updates for Q4 FY2024 (July 1st – September 30th)

Subtask 10.1 AMEC Strategy:

AMEC held a 2-hr **technical kickoff-meeting for BP2 on Monday, July 1 2024**, with refresher presentations on BP2 tasks. The presentations for each task focused on: Task overview, then Milestones, Deliverables, Personnel, Timeline, Location and facilities to be used. Risks and concerns and synergy with other tasks were also discussed.

Subtask 10.2 Industry Partnership Development

AMEC Co-Director Martin Wosnik and Co-Director George Bonner (CSI) participated in ICOE2024 in Melbourne, Australia, from September 17 to 19, 2024. Additionally, AMEC researcher Dr. Wesley Williams attended the conference. AMEC also participated in panels to build industry partnerships. Below are the presentations from AMEC researchers:

1. *George Bonner, P.E., Coastal Studies Institute*
   "Atlantic Marine Energy Center: Advancing the Marine Energy Industry And Powering The Blue Economy"
2. *Mike Muglia, East Carolina University Coastal Studies Institute*
   "Testing The Waters: Jennette's Pier As An Atlantic Marine Energy Center Marine Renewable Ocean Energy Test Platform"
3. *Martin Wosnik, University of New Hampshire*
   a. "US DOE Open-source Tidal Energy Converter (OSTEC) Test Bed – Enabling In-water R&D For Current Energy Conversion"
   b. "Calibration Of Fiber Optic Rosette Sensors For Measuring Bending Moment On Tidal Turbine Blades"
4. Wesley Williams, University of North Carolina at Charlotte
   "Numerical Modeling Of A Small Wave Energy Converter For Desalination"

Figure 10.2.1 AMEC researchers at ICOE

AMEC BIL Researchers, Dr. Wesley Williams and Dr. Mike Dickey, selected as winners for InDEEP challenge for Innovation in Distributed Embedded Energy. https://americanmadechallenges.org/challenges/indeep/results

Figure 10.2.2 InDEEP challenge logo and visual

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

AMEC participated in the 3rd UMERC conference held in Duluth, MN, from August 7 to 9, 2024. During the conference, AMEC presented ten oral presentations and nine poster presentations. Researchers Hossein Seyedzadeh from Stony Brook University and Jillian Eller from East Carolina University were awarded the 1st and 2nd best poster awards, respectively. Hossein’s presentation focused on "On the Hydrodynamic Analysis of a Vertical Axis MHK Turbine: Investigating Fish Trajectories via Large-Eddy Simulation," while Jillian's poster addressed "Marine Energy Stakeholder Engagement: Proposing MSP Challenge Board Game Workshops for AMEC Stakeholders." Additionally, AMEC had an exhibit table to facilitate networking and further discussions about our research.

Deliverable 10.3.2 2024 Summarized research status for the UMERC is completed.

Figure 10.3.1 AMEC researchers at UMERC 2024 at Duluth, MN August 2024

Figure 10.3.2 AMEC researchers from CSI at the AMEC table at UMERC 2024 at Duluth, MN August 2024

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

AMEC is re-establishing its connection to EMEC due to a personnel change.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

AMEC is re-establishing its connection to EMEC due to a personnel change.

Subtask 10.6 Expand communications to convey the capabilities, value, and successes of AMEC

AMEC continued to post updates to its LinkedIn account.

Lehigh University produced a video highlighting its research capabilities in implementing marine energy research. The video showcases Lehigh's researchers, research portfolio, and laboratory facilities, driving advancements in the marine energy sector and powering the blue economy. Here is the link to the video: https://youtu.be/dDtryq7y1jY?si=AsJKqYR2O4cSrTuJ

UNH research has written an article and social media post on AMEC's new award under the Bipartisan Infrastructure Law. Here is the link to the article: https://www.unh.edu/unhtoday/2024/09/harnessing-power-sea-renewable-energy

M. Wosnik had an interview with HydroLeader magazine in its July/August 2024 issue. In the interview, he discusses the future direction of the marine energy industry and the role of the AMEC. He also talks about the initial investment that AMEC received from WPTO to advance the marine energy industry and power the blue economy. This includes developing open-water test sites, specialized laboratory facilities, and numerical capabilities. Specific projects that are discussed include the Living Bridge Project and the development of a wave-powered water pump for kelp aquaculture.

Shared AMEC promotion materials at various workshops and conferences, including ICOE2024.

Figure 10.6.1 AMEC outreach materials at ICOE 2024

CSI has produced a flier for innovators engaged in the blue economy. It is in draft form and is for comments of the BoD and DOE.

Figure 10.6.2 Draft brochure for innovators in the blue economy (for comments)

<u>Subtask 10.7 Broaden and nurture partnerships as a Point of Contact, facilitator, and coordinator for the regional marine energy community.</u>

No update.

<u>Subtask 10.8 Promote maintenance and access to infrastructure and facilities.</u>

Cost overrun for Task 4.1 was covered. Progress on Task 4.6 is reported under its section.

<u>Subtask 10.9 Foster coordination with DOE and the other NMECs</u>

M. Wosnik, A. Banerjee, A. Khosnorejad, L. Dubbs, A. Gutierrez, and S. Pamboukes participated in the All-Centers' meeting on August 6, 2024, at Duluth, MN. Discussions were focused on the BIL tasks, specifically strategy development, ME short courses, and lessons learned.

Updates for Q1 FY2025 (October 1st – December 31st)

<u>Subtask 10.1 AMEC Strategy:</u>

Bi-weekly AMEC Co-Directors meetings were held on Mondays via MS Teams (1130-1300 ET time slot).

M. Wosnik and L. Dubbs participated in the International WaTERS (Wave and Tidal Energy Research Sites) 2024 Consenting Workshop on November 18–19, 2024, in Halifax, Nova Scotia, Canada. This invite-only event focused on regulations and consenting processes for open-water test centers. Delegates visited the Fundy Ocean Research Centre for Energy (FORCE) test site in Parrsboro, Bay of Fundy, Nova Scotia, known for having the highest tides in the world. The International WaTERS network promotes collaboration and knowledge sharing between global regions and test centers.

Subtask 10.2 Industry Partnership Development

CSI met with NREL representatives to discuss potential collaborations. One ongoing partnership between the two institutions is deploying NREL's Hydraulic and Electric Reverse Osmosis (HERO) Wave Energy Converter (WEC) at Jeannette's Pier in the Outer Banks of North Carolina. Deployed in March 2024, the HERO-WEC aims to harness ocean wave energy to desalinate water through reverse osmosis.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

No update.

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

No update.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

No update.

Subtask 10.6 Expand communications to convey the capabilities, value, and successes of AMEC

Weekly updates on LinkedIn are published to communicate AMEC activities.

AMEC researchers from Lehigh University attended North American Wind Energy Academy (NAWEA) 2024 Wind Tech Conference. Mohd Hanzla presented his work on Spectral response on Tidal Turbines subjected to free stream turbulence. Kevin Wyckoff presented his work on Influence of OWT modeling on Optimal Water Power Flow of Grids.

Kevin Flora from Stony Brook University presented his paper titled "Computational investigation of vegetation impacts on riverine hydrokinetic turbines" at the 6th IAHR Africa Congress, themed "African Water Security in the Context of Climate Change," held in Benguerir and Marrakech, Morocco, from December 9 to 12, 2024.

AMEC universities came out with press releases regarding the new BIL award:

UNH: Harnessing the Power of the Sea for Renewable Energy https://www.coastalstudiesinstitute.org/powering-north-carolinas-blue-economy/

CSI: Powering North Carolina's Blue Economy https://www.coastalstudiesinstitute.org/powering-north-carolinas-blue-economy/

Lehigh: DOE awards $12 m to expand marine energy initiatives at Lehigh and partner universities https://engineering.lehigh.edu/news/article/doe-awards-12-million-expand-marine-energy-initiatives-lehigh-and-partner-universities

Subtask 10.7 Broaden and nurture partnerships as a Point of Contact, facilitator, and coordinator for the regional marine energy community.

No update.

Subtask 10.8 Promote maintenance and access to infrastructure and facilities.

Cost overrun for Task 4.1 was covered. Progress on Task 4.6 is reported under its section.

Subtask 10.9 Foster coordination with DOE and the other NMECs

Participated in monthly NMEC office hours to keep abreast with DOE guidance. Met separately with other NMECs to discuss common issues arising in NMEC implementation.

Updates for Q2 FY2025 (January 1st – March 31st)

Subtask 10.1 AMEC Strategy:

Bi-weekly AMEC Co-Directors meetings were held on Mondays via MS Teams from 11:30 AM to 1:00 PM ET. Additionally, the Board of Directors met in person at Lehigh University on January 13-14 to plan the AMEC strategy and AMEC summer short course funded through the Infrastructure Investment Jobs Act (IIJA).

AMEC met with the AMEC Advisory Board (AB) online on January 27. During this meeting, we updated the AB on new projects and sought their insights and guidance on the draft AMEC strategy.

Photo 10.1.1 AMEC BoD visiting Lehigh University graduate students and facilities

Subtask 10.2 Industry Partnership Development

Martin Wosnik, AMEC Director, and George Bonner, P.E., AMEC Co-Director at the Coastal Studies Institute in North Carolina, participated in the annual TEAMER - Testing Expertise and Access for Marine Energy Research Technical Board meeting in San Diego, California, from February 25 to 27, 2025. The participants had the opportunity to visit the Scripps Ocean-Atmosphere Research Simulator (SOARS) at the Hydraulics Laboratory of the Scripps Institution of Oceanography at UC San Diego.

The partnership with the Massachusetts company Blue Shift continues as they explore a potential collaboration with AMEC through UNH to test their water desalination program. AMEC Project Engineer S. Pamboukes is facilitating this partnership between Blue Shift and UNH.

A new university center at Lehigh University, the Center for Advancing Community Electrification Solutions (ACES), led by AMEC Co-Director Arindam Banerjee and Associate Director Shalinee Kishore, has recently been established. This affiliation strengthens AMEC's efforts in electrification solutions throughout the Northeast region.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

AMEC researchers published eight journal articles in the special issue of the international scientific journal Renewable Energy. This special issue features selected papers from the second annual conference of the University Marine Energy Research Community, which was hosted by AMEC and the University of New Hampshire in Durham, NH, in October 2023. Please see "Outputs" section below for the whole list.

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

AMEC is currently reviewing a proposal from the European Marine Energy Centre (EMEC) that includes developing a business plan for operating a scaled tidal energy test site at UNH and a scaled wave energy test site at CSI.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

AMEC is currently reviewing a proposal from the European Marine Energy Centre (EMEC) that includes developing a business plan for operating a scaled tidal energy test site at UNH and a scaled wave energy test site at CSI.

Subtask 10.6 Expand communications to convey the capabilities, value, and successes of AMEC

Weekly updates on LinkedIn are published to communicate AMEC activities.

AMEC participated in the Blue Innovation Symposium (BIS) in Newport, Rhode Island, from February 11-13. Martin Wosnik led a marine energy panel featuring representatives from Ocean Renewable Power Corp (ORPC), Adler Pollock & Sheehan, and Littoral Power Systems. This event showcased advancements in marine energy and promoted discussions on industry trends. BIS is a key event for industry players in the blue economy in the Northeast region.

Photo 10.6.1: M. Wosnik leads a marine energy panel at the Blue Innovation Symposium, RI, on February 12

Amy Thompson, AMEC Environmental Specialist, attended the Maritime & Offshore Wind Conference at the Old Dominion University (ODU) on Tuesday, March 25. The event showcased advancements and collaborative projects in the maritime and offshore wind sectors through presentation panels, keynote speakers from LS Cable and System and Antwerp Maritime Academy, and exhibitor tables.

Ali Khosronejad represented AMEC at the North Carolina Renewable Ocean Energy Program (NCROEP) symposium held at CSI on March 27-28, where he contributed to discussions on renewable energy opportunities and challenges. The AMEC Co-Director G. Bonner and Associate Director L. Dubbs from the Coastal Studies Institute lead the NCROEP, which advances interdisciplinary marine energy solutions across UNC System partner colleges of engineering at NC State University, UNC Charlotte, and NC A&T University. Ali Khosronejad, AMEC Co-Director from Stony Brook University, shared updates about his AMEC projects during the symposium. Mohammed (Mo) Gabr, AMEC researcher at North Carolina State University, was awarded the 2025 "Edge Award" for his outstanding research and innovations in ocean energy.

AMEC participated in Water Power Week, held at the Capitol Hilton in Washington, DC, from March 31 to April 2. The AMEC group included Martin Wosnik (AMEC Director), Andressa Gutierrez (AMEC Program Manager), Lindsay Dubbs (AMEC Associate Director at the Coastal Studies Institute), and Wesley Williams (AMEC project leader), and showcased AMEC's research, key facilities, and upcoming short courses scheduled for Durham, NH, in the summer of 2025, and Wanchese, NC in the summer of 2026. L. Dubbs participated in a panel session titled "A Collaborative Framework for Marine Energy Project Permitting: Lessons Learned." It provided an overview of the permitting and licensing process, discussed strategies for managing regulatory risks, and explored a collaborative approach that simplifies these processes through interest-based negotiation.

<u>Subtask 10.7 Broaden and nurture partnerships as a Point of Contact, facilitator, and coordinator for the regional marine energy community.</u>

AMEC continues to pursue partnerships within the regional ME community by attending conferences and addressing direct inquiries.

<u>Subtask 10.8 Promote maintenance and access to infrastructure and facilities.</u>

Cost overrun for Task 4.1 was covered. Progress on Task 4.6 is reported under its section.

<u>Subtask 10.9 Foster coordination with DOE and the other NMECs</u>

Participated in the monthly NMEC office hours to stay updated on DOE guidance. Met separately with other NMECs (PMEC, HMEC, SMEC) to discuss common issues in NMEC implementation. Took part in meetings with NMEC operations and communications focal points to address operational and communication issues within the NMECs.

Updates for Q3 FY2025 (April 1st – June 30th)

<u>Subtask 10.1 AMEC Strategy</u>

AMEC continued to post updates on its LinkedIn account.

Relatedly, under the IIJA funding, AMEC has completed its strategy plan for 2025-2035 and has submitted its draft to WPTO for comments.

Subtask 10.2 Industry Partnership Development

From April 14 to 17, 2025, AMEC Director M. Wosnik and AMEC project leader Wesley Williams of UNC Charlotte, participated in the IEC TC-114 Plenary Meetings held in Dublin, Ireland. The IEC Technical Committee 114 develops and publishes marine energy standards for wave, tidal, and other water current converters.

- AMEC staff are involved in the IEC TC-114 as subject matter experts representing the United States in the following areas:
- Early-stage Tidal Energy Converters- Martin Wosnik (University of New Hampshire), Co-convener
- Measurement and characterization of turbulence – Arindam Banerjee (Lehigh University), Co-convener
- Design Requirements of Marine Energy Systems – Wesley Williams (University of North Carolina at Charlotte)

During the plenary meeting on Wednesday and Thursday, Martin Wosnik provided an update on the Open-Source Tidal Energy Converter (OSTEC) project which is set to deploy in 2025, and also discussed the Axial Flow Turbine (AFT) towing tank test bed developed under AMEC's DE-EE0009450 funding, along with their role in applying and developing marine energy standards. The various national delegations provided updates on progress in their countries, including impressive marine energy technology deployments across Northern Europe and Asia.

CSI participated in the State Energy Conference in Raleigh, NC and displayed an AMEC booth on April 29-30, 2025.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

AMEC has submitted several abstracts that have been accepted to the upcoming UMERC+OREC conference in Corvallis, OR, on August 12-14, 2025.

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

AMEC is still reviewing the EMEC proposal.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

CSI Summer Engineering Intern, Ryan Page, developed an initial draft of a business plan for operating Jennette's Pier scaled energy test site and operating CSI's wave tank as TEAMER Facilities.

Subtask 10.6 Expand communications to convey the capabilities, value, and successes of AMEC

Co-Director, George Bonner (CSI), participated in "From Billions to Trillions: Catalyzing Private Investment in Climate Solutions" event at Duke University on April 9, 2025.

Co-Director, George Bonner (CSI), hosted NCSU Albright Entrepreneur Scholars (6 students) on Blue Economy Innovation visit to CSI, Jennette's Pier, and Wanchese Industrial Park on April 11, 2025.

Co-Directors, Geoge Bonner and Dr. Lindsay Dubbs (CSI), shared on live YouTube and radio "Talk of Town" broadcast on AMEC research and the value of marine energy in powering the Blue Economy on April 11, 2025. Here is the link:

https://www.youtube.com/live/Cgc24h9usuE?si=g6ilQygtiPgutSrH

Dr. Mike Muglia (CSI) presented on CSI's marine energy research and testing at the 2025 International Partnering Forum (IPF) on May 1, 2025.

Subtask 10.7 Broaden and nurture partnerships as a Point of Contact, facilitator, and coordinator for the regional marine energy community.

Template developed to develop partnerships as POC for marine energy.

Subtask 10.8 Promote maintenance and access to infrastructure and facilities.

Corey Adams and Taz Lancaster (CSI) completed repairs to the wave tank at CSI.

Corey Adams (CSI) coordinated with NC A&T and East Carolina University Senior Engineering Capstone teams to allow access to the wave tank at CSI and train them to use it to test a wave monitoring instrument and WECs.

Amy Thompson and Lindsay Dubbs updated SOPs, addressed instrument calibrations and repairs, and continued passive acoustic monitoring, water quality, and plankton (biofouling) baseline data collections at Jennette's Pier.

Subtask 10.9 Foster coordination with DOE and the other NMECs

Participated in the monthly NMEC office hours to stay updated on DOE guidance. Met separately with other NMECs (PMEC, HMEC, SMEC) to discuss common issues in NMEC implementation. Took part in meetings with NMEC operations and communications focal points to address operational and communication issues within the NMECs.

Updates for Q4 FY2025 (July 1st – September 30th)
Subtask 10.1 AMEC Strategy

Bi-weekly AMEC Co-Directors meetings were held on Mondays via Zoom (12:30-2PM ET rescheduled from 1130-1300 ET time slot).

Subtask 10.2 Industry Partnership Development

On July 14, M. Wosnik and S. Pamboukes gave a tour to Winston D'Souza from Lloyd's Register and Bill Staby from Bluewater Network LLC. During their visit to facilities at UNH, they toured several facilities, including the OSTEC lab, the Living Bridge, and the Judd Gregg Marine Research Complex in New Castle, NH.

G. Bonner, P.E., Co-Director of AMEC, and L. Dubbs, Associate Director of AMEC at the Coastal Studies Institute, discuss AMEC's research and the significance of marine energy in supporting the Blue Economy in this episode (link: https://lnkd.in/e4Ei5XF6). "Talk of the Town" is a popular morning show hosted by Henry Hinton airing on Eastern North Carolina radio stations Talk 96.3 (WRHT) and 103.7 (WTIB).

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

A total of 25 presentations (11 oral and 14 poster) were delivered by researchers affiliated with AMEC, in UMERC+OREC in Corvallis, OR, on August 12-14. Lindsay Wentzel from the Coastal Studies Institute (CSI) was recognized for giving one of the best presentations at the conference. Her research, titled "OpenCTD as a Low-Cost Tool for Small-Scale Wave Energy Characterization and Future Development as a Wave-Powered Instrument," won a presentation award from UMERC.

On Day 1 of UMERC, Lindsay Dubbs and Linda D'Anna led a Stakeholder Engagement Workshop to discuss AMEC's approach to stakeholder engagement and to refine stakeholder analysis of participants. On Day 2, Linda D'Anna participated in a panel titled "Working with Communities to Advance Marine Energy," which focused on best practices for engaging with and partnering with communities, as well as methods for assessing community readiness for marine energy development. On Day 3, Martin Wosnik was a panelist at a session on "Designing the Marine Energy Curriculum" and shared insights on AMEC's recent "Introduction to Marine Energy" short course.

Subtask 10.4 Business plan for operating scaled tidal energy test site at UNH

On September 5, AMEC Director Martin Wosnik, Co-Director George Bonner, P.E., and Research Scientist Mike Muglia represented AMEC at the International WaTERS workshop in Madeira, Portugal, organized by the European Marine Energy Center (EMEC). International WaTERS is an invitation-only workshop of the world’s leading marine energy test centers. AMEC provided updates on our two open-water energy test sites: Jennette's Pier test site in North Carolina specializes for wave energy testing, and the Tidal Energy Test Site in Portsmouth, New Hampshire, for grid-connected tidal turbine testing.

Martin Wosnik and George Bonner had a separate meeting with Dernis Mediavilla and Lily Wain from the European Marine Energy Center (EMEC) while in Madeira to discuss how to proceed with Business Plan Development. Discussions are ongoing.

Subtask 10.5 Business plan for operating scaled wave energy test site at CSI

same as subtask 10.4

Subtask 10.6 Expand communications to convey the capabilities, value, and successes of AMEC

AMEC continued to publish weekly updates on its LinkedIn account. AMEC contributed to creating a NHA Powerhouse article (https://lnkd.in/eNWAAn6b) on NMECs and an infographic (https://www.linkedin.com/feed/update/urn:li:activity:7373747507778211840) showcasing NMECs' accomplishments.

Subtask 10.7 Broaden and nurture partnerships as a Point of Contact, facilitator, and coordinator for the regional marine energy community.

Mohd Hanzla, an AMEC researcher; Martin Wosnik, AMEC Director; George Bonner, P.E., co-Director of AMEC at the Coastal Studies Institute; Amy Thompson, AMEC Environmental Specialist participated in the TEAMER - Testing Expertise and Access for Marine Energy Research Physical Testing/Experimental Facility Summit, held at the University of Michigan in Ann Arbor, MI, on July 8-9. This facility summit focused its discussions on Lab & Bench, Tank/Basin/Tunnel/Flume, and Open Water facilities. The group visited the Aaron Friedman Marine Hydrodynamics Lab, which offers both towing tank and wind-wave test facilities and is dedicated to studying and testing various marine and hydrodynamic phenomena.

On July 15, Martin Wosnik, AMEC Director, attended another TEAMER summit focusing on Modeling, Expertise, and Commercialization. This event was hosted by Verdantas Flow Labs in Holden, MA, and occurred on July 15 and 16. These TEAMER facility summits aim to strengthen collaboration within the network and enhance communication and processes.

AMEC attended the European Wave and Tidal Energy Conference (EWTEC), an international, technical and scientific conferences focused on marine renewable energy, in Madeira, Portugal, from September 7 to 11, 2025. EWTEC is widely respected for its high quality of academic and industrial contributions. About 400 marine energy experts from around the world gathered at the 16th EWTEC, and AMEC researchers had the opportunity to meet with many of them. Here are the AMEC presentations given at the conference. Each includes a peer-reviewed conference paper that was published through EWTEC. Click on the link after each title to read the abstract:

- Wave-powered water pump design for improved performance https://lnkd.in/edJ97Gri, Chelsea Kimball, Martin Wosnik
- UNH-MODAQ: An implementation of NREL's Modular Ocean Data Acquisition System for the Open-Source Tidal Energy Converter (OSTEC) Project https://lnkd.in/eYMRwVeD, Mason Bichanich, Aidan Bharath, Martin Wosnik, Robert Raye, Parviz Sedigh, Charles Candon
- A Systems Integration Approach to an Instrumented Tidal Energy Converter within an Open-Source Testbed https://lnkd.in/eX67hRJT, Parviz Sedigh, Mason Bichanich, Martin Wosnik, Aidan Bharath, Vincent Neary, Robert Cavagnaro

- Power Take-Off Design, Integration and Commissioning of an Instrumented Open-Source Tidal Energy Converter (OSTEC) Testbed https://lnkd.in/eYJzx6gh, Parviz Sedigh, Robert Cavagnaro, Aidan Bharath, Vincent Neary, Mason Bichanich, Martin Wosnik
- A 1-m scale axial-flow turbine instrumented test bed for the UNH towing tank – comparison of experimental and numerical results https://lnkd.in/eerxMN-y,Megan Andersen, Dongyoung Kim, Vincent Neary, Martin Wosnik

Subtask 10.8 Promote maintenance and access to infrastructure and facilities.

- A database of AMEC facilities and infrastructure has been completed, and is undergoing final review before being posted on the AMEC website.
- Work on the new programmed widgets to update Jennette's Pier interactive video educational platform to include content on AMEC research is progressing as expected.
- Subtask and Deliverable 10.8.3 was completed in FY 2024.

Subtask 10.9 Foster coordination with DOE and the other NMECs

Participated in the monthly NMEC office hours to stay updated on DOE guidance. Met separately with other NMECs (PMEC, HMEC, SMEC) to discuss common issues in NMEC implementation. Took part in meetings with NMEC operations and communications focal points to address operational and communication issues within the NMECs.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Subtask 10.1 AMEC Strategy:

The additional Operations Fund under negotiations will support Task 10. Operate AMEC. Additional activities under this Task will be added as soon as the Operations Funds award is finalized.

The anticipated BIL funding will also support activities in Task 10 Operate AMEC specifically the Task on Strategy Development.

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

Hosting the UMERC conference at UNH enabled universities and industries located along the East Coast participate in the event.

Updates for Q2 FY2024 (January 1st – March 31st)

None

Updates for Q3 FY2024 (April 1st – June 30th)

None

Updates for Q4 FY2024 (July 1st – September 30th)
Some activities in Task 10 will complement those funded by BIL EE-0011379, particularly in the Strategy Development task. Synchronizing these activities would be beneficial.

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
Some activities in this task complement IIJA Task 2 well, identifying synergies between the two will be beneficial.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Progress as expected, see above. Nothing additional to report.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
The delay in the approval process could potentially impact the project timeline, including the recruitment of students. This could have consequences for the overall success of the project. Revisiting the workplan and budget will be worthwhile when AMEC receives the official approval for BP2.

Updates for Q2 FY2024 (January 1st – March 31st)
None

Updates for Q3 FY2024 (April 1st – June 30th)
None

Updates for Q4 FY2024 (July 1st – September 30th)
We request comments on our draft brochure for innovators (Fig. 10.6.2).

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
The uncertainty around federal guidelines impacts our ability to plan and implement our work scope for the remainder of the project. Specific concerns include the effects of tariffs on supplies and parts which cannot be sourced in the U.S. and potential changes of indirect cost rates mid-project. As a result our ability to hire or continue to fund graduate students would be compromised.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
The uncertainty around the re-review of existing DOE awards earlier this year, including the award to AMEC under DE-EE0009450, has caused general disruption in the planning and continuity of project activities, including hiring of graduate students. We are managing the best we can. We are very grateful for the continued support by WPTO.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Plans for next quarter are attending the Water Power Week in Washington DC on March 13-14, 2024 and Blue Innovation Symposium 2024 in Middletown RI on February 26-29, 2024.

Updates for Q2 FY2024 (January 1st – March 31st)
No update.

Updates for Q3 FY2024 (April 1st – June 30th)
We plan to attend the UMERC + METS conference on August 7-9 in Duluth, MN. We will also participate in the NMEC meeting with WPTO on August 6, which is co-located with the conference in Duluth, MN.

Updates for Q4 FY2024 (July 1st – September 30th)
Drs. Lindsay Dubbs and Martin Wosnik will be participating in the International WaTERS Consenting and Permitting Workshop in Nova Scotia in November 2024.

Updates for Q1 FY2025 (October 1st – December 31st)
We have scheduled an Advisory Board meeting in the next quarter.

Updates for Q2 FY2025 (January 1st – March 31st)
Continue with communication initiatives, strategy development, outreach activities, and partnership with EMEC.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Continue with activities as per SOPO.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
D.10.3.1 was completed: Summarized research status for the UMERC

Updates for Q2 FY2024 (January 1st – March 31st)
Deliverable 10.6.1: A professionally produced video giving an overview of AMEC by the end of FY 202 (Under Operations DNFA SOPO).

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
D.10.3.2 was completed: Summarized research status for the UMERC

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

AMEC researchers have published eight journal articles in the special issue of the prestigious, high-impact international scientific journal Renewable Energy (publisher: Elsevier).

1. Wave-powered water pump for upwelling in aquaculture: Numerical model and ocean test, Chelsea Kimball, M. Robinson Swift, Martin Wosnik
https://doi.org/10.1016/j.renene.2024.122040

2. In-situ blade strain measurements and fatigue analysis of a cross-flow turbine operating in a tidal flow, Mason Bichanich, Aidan Bharath, Patrick O'Byrne, Michael Monahan, Hannah Ross, Robert Raye, Casey Nichols, Charles Candon, Martin Wosnik
https://doi.org/10.1016/j.renene.2024.121977

3. Performance of cross-flow turbines with varying blade materials and unsupported blade span, Nicole Marone, Matthew Barrington, Budi Gunawan, Jarlath McEntee, Martin Wosnik
https://doi.org/10.1016/j.renene.2024.121925

4. Technoeconomic optimization of coaxial hydrokinetic turbines, Mehedi Hasan, Matthew Bryant, Andre Mazzoleni, Kenneth Granlund https://doi.org/10.1016/j.renene.2024.122041

5. Near wake evolution of a tidal stream turbine due to asymmetric sheared turbulent inflow with different integral length scales Cong Han, Arindam Banerjee https://doi.org/10.1016/j.renene.2024.121833

6. Large eddy simulation of a utility-scale horizontal axis turbine with woody debris accumulation under live bed conditions, Meric Aksen, Hossein Seyedzadeh, Mehrshad Gholami Anjiraki, Jonathan Craig, Kevin Flora, Christian Santoni, Fotis Sotiropoulos, Ali Khosronejad https://doi.org/10.1016/j.renene.2024.122110

7. Economic dispatch of offshore renewable energy resources for islanded communities with optimal storage sizing, Kevin Wyckoff, Faegheh 'Farrah' Moazeni, Javad (Pouya) Khazaei, Arindam Banerjee https://doi.org/10.1016/j.renene.2024.122153

8. Marine spatial planning techniques with a case study on wave-powered offshore aquaculture farms; Gabriel Ewig, Arezoo Hasankhani, Ph.D., Eugene Won, Maha N. Haji https://doi.org/10.1016/j.renene.2024.121791

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Presentations made in EWTEC 2025 as mentioned in project activities completed, with peer-reviewed papers published as detailed above.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

The UMERC Conference helps AMEC to strengthen its connection to ME industry. Specifically, it helped communicate the dissemination of research findings generated by AMEC, among others.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

Subtask 10.3 Coordination with UMERC for Rapid Data Dissemination and Technology Transfer Opportunities

The UMERC Conference helps AMEC to strengthen its connection to ME industry. Specifically, it helped communicate the dissemination of research findings generated by AMEC, among others.

Updates for Q1 FY2025 (October 1st – December 31st)

No update.

Updates for Q2 FY2025 (January 1st – March 31st)

A well-operated AMEC will attract more partnerships and build trust with stakeholders in the ME community.

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)

Nothing to report.

Task 11.0 MRE Stakeholders Engagement

Major Project Goals and Objectives

Employ a combination of qualitative and quantitative methods to build on outreach activities and engage more deeply with stakeholder groups for multi-directional exchange of information. This engagement directly supports forging partnerships between the Marine Energy Industry and whole of community stakeholders, including Group 1 (Those directly involved in the sector– researchers, industry, and government–interested in the energy of moving water); Group 2 (Those with interest in the existing uses of the marine environment where MHK installations may be located, including regulatory agencies responsible for preserving environmental quality and upholding legal protections), and Group 3 (Those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from MHK energy)within the Blue Economy.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

Subtask 11. 1: 11.1 Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).

We continue to receive responses to the AMEC Universe Invitation to Engage. There were eight additional responses from October through December, 2023, for a total of 88 responses from unique respondents since the survey was launched.

Stakeholder engagement team Ph.D. student, Jillian Ellen, presented the collaborative industry-academia research and engagement project focused on improving communication of marine energy research needs between experts and non-experts at the UMERC 2023 conference. We received 79 responses to the presentation, in the form of questions to stakeholder groups. Of the responses received, 39 included contact information. Since receiving the responses, we sent respondents a thank you message and coded the responses using categories of questions and the groups to whom they are posed (e.g., questions posed to end users about power profiles and energy needs). We began drafting individualized correspondence to groups based on the codes and will include guidance for improving the questions asked and an invitation to focus groups to refine questions.

Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.

Questions stemming from the UMERC presentation questions we received (Subtask 11.1) will be posed to end users, coastal communities, and other stakeholders through surveys and direct email messages. Responses will be widely shared through the AMEC website and at future conference presentations.

Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.

We received and responded to feedback provided by the Department of Energy staff on the AMEC Testing Community Collaboration Workshop report and website entry. Accordingly, we began drafting written test descriptions to add to all graphics to help explain them and provide access to those with vision impairments. We also created a list of lessons learned from the test workshop and have begun identifying corresponding graphics that we can share as snippets with workshop participants alongside the list of lessons learned.

Subtask 11.4. Data analysis and sharing of results.

We began drafting a manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

<u>Subtask 11. 1: Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).</u>

Invitation to Engage

We continue to receive responses to the AMEC Universe Invitation to Engage. From January 2 through March 31, 2024, there were 22 more responses, and from April 1 to June 30, 2024, there were 11 more. This brings the total number of responses to date to 111 responses from unique respondents since the survey was launched.

Deepening communication efforts

We have devised a communication series to highlight how collaboration among AMEC Universe members can advance individual missions and foster future collaborations. For the series, we have planned to craft and distribute short stories highlighting collaborations between AMEC researchers and others in our larger "Universe" intended to engage, inform, and inspire other ME researchers and others in the sector. The stories will describe the problem or issue the collaboration was initiated to address, provide a summary and notable outcomes of the collaborative work, and highlight insights from the collaboration members. The format will be visual blogs or audio reports, as appropriate.

Inter expertise communication

Stakeholder engagement team Ph.D. student, Jillian Eller, presented the collaborative industry-academia research and engagement project focused on improving communication of marine energy research needs between those with varied expertise at the UMERC 2023 conference. This interactive presentation asked UMERC attendees to write and submit responses to the following prompt: "What questions for prospective marine energy users or stakeholders would advance your work if answered?" We received 79 response cards to the presentation, in the form of questions to stakeholder groups. Of the responses received, 39 included contact information, which we will refer to as attributed responses. There were 91 individual questions extracted from these 39 cards. The unattributed responses contained another 70 questions.

Since receiving the responses, we sent respondents two messages: a thank you message and then a follow-up email with guidance regarding best practices for corresponding with others who hold different expertise and an invitation to continue to workshop questions. We have not yet received any responses accepting the invitation to continue workshopping questions.

We also coded the attributed responses using categories of questions (content codes) and the groups to whom they are posed (audience codes). We identified and used 29 unique content codes and six audience codes (communities, end-users, developers, researchers, investors, and regulatory agencies). Most of the questions were posed to communities (n=31) or end users (19) while only 2 were posed each to researchers and investors and 1 to regulatory agencies.

While awaiting responses to our invitation to work on the submitted questions, we have workshopped submitted questions, using the best practices identified, to produce refined questions under several broad themes, like “impressions of need,” “community ownership and involvement,” “weighing energy options,” and “continuing the conversation”. We are preparing to share the workshopped questions at the 2024 UMERC conference (through a poster presentation). We will engage with other conference attendees who visit our poster to gather feedback on the workshopped questions.

Environmental risk workshops with PNNL

We joined forces with the Pacific Northwest National Laboratory (PNNL) to support an outreach and engagement process around the science of what we know about environmental and social effects of marine energy development, particularly as they relate to permitting and development. An in-person stakeholder workshop with 7 participants focused on tidal energy was held in October 2023 in New Hampshire, and two more workshops were held in North Carolina in March 2024 with a total of 15 participants and a focus on ocean currents. North Carolina participants primarily represented agencies and organizations with a couple of local residents. PNNL staff presented insights into the state of the science of marine energy environmental and social effects, and attendees asked questions and expressed their interest and concerns about marine energy.

<u>Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.</u>

Blue economy engagement groundwork

As part of the preparation and planning for engagement with communities and potential marine energy end users to answer the questions we have workshopped under our inter expertise communication efforts, Stakeholder Engagement Team undergraduate student Nicole Coursey (UNC-CH) compiled a list of startups, entrepreneurs, angel investors, energy providers, innovation centers, and other stakeholder groups that might have an interest in marine energy and could be potential targets for engagement and relationship building with AMEC. She initially sought out these environmental and ocean-focused stakeholders using LinkedIn, going from connection to connection, researching people, companies, and organizations, taking note of their name, location, partner organizations, and mission/purpose. To support future engagement efforts, she created an infographic one-pager containing basic marine energy facts and device applications. For this, she identified examples of marketable marine energy powered blue economy applications by reviewing team proposals for the Marine Energy Collegiate Competition (MECC) 2020 to 2022. Many of these focused on devices for aquaculture, ocean observation and data collection, at-sea charging, desalination, among others. This product will function as a leave-behind and conversation tool for the engagement team to use when connecting with stakeholders who could potentially utilize marine energy technology.

In addition, Dr. Dubbs attended the Blue Innovation Symposium in Rhode Island in February 2024 and helped man a booth there. Participation in this symposium, and especially visiting booths of others, provided context to frame the work of AMEC and the ME sector for those in the innovation space within the blue economy. We realized that we need tangible examples of our "products" to share with others. This helped guide the leave behind that Nicky created and our plans for engaging with these stakeholders in the future.

Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.

We received and responded to feedback provided by the Department of Energy staff on the AMEC Testing Community Collaboration Workshop report and website entry. Accordingly, we began drafting written test descriptions to add to all graphics to help explain them and provide access to those with vision impairments.

We also created a list of lessons learned from the test workshop and have begun identifying corresponding graphics that we can share as snippets with workshop participants alongside the list of lessons learned.

Subtask 11.4. Data analysis and sharing of results.

We continued progress on a manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop we conducted in Spring 2023. We have outlined the manuscript and are considering the appropriate statistical analysis of workshop statements to explore relationships beyond simple summary statistics.

Subtask 11.5 Stakeholder outreach and engagement training

We created and shared a guidance document regarding best practices for inter expertise communications with respondents to the UMERC 2023 inter expertise communications presentation by Ph.D. student, Jillian Eller. This document will also be posted on the AMEC website.

Updates for Q4 FY2024 (July 1st – September 30th)

Subtask 11. 1: Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).

Invitation to Engage

From July 1 through September 30, 2024, there were 5 additional responses to the AMEC Universe Invitation to Engage. This brings the total number to 116 responses from unique respondents since the survey was launched.

Inter expertise communication

We continued analysis of the questions submitted by attendees to our 2023 UMERC conference presentation on improving communication of marine energy research needs between those with varied expertise. Respondents posed 170 usable questions across 29 categories and 6 target audiences (Fig.1). The most common ranged from "power needs" and "concerns", which centered on communities and potential end users, to "technical data sharing" and "constraints", which targeted researchers and developers.

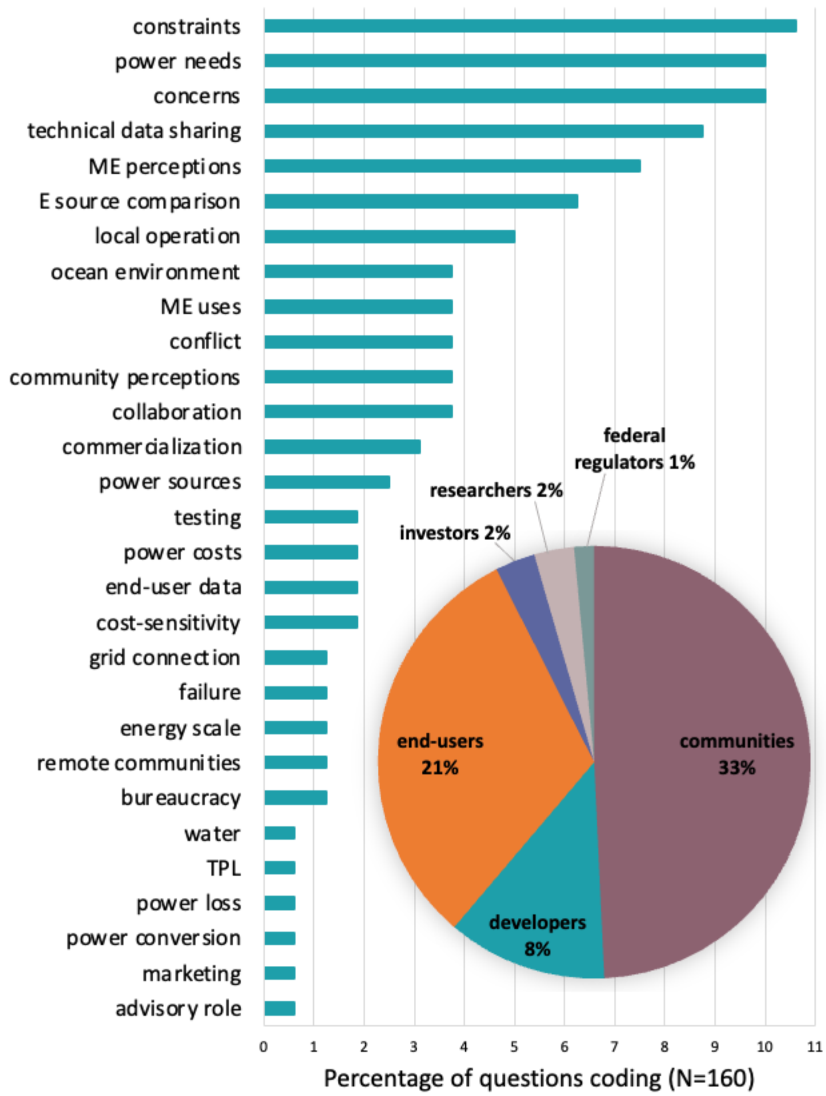


Figure 1. Frequency of content (bars, N=160 questions, attributed and not) and audience codes (pie, N=67 out of 90 attributed questions discerned audience) applied to UMERC 2023 attendees' questions for marine energy stakeholders.

We analyzed the questions that marine energy stakeholders have in mind for other stakeholders for audience, theme and language (Figs. 2 and 3). This information about themes, target audiences, and language will be useful to guiding our conversations with coastal communities and those with a potential interest in using marine energy, and for relaying what we learn back to those who asked the questions.

Theme:
Environmental & Social Impact Concerns

Fig 2. Word cloud of content of questions in theme: environmental & social impact concerns. Larger size indicates more frequent usage. N=12 Qs.

Theme:
Impressions of Need

Fig 3. Word cloud of content of questions in theme: impressions of need. Larger size indicates more frequent usage. N=5 Qs.

We shared our analysis to date along with workshopped and refined questions with UMERC 2024 participants through a poster presentation entitled *Questioning as Engagement: Strategies for Building Stakeholder Engagement*. The poster (and presenters who staffed it during each poster session) sought comments on the refined questions, which we plan to pose during our spring 2025 in-person stakeholder engagement campaign along the east coast of the US. We did not receive any further suggestions for improvement from those who visited our poster and feel confident that the emergent questions reflect those of the community who posed them. These refined questions are reported under Task 11.2.

AMEC stakeholder engagement team graduate student, Jillian Eller also presented a poster at UMERC 2024, inviting those in the marine energy community to learn about marine energy in the context of the MSP Challenge Board Game. Jillian utilized the poster session to collect information from UMERC attendees about potential MSP Challenge Board Game hosts while sharing their research questions and their proposed approach related to the game.

<u>Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.</u>

Blue economy engagement groundwork

In preparation for meetings, focus groups, and MSP challenge workshops with coastal community and blue economy stakeholders in spring and summer of 2025, we compiled a list of community organizations, aquaculture facilities, and blue innovation start-ups and networks. We also gathered content and materials to initiate conversations requesting meetings with these potential collaborators.

We grouped questions stemming from responses to our UMERC 2023 presentation on improving communication of marine energy research needs between those with varied expertise by content and intended audience codes to reveal themes. Questions aimed at coastal community stakeholders were sorted by theme and combined and refined (Table 1). These are the questions that we will pose to community and blue economy stakeholders. The same refinement must still be done for the questions aimed at other end-users such as aquaculture facilities.

Table 1. Refined questions stemming from responses to our UMERC 2023 presentation regarding our project focused on improving communication of marine energy research needs between those with varied expertise.

Themes	Refined questions to be asked of coastal communities
Impressions of need	What opportunities can you imagine for marine energy to provide power for your community?
Community ownership and involvement	What role do you think your community would be eager to play, or at least willing and able to play, in the operation and maintenance of your energy supply system?
Environmental and social impact concerns	What hesitations or concerns regarding marine energy do you have for your community?
Weighing energy options	Is there anything that you would change about your current sources of energy? When considering new sources of energy, what is most important to you and how do you envision it would be worse or better than your current sources?
Continuing the conversation	Can AMEC and the researchers affiliated with us contact you in the future and/or share information about our work and marine energy developments?

Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.

We continue to analyze our stakeholder engagement efforts and adapt to maximize the breadth and depth of connections with those with interest in marine energy.

Subtask 11.4. Data analysis and sharing of results.

We continued progress on a manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop we conducted in Spring 2023. We began statistical analysis of workshop statements to explore relationships beyond simple summary statistics.

Results and plans were also shared via our UMERC 2024 poster presentations and workshops that we participated in during the conference.

Subtask 11.5 Stakeholder outreach and engagement training

We have nothing new to report at this time.

Updates for Q1 FY2025 (October 1st – December 31st)

Subtask 11. 1: Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).

Invitation to Engage

From September 30 through December 30, 2024, there were 6 additional responses to the AMEC Universe Invitation to Engage. This brings the total number to 122 responses from unique respondents since the survey was launched.

Inter expertise communication

We continued analysis of the questions submitted by attendees to our 2023 UMERC conference presentation on improving communication of marine energy research needs between those with varied expertise.

We continued compiling contacts for coastal community stakeholders. We emailed five individuals from maritime community organizations to request a conversation regarding their community's energy needs and reservations. We heard back from one individual interested in speaking with us.

We emailed an additional six contacts from organizations within 1 hour drive from Newport Rhode Island to offer to meet with them in-person while in the region for the Blue Innovation Symposium. We have not yet received any responses.

Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.

Blue economy engagement groundwork

We continued analysis of the questions submitted by attendees to our 2023 UMERC conference presentation on improving communication of marine energy research needs between those with varied expertise.

We focused on questions for Blue Economy developers and prepared supporting materials to take these questions to the Blue Innovation Symposium (Newport, RI; Feb. 11-13, 2025).

Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.

We continue to analyze our stakeholder engagement efforts and adapt to maximize the breadth and depth of connections with those with interest in marine energy.

Subtask 11.4. Data analysis and sharing of results.

We continued progress on a manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop we conducted in Spring 2023. We continued statistical analysis of workshop statements to explore relationships beyond simple summary statistics. We have decided to submit this manuscript to PlosOne.

Subtask 11.5 Stakeholder outreach and engagement training

We have nothing new to report at this time.

Updates for Q2 FY2025 (January 1st – March 31st)

Subtask 11. 1: 11.1 Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).

Invitation to Engage

We continue to receive responses to the AMEC Universe Invitation to Engage. There were eight additional responses from January through March, 2025, for a total of 130 responses from unique respondents since the survey was launched.

Engagement with researchers

We distributed a questionnaire to all research teams working on AMEC tasks for budget period 2. This was the same set of questions distributed to the budget period 1 researchers. The goal of the questionnaire is to better understand the research tasks so that we may communicate them to other stakeholders, including those outside of academia. The information provided through the questionnaire will be used to create or update an illustration of each task's work that will be incorporated into the invitation to engage with AMEC.

Entanglement working group

Lindsay Dubbs corresponded with sea turtle researchers, disentanglement and stranding professionals, and those developing anti-entanglement technology innovations to begin to organize a sea turtle entanglement working group. She has planned for the first working group meeting to be held as a hybrid – in-person and virtual – meeting for May 20, 21, or 22 (meeting date still pending confirmation) in Beaufort, NC (or virtual). The working group will discuss what is known about the risk of entanglement of sea turtles in marine energy devices and associated oceanographic and environmental monitoring equipment and means by which to fill gaps in understanding as well as potential solutions that may prevent entanglement and stranding of sea turtles and marine mammals. This work is being supported by a Pacific Northwest National Labs outreach effort led by Andrea Copping and Lenaig Hemery, who are creating outreach materials, including a video about entanglement risks and best practices to reduce that risk.

MSP Challenge

Jillian Eller successfully hosted their first Marine Spatial Planning game session at East Carolina University with their peers in February as a test run. The game session went smoothly, participants enjoyed it and expressed that they learned a great deal about marine spatial planning and marine energy siting through the game play, and Jillian has refined plans for the game following the experience and reflection. They are in conversation with the Mid-Atlantic Regional Council on the Ocean to present at their upcoming conference to recruit participants for data collection MSP Challenge games in the coming months.

<u>Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.</u>

Blue economy engagement

Lindsay Dubbs attended the Blue Innovation Symposium in Rhode Island from February 11-13 and surveyed thirteen blue economy innovators, primarily those who have developed ocean observing instruments. The intention was to learn how and what to ask about in the survey instrument that the engagement team will create for wider distribution to the blue economy. She learned that maximum power requirements for devices ranged from 50 mW to 2500 W and that most of the devices were battery powered. Nearly all of those surveyed said that with more power, they would increase sampling rates or instrumentation. Challenges mentioned included biofouling and connecting with industries that may benefit from their technologies. In response to where we can connect with more blue innovators, the Oceanology and Ocean business conferences were the only suggestions.

Linda D’Anna found a survey instrument created by researchers in Australia who were interested in learning about the needs of and challenges faced by those working in aquaculture. Linda subsequently emailed the Australian researchers to inquire about using elements of their survey for our own and/or collaborating on a multinational project using their instrument and the results that they have acquired.

<u>Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.</u>

After the experience administering a draft survey at the Blue Innovation Symposium in Rhode Island and reflecting upon responses and feedback, we realized that one survey to all blue economy stakeholders will not be sufficient, so we plan to create three to four targeted surveys to distribute to individual groups in the blue economy space. Those groups include aquaculture professionals, those in the ocean observing (blue innovation) space, coastal communities, and those working on desalination technologies. We elaborate on that effort under subtask 11.2.

<u>Subtask 11.4. Data analysis and sharing of results.</u>

We continued progress on a manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop we conducted in Spring 2023.

<u>Subtask 11.5 Stakeholder outreach and engagement training.</u>

Linda D'Anna and Lindsay Dubbs submitted a proposal to Samantha Quinn, the organizer of UMERC, to hold a training workshop at the August 2025 UMERC conference, and Samantha accepted the proposal. The workshop is planned for August 12th from 9 am – 12 pm.

Updates for Q3 FY2025 (April 1st – June 30th)

<u>Subtask 11. 1: 11.1 Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).</u>

Invitation to Engage

We continue to receive responses to the AMEC Universe Invitation to Engage, though the response rate has declined. We only received one additional response from April through June, 2025, bringing the total number of responses from unique respondents to 131 since the survey was launched.

Communication with AMEC researchers

We continue to collect information from AMEC research teams about their projects for graphic creation by Viola Clark and for communication with stakeholders.

Entanglement working group

Lindsay Dubbs held the first sea turtle entanglement working group meeting (virtual) between sea turtle researchers, disentanglement and stranding professionals, and those developing anti-entanglement technology innovations on May 20, 2025 from 2-3:30 pm. The working group discussed goals and products and future meeting topics and presentations and drafted a charter. They also reviewed and discussed the draft of a flier created by Pacific Northwest National Labs (led by Andrea Copping and Lenaig Hemery), to communicate the risk of entanglement of sea turtles in marine energy devices and associated oceanographic and environmental monitoring equipment. The group felt that the flier was acceptable in communicating the risk posed by few small-scale marine energy deployments, but that the risk was not well known for larger developments. The next meeting is scheduled for August 4.

Engagement with regulators

Amy Thompson met with several state agency representatives (Division of Coastal Management and Division of Marine Fisheries) to tell them about AMEC and the wave energy test center at Jennette's Pier, and environmental impact analysis. She gave presentations and answered questions. Agency representatives expressed appreciation for being updated on our plans and progress.

Jacqueline Ganter, graduate student at UNC-Chapel Hill (CSI affiliated), regularly meets with representatives from NOAA to explore the legitimacy of including rehabilitated sea turtle tag data in studies of sea turtle distributions and behavior. Agency representatives have shared their datasets with her for the analysis, which could expand the usable dataset of tagged turtles to better inform our understanding of their use of the marine environment to mitigate and avoid risks introduced by marine energy development.

MSP Challenge

Jillian Eller introduced approximately 60 ocean planners and many early-stage offshore renewable energy to the MSP Challenge and inclusion of marine energy in marine spatial planning (see photo below). They gave a presentation and demonstrated the MSP Challenge game at the Mid-Atlantic Regional Council on the Ocean (MARCO) Ocean Forum the week of May 5, 2025 and a game session during the North American INORE Symposium in Boston the week of June 9, 2025.

At the MARCO Ocean Forum, they interacted with practitioners in the fields of ocean planning, including sectoral representation from wind energy, oyster aquaculture, sport fishing, and coastal business improvement districts, as well as representatives from the federal and state governments, nonprofits, education, academia, data science professionals, tribal leaders, and students. There was a lot of interest about the board game from folks with the VA Coastal Zone Management program, MARACOOS, various aquariums, NY Department of State (who does public outreach events on Long Island and they have followed up with organizations that expressed interest with the hopes of scheduling data collection game sessions once they receive Institutional Review Board approval.

At the North American INORE Symposium, Jillian held a session of the MSP Challenge game and gathered feedback from participants. The feedback on their marine energy fact sheet that they developed for the game was especially informative given this group's familiarity with marine energy.


Participants at the North American INORE Symposium playing the MSP Challenge, facilitated by Jillian Eller.

Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.

Blue economy engagement

Valeria Rico, summer intern, led the creation of questionnaires to target three separate groups of possible marine energy end-users: aquaculture, desalination, and blue innovation. The team had previously decided that one questionnaire for all possible end-users would not be workable because of the diversity of needs and the multiple ways different blue economies interact with the ocean. Some questions recur across questionnaires to allow for comparison, such as the measure of opening to using marine energy, but others are specific to each group's energy uses and circumstances. Under the direction of Linda D'Anna and Lindsay Dubbs, Valeria iterated questions and possible responses, created the surveys in the Qualtrics platform, drafted recruitment materials or "invitations" to take the surveys, completed human subjects research ethics review of the survey materials via an amendment to our existing Institutional Review Board application, compiled a database of invitation recipients, and created a data analysis plan.

Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.

As mentioned in 11. 1, Jillian Eller has been continuously reflecting upon and making updates to facilitation protocols, data collection instruments, and marine energy fact sheets for the MSP Challenge boardgame based on feedback and questions during game sessions and presentations about the game and its value.

Subtask 11.4. Data analysis and sharing of results.

Lindsay Dubbs served on a panel at Waterpower Week on April 1 about applying collaboration to permitting. In this panel, she shared information about experiences engaging with environmental research and regulatory communities.

We continued progress on a manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop we conducted in Spring 2023. Viola Clark reviewed the draft and provided comments and additional resources about the World Cafe Process.

Subtask 11.5 Stakeholder outreach and engagement training.

Linda D'Anna and Lindsay Dubbs began planning for the training workshop at the August 2025 UMERC conference. The workshop will occur August 12th from 9 am – 12 pm.

Updates for Q4 FY2025 (July 1st – September 30th)

Subtask 11. 1: Engagement with those directly involved in the ME sector (researchers, industry, and government) and those with interest in the existing uses of the marine environment where MHK installations may be located (regulatory agencies responsible for preserving environmental quality and upholding legal protections).

Entanglement working group

The sea turtle entanglement working group met on August 4, 2025. Working group members from the Coastal Studies Institute, NC Sea Grant, NC Wildlife Resources Commission, the North Carolina Aquarium, NOAA (representative from the Conservation Biology branch and the Sea Turtle Stranding and Disentanglement Coordinator for the greater Atlantic), the Marine Mammal Stranding Network, and Coonamescett Farm Foundation finalized our charter. Our group decided to create materials to distribute to AMEC universe members doing work in the western Atlantic Ocean about best practices for preventing entanglement of sea turtles in scientific equipment and marine energy devices and guidance for responding to entanglements and to write a manuscript/report about the state of the science regarding the risks around sea turtle entanglement and potential deterrents. The discussion included many helpful specifics offered by sea turtle ecologists and those with stranding response expertise. We also reviewed a revised version of a PNNL flier about the risk of entanglement. There were questions about the image used and that was conveyed to PNNL who quickly provided responses that will be discussed at the next sea turtle entanglement working group meeting in 2 months.

Engagement with regulators

Jacqueline Ganter, graduate student at UNC-Chapel Hill (CSI affiliated), continues to regularly meet with representatives from NOAA to explore the legitimacy of including rehabilitated sea turtle tag data in studies of sea turtle distributions and behavior. Agency representatives have shared their datasets with her for the analysis, which could expand the usable dataset of tagged turtles to better inform our understanding of their use of the marine environment to mitigate and avoid risks introduced by marine energy development.

MSP Challenge

Jillian Eller continues to finalize their gameplay protocols and survey instruments to facilitate MSP Challenge game sessions with community groups in the AMEC region. They have submitted their materials to the Institutional Review Board at East Carolina University for approval and have to wait to receive that approval before they can move forward with recruitment and data collection (maps and surveys) via the game.

Subtask 11.2 Engagement with those with research, public service, and emerging economic interests surrounding the blue economy that may benefit from ME.

Blue economy engagement

The questionnaires targeting three separate groups of possible marine energy end-users, aquaculture, desalination, and blue innovation, were approved by ECU's Institutional Review Board, and Valeria Rico coordinated initial distribution in late July to the contact lists she had assembled. By the end of this reporting period, we have received 8 completed surveys from the aquaculture group, 7 from the blue innovation group, and 6 from the desalination group. Though limited, this is an acceptable initial response given the "cold" nature of the disseminating emails.

Subtask 11.3. Evaluate and modify stakeholder outreach and engagement activities.

Jillian Eller has committed to preparing several detailed blog posts about stakeholder engagement that will be posted to the AMEC website and announced through a AMEC Universe listserv and social media. These posts will provide a deeper connection with AMEC Universe members.

Subtask 11.4. Data analysis and sharing of results.

Linda D'Anna participated in the panel, "Working with Communities to Advance Marine Energy," at the 2025 UMERC+OREC conference on August 13th. The panel explored best practices for engaging and partnering with communities and approaches for understanding community readiness for marine energy development. As part of the panel, Linda's presentation, "Building capacity for community engagement: Research to advance theory and practice of social acceptance," shared several aspects of the engagement team's work, including efforts to share best practices for engaging with nontechnical audiences with marine energy researchers and developers. The presentation connected a key outcome of these efforts - researchers' interest in how other stakeholders view the appropriateness of marine energy - to research to better understand social acceptance of marine energy. This research includes efforts to characterize coastal place meanings among local residents, mental modeling exercises with various stakeholders about marine energy development, and survey efforts to assess potential factors in support for developing marine energy.

Jacqueline Ganter presented a poster about her sea turtle research to date and plans for data analysis at the UMERC conference in Corvallis, OR on August 13, 2025.

Subtask 11.5 Stakeholder outreach and engagement training.

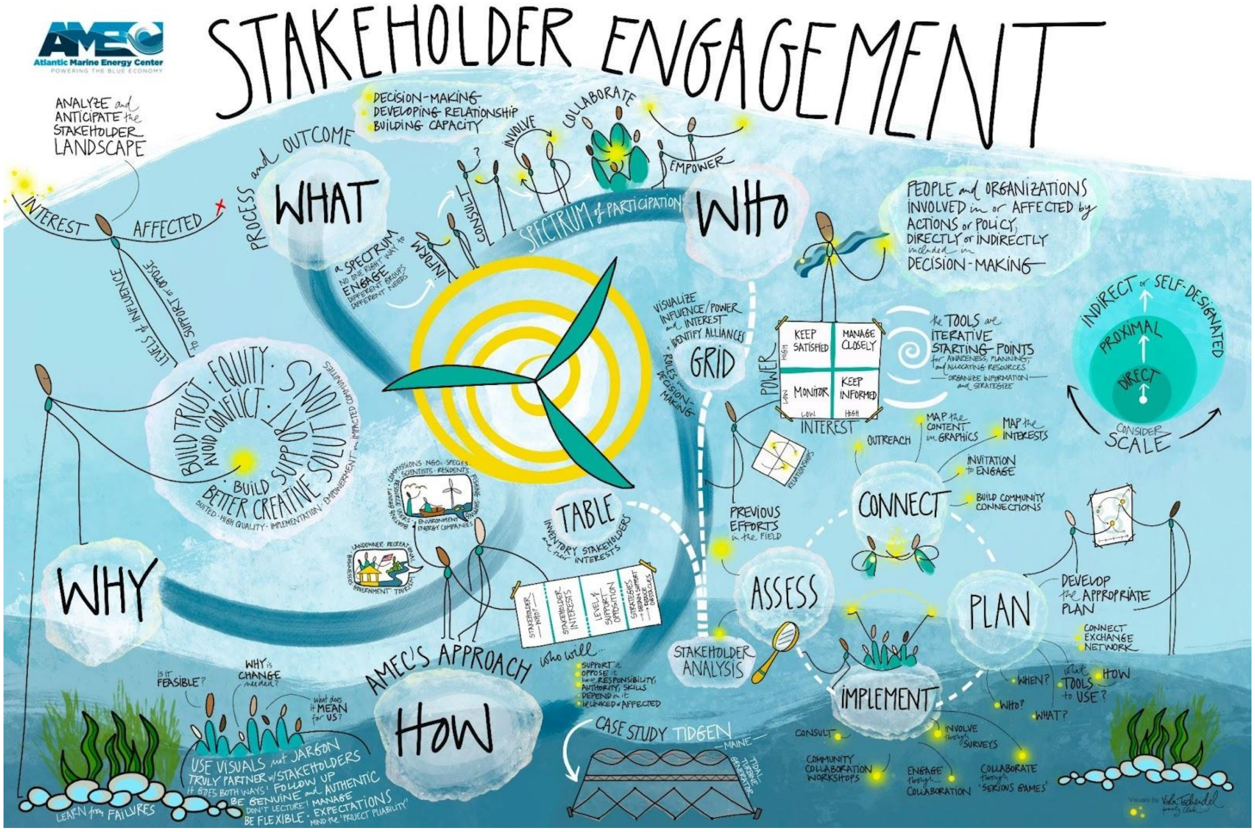
Linda D'Anna and Lindsay Dubbs, in collaboration with Viola Tschendel (previously Viola Clark) spent considerable time this quarter preparing for, delivering, and following up on a

Stakeholder Engagement Training workshop. The workshop was held at the 2025 UMERC conference in Corvallis, Oregon on August 12th from 9 am - 12 pm.

The purposes of the workshop were to provide participants with a pathway to start thinking about stakeholder engagement, enforce the need for stakeholder engagement specialists or social scientists trained in engagement, and introduce stakeholder analysis tools. In other words, the workshop was designed to focus on the "groundwork" of stakeholder engagement.

We had 29 people from academia (students and faculty), national labs, and federal agencies participate in the workshop. The workshop began with a presentation about AMEC, stakeholder engagement, and AMEC's approaches to stakeholder engagement. Participants then formed break-out groups in which they shared about what they had attempted and/or seen/experienced of stakeholder engagement in their own personal worlds/work (Photos). After each group shared 3 experiences of what worked and what didn't work in their experiences with the full room, Drs. D'Anna and Dubbs gave a presentation of stakeholder analysis tools and introduced the stakeholder table, which identifies stakeholders and their interests, and the stakeholder matrix, which graphs the level of interest and power of the different stakeholder groups where quadrants indicate the needed or appropriate type of engagement.

Viola Tschendel recorded the discussion graphically to serve as a visual reminder of workshop content and participant sharings so that participants can reference the workshop materials afterwards, as they design stakeholder engagement for their own projects (Illustration). This graphical recording will be sent as a digital file, along with a workshop report, to all workshop participants.



Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

We are trying to make progress, but the delay in the BP2 approval process presents challenges to retaining and recruiting students, and planning for necessary travel and timelines for planned engagement activities.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

We are making progress on all milestones and deliverables. We have ambitious plans for the next year, but are on track for meeting deadlines, including those that are self-imposed.

Updates for Q4 FY2024 (July 1st – September 30th)

Subtask 11.1

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.1.1) was July 31, 2024, we will continue to collect data through the remainder of the project. We will present the data resulting from the conversations as we collect it (D11.1.1). The maps reflecting stakeholder marine spatial planning exercises (D11.1.2) will not be completed and submitted until after our spring and summer 2025 workshops.

Subtask 11.2

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.2.1) was July 31, 2024, we will continue to collect data through the remainder of the project. Survey data and data stemming from focus groups and conversations (D11. 2.1) will not be completed and submitted until after our spring and summer 2025 workshops.

Subtask 11.3

We will continue to analyze stakeholder engagement outcomes (M11.3.1) through the remainder of the project as planned. We will note and then adapt our efforts accordingly.

Subtask 11.4

We will continue to share stakeholder engagement outcomes (M114.1) with respondents and participants as well as through reports through the remainder of the project as planned. We are updating the stakeholder registry/log (D11.4.1) as we connect with stakeholders as planned.

Subtask 11.5

We have created and shared best practices for communication, so are in part ahead of schedule but have plans to create and share an additional learning module (M11.5.1) reflecting upon what we learn through the whole stakeholder engagement project. We are on track to deliver that learning module (D11.5.1) on time.

Updates for Q1 FY2025 (October 1st – December 31st)

Nothing further to report.

Updates for Q2 FY2025 (January 1st – March 31st)

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.1.1) was July 31, 2024, we will continue to collect data through the remainder of the project. We will present the data resulting from the conversations as we collect it (D11.1.1). The maps reflecting stakeholder marine spatial planning exercises (D11.1.2) will not be completed and submitted until after our spring and summer 2025 workshops, by spring of 2026.

We will continue to analyze stakeholder engagement outcomes (M11.3.1) through the remainder of the project as planned. We will note and then adapt our efforts accordingly.

We will continue to share stakeholder engagement outcomes (M114.1) with respondents and participants as well as through reports through the remainder of the project as planned. We are updating the stakeholder registry/log (D11.4.1) as we connect with stakeholders as planned.

We have created and shared best practices for communication, so are in part ahead of schedule but have plans to create and share an additional learning module (M11.5.1) reflecting upon what we learn through the whole stakeholder engagement project. We are on track to deliver that learning module (D11.5.1) by spring of 2026.

Updates for Q3 FY2025 (April 1st – June 30th)

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.1.1) was July 31, 2024, we will continue to collect data through the remainder of the project. We will present the data resulting from the conversations as we collect it (D11.1.1). The maps reflecting stakeholder marine spatial planning exercises (D11.1.2) will not be completed and submitted until after our spring, summer, and fall 2025 workshops, by spring of 2026.

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.2.1) was July 31, 2024, we will continue to collect data through the remainder of the project. Survey data and data stemming from focus groups and conversations (D11. 2.1) will not be completed and submitted until after our spring, summer, and fall 2025 workshops, by spring of 2026.

We will continue to analyze stakeholder engagement outcomes (M11.3.1) through the remainder of the project as planned. We will note and then adapt our efforts accordingly.

We will continue to share stakeholder engagement outcomes (M114.1) with respondents and participants as well as through reports through the remainder of the project as planned. We are updating the stakeholder registry/log (D11.4.1) as we connect with stakeholders as planned.

We have created and shared best practices for communication, so are in part ahead of schedule but have plans to create and share an additional learning module (M11.5.1) reflecting upon what we learn through the whole stakeholder engagement project. We are on track to deliver that learning module (D11.5.1) by spring of 2026.

Updates for Q4 FY2025 (July 1st – September 30th)

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.1.1) was July 31, 2024, we will continue to collect data through the remainder of the project. We will present the data resulting from the conversations as we collect it (D11.1.1).

The maps reflecting stakeholder marine spatial planning exercises (D11.1.2) will not be completed and submitted until after our workshops/game sessions. IRB review of the survey instrument associated with the game protocol is taking more time than anticipated, and Jillian is not able to schedule games until they receive IRB approval. We still anticipate having maps to share by spring 2026.

Though the due date for collecting and compiling qualitative and quantitative data from stakeholders (M11.2.1) was July 31, 2024, we will continue to collect data through the remainder of the project. Survey data and data stemming from focus groups and conversations (D11. 2.1) will not be completed and submitted until spring of 2026.

We will continue to analyze stakeholder engagement outcomes (M11.3.1) through the remainder of the project as planned. We will note and then adapt our efforts accordingly.

We will continue to share stakeholder engagement outcomes (M114.1) with respondents and participants as well as through reports through the remainder of the project as planned. We are updating the stakeholder registry/log (D11.4.1) as we connect with stakeholders as planned.

We have created and shared best practices for communication, so are in part ahead of schedule but have plans to create and share an additional learning module (M11.5.1) reflecting upon what we learn through the whole stakeholder engagement project. We are on track to deliver that learning module (D11.5.1) by spring of 2026.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
The delay in the BP2 approval process presented challenges, including that we missed the deadline to fund Ph.D. student, Jillian Eller on AMEC for 2024/2025. Fortunately, Jillian and their department secured and allocated funding, respectively, to allow them to continue their dissertation work regardless. The funding gap also meant that we paid for travel from other funds not reimbursable now.

A critical challenge in stakeholder engagement is time. The kind of stakeholder engagement that includes two-way exchanges of ideas and information that leads to collaborative progress on an issue is a slow process. It is a cumulative effort that builds slowly on the success of each previous step and connection. In this work, we are asking busy people to make time to expand their networks and share knowledge, meaning the work can only proceed as quickly as they can respond. Further, establishing connections and the open flow of information requires building trust and proving competency. These are slow processes.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing further to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing further to report

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to Report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to Report.

Updates for Q4 FY2025 (July 1st – September 30th)
Our progress on certain tasks may be delayed because of delays in IRB approval.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
We plan to prepare and submit at least two abstracts to UMERC 2024: one on the Marine Spatial Planning (MSP) Challenge workshops we are planning for spring 2025 and one on the outcomes to date of the expert/non-expert communication effort we launched at UMERC 2024. We also plan to follow-up with those who submitted questions with contact information during the UMERC 2023 presentation on the expert/non-expert communication effort. We will work with those who agree to participate in focus groups to refine the questions they submitted with the goal of refining them to the point where they can be posed to ME end users (including those in the blue economy and coastal communities). We will continue to work on MSP Challenge workshop planning and manuscript preparation.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
We will present two posters at UMERC 2024: one on the Marine Spatial Planning (MSP) Challenge workshops we are planning for spring 2025 and one on the Inter Expertise Communication effort that we launched at UMERC 2023.

We will continue to work on MSP Challenge workshop planning for spring 2025.

Questions gathered and workshopped through our Inter Expertise Communication efforts (under Subtask 11.1) will be posed to end users, coastal communities, and other stakeholders. We will be conducting targeted outreach via email and follow-up phone call to relevant individuals and organizations we are currently identifying, as well as those identified by other efforts under this Subtask.

We intend to consult with Ashley Brooks about our plans to use the Justice 40 Tool to identify communities with a high energy burden.

We will continue working on the manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

Updates for Q4 FY2024 (July 1st – September 30th)
We will continue to work on planning for our spring 2025 outreach campaign, which will require significant travel for our team. The campaign will involve facilitation of MSP Challenge workshops with stakeholders across all groups and organization and implementation of focus groups and individual meetings (as appropriate) with stakeholders with interests in blue economy applications of marine energy. During these meetings and focus groups, we will pose questions to end users, coastal communities, and other stakeholders stemming from our 2023 UMERC presentation (under Subtasks 11.1 and 11.2). We will be conducting targeted outreach via email

and follow-up phone calls to relevant individuals and organizations we have already identified and try to expand the network to others from there.

We intend to consult with Ashley Brooks about our plans to use the Justice 40 Tool to identify communities with a high energy burden.

We will continue working on the manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

We will interview budget period 2 AMEC project teams and then work with Viola Clark to create illustrations of each project's objectives similar to the illustrations created for projects in budget period 1 of AMEC.

Updates for Q1 FY2025 (October 1st – December 31st)

We will continue to work on planning for our spring 2025 outreach campaign, which will require significant travel for our team. The campaign will involve facilitation of MSP Challenge workshops with stakeholders across all groups and organization and implementation of focus groups and individual meetings (as appropriate) with stakeholders with interests in blue economy applications of marine energy. During these meetings and focus groups, we will pose questions to end users, coastal communities, and other stakeholders stemming from our 2023 UMERC presentation (under Subtasks 11.1 and 11.2). We will be conducting targeted outreach via email and follow-up phone calls to relevant individuals and organizations we have already identified and try to expand the network to others from there.

We will continue working on the manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

We will interview budget period 2 AMEC project teams and then work with Viola Clark to create illustrations of each project's objectives similar to the illustrations created for projects in budget period 1 of AMEC.

Updates for Q2 FY2025 (January 1st – March 31st)

We will continue to plan for and implement our spring 2025 outreach campaign, which will require significant travel for our team. The campaign will involve facilitation of MSP Challenge workshops with stakeholders across all groups and organization and distribution of targeted surveys to stakeholders with interests in blue economy applications of marine energy. During these meetings and in the surveys, we will pose questions to end users, coastal communities, and other stakeholders stemming from our 2023 UMERC presentation (under Subtasks 11.1 and 11.2).

We will continue working on the manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

We will continue to interview budget period 2 AMEC project teams and then work with Viola Clark to create illustrations of each project's objectives similar to the illustrations created for projects in budget period 1 of AMEC.

We will hold sea turtle entanglement working group meetings with sea turtle experts, stranding and disentanglement professionals, and technology developers. In the working group meetings, we will discuss the risk of sea turtle entanglement with marine energy installations and associated oceanographic and environmental monitoring equipment, gaps in our knowledge about the risk and data needs to fill those gaps, and technological solutions to address the risks. PNNL is creating a video and other outreach materials regarding the risks to be used at focus groups and modified based on focus group discussions.

Updates for Q3 FY2025 (April 1st – June 30th)

We will continue to plan for and implement our spring through fall 2025 outreach campaign, which will require significant travel for our team. The campaign will involve facilitation of MSP Challenge workshops with stakeholders across all groups and distribution of three separate surveys to stakeholders in aquaculture, desalination, and blue innovation (blue economy applications of marine energy). During these meetings and in the surveys, we will pose questions to end users, coastal communities, and other stakeholders stemming from our 2023 UMERC presentation (under Subtasks 11.1 and 11.2).

We will continue working on the manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

We will continue to interview budget period 2 AMEC project teams and then work with Viola Clark to create illustrations of each project's objectives similar to the illustrations created for projects in budget period 1 of AMEC.

Valeria Rico will distribute her surveys to blue economy individuals, companies, and organizations and compile and interpret response data as it is received.

We will hold a sea turtle entanglement working group meeting with sea turtle experts, stranding and disentanglement professionals, and technology developers. In the working group meetings, we will discuss the risk of sea turtle entanglement with marine energy installations and associated oceanographic and environmental monitoring equipment, gaps in our knowledge about the risk and data needs to fill those gaps, and technological solutions to address the risks. PNNL is creating a video and other outreach materials regarding the risks to be used at focus groups and modified based on focus group discussions.

Jacqueline Ganter. will continue her research comparing data from tagged rehabilitated sea turtles to tagged non-rehabilitated turtles. She will do this in communication and collaboration with sea turtle researchers and regulatory agency representatives. She will also be presenting a poster about her research at the UMERC conference in Corvallis, OR in August 2025.

Jillian Eller will update their marine energy fact sheet and data collection and facilitation protocols for the MSP Challenge based on feedback from the INORE and MARCO experiences. Jillian is aspiring to receive IRB approval so that they can arrange for MSP Challenge games with contacts she made last quarter.

Updates for Q4 FY2025 (July 1st – September 30th)
We will continue working on the manuscript about the World Cafe process for stakeholder engagement and its use for the AMEC Testing Community Collaboration Workshop.

We will continue to interview budget period 2 AMEC project teams and then work with Viola Clark to create illustrations of each project's objectives similar to the illustrations created for projects in budget period 1 of AMEC.

Valeria Rico will continue to distribute her surveys to blue economy individuals, companies, and organizations and compile and interpret response data as it is received.

We will hold a sea turtle entanglement working group meeting with sea turtle experts, stranding and disentanglement professionals, and technology developers. During the meeting, we will discuss the risk of sea turtle entanglement with marine energy installations and associated oceanographic and environmental monitoring equipment, gaps in our knowledge about the risk and data needs to fill those gaps, and technological solutions to address the risks. We will also work on guidance regarding best practices to avoid entanglement and to respond to instances of sea turtle entanglement. We will continue to discuss PNNL outreach materials regarding the risks to be used at focus groups and offer the PNNL feedback.

Jacqueline Ganter. will continue her research comparing data from tagged rehabilitated sea turtles to tagged non-rehabilitated turtles. She will do this in communication and collaboration with sea turtle researchers and regulatory agency representatives.

Jillian Eller will update their marine energy fact sheet and data collection and facilitation protocols for the MSP Challenge based on feedback from the INORE and MARCO experiences. Jillian is aspiring to receive IRB approval so that they can arrange for MSP Challenge games with contacts they made last quarter.

We will send a follow-up message to participants in the 2025 UMERC Stakeholder Engagement workshop that will contain a pdf of the graphical recording from the workshop and a report for their future reference.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

- A guidance document regarding best practices for inter expertise communications that was shared with respondents to the UMERC 2023 inter expertise communications presentation by Ph.D. student, Jillian Eller
- Revised Marine Energy Testing Community Collaboration Workshop report (posted on AMEC website)
- Two UMERC posters
- Refined inter expertise questions that will be posed to coastal communities and blue economy end users
- Leave behind flier for blue economy target audience created by undergraduate summer intern, Nicky Coursey

Updates for Q4 FY2024 (July 1st – September 30th)

- Presentation of two UMERC posters.
- Testing workshop outcomes and illustration snippets distributed to workshop participants.

Updates for Q1 FY2025 (October 1st – December 31st)

- Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)

- Draft survey instrument
- Working draft of manuscript
- Poster for UMERC 2025 (Ganter)
- Proposal and outline for UMERC 2025 training workshop

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)

- Survey instruments for end users
- UMERC stakeholder engagement training illustration
- Final poster for UMERC 2025 (Ganter)
- MSP Challenge protocols and survey instruments submitted to IRB for approval
- Sea turtle entanglement working group final charter, manuscript outline, and draft entanglement response guidance document

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
This work will continue to connect AMEC research and educational work with that of the marine energy sector and those who will benefit or otherwise be affected by marine energy development through stakeholder communication and engagement.

Updates for Q4 FY2024 (July 1st – September 30th)
This work will continue to connect AMEC research and educational work with that of the marine energy sector and those who will benefit or otherwise be affected by marine energy development through stakeholder communication and engagement.

Updates for Q1 FY2025 (October 1st – December 31st)
This work will continue to connect AMEC research and educational work with that of the marine energy sector and those who will benefit or otherwise be affected by marine energy development through stakeholder communication and engagement.

Updates for Q2 FY2025 (January 1st – March 31st)
This work will continue to connect AMEC research and educational work with that of the marine energy sector and those who will benefit from or otherwise be affected by marine energy development through stakeholder communication and engagement.

Updates for Q3 FY2025 (April 1st – June 30th)
This work will continue to connect AMEC research and educational work with that of the marine energy sector and those who will benefit from or otherwise be affected by marine energy development through stakeholder communication and engagement.

Updates for Q4 FY2025 (July 1st – September 30th)
This work will continue to connect AMEC research and educational work with that of the marine energy sector and those who will benefit from or otherwise be affected by marine energy development through stakeholder communication and engagement.

Task 12.0 Education and Workforce Development Activities

Major Project Goals and Objectives

AMEC will engage in educational activities and workforce development to recruit and train the next generation of scientists and engineers for MRE and PBE.

In BP2, Education and Workforce Development Activities that were planned in BP1 will be conducted. This includes MRE/PBE-oriented short courses, conferences, workshops, online programs, including undergraduate students in AMEC-related activities and participating in K-12 education experiences. AMEC will collaborate with National Laboratories on workforce development activities, e.g., internships, graduate scholarships, webinars, short courses.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

12.4 Participate in existing K-12 education experiences

AMEC participated in the Ocean Discovery Day at UNH Chase Ocean Engineering Laboratory on October 20, 2023. Over 1,500 school kids enjoyed a fun-filled field trip on Friday, and over 800 people attended our Open House on Saturday. More than 40 stations featured activities, displays and demonstrations to engage participants.

Figure 12.4.1 Photo collage from Ocean Discovery Day October 20, 2023. (from top left, counterclockwise) photo of participants with the engineering and wave tank, M. Wosnik at the wave tank, Fluid Dynamics of Flow in Benthic Ecosystems demonstration, AMEC students

presenting turbines, Dr. Julie Paprocki presenting on Sand Castle Construction & Sand Sieving/Settling, Visualization Laboratory, 3-D Topography Sandbox

Updates for Q2 FY2024 (January 1st – March 31st)
No update.

Updates for Q3 FY2024 (April 1st – June 30th)
12.2 Engage undergraduate students in MRE and PBE

AMEC participated in the Marine Energy Collegiate Competition (MECC) held in Portland, Oregon, last May 2024. Two MECC student groups were fielded by the AMEC universities, the University of New Hampshire and the University of North Carolina—Charlotte. The University of New Hampshire team won first place overall, the Technical Design Challenge, and the Business Plan Challenge. The UNH project was "Drift-RMT: Powering Drifter Buoys with Wave Energy and Rotating Mass Technology." Martin Wosnik, AMEC Director, advised the team.

The University of North Carolina at Charlotte team won the Rising Star award. The UNCC project was "Duck-duck-goose: Versatile Marine Energy Point Absorber." Saffeer M. Khan, PhD, P.E., advised the team.

12.4 Participate in existing K-12 education experiences

On April 16, AMEC hosted about 80 middle school students from Manchester Hillside Seventh Grade for a visit to the Chase laboratory. The AMEC Director, Martin Wosnik, introduced the students to the Chase lab and its focus on marine energy. The students also visited the Structural Engineering Labs and the UNH Flow Physics Facility. Additionally, they had the chance to attend a presentation by the UNH MECC team on their project for the MECC.

CSI also conducted its annual summer camp for K-12 children, including the Sustainable Seas camp. The two-week summer camp is designed for 10-15-year-olds and focused on oceanography and coastal engineering, with a significant renewable energy component. The thirty-two campers enrolled learned about microgrids, wind and ocean energy, and created models of wind turbines and wave energy converters.

Since January 1, 2024, CSI has reached over 1,000 members of the public to share information and activities related to marine energy. The activities other than the Sustainable Seas camp include in-depth programs with a marine energy focus delivered to 13 different schools or education groups, where 664 students, teachers, or life-long learners from North Carolina and as far away as California participated. An additional 330 people learned about CSI and AMEC marine energy research through the CSI open house (April 20, 2024) and monthly CSI tours open to the public. CSI continued to integrate the SIWEED (developed by SANDIA) wave tank in education programming. CSI leveraged a summer intern, Jazmyn Fuentes, from NC State to develop standard procedures for operation of the tank.

Updates for Q4 FY2024 (July 1st – September 30th)

12.4 Participate in existing K-12 education experiences

On July 16, 2024, AMEC hosted engineering majors from St. Paul's School's Advanced Studies Program (ASP) at the Chase Lab. The ASP is a summer program for talented high school students across New Hampshire. The students were particularly impressed with the facilities, especially the axial flow turbine experiments in the tow tank, the interactive sand display for exploring topography, and the uncrewed surface vessels used for various research projects.

Figure 12.4.1 Students from St. Paul's School ASP

CSI summer intern, Jazmyn Fuentes, completed research on powering blue economy and presented at NC State University Summer Research Symposium. She was also selected to participate in C3E 2024 Research Symposium at Stanford. https://c3e.org/2024-symposium

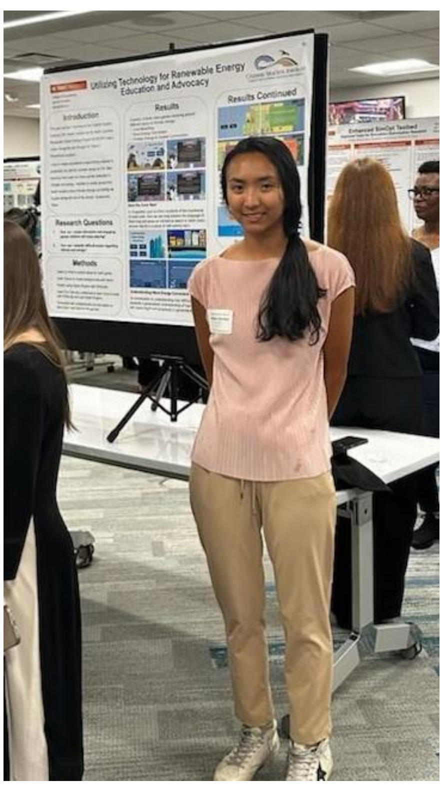


Figure 12.4.2 Jazmyn Fuentes with her poster presentation

Updates for Q1 FY2025 (October 1st – December 31st)

AMEC participated in the UNH Ocean Discovery Day on October 4-5 in Durham, NH. For marine energy, we demonstrated our 1-m scale axial flow and cross flow tidal turbines (towing tank test beds), which kids could also touch and spin (careful, sharp trailing edges!). Designed and 3D-printed a small desk-top version of the axial flow turbine, and instrumented it so students could spin it and light up a green LED bar ("you're making green energy!").

Some of the marine energy exhibits were the following:

- Showed embedded optical fibers in two spare turbine blades of different materials and showed students how to measure blade bending with light.
- Showed a small hand-operated wave tank with a working model wave energy converter that students would try to move up and down with the waves to "light up" a city on the shore (with an LED bar). We also had our wave-powered water pump on display.
- Demonstrated wave measurements and a floating offshore wind turbine model

AMEC conducted a webinar with TEAMER on October 24, 2024 to discuss with AMEC researchers available assistance in technical assistance through their facility.

Updates for Q2 FY2025 (January 1st – March 31st)

<u>Subtask 12.2 Engage undergraduate students in MRE and PBE</u>

AMEC at UNH engaged three interns (Alexandra Forbes, Lindsay Fortin, Catherine Kiburis) from the UNH College of Liberal Arts. They were trained to categorize ME and PBE knowledge products and the facilities database, improve the AMEC website, and collate articles about AMEC.

<u>Subtask 12.3 MRE and PBE-specific curriculum</u>

M. Wosnik at UNH taught ME 706/806 Physics and Engineering Principles of Renewable Energy in Spring 2025.

<u>Subtask 12.4 Participate in existing K-12 education experiences</u>

On March 22, CSI hosted the NC Renewable Energy Challenge. CSI organizes this annual event with support from the North Carolina Renewable Ocean Energy Program, KidWind, and Jennette's Pier. The competition encourages students to design efficient alternative energy devices, promoting interest in green technology and helping develop essential skills for future careers in the renewable energy sector. AMEC Education Specialist Lauren Kerlin facilitated the event, while AMEC Associate Director Lindsay Dubbs and Co-Director George Bonner served as judges for the marine energy category.

Updates for Q3 FY2025 (April 1st – June 30th)

AMEC Director Martin Wosnik presented the latest advancements in research and infrastructure developments at AMEC in a seminar last April 11 titled "Marine Energy Research and Development at the Atlantic Marine Energy Center." The seminar was part of the Ocean Seminar series co-sponsored by the Center for Coastal and Ocean Mapping / NOAA-UNH Joint Hydrographic Center and the Center for Ocean Engineering at the University of New Hampshire. As part of the Ocean Seminar series, on April 18, Arezoo Hasankhani, AMEC project leader, presented her research on Wave Energy Converters (WECs) and their role in enhancing electricity generation while supporting applications within the blue economy, such as offshore aquaculture. She also discussed recent advancements in design and control methods that improve energy capture efficiency, as well as the power requirements and conceptual designs for a wave-powered aquaculture platform. She further discussed marine spatial planning considerations for deploying these technologies in the Northeastern United States.

The Sanborn Submarine Team returned to UNH to test their human-powered submarine in the engineering tank located at Chase Laboratory. This group of students from Sanborn Regional High School in New Hampshire was preparing to compete in the International Submarine Races, scheduled to take place from June 22 to 27 in Maryland. The International Submarine Race aims to provide valuable educational experiences for engineering and science students from around the world. It is sponsored by the Foundation for Underwater Research and Education (FURE) and hosted by the Naval Surface Warfare Center Carderock Division (NSWCCD). WMUR-TV's NH Chronicle documented the event. You can watch this video where AMEC Director Martin Wosnik discusses UNH's engineering tank and its capabilities. Here is the link to the video: https://www.wmur.com/article/chronicle-sanborn-unh-submarine-racing/65103280

Co-Director, George Bonner, and Dr. Mike Muglia presented on AMEC at the Salty Dawg Speaker Series at the Graveyard of the Atlantic Museum on June 10, 2025.

Co-Director, George Bonner (CSI), participated in the NC A&T Senior Engineering Capstone presentations including sponsored team on OWC marine energy device in May 2025.

The UNC Charlotte Marine Energy Collegiate Competition (MECC) Team was recognized as poster competition winners (CSI) on May 22, 2025. A student team from UNH also participated in the MECC 2025.

CSI hosted a student visit to Dominion Energy’s Coastal Virginia Offshore Wind Farm on June 25, 2025. AMEC Environmental Specialist, Amy Thompson, participated in this visit.

CSI hosted an Open House which included an AMEC booth and marine energy technical and wave tank demonstrations on May 17, 2025.

NCAT visited CSI on May 29, 2025.

Updates for Q4 FY2025 (July 1st – September 30th)

12.1 Run AMEC webinar series

Nothing to report.

12.2 Engage undergraduate students in MRE and PBE

On July 23, Martin Wosnik led tours of the Living Bridge Project and the AMEC-UNH Tidal Energy Test Site to about 40 NH Department of Transportation (NHDOT) and HNTB interns.

AMEC at CSI hosted a NC State engineering student (Ryan Page) and a UNC-Chapel Hill public policy student (Valeria Rico) for summer internships. Ryan, under the mentorship of George Bonner, learned how to create a business plan and other accreditation deliverables, which he applied to drafts for AMEC. Valeria was mentored by Drs. D'Anna and Dubbs in designing a survey instrument for blue economy individuals and organizations and identifying contacts within Blue Economy sectors. Both Valeria and Ryan have been documenting their learning and progress in posters that will be presented at the end of the summer. Anna Horton (UNC-CH; fall 2025) began an internship with Amy Thompson in September. She is assisting Amy in collecting baseline soundscape samples from the Jennette's Pier Wave Energy Test Center that will aid permitting and testing of marine energy devices in the future. Anna is also doing a project to characterize fish generated bioacoustics and to create an interactive educational display about the Jennette's Pier soundscape for the Pier house.

12.3 MRE and PBE-specific curriculum

AMEC taught the first Introduction to Marine Energy Short Course of the Atlantic Marine Energy Center (AMEC), at University of New Hampshire, 3-9 August 2025. 27 students from 17 universities in 14 U.S. states participated. AMEC faculty and graduate students developed and delivered a comprehensive curriculum, including lectures, laboratory experiments, tours and field trips. This course was funded through DE-EE0011379, and a more detailed report is provided in the Quarterly Report for this award.

Lindsay Dubbs (Associate Director at CSI) taught course sessions on marine energy and PBE topics for their Outer Banks Field Site program offered to UNC-Chapel Hill undergraduate students studying environmental studies and science. Lindsay Dubbs taught a session on environmental monitoring and soundscape characterizations for ENEC 489: Ecological Processes in Coastal Systems and classes in jurisdiction and offshore permitting, with a marine energy bent, for ENEC 351: Coastal Law and Policy.

12.4 Participate in existing K-12 education experiences

Amy Thompson prepared and presented about cetacean acoustics for the CSI Coastal Kingdoms summer campers on Thursday, July 24, 2025.

CSI hosted a Blue Horizons Summer Camp from July 28 to August 1, 2025 to introduce students to coastal sustainability, renewable energy, including marine energy. Students built and tested wave energy converters as well as underwater turbines (13 students).

CSI participated in the North Carolina 4H Electric Congress on July 16, 2025 for middle school students and educated participants on marine energy. (100 students).

George Bonner presented marine energy and AMEC, and Amy Thompson on environmental monitoring, for the NC STEM East Alliance group (K-12 teachers) that visited CSI on July 30 and 31, 2025 (31 Middle and High School Teachers). Lauren Kerlin facilitated a workshop in which teachers were trained in how to incorporate a lesson and activity about wave energy converters in their classrooms.

Amy Thompson prepared materials to support educational outreach regarding marine energy and environmental monitoring for K-12 visitors as well as the general public while doing environmental monitoring on Jennette's Pier. Many interested visitors had approached her with questions about the samples and data she was collecting, prompting development of outreach materials.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
None reported.

Updates for Q4 FY2024 (July 1st – September 30th)
The activities under this Task will complement the activities under Task 1, ME Short Course Development and Implementation of the AMEC BIL funding EE-0011379. Identifying activities that may be synched will be beneficial.

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
None reported.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)

None reported.

Updates for Q2 FY2024 (January 1st – March 31st)

None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

None reported.

Updates for Q4 FY2024 (July 1st – September 30th)

[Enter update here. Start with any requests you have for the DOE project team. Your update for this section should be a narrative addressing significant challenges, risks, and mitigation plans. "Nothing to Report" is a valid entry.]

Updates for Q1 FY2025 (October 1st – December 31st)

No update.

Updates for Q2 FY2025 (January 1st – March 31st)

None reported.

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)

Nothing to report.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)

Attend coordination meetings with PMEC and the other NMECs

Updates for Q2 FY2024 (January 1st – March 31st)

None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

None reported.

Updates for Q4 FY2024 (July 1st – September 30th)

No update.

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
None reported.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Continue as per SOPO.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
None reported.

Updates for Q4 FY2024 (July 1st – September 30th)
No update.

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
[Select an option. Reminder: outputs include, but are not limited to, publications, presentations, websites, inventions, patent applications, licenses, technologies, techniques, software, databases, models, video/audio products, equipment, instruments, and educational materials.]

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

K-12 students in NH participating in the UNH Ocean Discovery Day will promote awareness of marine energy and blue economy applications. These students with increased awareness might consider a degree program or career in STEM.

Updates for Q2 FY2024 (January 1st – March 31st)

None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

K-12 students touring UNH and participating in CSI summer camps will promote awareness of marine energy and blue economy applications. These students with increased awareness might consider a degree program or career in STEM.

Updates for Q4 FY2024 (July 1st – September 30th)

No update.

Updates for Q1 FY2025 (October 1st – December 31st)

No update.

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

No change.

Updates for Q4 FY2025 (July 1st – September 30th)

AMEC continues to engage undergraduate students in marine energy and Powering the Blue Economy activities, develop and develop ME and PBE-specific curriculum and participate in K-12 education experiences. We believe these activities carry significant cumulative impact.

Task 13.0 Infrastructures Upgrade and Capabilities Development, BP2

Major Project Goals and Objectives

Infrastructure upgrades and capability development have been carefully selected to meet our goal of being able to support MRE development (TRL 1-6) and PBE (TRL 1-8), including cross-cutting applications.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

No update

Updates for Q2 FY2024 (January 1st – March 31st)

No update

Updates for Q3 FY2024 (April 1st – June 30th)

13.1 - Taz Lancaster was recruited and started as Program Manager for CSI AMEC to advance testing program. Taz brings leadership and maritime experience in Marine Operations, Safety, and Quality Assurance through work with Maritime Incident Response Team. He is a licensed Captain.

Updates for Q4 FY2024 (July 1st – September 30th)

CSI completed recruitment for Environmental Specialist Position for open water testing. Candidate is scheduled to onboard 4 November 2024 and has experience in NEPA, permitting, and working with maritime stakeholders.

Updates for Q1 FY2025 (October 1st – December 31st)

No update.

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

The AMEC marine DC microgrid infrastructure, consisting of three interconnected multiport converter nodes, was fully established during this quarter. A major advancement involved the integration of a 100Ah, 350V EV battery and two commercial CE+T Stabiliti 30C3 multiport converters. This expanded system enables battery charging, PV harvesting, and real-time testing across AMEC nodes.

Initially, the research team tested AMEC Node 2 (CE+T Stabiliti 2) and Node 3 (FREEDM 10 kVA GEH MPC) in coordination, using a WEC emulator and AC supply to power Node 2. During this test, a 40Ah, 135V battery connected to the FREEDM GEH was successfully charged. Following this, the team added a second CE+T Stabiliti converter and integrated the 100Ah battery with the existing microgrid setup.

Upon full integration, the team successfully operated Node 1 (CE+T Stabiliti 1) and Node 2 (CE+T Stabiliti 2) in tandem. In this coordinated test, the system routed 2.4 kW of PV energy from Node 2 to charge the 100Ah battery connected to Node 1 via a shared DC bus, demonstrating proper coordination and power transfer between nodes.

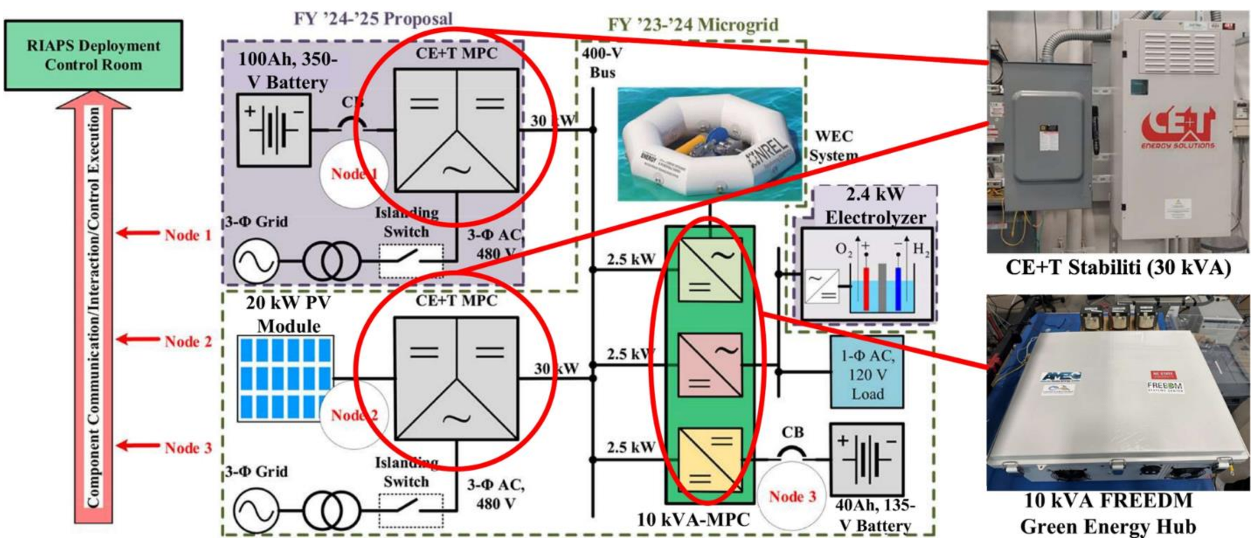


Fig. 13.1: Automated and Scalable Marine DC Microgrid System with 10kVA FREEDM Green Energy Hub

Here, figure 13.1 represents the three-node structure of the AMEC marine DC microgrid. The following figure 13.2 represents the testing configuration of the AMEC Node 2 and AMEC Node 3 operating together and harvesting WEC power and figure 13.3 represents the testing configuration of the AMEC Node 1 and AMEC Node 2.

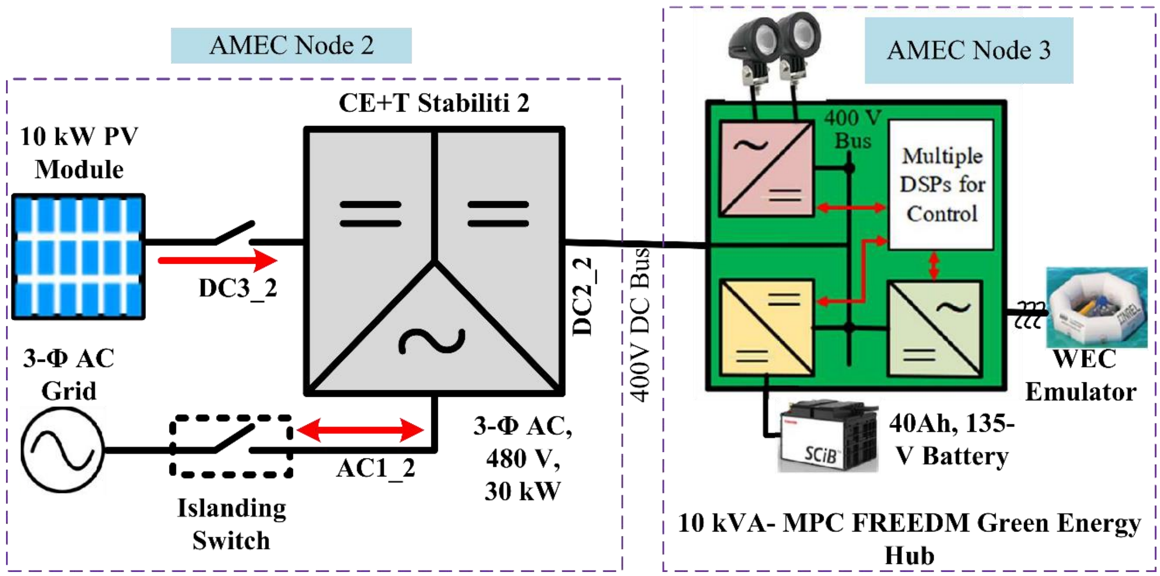


Fig. 13.2: Experimental setup of the 10kVA FREEDM Green Energy Hub (AMEC Node 3) battery charging and supplying split phase inverter through CE+T Stabiliti MPC (AMEC Node 2).

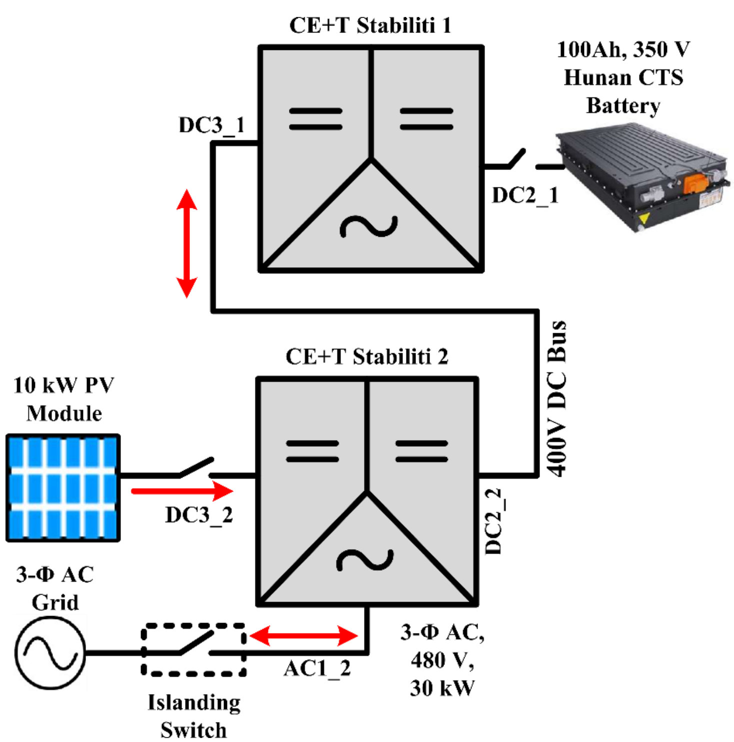


Fig. 13.3: Experimental Configuration of Operating both CE+T Stabiliti (AMEC Node 1 and 2) together.

AMEC I/JA researchers (Dr. Wesley Williams and Dr. Michael Dickey) were selected Phase II winners in DOE INDEEP competition for their role in Blue Economy Start-Up WATER BROS.

Updates for Q4 FY2025 (July 1st – September 30th)

Application to TEAMER to list the 10kVA FREEDM GEH as a testing facility:

As part of the AMEC Budget Period 2 proposal, reporting the 10 kVA FREEDM Green Energy Hub (GEH) as a TEAMER facility was a deliverable. The FREEDM team compiled technical documentation, validated test results, and safety protocols to demonstrate the system's readiness as a marine energy test platform. The application showcased the GEH's ability to emulate Wave Energy Converter (WEC) outputs, manage power flow among multiple ports, and safely operate under real-time control. All operational data, control architecture, and expertise were submitted to establish the 10 kVA GEH as a functional, safe, and replicable marine microgrid research facility.

We proposed the 10 kVA FREEDM GEH as a TEAMER-eligible testbed designed for marine microgrid and WEC integration studies. The system, built around a modular multi-port converter (MPC), can emulate WEC outputs, charge/discharge batteries, and supply AC loads simultaneously. Located in the FREEDM High Bay lab, the facility provides a professional and safety-certified environment for external researchers. The application emphasized our team's technical expertise, supervisory control interface, and validated use cases, positioning the facility as a national asset for TEAMER users to test converter control strategies and energy management algorithms.

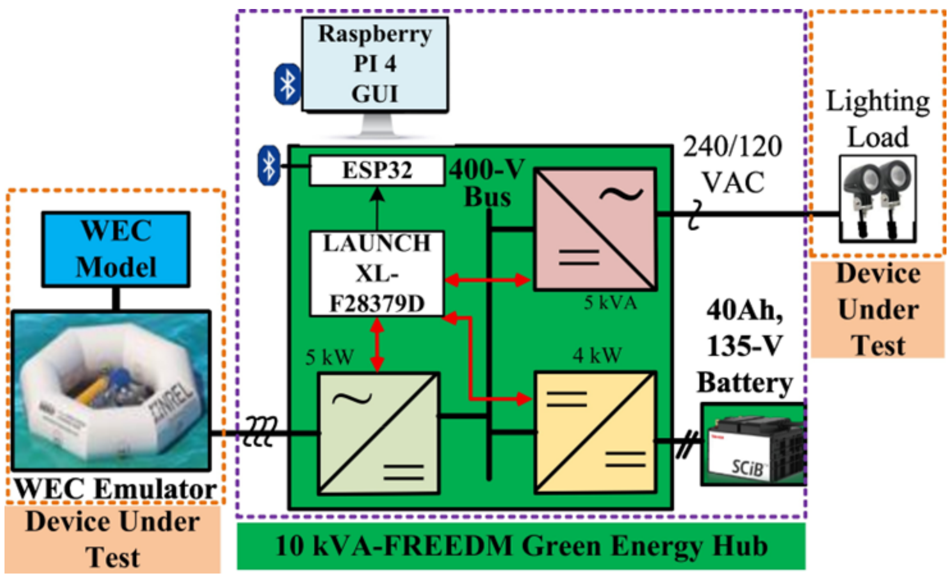


Fig. 13.1: 10 kVA FREEDM GEH MPC setup

The 10 kVA FREEDM GEH is a three-port multi-port power converter integrating a 400 V DC bus, a 5 kVA WEC port, a 135 V bidirectional battery port, and a 5 kVA split-phase AC port. It uses SiC-based converters operating at 75 kHz, managed by a dual-core TI F28379D DSP and a Python-based GUI for real-time control and data logging. Built-in protections include over-voltage, under-voltage, over-current, and relay interlocks. The system supports flexible testing of WEC emulation, BESS operation, AC load regulation, and external DC/DC charger validation. Supplementary FREEDM lab assets—such as a 40 kW PV array, 350 V EV battery, and CE+T 30 kVA converters—expand its testing capability.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

No update.

Updates for Q2 FY2024 (January 1st – March 31st)

No update.

Updates for Q3 FY2024 (April 1st – June 30th)

No update.

Updates for Q4 FY2024 (July 1st – September 30th)

No update.

Updates for Q1 FY2025 (October 1st – December 31st)

No update.

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

All three nodes of the AMEC DC microgrid were successfully integrated and tested with energy storage and PV. The subtask is on track and entering system-level validation.

Updates for Q4 FY2025 (July 1st – September 30th)

The progress of this task is on track.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to Report

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to Report

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to Report

Updates for Q4 FY2024 (July 1st – September 30th)
No update.

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
No major technical challenges have been identified this quarter. Testing revealed minor power losses during energy routing.

Updates for Q4 FY2025 (July 1st – September 30th)
No major technical challenges have been identified this quarter.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
No update

Updates for Q2 FY2024 (January 1st – March 31st)
No update

Updates for Q3 FY2024 (April 1st – June 30th)
No update

Updates for Q4 FY2024 (July 1st – September 30th)
No update

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
Operate all three nodes of the AMEC marine DC microgrid—two CE+T Stabiliti converters and the FREEDM 10 kVA MPC—and demonstrate coordinated power routing across the network.

Updates for Q4 FY2025 (July 1st – September 30th)
Our next task is to develop a distributed control network for the entire AMEC microgrid including the Node 1,2 and 3. The other task is to closely monitor the progress of the TEAMER facility application review process. We will also operate the three nodes of the AMEC microgrid together using distributed control.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
[Select an option. Reminder: outputs include, but are not limited to, publications, presentations, websites, inventions, patent applications, licenses, technologies, techniques, software, databases, models, video/audio products, equipment, instruments, and educational materials.]

Updates for Q2 FY2024 (January 1st – March 31st)
[Select an option. Reminder: outputs include, but are not limited to, publications, presentations, websites, inventions, patent applications, licenses, technologies, techniques, software, databases, models, video/audio products, equipment, instruments, and educational materials.]

Updates for Q3 FY2024 (April 1st – June 30th)
[Select an option. Reminder: outputs include, but are not limited to, publications, presentations, websites, inventions, patent applications, licenses, technologies, techniques, software, databases, models, video/audio products, equipment, instruments, and educational materials.]

Updates for Q4 FY2024 (July 1st – September 30th)
[Select an option. Reminder: outputs include, but are not limited to, publications, presentations, websites, inventions, patent applications, licenses, technologies, techniques, software, databases, models, video/audio products, equipment, instruments, and educational materials.]

Updates for Q1 FY2025 (October 1st – December 31st)
No update.

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

[Enter "Impact" text. This section should be a concise narrative describing the impact this project has on industry, technology, and society. This is an opportunity for recipients to explain the value of using taxpayer money to fund the project.]

Updates for Q2 FY2024 (January 1st – March 31st)

[Enter "Impact" text. This section should be a concise narrative describing the impact this project has on industry, technology, and society. This is an opportunity for recipients to explain the value of using taxpayer money to fund the project.]

Updates for Q3 FY2024 (April 1st – June 30th)

[Enter "Impact" text. This section should be a concise narrative describing the impact this project has on industry, technology, and society. This is an opportunity for recipients to explain the value of using taxpayer money to fund the project.]

Updates for Q4 FY2024 (July 1st – September 30th)

[Enter "Impact" text. This section should be a concise narrative describing the impact this project has on industry, technology, and society. This is an opportunity for recipients to explain the value of using taxpayer money to fund the project.]

Updates for Q1 FY2025 (October 1st – December 31st)

No update.

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

This task has successfully demonstrated a scalable and modular marine DC microgrid architecture. The integration of multiple commercial converters and high-voltage battery storage enables realistic emulation of marine microgrid operations and strengthens the project's ability to support hybrid renewable energy systems.

Updates for Q4 FY2025 (July 1st – September 30th)

We have successfully reported our 10-kVA FREEDM GEH as a facility for the TEAMER. Anyone can test their charge controller or Wave energy converter model using our testbed. We will try to publish the distributed control in the next quarter.

Task 14.0 Accreditation

Major Project Goals and Objectives

For clarification we note that the term “accreditation” is being used as general shorthand for formal recognition as a marine energy test laboratory or center, whether under ISO (“accredited as a test laboratory”) or IEC (“recognized as a test laboratory”). For accurate language we refer to the documentation published by the respective organizations.

In Budget Period 1, AMEC contracted the European Marine Energy Center (EMEC) to conduct an Accreditation Roadmap and Gap Analysis for UNH’s Tidal Energy Test Site at Memorial Bride in Portsmouth, NH and CSI’s Wave Energy Test Facility at Jennette’s Pier in Nags Head, NC. Three workshops were held, with participation of experts from the National Renewable Energy Laboratory. Site visits by EMEC to the UNH and CSI test sites were conducted.

In its final report, EMEC recommended that “AMEC pursue the ability to perform testing at least in line with the ISO 17025 and the ISO/IEC TS 62600 Marine Energy Specifications but do not seek formal accreditation at this stage.

Instead of pursuing formal “accreditation” under ISO, AMEC will take critical steps that would allow it to pursue “designation” as a Marine Energy Sector IECRE Testing Laboratory (RETL) for testing of intermediate and PBE scale current and wave energy converters in the future. These steps will include conducting an in-water test of current and wave energy converters at the respective test sites in the respective declared competence areas, the assessment (audit) of these tests and processes relevant to accreditation by a qualified third party, and writing reports on the tests and the third party assessments (audits) by the respective organizations.

Key areas identified in the EMEC report requiring focus in order to pursue accreditation include:

- The appointment of the relevant staff: a technical manager, quality manager, and test Engineers
- The introduction of organizational procedures and documentation
- The use of equipment compliant with ISO 17025, and any relevant testing standard or specification that is used. This will include compliance in terms of use, instrument class, calibration/conformity certification, and in-house calibration procedures and documentation. Note that cost information on the items will be developed under Task 10.4 and 10.5.

Organizations can become recognized as a marine energy test laboratory through the “IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications” (IECRE System). The steps required for confirmation and “designation” as an IECRE Testing Laboratory (RETL) in a declared competence area are given in IECRE administrative Document (AD 007).

The intermediate or PBE scale test sites are: UNH’s Tidal Energy Test Site at Memorial Bride in Portsmouth, NH (IEC 62600-202 – scaled tidal testing) and CSI’s Wave Energy Test Facility at

Jennette's Pier in Nags Head, NC (IEC 62600-103 – scaled wave testing). AMEC will provide feedback to IEC with regards to the applicable IEC TS-62600 Marine Energy Standards.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)

Revised SOPO for BP2 to reflect the difference in approach of "accreditation" vs "recognized testing". Added preparation subtasks in SOPO to avoid NEP holds on entire tasks.

Updates for Q2 FY2024 (January 1st – March 31st)

None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

Re-initiated contact with EMEC project lead Myles Heward, who was waiting for BP2 to start and continue to support this task. We learned that Myles was on long-term sick leave, and contacted his backup at EMEC. Further updates in this on Q4.

Updates for Q4 FY2024 (July 1st – September 30th)

Some progress made toward Subtask 14.1 – Preparation for UNH Demonstration of Proficiency in Tidal Energy Converter Testing. SOPs are being aggregated and in places drafted from scratch. Researching the requirements of IECRE RETL process in order to identify the necessary steps towards accomplishing that process.

Work is being performed to prepare the turbine deployment platform for a 2025 deployment of the OSTEC turbine. TDP will be electrically and mechanically disconnected from the Memorial Bridge pier and ferried back to the UNH pier for demobilization and refitting for a 2025 test. Staff engineers will work with the OSTEC team to prepare instrumentation for the upcoming deployment.

Updates for Q1 FY2025 (October 1st – December 31st)

Met with EMEC to discuss proposal and scope of services relating to continued work in BP2 relating to pursuit of test lab accreditation. Scope of services to include planning of business plan for test sites (Task 10), evaluation of standard operating procedures, assistance in navigating IECRE process, assistance in ensuring compliance with ISO17025.

Initiated discussions with IEC working group members and leaders including B. Staby and J. Colby. Provided valuable insight toward the direction of pursuit of test lab accreditation.

Continued aggregation and organization of SOPs.

CSI Program Manager Taz Lancaster and AMEC Project Engineer S. Pamboukes working together to pursue test lab accreditation at both CSI and UNH open water test sites.

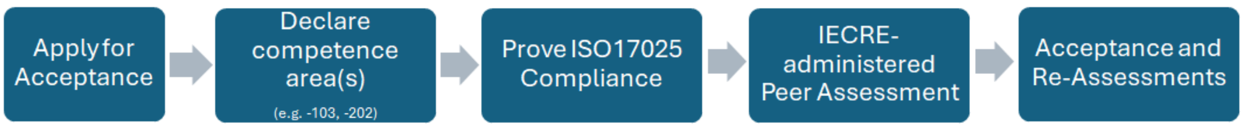
Assisting with instrumentation and data collection planning at UNH test site for OSTEC project to be deployed in 2025. This turbine may serve as a test article for demonstration of proficiency with marine energy device testing as per IECRE system process.

Met with DOE and NMFS representatives to discuss status of ongoing Programmatic BA for UNH test site. Draft is very developed, needs to be finished for submission and discussion with DOE and NMFS.

Updates for Q2 FY2025 (January 1st – March 31st)

Based on meetings during Q1 and Q2 FY2025 (February 4), AMEC received a proposal in late Q2 from EMEC for services related to continued pursuit of test site accreditation. AMEC is reviewing the proposal to determine which services to select and how best to engage EMEC.

UNH and CSI took a closer look at ISO & IECRE accreditation processes to better understand and identify requirements ahead of accreditation. Summarizing IECRE document *Simplified RETL Acceptance Process*, the following flow chart was generated:



Some barriers were identified:

- No significant body of IECRE-compliant Test Reports exist within AMEC. These are somewhat of a prerequisite for application for acceptance as a Renewable Energy Test Laboratory.
- The IECRE System includes Operational and Administrative documents relating to specific IEC TC114 Technical Specifications: -3 and -200. The competence areas of interest to UNH and CSI are -102 and -202. Until Operational and Administrative documents relating to those Technical Specifications are invoked by the IECRE, AMEC cannot declare competency in those areas.
- As part of the RETL acceptance process, the Test Laboratory will need to demonstrate compliance with ISO17025, by way of either existing ISO17025 accreditation, or by demonstrating consistency with ISO17025 during the RETL assessment process.

To address these barriers in the interest of making progress towards accreditation, the following actions can be taken:

- Begin to issue Test Reports that are declared to be compliant with a given Technical Specification whenever possible. While these would not be “formal” Test Reports, as AMEC is not an RETL, they would begin to build a body of work that demonstrates that AMEC is well acquainted with and able to test in a way that is compliant with technical specifications. This would be valuable by the time that AMEC formally applies for acceptance.
- AMEC can assist the IECRE with generation of competence area documents, and/or consider declaration of competency in existing areas such as -3 and -200 which are currently actionable.
- AMEC can work towards ISO17025 accreditation or at least compliance, as this is effectively a requirement of the IECRE system process. ISO17025 is a widely used

standard, so a great body of assistive resources such as trainings and consultants would be available to assist.

AMEC will consider and prioritize these efforts to work towards accreditation.

Towards M14.1.1, UNH and CSI aggregated significant existing SOPs from their respective universities. The universities expect that most if not all relevant SOPs have been accumulated, leaving them simply to reviewed and updated to accomplish this milestone. Further development of SOPs will be focused on A) SOPs that directly support the accreditation processes and B) those that are important to the safe and effective operations of the respective marine energy test centers.

Updates for Q3 FY2025 (April 1st – June 30th)

S. Pamboukes (UNH) and A. Thompson (CSI) met to discuss actions that can be made to work towards ISO17025 accreditation/compliance. They are researching A2LA accreditation processes, and training courses through their training partner, A2LA Workplace Training. Researched off-the-shelf Quality Management System software products that may be an efficient way to implement QMS within AMEC's labs, rather than developing from scratch.

They've researched other organizations who maintain ISO accreditation with respect to the IEC technical specifications, as to perhaps reference their organization's process and approach towards gaining such accreditation. S. Pamboukes met with Rebecca Fao of NREL – Rebecca is a Group Manager for NREL's water power technology validation team. She manages NREL's ISO17025 accreditation against IEC TC114 technical specifications. Gained valuable insight on the accreditation process, and NREL's approach.

Towards permitting and NEPA consultation at AMEC/UNH's Tidal Energy Test Site, a completed Programmatic Biological Assessment was submitted to DOE, who in turn reviewed it and forwarded it to NOAA/NMFS. This programmatic BA covers the recurring deployment of marine energy converters at the tidal energy test site. If granted an NLAA process, this consultation should streamline and expedite the BA/approval process when AMEC seeks to install new test articles at their test site. Notably, an NLAA determination would allow UNH/AMEC to list their Piscataqua River test site as an authorized TEAMER facility.

Updates for Q4 FY2025 (July 1st – September 30th)

In Q4 2025, a MOD 10 SOPO revision was made to incorporate UNH tasks from the Open-Source Tidal Energy Converter (OSTEC) AOP 2.2.8.701 Design and Testing of an Open-Source Tidal Energy Converter (TEC) to Advance Marine Energy IEC Standards into the DE-EE0009450 work scope. Accordingly, AMEC/UNH has shifted considerable attention towards the preparation and completion of these associated subtask 14.0 milestones and deliverables.

<u>Subtask 14.1, Preparation for UNH Demonstration of Proficiency in Tidal Energy Converter Testing</u>

In Q4 2025, significant efforts and progress was made towards the following:

- design, fabrication, and assembly of a TDP extension structure
    - structural analysis, design for buoyancy considerations, plans for corrosion-resistant coatings, assessment of demand on PGA/VGP structures
- design, planning, acquisition, and installation of an instrumentation shed for the TDP
    - planning shed to house all electronics, designing workstations, customizing and adapting the custom-off-the-shelf product to suit the exact needs of the TDP
- Planning and preparing a suite of instruments and sensors for performance and environmental monitoring including but not limited to ADVs, ADCPs, load cells, weather stations, inertial measurement units, etc.
    - Planning cable runs, modifying cables to suit the demands of the TDP and hardware integration into MODAQ, integrating instruments into MODAQ and performing bench tests
- Preparing the OSTEC turbine for installation to the TDP and imminent deployment
    - Including assembly of all electromechanical components, installation of internal sensors, addition of cable routing features, production of custom tooling and assembly equipment, modification as needed to purchased or custom-fabricated components, dry testing of the turbine assembly.

Figure 14.0.1 – A substantially completed OSTEC turbine resting upon it's test stand (blue). The OSTEC turbine was completed during Q4 2025.

Figure 14.0.2 – The AMEC/UNH turbine deployment platform undergoing major refit: the addition of a 6-foot wide "platform extension". The extension moves the TDP further away from the bridge pier that it is moored to, positioning a turbine's rotor area further away from the turbulent boundary layer that is shed when incoming waterflow interacts with the concrete pier.

With respect to specific milestones and deliverables, the most notable accomplishment would be towards Milestone M14.1.5 – completion of OSTEC instrumented marine turbine assembly in lab, and dry-testing of the turbine in the lab. As of Q4 2025, the OSTEC turbine is indeed completed and ready for installation on the TDP. Milestones and deliverables associated with Subtask 14.1 will require the production of specific documents and reports such as a dry test summary, an experimental test plan, operating procedures and maintenance manual, etc. These documents are being prepared in parallel with the physical tasks associated with building a novel turbine and preparing for deployment.

Notably, the OSTEC turbine will be used as a test article for the generation of test reports consistent with IEC requirements. This is an important step towards accreditation of AMEC's AMEC-UNH Tidal Energy Test Site, as the IECRE process requires a demonstration of proficiency in the testing of tidal energy devices, and a review of prior years' test reports when considering a lab as an RETL.

14.3 Preparation for CSI Demonstration of Proficiency in Wave Energy Converter Testing

At CSI, Amy Thompson participated in the 2025 Ocean Observatories Initiative Facility Board Summer School on Acoustics in Seattle, WA from 7/14-7/18).

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

The revised SOPO provides a clearer approach to this task than we were able to formulate at the beginning of the AMEC work scope.

Updates for Q2 FY2024 (January 1st – March 31st)

None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

The EMEC project lead Myles Heward becoming unavailable again has us concerned about the continuity and level of support we will be able to receive from EMEC. Also, while we had agreed

Updates for Q4 FY2024 (July 1st – September 30th)

Progress on this task is ramping up. Need to meet with relevant contacts to develop a thorough understanding of the IECRE RETL process, such that it can be accomplished here at UNH.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
The working groups have a better understanding of the IECRE system process, its requirements, and dependencies ahead of achieving accreditation. Actionable steps towards accreditation have been identified and work on them can begin imminently. A proposal from EMEC has been received, so AMEC can review and elect services to assist with accreditation as needed.

Updates for Q3 FY2025 (April 1st – June 30th)
Identified partner organizations who can provided valuable insights on the ISO accreditation process. Researched and identified training programs and opportunities that may be of benefit to AMEC staff.

The submission of a completed Programmatic Biological Assessment is significant.

Updates for Q4 FY2025 (July 1st – September 30th)
New milestones & deliverables were introduced to the AMEC -9450 work scope during this quarter. Significant progress was made towards all of them, specifically the completion of the OSTEC turbine itself.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)

The EMEC project lead Myles Heward becoming unavailable again has us concerned about the continuity and level of support we will be able to receive from EMEC.

Also, while we had agreed on an overall budget for EMEC for the entire AMEC work scope ($120k, with ~ $55k spent in BP1), now that the tasks for BP2 are more fully defined, EMEC will certainly want to rescope and provide a budget for their support. We don't know yet what that cost will be.

Updates for Q4 FY2024 (July 1st – September 30th)
No update

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
The OSTEC turbine has been completed, but cannot be deployed until NEPA approvals have been received. The Programmatic Biological Assessment submitted during the prior quarter is still under review with NMFS.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
Re-engage with EMEC with new project personnel. Discuss scope, timelines, cost.

Updates for Q4 FY2024 (July 1st – September 30th)
Re-engage with EMEC with new project personnel. Also contact relevant DOE representatives who may have experience in this field.

Updates for Q1 FY2025 (October 1st – December 31st)
Ideally, complete Milestone 14.1.1. Receive, negotiate, and implement scope of services from EMEC. Continue to pursue IECRE system process.

Updates for Q2 FY2025 (January 1st – March 31st)
Based on the improved understanding and definition of the IECRE system process, AMEC has identified actionable steps that can be taken towards IECRE/ISO accreditation. AMEC will prioritize actions and begin to work towards them.

AMEC will also evaluate EMEC's proposal and choose to engage as needed.

With SOPs largely aggregated, they can be revised and updated as needed in order to complete Milestone 14.1.1.

M. Wosnik will engage with IECRE personnel during IEC TC-114 Plenary in April 2025.

Updates for Q3 FY2025 (April 1st – June 30th)
AMEC will confer with DOE/NOAA on programmatic BA approval process and provide additional documents or information as needed, in pursuit of an NLAA concurrence.

S. Pamboukes and A. Thompson will continue to pursue alignment with ISO17025 accreditation, ideally identifying valuable classes that could be taken to offer a headstart on this laboratory organization.

Updates for Q4 FY2025 (July 1st – September 30th)
Ideally, NEPA holds will be lifted and UNH/AMEC can proceed with installing the turbine to TDP, preparing the TDP for install at the AMEC-UNH Tidal Energy Test Site, and beginning both shakedown and actual tests of the marine energy device.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Updated, detailed SOPO for BP2 for this Task.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
None reported.

Updates for Q4 FY2024 (July 1st – September 30th)
[Select an option. Reminder: outputs include, but are not limited to, publications, presentations, websites, inventions, patent applications, licenses, technologies, techniques, software, databases, models, video/audio products, equipment, instruments, and educational materials.]

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
The completed OSTEC turbine is a significant output of this quarter. Complete CAD models of the TDP, extension, instrumentation shed, turbine, tower, and yaw assembly are all maintained by UNH/AMEC. The UNH TDP is undergoing refits and is ready to receive the OSTEC turbine.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
None reported.

Updates for Q2 FY2024 (January 1st – March 31st)
None reported.

Updates for Q3 FY2024 (April 1st – June 30th)
None reported.

Updates for Q4 FY2024 (July 1st – September 30th)
None reported.

Updates for Q1 FY2025 (October 1st – December 31st)
None reported.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Task 15.0 Integrating waterway and tidal induced turbulence into MRE design by digital twinning at laboratory and field scales

Major Project Goals and Objectives

Conduct high-fidelity digital twinning of tidal energy devices deployed at the UNH Tidal Energy Test Site at Memorial Bridge in Portsmouth, NH. Validate and demonstrate the predictive power of a digital twinning approach (developed in BP1) for real-life tidal energy sites. The numerical approach for this task will be based on the high-fidelity VFS code developed at SBU. Laboratory experiments at LU will demonstrate the ability of the model to simulate MHK devices in a range of turbulence inflow conditions. The developed numerical framework will then be employed to conduct high-fidelity digital twinning of MHK devices at the UNH Tidal Energy Test Site at Memorial Bridge in Portsmouth, NH.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

SBU team has created a digital map of the UNH Tidal Energy Test Site and started conducting some preliminary high-fidelity modeling of the tidal flow in a 5 km long reach of the waterway around the test site. These initial test runs allow the team to fine-tune the digital map of the waterway bathymetry and infrastrcuture (for inclusion in the simulations). Also, a number of inflow boundary conditions are being tested to explore their effect on the flow within the domain.

Development of the Doppio-based Great Bay Modeling System (GBMS)

Previous versions of our numerical model for the Great Bay and coastal ocean in the Gulf of Maine used output from the Gulf of Maine Forecasting System (GOMOFS). However, GOMOFS is designed as a short-term forecasting system (not specifically for hindcasting) and has several limitations that present difficulties in practical usage with (broadly) oceanographic and (specifically) tidal energy resource assessment applications. For model-data assessment, GOMOFS output used for subtidal and offshore boundary conditions for the Great Bay model is only stored by NOAA temporarily for two months and then the high-resolution data deleted and no longer available (after all, it is designed as a nowcasting/forecasting system without mandate for longer term archival storage). We have been downloading daily GOMOFS forecasts for the past couple of years to try to retain GOMOFS forecasts at the highest resolution possible. Simulation experiments prior to our archived data cannot be done with GOMOFS as the offshore boundary condition. Because, much field data used for model validation (e.g., ocean currents, water levels, sea temperature and salinity) was collected much before our GOMOFS archive (dating back to NOAA data collected in 2007), our model validation (hindcast capability) of our Great Bay Modeling System (henceforth, GBMS) is severely limited in that the offshore boundary conditions contain only tidal constituent information without subtidal (weather forced) or hydrographic (stratification) information. Therefore, we have modified the GBMS to instead utilize a different archived model output with equally good (as with GOMOFS) model dynamics, namely the Doppio model (López et al., 2020) with model domain spanning the mid-Atlantic Bight to (and including) the Gulf of Maine. Doppio model simulations have been archived from 2007 to present (and continue) and are publicly available for download. We have downloaded the archives for the Gulf of Maine since 2007 and are now able to hindcast our GBMS for anytime since 2007. Moreover, because the Doppio model includes a data assimilation system (which GOMOFS does not), archived Doppio output is expected to give better model-data agreement than other non-assimilative models (like GOMOFS).

Over the past several months we have downloaded the Doppio output files and adapted them to a modified GBMS. We have then run lengthy simulations lasting several months during the year 2007 when the NOAA ADCP current data array was deployed. For the first in using model simulation (that we are aware of) we were able to compare field observations with a model simulation that includes model boundary conditions for subtidal, tidal, river flux, and atmospheric forcing for the time when the 2007 data were collected. Figure XX shows verification results for the 2007 hindcast experiments using the GBMS with the Doppio output. All observation and model predictions at all sampling locations are shown. Colors indicate the numbers of comparisons (ranging ~10-10,000) for those model-data values. Model-data agreement is excellent with r2 values (correlation squared; indicating the fraction of variance explained by the model) of 0.96, 0.93, and 0.97 for water levels (h, m), E-W (u, m/s) velocities, and N-S (v, m/s) velocities, respectively. Configurations for the other forcing (tidal component from TPXO, river discharge from USGS, and atmospheric forcing from ERA5) are not changed from the previous GOMOFS runs. Note that this direct comparison between model and observation cannot be conducted by previous version of GBMS using GOMOFS due to the absence of subtidal forcing data prior to 2022. Model-data comparisons for other periods are under way, and a manuscript describing our verified GGMS is in preparation. The GBMS will be available for AMEC collaborators, other researchers, and the public for their usage and ingestion. We are also able to run simulations as needed for collaborative research activities. Tidal resources assessment using the verified Doppio-based GBMS for the Memorial Bridge region is currently underway.

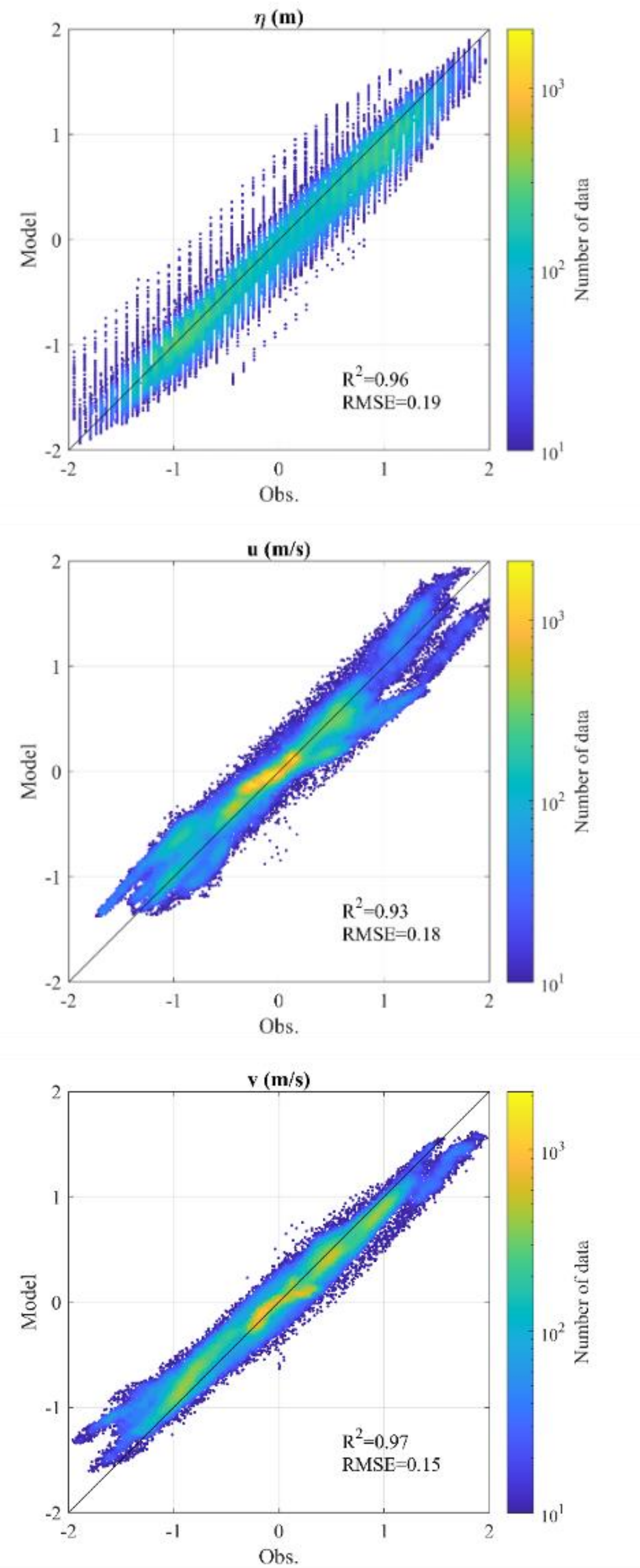


Figure 15.1. Direct hindcast comparison between the Doppio-based GBMS model and observations obtained by NOAA in 2007.

Development of fine-scale bathymetric grid for the Memorial Bridge site

High resolution bathymetry from NOS compiled multi-beam and single-beam echo-sounding data obtained in 2000-2001 acquired online (https://www.ngdc.noaa.gov/nos/H10001-H12000/H11014.html). Direction to these (and other) data was provided by the UNH Center for Coastal and Ocean Mapping. These data are the highest resolution available. We attempted to obtain more recent (2020) variable resolution multi-beam data (https://www.ngdc.noaa.gov/nos/F00001-F02000/F00810.html) obtained by the NOAA R/V Hassler; however, we are having difficulties geo-reference the finest resolution data within this data set and have reached out to NOAA for assistance. Figure YY shows a color map of the high resolution data from 2000-2001. For high-resolution modeling purposes, we believe these data will suffice.

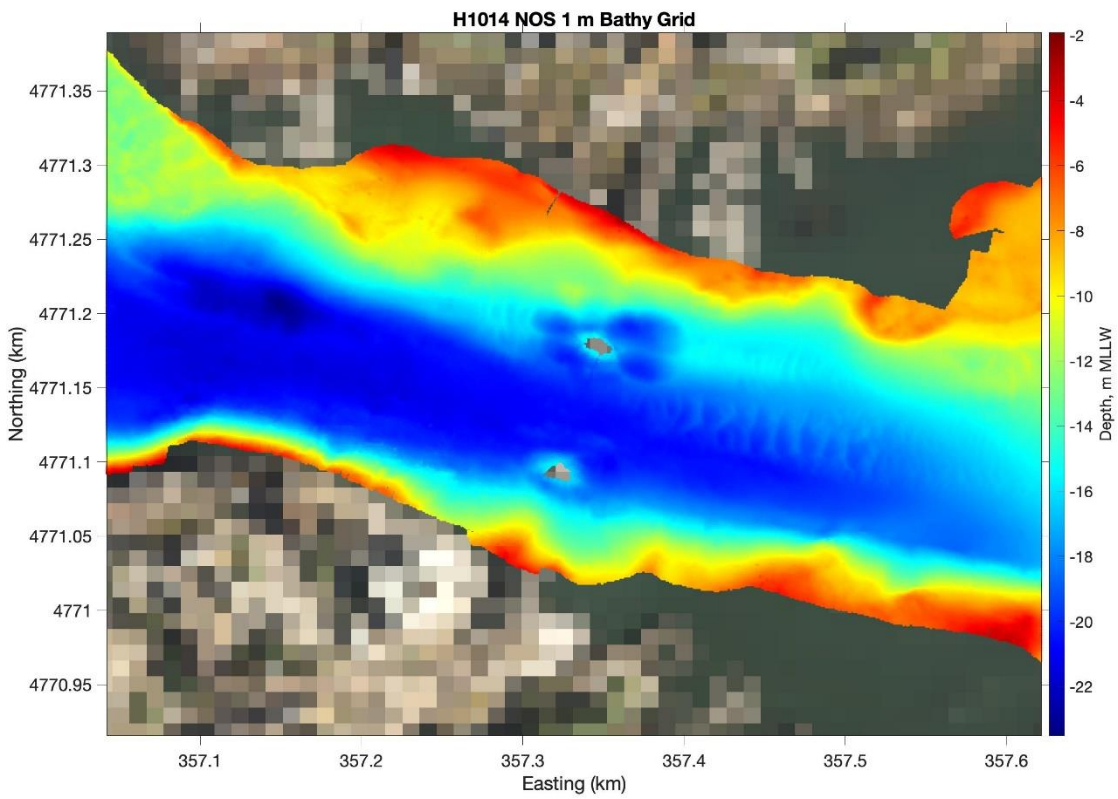


Figure 15.2. Direct hindcast comparison between the Doppio-based GBMS model and observations obtained by NOAA in 2007.

Reference

López, A. G., Wilkin, J. L., & Levin, J. C. (2020). Doppio–a ROMS (v3. 6)-based circulation model for the Mid-Atlantic Bight and Gulf of Maine: configuration and comparison to integrated coastal observing network observations. Geoscientific Model Development, 13(8), 3709-3729.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Working with the field-scale digital map of the study site is time-consuming as its high-fidelity simulation requires hundreds of CPUs for weeks. Overall, the SBU team expects to complete this sub-task on time, provided the collaborations among SBU, UNH, and LU in this task proceed as planned.

We have reached the point where the GBMS Model has the best available boundary and forcing conditions (obtained from other models) allowing for the best possible model simulations (now verefied). We will proceed with tidal resource assessments using this model and are preparing a manuscript describing the GBMS system with verification, and to present tidal resources assessment for the Memorial Bridge site (and nearby region).

Updates for Q1 FY2025 (October 1st – December 31st)
SBU team has worked with UNH team to fine tune the digital map of the Portsmouth River around UNH test site at Memorial Bridge. This is done by comparing the preliminary digital map built at SBU with the field-measured sonar data available for the site and adjusting the digital map accordingly. For example, in Fig. XX, we present a portion of the study site where the digital map of the river (black line) is compared and adjusted with the sonar data for the river bathymetry (black dots).

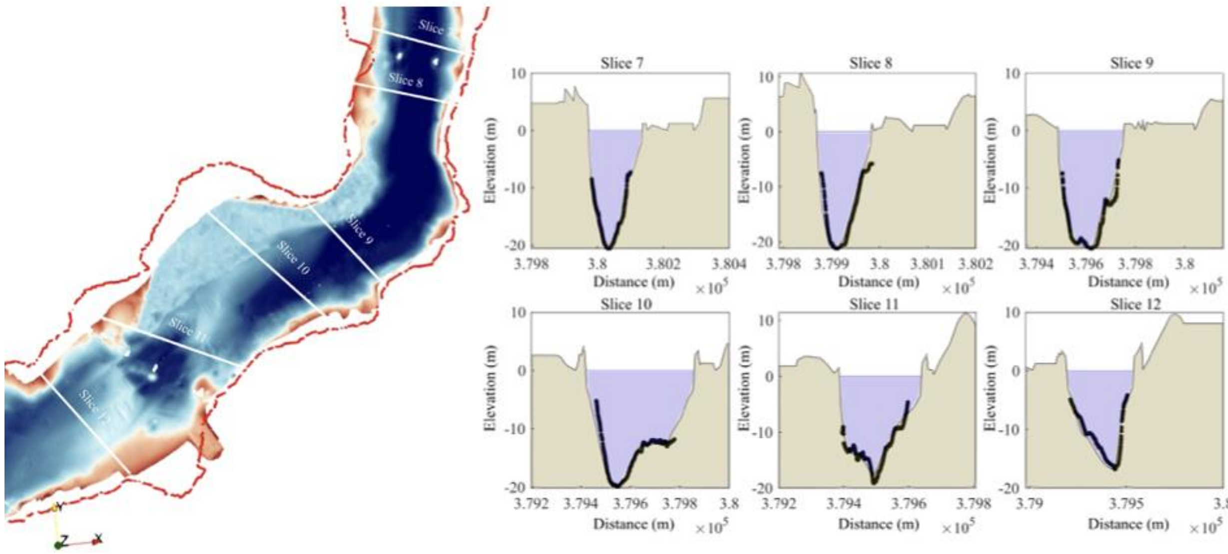


Figure 15.3: Fine-tuning the digital map of the study area in Portsmouth River using the sonar data.

Further, the SBU team has conducted preliminary flow field simulations to model -- using 10-cm-resolution grid system – the ebb (Fig. YY) and flood (Fig. ZZ) flow in the study site of the Portsmouth River (5 km region) around the UNH test site at Memorial Bridge. These simulations allow us to investigate the sensitivity of the results to the incoming turbulence and obtain adequate inlet boundary condition for the future simulations.

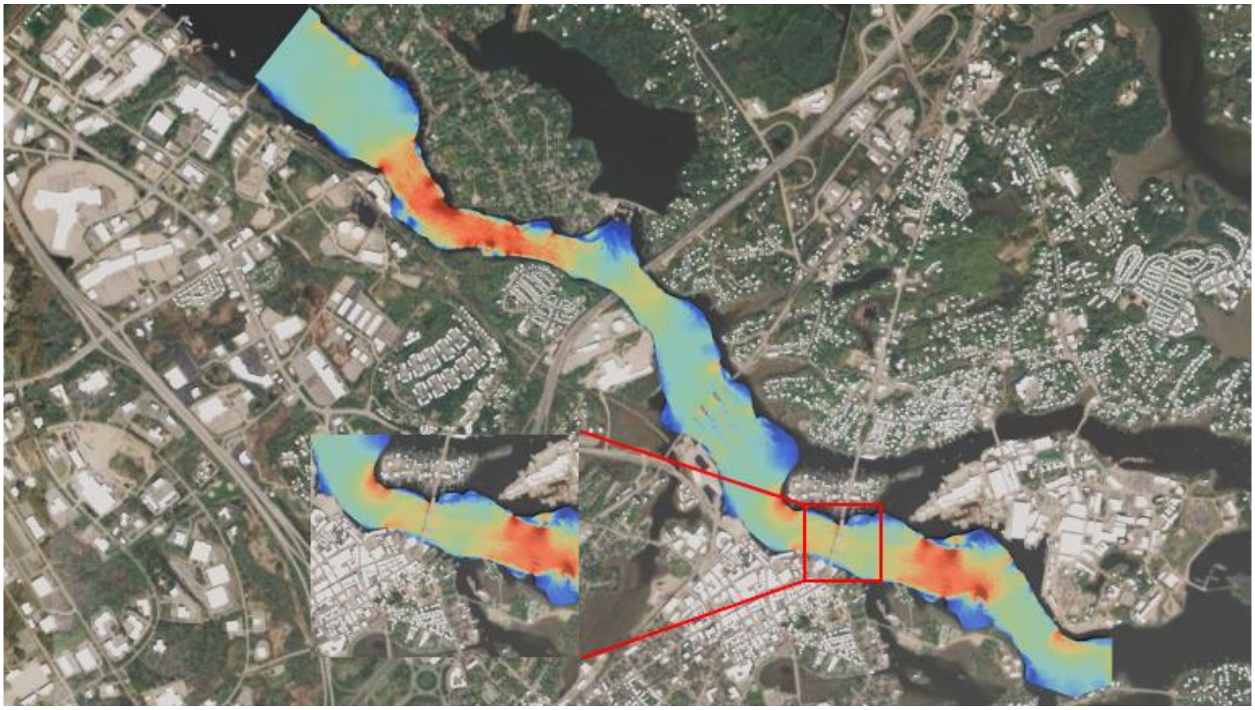


Figure 15.4: The ebb flow (instantaneous) of the study site in the Portsmouth River (red and blue regions show the high and low-velocity regions).

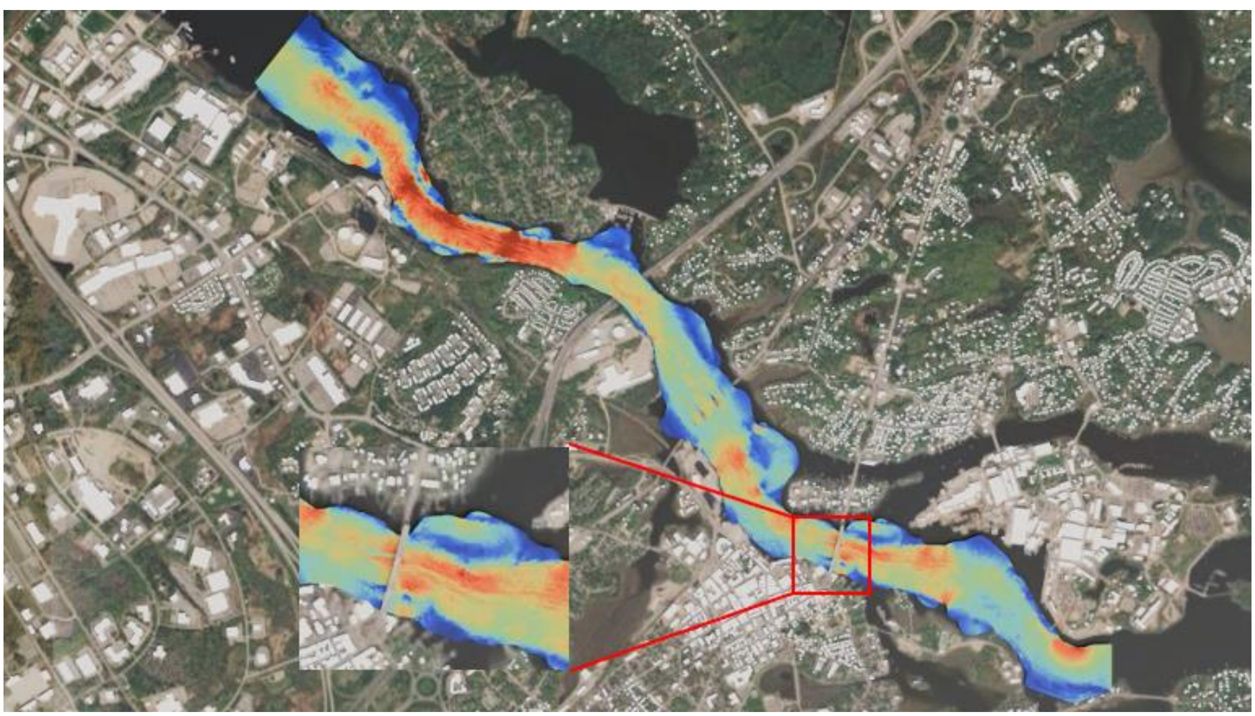


Figure 15.5: The flood flow (instantaneous) of the study site in the Portsmouth River (red and blue regions show the high and low-velocity regions).

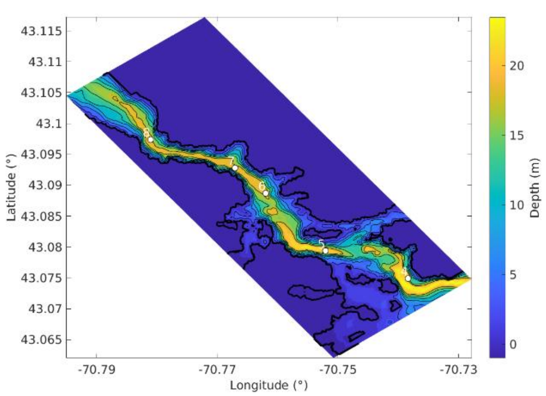
UNH Team has run simulations with the Great Bay Modeling System for periods in 2007, 2015, 2015, 2018, 2019, 2021, and 2022, using forcing and boundary conditions supplied by the Doppio Model, ECMWRF, and USGS River Gauging stations. Comparisions between model and available historical field observations are in good agreement for flows and water levels, as well as salinity. Temperature fields sometimes result in unrealistic values and lead to numerical instability which we believe are related to the wetting and drying algorithms used in ROMS (a known issue). This is mildly concerning as numerical results may be affected for other variable output. We are re-running the models without wetting and drying. We do not believe that this will be an issue unless we address flooding and inundation, which are beyond the scope of this work.

As indicated above, the UNH Team has been working with the SBU Team to provide the best available bathymetry data for the site. Additional field observations are planned for the spring for verification of the bathymetry data obtained in previous years.

Updates for Q2 FY2025 (January 1st – March 31st)

The SBU team, in collaboration with UNH and LU partners, have made good progress on the high-fidelity numerical modeling of small-scale flume experiments at LU and field-scale tidal river around the UNH test site. A summary of the initial efforts to complete this task was presented in Q1 2025. A detailed description of the activities of this subtask will be reported in the next quarterly report.

UNH developed a finer-scale nested subdomain model, based on the Great Bay Modeling System, to provide boundary conditions for the large-eddy simulation model developed by Stony Brook University. The spatial resolution of the nested subdomain model is about 17 m.



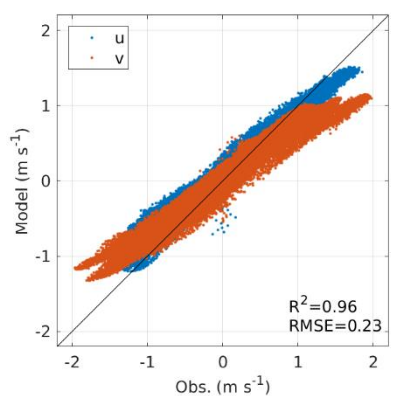


Figure 15.6. Model grid for the finer-scale nested subdomain (left panel) and verification result for hindcasting experiment in 2007 (right panel).

Hindcasting output in April 2017 is generated and provided to Stony Brook University team with cross-section in situ observations. System generating inputs for large-eddy simulation based on the ROMS model output is under development.

Updates for Q3 FY2025 (April 1st – June 30th)

Through this report, we describe the progress while creating a digital mapping of the field-scale river, computational details of the model, imposition of turbulent boundary conditions, and hydrodynamic-based site selection methodologies. Finally, it aims to (1) find an adequate location for a tidal farm within the river and (2) optimize the placement of individual turbines within the selected site. Assessments serve as early attempts on the development of large-scale hydrokinetic energy projects' installment on Portsmouth Harbor.

Given geographical dependency of tidal energy, the area of interest for hydrokinetic farms is chosen as a portion of the Piscataqua river. The Piscataqua river locates in the northeastern United states, forming a portion of the interstate boundary between Maine and New Hampshire (see Figure 1a). At its lower reaches, the Piscataqua River opens into Portsmouth Harbor, providing a direct connection to the Gulf of Maine (see Figure 15.7b). Upstream, it branches into the Salmon Falls River and Cocheco River, which serve as their primary tributaries.

Figure 15.7: Satellite images of the Piscataqua River site (map data by QGIS). The river (a) is located in the northeastern United States, forming a portion of the interstate boundary between Maine and New Hampshire and (b) experiences ebb and flood tides

Particularly, the Piscataqua river is chosen since narrow and deep channel feature of the river leads to experiencing some of the fastest tidal currents on the U.S. East Coast. Along with strong tidal currents, the river experiences with ebb and flood tides. These conditions enable us to be beneficial in energy exploration; yet socio-economical significances of the Portsmouth Harbor (being only deep draft harbor located in New Hampshire) require advanced solutions in assessment of energy potential management.

Digital Elevation Model (DEM) of the Piscataqua River within study area: Digital map of floodplain and riverbed topographies was achieved using separate datasets from aerial topographic

LiDAR and multibeam sonar acquisitions (see Figure 15.8a and Figure 15.8b). We sourced the above-water topographic data from publicly available dataset which can be accessible through the website:" https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=9532/details/9532". Additionally, the bathymetric data from a field survey conducted by the US Army Corps of Engineers aboard the vessel Popham Beach in September 2019. The sound interval was approximately 1 meter. You can access these data through the website: ". Generated surface can be seen as elevation-represented colormaps and elevation contours from the water surface level to approximately 30 meters above sea level.

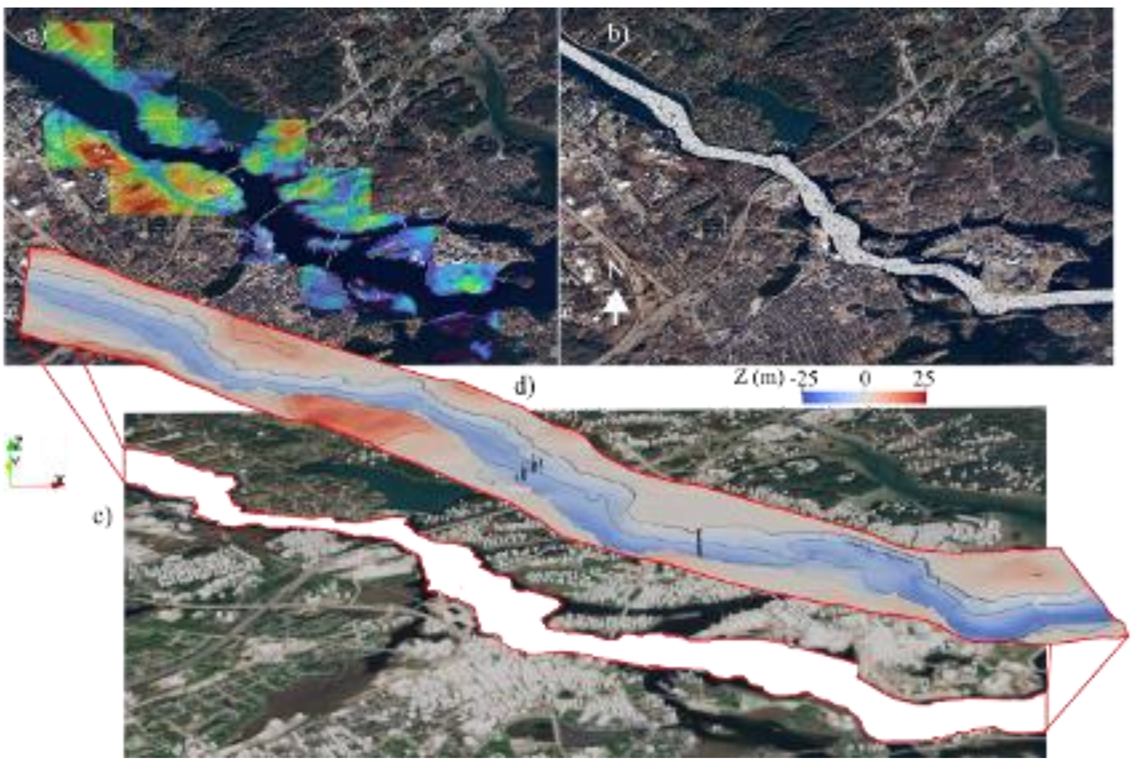


Figure 15.8: Digital map of the Piscataqua River and Portsmouth Harbor. Generated surface is created through integration of a) LiDAR dataset to represent over water surface and b) multibeam sonar datasets for the riverbed. c) shows two-dimensional projection of the riverbed and the red borderline delineates the riverbed area corresponding to the water level. the contour line Z=0. d) depicts the 3D generated surface with elevation-represented colormap where negative values indicate the topography changes along the river and positive values show over water level bathymetry.

Then, we calibrated the bed with data acquired by the University of New Hampshire research team. 16 cross-sections were randomly extracted normal to the thalweg line of the generated surface. In general, the cross-sections (see Figure 15.9) exhibited a good agreement with field measurement. The 3D surfaces of the bridge pier structures pertained to the Sarah-Mildred and Memorial bridges are discretized with an unstructured triangular mesh and embedded in the flow domain. The details of the domain will be described in the next section.

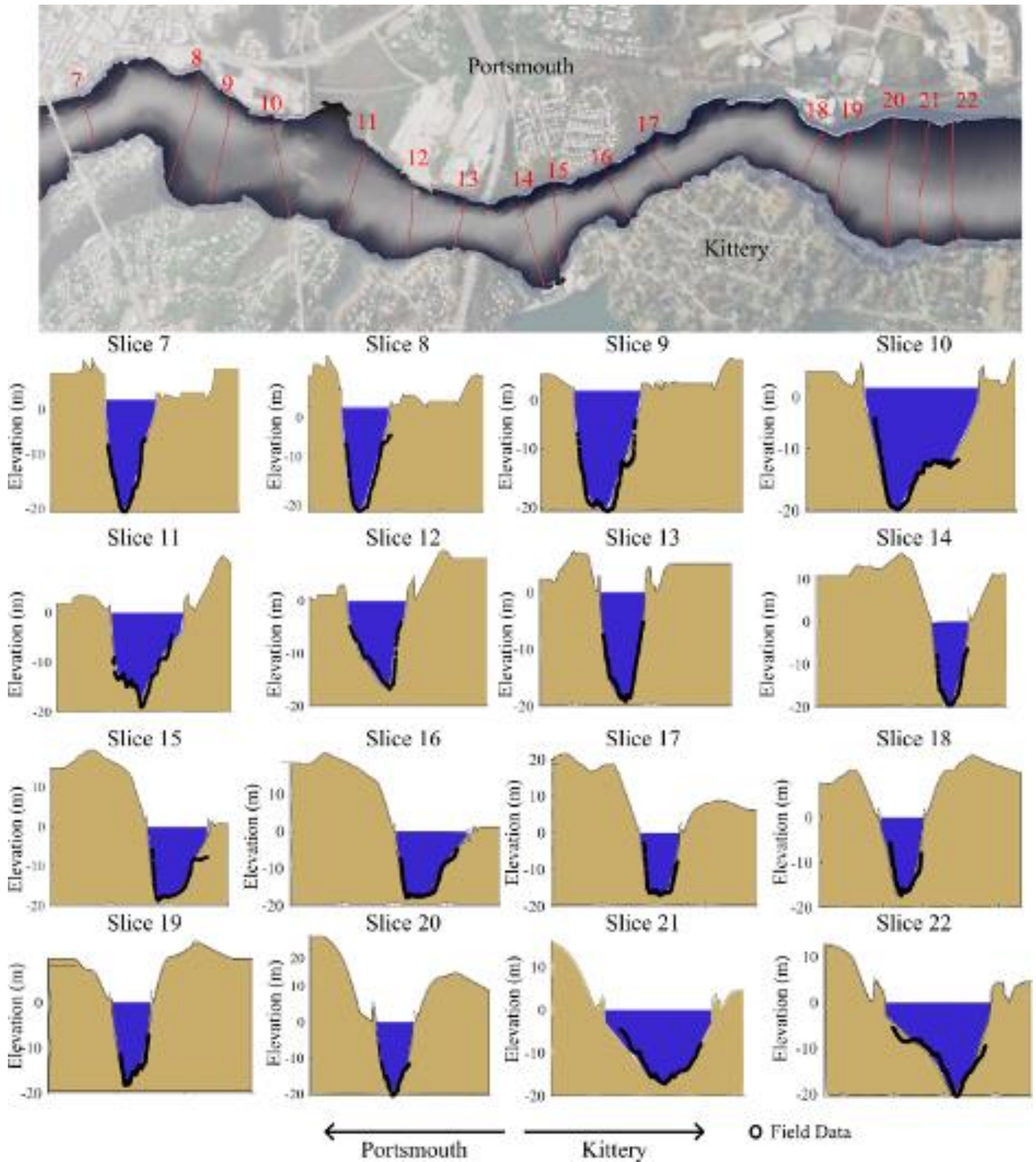


Figure 15.9. verifying the accuracy of the digital map of the Piscataqua River using sonar data.

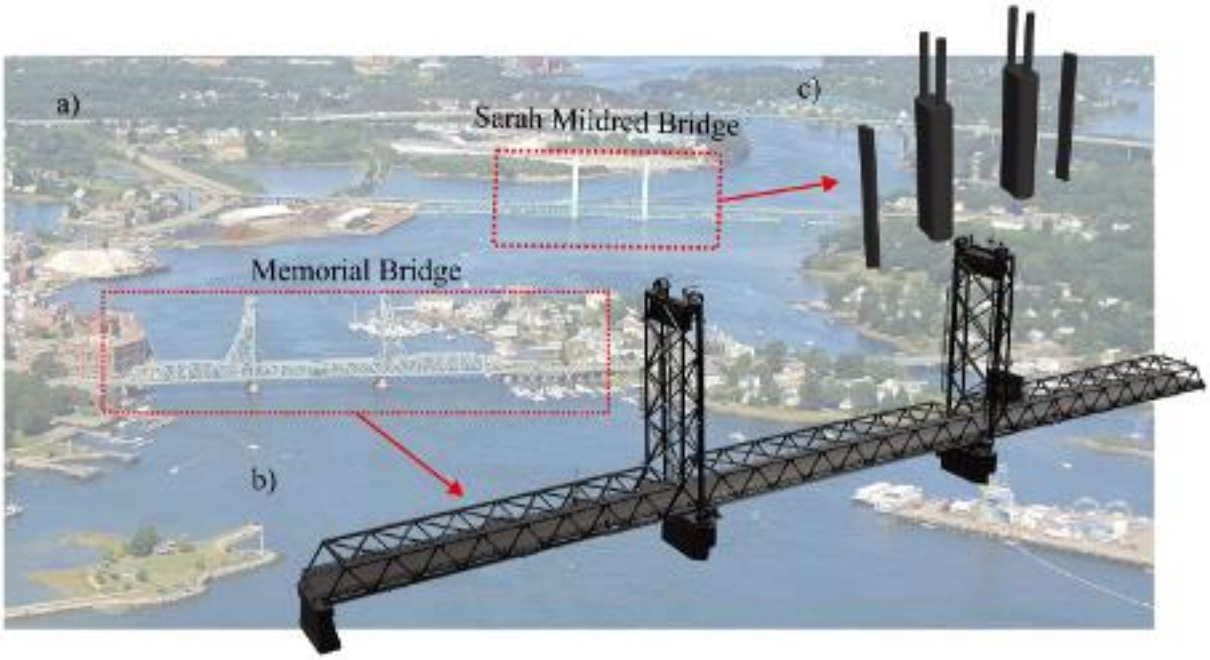


Figure 15.10. Integrating geometry of the existing infrastructure with the digital map of the river.

The study is based in particular on a two-tier grid strategy that is adopted to balance computational cost and flow resolution requirements. Both computational domains normalized by the maximum water depth (of 25m with incoming velocity of 2.5 m/s).

The initial simulations, performed without any turbine installations, are aimed at finding an adequate location for a tidal farm within the river which necessitates a relatively coarser grid. Therefore, the initial part of the study enables us to capture intricate turbulent characteristics governed due to current hydraulics structures and flow patterns of the river's topography. The computations domain is generated based on actual river bathymetry, reconstructed from geospatial survey data as described in Section 2. Once we generate the digital map of the Piscataqua River, we decide on the study area to assess the potential hydrokinetic energy for the prospect tidal farm. Fig. 15.11a presents a 2D projection of the study area. The red borderline in the riverine study areas delineates the study areas, corresponding to the contour line $z = 0$. High-fidelity numerical simulations performed in a 6 km long reach and approximate 450 m width of the Piscataqua river and Portsmouth Harbor.

Figure 15.11. Top view of the study area within the Piscataqua river.

Moreover, certain sub-branches of the river are excluded from the domain (see Fig. 15.11b). Among these, two distributaries—labeled I and II—are located between Portsmouth Harbor and Badger's Island, and between Badger's Island and Kittery, respectively. These branches may contribute to complex turbulent structures in the river, significantly affecting the flow field. However, incorporating these distributaries into the computational model would substantially increase the computational demands, rendering the simulations impractical given current resource constraints. To that end, these branches are omitted to focus on the primary flow channel where turbine arrays prospect to be installed. Yet, the potential influence of these excluded branches on the overall hydrodynamics is assessed through validation with field measurements and discussed in the following section.

The flume's computational domain was discretized by approximately 225 million computational grid nodes, with a uniform resolution of 75, 125, and 25 cm in streamwise, spanwise, and vertical directions, respectively (denoted as Grid-I tabulated in Table 1). The non-dimensional time step was selected to ensure that the maximum Courant–Friedrichs–Lewy number remained below 1.0. Finally, the numerical simulation for each case was carried out with 4 nodes of 96 processors on a Linux cluster (AMD Epyc). On average, 20,000 CPU hours were required to reach statistically converged flow fields.

Table 1: Details of the computational grid systems and time steps for the flow solver. Ny, and Nz are the number of computational grid nodes in streamwise, spanwise, and vertical directions, respectively. Dx, Dy, and Dz are the spatial steps of the flow solver normalized with the water depth, H. The time step normalized with the bulk velocity and water depth is given in row three.

Parameter	Grid I	Grid II
N_x, N_y, and N_z	4501, 501, 101	1057, 1041, 101
D_x, D_y, and D_z (cm)	75, 125, and 25	
Δt	0.005	0.005
H (m)	25	25
U_∞ (m/s)	2.5	2.5
Re_H	6.25	6.25

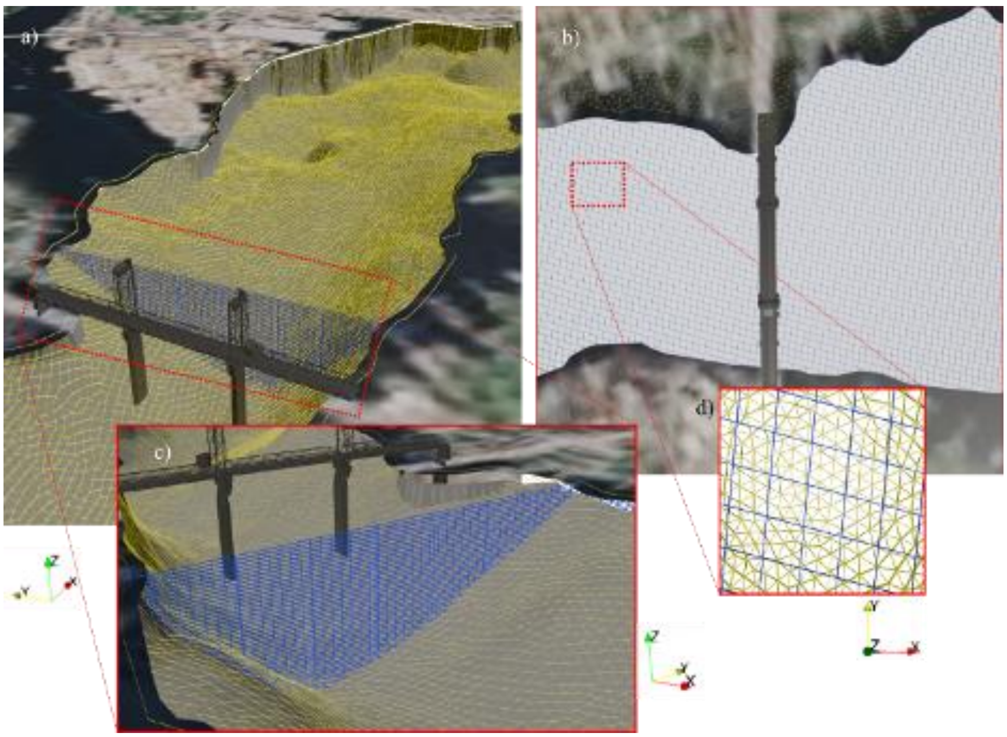


Figure 15.12. discretized digital map of the river including the unstructured grid system of the immersed boundary to discretize the river bathymetry and the structure background mesh where the equations of fluid motion are solved.

Following finding an adequate location for a tidal farm along the river through LES-based hydrodynamic analysis utilizing Grid-I, we are able to define the inlet boundary conditions by interpolating the velocity fields obtained from coarser grid system to finer one which, in this study, is denoted as Grid-II in Table 1. The transition from the course to fine grid not only enabled efficient computational resource management but also ensured that the upstream flow conditions influencing the turbine behavior were physically accurate and representative of the natural river dynamics. This approach allowed for a more reliable prediction of turbine performance and array-scale hydrodynamic impacts in a realistic riverine setting.

Table 2. Various velocity boundary conditions imposed at the inlet of the study area.

Model	Tidal Type	Inlet B.C.
FL-Lo	Flood	Log-law Velocity Profile

FL-SC	Flood	Precursor Straight-Channel Simulation
FL-RF	Flood	Precursor River Simulation
FL-ROMS	Flood	Precursor through ROMS Simulation
EB-Lo	Ebb	Log-law Velocity Profile

To accurately model complex field-scale hydrodynamics using LES, careful treatment of the inlet boundary conditions is essential. To prescribe the inflow conditions of the flood and ebb flows in the river, the influence of different turbulent inflow strategies on the development of turbulence along the river, a series of ebb and flood tides' simulations are performed, each using a distinct method for defining the inlet boundary conditions and tabulated in Table 2. Particularly, four flood simulations were conducted using the following approaches:

- A piecewise analytical velocity distribution based on the logarithmic law of the wall was imposed on numerical simulations for flood and ebb tides which are defined as FL-Lo and EB-Lo, respectively. This method provides a simplified representation of near-bed velocity gradients but does not explicitly capture turbulent fluctuations. It is a relatively simple method due to time-independence and lack of capturing expected eddies.
- The second approach employed a precursor simulation with periodic boundary conditions in a streamwise direction. To implement this, the river inlet was extended 300 meters upstream to create a periodic domain (see fig:10a). This method introduces time-dependent turbulent structures at the inlet, although the geometric simplicity of the straight channel may not fully capture the complexity of the river's natural bathymetry.
- In the third case, turbulent inflow conditions were extracted from a separate LES of the actual river geometry, located just upstream of the study area. Instantaneous flow fields from a precursor simulation over a 500-meter upstream reach were recorded once the total kinetic energy reached a quasi-steady state. This approach provides the highest fidelity in capturing the natural turbulence characteristics expected during flood tides. The outlet cross-section of the upstream simulation domain was made identical to the inlet cross-section of the main study domain.
- The final simulation integrated with the ROMS model framework conducted by the UNH research team. River's inlet boundary conditions are outsourced by interpolating the velocity fields in the ROMS model. This condition aimed to provide turbulent memory of the river considering the larger span of the river including ocean. (JANG).

To start, we compare the simulation results with measured flow field obtained in collaboration with the University of New Hampshire (UNH) under the Atlantic Marine Energy Center (AMEC) initiative. Field measurements were acquired along the Piscataqua River in the vicinity of Memorial Bridge using the Compact Acoustic Bottom-Mounted ADCP Survey System (CBASS) mounted on a jet ski platform. The system employed a downward-looking Acoustic Doppler

Current Profile (ADCP) to capture cross-channel current profiles at high spatial and temporal resolution. Data was collected over a continuous period of approximately 26 minutes, capturing the transient flow dynamics during peak tidal conditions. For numerical validation, two tidal scenarios were modeled using Large Eddy Simulations:

- Maximum Spring Flood, occurring on April 28, 2017, at 11:31 EST
- Maximum Ebb Tide, occurring on May 1, 2017, at 08:31 EST

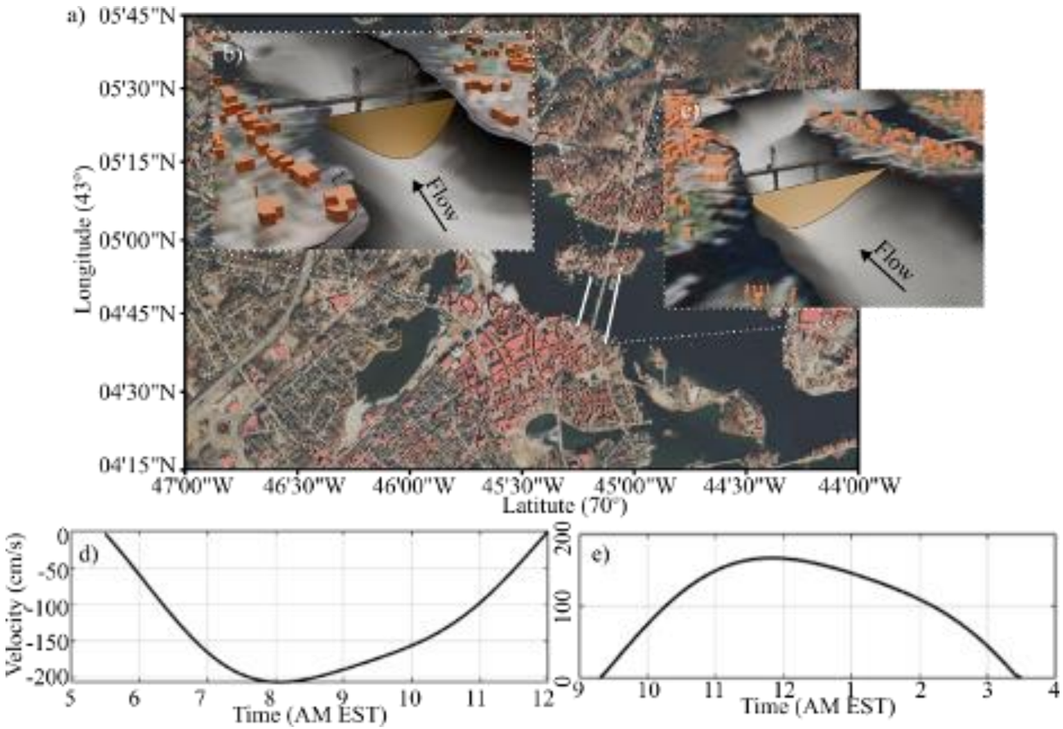


Figure 15.13. ADCP Measurment cross section within the study area along with the time variation of flow velocity at a single point. The sonar data at the two cross planes are utilized for model validations.

The ADCP measurements for the ebb and flood tides conditions are conducted along two different conditions cross sections upstream and downstream of the Memorial bridge location (see Figure 15.13a). Specifically, one can see the cross sections during ebb tide (Figure 15.13b) and flood tide (Figure 15.13c) in 3D view. The tidal currents near the Memorial bridge were derived from current predictions provided by the National Oceanic and Atmospheric Administration (NOAA). Specifically, data from the Memorial Bridge buoy (Station ID: PIR0705), located near the measurement site, were used to reconstruct the tidal velocity inputs. The data, recorded at a reference depth of 8 feet, were accessed via the NOAA Tidal Currents database: "https://tidesandcurrents.noaa.gov/noaacurrents/predictions.html?id=PIR0705_16" and covered the simulation period with 6-minute intervals. While the ebb tide measured during May 1, 2017, at 08:31 EST was depicted in Figure 15.13d, Figure 15.13e exhibits the maximum flood tide during April 28, 2017, at 11:31 EST. With these measurements, we observed XX cm/s and YY cm/s maximum tidal currents for ebb and flood tides, respectively.

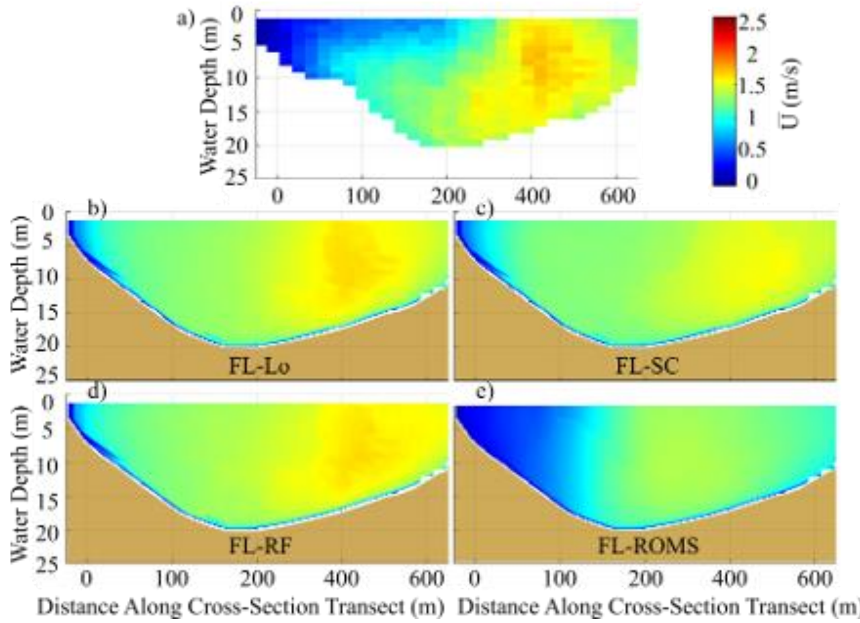


Figure 15.14. The selected cross plane for model validation.

Proceeding for validation cases, we should remind the readers that these measurements were performed using the ADCP mounted on a jet ski. Therefore, although intended transects followed a straight line as shown in Fig. 15.13a, the use of mobile platform introduced minor deviations due to navigation variability. Thus, we investigated the flow features within +/-5m in streamwise direction to eliminate minor deviations due to navigation variability.

To assess the model performance, we first run the instantaneous simulations under flood and ebb tides running on Grid-I (see Table 1). Once instantaneous simulations' kinetic energy stabilized, we time-averaged the results until the mean statistics converged. In particular, we compare the field data with flood tide scenarios by assessing time-averaged velocity magnitudes along the cross section and the qualitative assessment is visualized using colormaps in Fig. 15.14. We overall obtain strong agreement with the spatial flow patterns observed in the field data. Specifically, FL-Low (Fig. 14b) and FL-RF (Fig. 14d) indicate the maximum time-averaged velocity magnitude footprint of the region in the cross section. However, in shallow depths on the left bank direction through Portsmouth, we overestimated the time-averaged results for FL-Lo, FL-SC, and FL-RF. This could indicate that storing memory of the turbulence in upstream region for FL-ROMS enables us to accurately detect the shallow region.

Supporting the qualitative assessment, a quantitative analysis was conducted by extracting two vertical profiles along the cross section (see Figure 15.15). Figure 15.15a exhibits the vertical lines, A-A and B-B, along the cross section of the field data and the time-averaged velocity magnitudes are shown in Fig. 15.15b and Fig. 15.15c, respectively. These velocity profiles are directly compared to the corresponding ADCP measurements. The comparison shows close agreement in both magnitude and profile shape, indicating the model's ability to accurately capture the vertical structure of the tidal current.

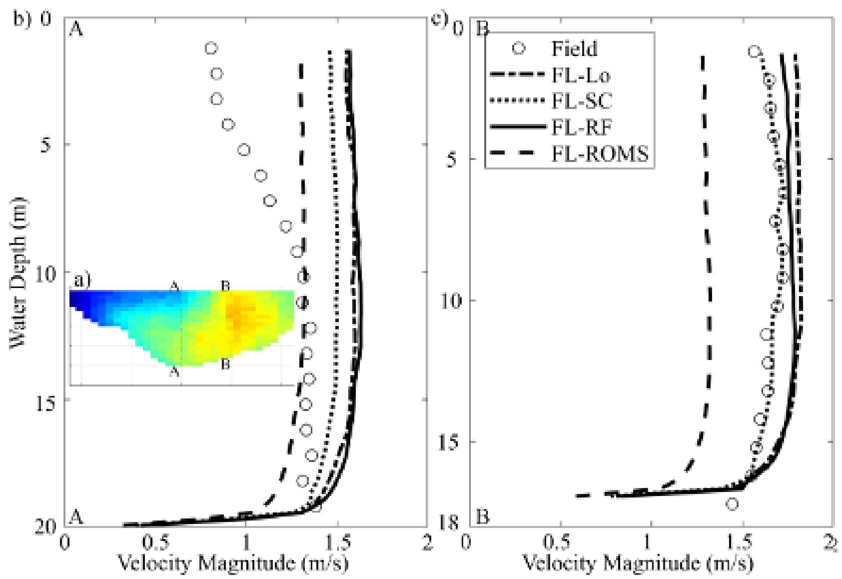


Figure 15.15. Comparing vertical velocity profiles from numerical model with various boundary conditions and the ADCP measurements (hollow circles).

Lastly, we present ebb tide validation. For this case, a horizontal transect was extracted along the measurement path, and the velocity magnitude along this line was plotted and compared with the field data. Despite minor spatial discrepancies due to platform motion, the ebb tide results also demonstrate strong consistency between the simulation and measurement, further supporting the model's validity under different tidal phases.

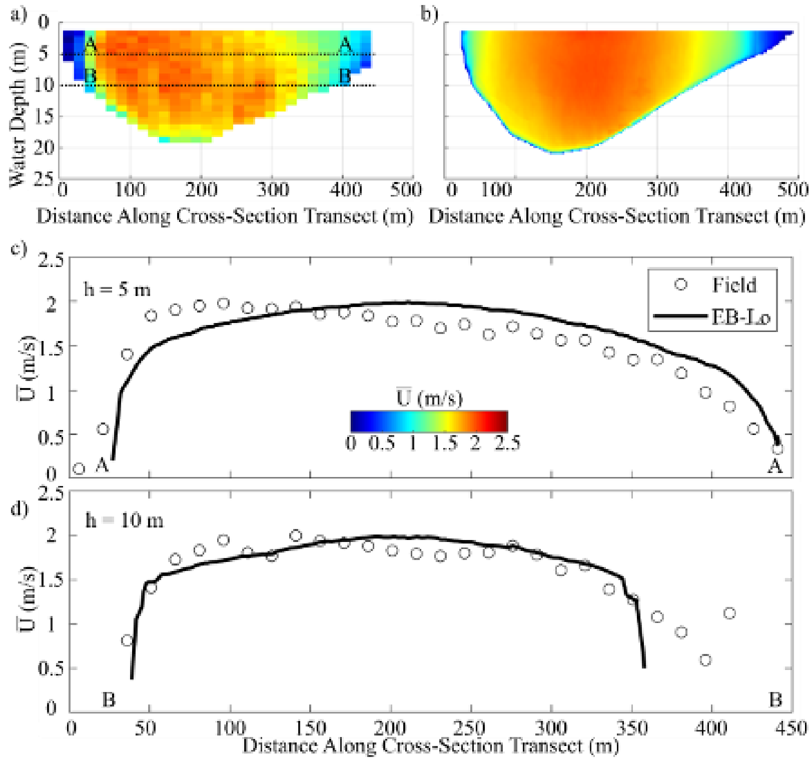


Figure 15.16. Model validation using ADCP data along transverse velocity profiles.

Updates for Q4 FY2025 (July 1st – September 30th)

In an effort to better understand the components of the forcing (tidal, subtidal, atmospheric, river) and its effects on currents in the estuary, the Great Bay Modeling System was used to hindcast large storm-forced flooding events in the Great Bay. Figure 15.17 shows the three largest (in surface elevation) flooding events (colored triangles) observed by NOAA's Seavey Island tide gauge (black solid line), located near the tidal turbine test site at the Portsmouth Naval Shipyard. Although the largest flooding event in January 2024 (yellow triangle) is underestimated, the GBMS clearly captures the flooding events (blue dashed line; almost identical to the other colored lines). Upper panels in Figure 15.17 show time series of spatially averaged wind velocity components over the Great Bay and indicate that the flooding events are coincident with winds directed northwestward (onshore). To identify which forcing component is most responsible for driving the elevated sea levels, sensitivity experiments in which each forcing is removed sequentially were conducted (colored dashed lines). The results indicate that the most important forcing of the flooding events is the subtidal component driven at the offshore boundary. The flooding events are insensitive to all the other forcing, including direct wind drag across the water surface. The coincidence of flooding events with onshore-directed winds yet not sensitive to local winds, implies that the flooding events are controlled by the larger scale atmospheric wind patterns that drive subtidal currents at the mouth of the estuary. Additional analysis of the atmospheric conditions during flooding events is being conducted.

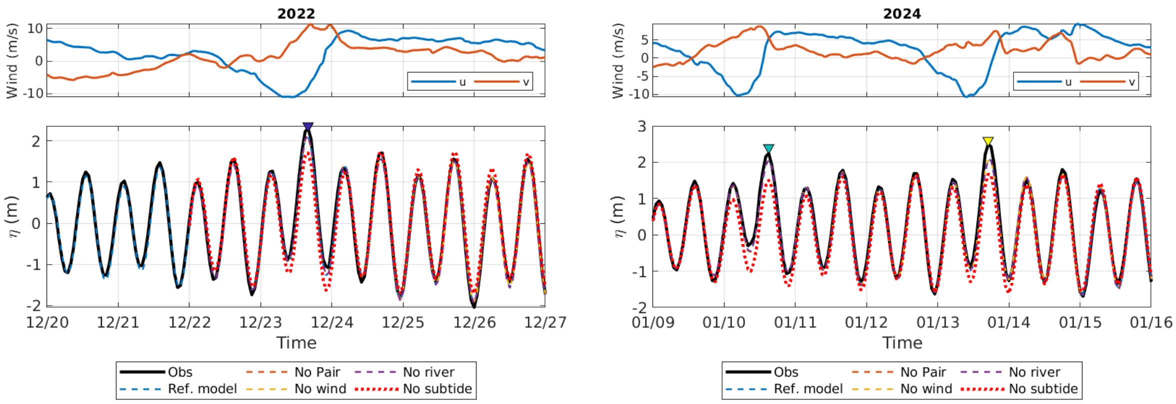


Figure 15.17. Observed (black solid line) and modeled (colored dashed line) sea surface height at the Seavey station during the three largest flooding events. Blue dashed line indicates reference (control) experiment results resolving all forcing. The subtidal current boundary condition is the most important factor needed to resolve flooding events.

A multibeam bathymetric survey was conducted in July 2025 near the tidal turbine test site in the Piscataqua River at the Memorial Bridge (Figure 15.18). The preliminary grid has spatial resolution of 2 m. The data were collected in collaboration with Roland Arsenault of the Center for Coastal and Ocean Mapping. A refined grid with additional quality checks is underway.

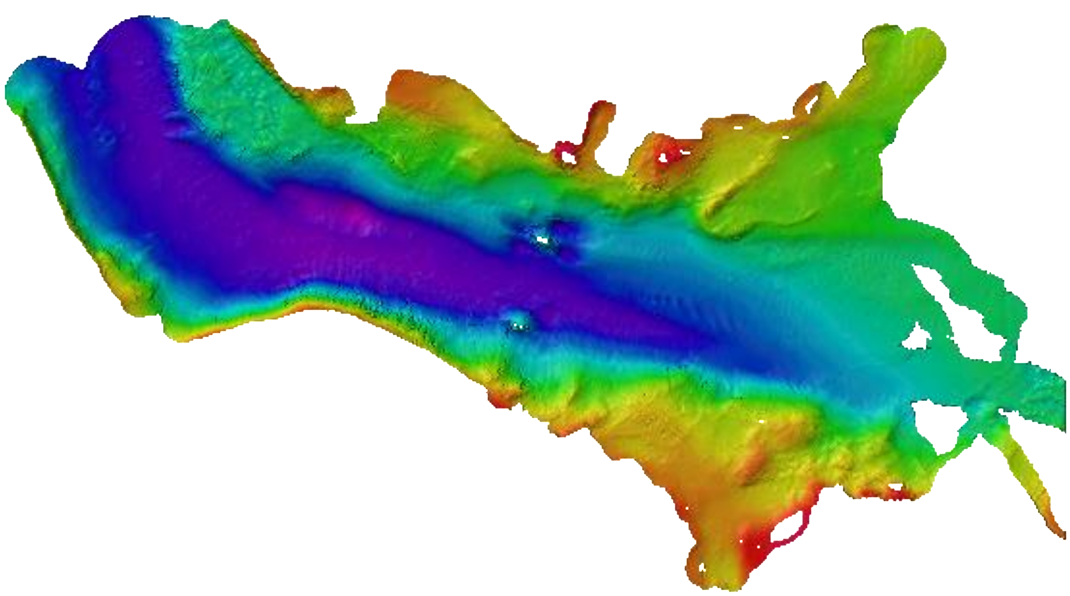


Figure 15.18. Multibeam bathymetry with 2 m grid resolution obtained near the Memorial Bridge Test site in the Piscataqua River. Color scale ranges from +1 m (red) to –22 m (blue) relative to NAVD88 (about mean sea level).

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Task 15.1 has a NEPA hold on vessel-based acoustic flow and bathymetry measurements that we will work on with DOE to get resolved.

Updates for Q4 FY2024 (July 1st – September 30th)

[Enter update here. Start with any requests you have for the DOE project team. Your update for this section should be a narrative addressing significant challenges, risks, and mitigation plans. "Nothing to Report" is a valid entry.]

Updates for Q1 FY2025 (October 1st – December 31st)

The high-fidelity simulations of the test site at SBU are computationally expensive. We are considering upgrading our computing cluster at SBU for efficient simulations of this task.

Updates for Q2 FY2025 (January 1st – March 31st)

None.

Updates for Q3 FY2025 (April 1st – June 30th)

None.

Updates for Q4 FY2025 (July 1st – September 30th)

Nothing to report.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
We plan to conduct a coordination kick-off meeting with all AMEC institutions currently working on this task (UNH, SBU, LU).

Updates for Q4 FY2024 (July 1st – September 30th)
Performing consorted collaborations among SBU, LU, and UNH to allow for timely and smooth transfer of data among the three teams.

Tidal resource assessment completion and manuscript finished and submitted for publication consideration.

Further review of more recent variable resolution data, and consideration of obtaining new field observations to verify previous surveys.

Updates for Q1 FY2025 (October 1st – December 31st)
The SBU team will continue working with our partners at UNH and LU to use their data to finalize the simulations of this task. Close collaboration with both teams is ongoing and we expect to make good progress toward the milestones of this subtask.

Updates for Q2 FY2025 (January 1st – March 31st)
We will continue collaborating to complete the high-fidelity simulations of the flume tests and the Portsmouth River. The simulation results will be then analyzed and documented.

The Great Bay Modeling System will be coupled with the large-eddy simulation model developed by Stony Brook University team by providing its output as input of the large-eddy simulation. It will be used to assess available tidal energy resource.

Updates for Q3 FY2025 (April 1st – June 30th)
No update.

Updates for Q4 FY2025 (July 1st – September 30th)
We plan to complete a series of simulations of the flood and ebb flows within the study area to locate adequate locations for tidal farm installation. Then, we will visually install tidal farms and attempt to (a) assess the performance of various tidal farm configurations, (b) find an optimal layout for the tidal farm, (c) make suggestions regarding potential tidal farms within the Piscataqua River.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report yet for SBU.

Updates for Q2 FY2025 (January 1st – March 31st)

Hindcasting output from 2007 to 2022 (will be extended to 2024) is successfully generated from the Great Bay Modeling System and stored in the system. Based on the hindcasting output, hindcast simulations between 2007 and 2022 can be readily conducted.

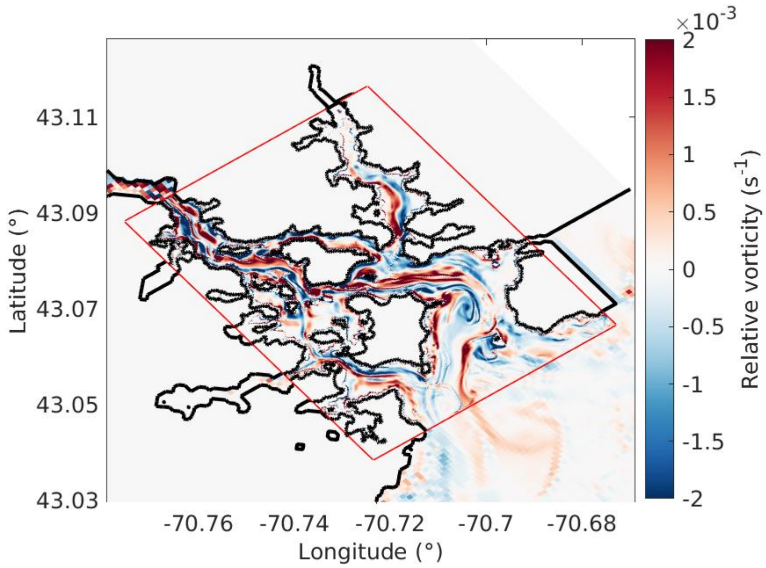


Figure 15.7. An example of nested subdomain simulation (inner region of red box) using the hindcasting output from the Great Bay Modeling System (outer region of red box). The subdomain simulation is from October to December 2015 when cross-sectional current observations were conducted.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
The team is working on an article to reflect the findings of the study in this task. The article will be submitted for publication with a peer reviewed journal

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report for SBU.

Updates for Q2 FY2025 (January 1st – March 31st)
None.

Updates for Q3 FY2025 (April 1st – June 30th)
None.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Task 16.0 Assessing hydrodynamic impacts of single and multiple hydrokinetic units and tidal farms on the marine environment using laboratory, field, and numerical studies

Major Project Goals and Objectives

This project seeks to assess the hydrodynamic and environmental impacts of MHK devices and arrays deployed in waterways with mobile sediment beds, suing the Great Bay Estuary and Portsmouth Harbor as a reference site.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Prof. Farrah Moazeni of Civil and Environmental Engineering at Lehigh will be joining this project in place of Prof. Panos Diplas who has retired from Lehigh. Farrah is part of the AMEC-IIJA project. Farrah and team (with the help of Arindam Banerjee) will be recruiting a post-doc/student to start working on experiments in the Lehigh sediment plume, possible at the start of Q4.

Updates for Q3 FY2025 (April 1st – June 30th)
Dr. Cong Han has been recruited as a post-doc to assist with sediment transport experiments and is expected to start on 9/1/25.

Updates for Q4 FY2025 (July 1st – September 30th)
Dr. Cong Han completed his PhD and has started work as a post-doc to assist with sediment transport experiments on 9/17/25. The team is currently waiting to get access to the sediment flume at Lehigh which is undergoing some annual maintenance .

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Project team has begun work and meets every other week for planning experiments.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)

Nothing to report.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

We plan to conduct a coordination kick-off meeting with all AMEC institutions currently working on this task (UNH, SBU, LU).

Updates for Q4 FY2024 (July 1st – September 30th)

Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Task 17.0: Power at Sea - Wave Energy Powered Water Pump

Major Project Goals and Objectives

This project will develop a stand-alone wave energy converter with a hydraulic/pump PTO to pump cooler, nutrient rich near-bottom water up to offshore aquaculture kelp or fish farms.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Planning for Subtask 17.1 Industry Case Study and Subtask 17.2 Design a commercial scale system.

Updates for Q2 FY2024 (January 1st – March 31st)
Work on Subtask 17.1 Industry Case Study and Subtask 17.2 Design a commercial scale system.

Developed a simple transport model for an macroalgae aquaculture installation. Used Gulf of Maine data set for water temperature and nitrate at varying depth with transport model to explore the effects of wave-powered water pumping.

Updates for Q3 FY2024 (April 1st – June 30th)
Work on Subtask 17.1 Industry Case Study and Subtask 17.2 Design a commercial scale system.

Coupled a model macroalgae aquaculture installation (industry case study) with the transport model to predict enhanced growth effect of kelp.

Continued literature search to gather additional data on how increased kelp growth rates and nitrate concentration is reported.

Updates for Q4 FY2024 (July 1st – September 30th)
Continued refining nutrient and temperature transport model for industry case study report (Subtask 17.1). Added third temperature measurement in the mid-depth water column from historic data to increase model accuracy. Continued development of report.

For Subtask 17.2, economic analysis of wave pump prototype and redesign begun. The cost to build each device will aim in determining the feasibility of a commercial scale system.

Updates for Q1 FY2025 (October 1st – December 31st)
Subtask 17.1 industry case study report first draft is nearly complete. Implemented varying flow rates of redesigned wave-powered water pump modeled by WEC-Sim into the nutrient and temperature transport model. Some preliminary results from the model are included here. Over the warmest months of the year, application of the upweller is modeled cooling a representative farm

area by approximately 0.6°C. This is significant for survivability of sugar kelps in the summer months. The increase in nitrate concentration is modeled at approximately 0.5 µMol/L throughout the representative farm area for the warmest months of the year. This will increase the amount of kelp grown in the representative farm. Estimates of how much additional kelp can be grown are in progress.

No additional progress to report on Subtasks 17.2 and 17.3.

Updates for Q2 FY2025 (January 1st – March 31st)

Subtask 17.2: The improved wave pump design manuscript was completed and submitted to EWTEC 2025 conference. The improved design features a larger spar buoy to increase the flow rate of the pump. The flow rate of the improved design for the equivalent maximum wave conditions as tested in AMEC BP1 Task 9 (JONSWAP 0.7 m significant wave height, 3.2 peak period) was 47.4 cubic meters per hour which is an increase of 11 times the ocean tested prototype (3.8 cubic meters per hour). Additionally, the device was designed and analyzed to confirm its self-righting capability, which is critical for operation for long periods offshore. The mooring design for the device was analyzed to survive the tensions experienced in the maximum wave conditions previously tested. The journal article will act as the deliverable for this task and requires peer-review and presentation at the EWTEC conference in September.

Subtask 17.1: These updated, increased flow rates from Subtask 17.2 will be utilized in the industry case study report for Subtask 17.1. This increased flow rate will increase the nutrient availability and decrease the temperature modeled in the representative kelp farm, and updates to the model and first draft report are in progress.

No additional progress to report on Subtask 17.3 at this time.

Updates for Q3 FY2025 (April 1st – June 30th)

No additional progress to report on Subtasks 17.1-3 at this time.

Updates for Q4 FY2025 (July 1st – September 30th)

The deliverable for Subtask 17.1 is an industry case study that examines nutrient transport and temperature effects of wave-powered water pumps installed in kelp aquaculture. Utilizing these modeled effects, the case study quantifies the amount of kelp that could be grown by utilizing wave pumps. The first draft is complete, and is undergoing the editorial process for journal submission.

Subtask 17.2 is completed. This deliverable encompassed an article included in the proceedings of the 16th European Wave and Tidal Energy Conference (EWTEC 2025). This design of a commercial scale wave-powered water pump system was modeled using WEC-Sim and was found to produce an increased flow rate from the ocean tested prototype by a factor of 12, and had an increased performance ratio of more than 6. The findings were presented in person at the EWTEC conference, and a peer-reviewed paper was published in the EWTEC 2025 Proceedings..

No additional progress was made on Subtask 17.3, however there is high likelihood that it will be completed by the end of Q1 FY2026.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Made a plan on how to proceed with BP2 work scope.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

The industry case study report (deliverable for Subtask 17.1) has made significant progress and will likely be complete by the end of next quarter.

The design of a commercial scale system report (deliverable for Subtask 17.2) has some progress and will also likely be complete by end of next quarter.

The report for Subtask 17.3 on reporting for IEC standards is expected to take a short amount of time and will also likely be completed by the end of next quarter. A list of items was recorded at the end of the field deployment which can be used towards completion of this task, along with a review of the standards.

Updates for Q1 FY2025 (October 1st – December 31st)

The deliverable for Subtask 17.1 is a report on an industry case study, and the first draft is nearly complete with preliminary results. While it was not completed this quarter, more availability in scheduling indicates completion should be attained by end of Q2 FY2025.

Subtask deliverables for Subtask 17.1 and 17.2 are combined within the industry case study report.

No additional progress was made on Subtask 17.3, however there is high likelihood that it will also be complete by the end of Q2 FY2025 due to the short amount of time expected for this task.

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

The deliverable for Subtask 17.1 is a report on an industry case study, and the first draft is nearly complete with preliminary results. While it was not completed this quarter, more availability in scheduling indicates completion should be attained by end of Q4 FY2025.

Subtask deliverables for Subtask 17.1 and 17.2 are combined within the industry case study report.

No additional progress was made on Subtask 17.3, however there is high likelihood that it will also be complete by the end of Q4 FY2025 due to the short amount of time expected for this task.

Updates for Q4 FY2025 (July 1st – September 30th)
Good progress overall.

Journal manuscript for an industry case study that examines nutrient transport and temperature effects of wave-powered water pumps installed in kelp aquaculture was prepared and is undergoing edits.

Subtask 17.2 is completed.

Subtask 17.3 is expected to be completed soon.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Work on Subtask 17.1 and 17.2.

Updates for Q2 FY2024 (January 1st – March 31st)
Continue work on Subtask 17.2.

Updates for Q3 FY2024 (April 1st – June 30th)
Continue work on Subtask 17.1 and 17.2, commence work on Subtask 17.3

Updates for Q4 FY2024 (July 1st – September 30th)
Planned to complete Subtask 17.1, 17.2, and 17.3. Additionally plan to have completed the editorial process for the journal manuscript (see Outputs).

Updates for Q1 FY2025 (October 1st – December 31st)
Planned to complete Subtask 17.1, 17.2, and 17.3 by the end of Q2 FY2025.

Updates for Q2 FY2025 (January 1st – March 31st)
Continue work on Task 17.1 and 17.3.

Updates for Q3 FY2025 (April 1st – June 30th)
Planned to complete Subtask 17.1, 17.2, and 17.3 by the end of Q4 FY2025

Updates for Q4 FY2025 (July 1st – September 30th)
Editing manuscript for Subtask 17.1 and complete 17.3.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Presented work on wave-powered water pump at UMERC 2023 conference October 2023 in Durham NH.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Submitted a journal manuscript on "Wave-powered water pump for upwelling in aquaculture: numerical model and ocean test" to a Special UMERC Issue of the journal *Renewable Energy* (Publisher: Elsevier) in June.

Updates for Q4 FY2024 (July 1st – September 30th)
Responding to first round of editorial reviews of manuscript on "Wave-powered water pump for upwelling in aquaculture: numerical model and ocean test" for the special UMERC issue of the journal of Renewable Energy.

An outreach (educational materials) wave energy demonstration project was completed this quarter. The goal of the demonstration is to provide an interactive model of wave energy in practice. A small wave tank with a manual wave paddle allows members of the public to create waves that activate a small WEC. Indicator lights turn on when the waves activate the WEC. The tank was planned for outreach, including the UNH Ocean Discovery Day which typically draws around 3000 people to the two-day event. Future uses for the tank could include proving small prototypes for various WECs or improving the wave pump design.

Updates for Q1 FY2025 (October 1st – December 31st)

"Wave-powered water pump for upwelling in aquaculture: numerical model and ocean test" in Renewable Energy has been published. Doi: https://doi.org/10.1016/j.renene.2024.122040

Submitted abstract for European Wave and Tidal Energy Conference (EWTEC) 2025 on wave pump redesign efforts.

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

No update.

Updates for Q4 FY2025 (July 1st – September 30th)

Kimball, Chelsea and Wosnik, Martin. Wave-powered water pump design for improved performance, Proceedings of the 16th European Wave and Tidal Energy Conference (EWTEC), Madeira, Portugal, September 7 -11, 2025. https://lnkd.in/edJ97Gri

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

The reports on the industry case study, commercial scale model, and feedback to IEC standards will all advance the field of wave energy and indicate the feasibility and benefit of utilizing a wave pump for improving aquaculture.

The journal article will advance the field of wave energy by providing an example of a field-tested wave energy device (which are rare) and present a validated numerical model for the wave pump (even more rare). Numerical models allow for faster and less expensive design prototyping, which can accelerate innovation in the wave energy industry.

Educational outreach on wave energy benefits the industry and research communities to garner public support for this novel research.

Updates for Q1 FY2025 (October 1st – December 31st)
The reports on the industry case study, commercial scale model, and feedback to IEC standards will all advance the field of wave energy and indicate the feasibility and benefit of utilizing a wave pump for improving aquaculture.

The journal article advances the field of wave energy by providing an example of a field-tested wave energy device (which are rare) and present a validated numerical model for the wave pump (even more rare). Numerical models allow for faster and less expensive design prototyping, which can accelerate innovation in the wave energy industry.

Educational outreach on wave energy benefits the industry and research communities to garner public support for this novel research.

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
No update.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Task 18.0 (MRE) Physics-based data-driven reduced-order models for site-specific optimization of MHK device arrays in tidal farms

Major Project Goals and Objectives

This project seeks to develop efficient reduced order models (ROMs) using convolutional neural networks (CNN) to generate site-specific realizations of turbulent flows around MHK turbines in real-life marine environments at a small fraction of the computational cost required by high-fidelity simulations. To do so, we will integrate site-specific data sets of waterway bathymetry and marine conditions with high-fidelity simulations using the VFS code and state-of-the-art machine learning algorithms to develop ROMs that can be used to efficiently optimize tidal turbine arrays in real-life settings. This computational approach will be demonstrated in the Memorial Bridge at Portsmouth, NH, which will be simulated as part of Tasks 15 and 16.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
This task requires input data from Tasks 15 and 16 to start.

Updates for Q1 FY2025 (October 1st – December 31st)
Not started yet.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q3 FY2025 (April 1st – June 30th)
Not started yet.

Updates for Q4 FY2025 (July 1st – September 30th)
In Fall 2025, the research team at SBU started to work on this task using the data obtained from Task 15. The goal is to develop AI algorithm that enables efficient prediction of tidal turbine wake flow and tidal array optimization. The initial stage of this task involves predicting the 3D flow field of the Piscataqua River. Once we establish a base AI for such prediction, then we can further develop the AI to handle wake flow fields in the presence of tidal turbine arrays.

High-fidelity large-eddy simulation (LES) provides the necessary physics but at a computational cost that inhibits rapid scenario testing (e.g., changing inflow, water levels, or turbine configurations). This project explores whether a neural network (NN) surrogate can approximate LES outputs for the Portsmouth River domain—specifically, the streamwise velocity field and the turbulent kinetic energy (TKE)—with enough fidelity to support quick what-if analyses.

A central motivation of this work is to address the long data-collection windows required to compute time-averaged turbulence statistics from instantaneous LES snapshots. Traditionally, hundreds or thousands of flow fields are needed before reliable averages can be extracted, which is costly both in simulation runtime and storage. Our goal is to develop a model that can learn from a limited number of instantaneous flow realizations and directly infer the corresponding time-averaged fields. Such a surrogate would eliminate the need to accumulate extensive ensembles, enabling faster hydrodynamic assessment and making LES-informed analyses more accessible for practical engineering decisions.

Past studies

Machine learning (ML) surrogates for turbulent flow prediction have gained traction as a way to reduce the reliance on expensive simulations. Convolutional neural networks (CNNs), autoencoders, and, more recently, diffusion- and transformer-based models have been trained to reconstruct velocity fields, predict Reynolds stresses, or accelerate reduced-order models. However, most of these studies have focused on idealized geometries such as periodic boxes of homogeneous isotropic turbulence or straight channel flows under canonical boundary conditions (e.g. [1,2,3]). These testbeds provide clean datasets but lack the geometric and hydrodynamic complexity of natural rivers.

Attempts to extend surrogates to more realistic flows have typically targeted atmospheric boundary layers or urban canopy flows (e.g., [4,5]), but riverine environments remain underexplored. A key difficulty is that natural rivers exhibit strong spatial heterogeneity: flow accelerates near constrictions, separates around bridge piers, and interacts with bathymetric variation. As a result, second-order turbulence statistics (e.g., Reynolds stresses) can differ by orders of magnitude between upstream and wake regions, leading to unstable or biased training if handled naively.

Another open challenge is generalization across boundary conditions. Many ML surrogates are trained on a single inflow specification and tested under the same or slightly perturbed conditions. However, for practical use in river engineering, models must remain robust when inflow conditions change (e.g., log-law vs. ROMS-driven profiles, seasonal variations in discharge). To date, few studies have systematically evaluated cross-boundary generalization, and those that have reported significant performance degradation when training and testing distributions differ [6,7].

In parallel, there has been a push to incorporate physics knowledge into ML models, either by designing physics-informed neural networks (PINNs) [8], or by crafting custom loss functions that penalize violation of conservation laws. Although promising, these methods have been mostly demonstrated in lower-dimensional or idealized settings. For realistic three-dimensional river domains, the literature remains thin.

The state-of-the-art demonstrates that ML surrogates can effectively reproduce canonical turbulence datasets. Still, significant gaps remain in (i) handling strongly heterogeneous natural domains, (ii) ensuring generalization across boundary conditions, and (iii) achieving stability when training on higher-order turbulence quantities. The Portsmouth River project addresses these gaps by curating LES data from a realistic river geometry and empirically testing preprocessing and training strategies aimed at stabilizing surrogate learning under such conditions.

Test case description

The Piscataqua River is the tidal river that flows through Portsmouth, New Hampshire, and forms part of the border between New Hampshire and Maine before discharging into the Gulf of Maine at Portsmouth Harbor. Numerical and observational studies [9,10] demonstrate that the river undergoes strong tidal asymmetry, nonlinear waveform evolution, and substantial changes in current speed under combined sea-level rise and storm surge conditions. Fortunately, the Memorial Bridge, spanning the river at Portsmouth, has been instrumented with sensors and even a tidal turbine for environmental monitoring [11], making the site one of the few real-world locations where high-resolution data are available to train ML models.

High-fidelity training dataset

The high-fidelity data used for training the model were gathered from an LES solver with a wall-model treatment to resolve the near-bed dynamics at high Reynolds number. The solver produced three-dimensional snapshots of the velocity components and second-order turbulence statistics (Reynolds stresses).

The dataset included both instantaneous fields (capturing unsteady turbulence) and time-averaged fields (capturing mean flow and turbulence intensities). This richness, though, came with its own challenges. Second-order statistics exhibited values differing by almost two orders of magnitude across the domain. For instance, near the inlet region, turbulence intensity was rather fair, while in the wake of bridge piers, Reynolds stresses spiked sharply. This heterogeneity proved to be one of the major obstacles for our model training, as unscaled datasets caused unstable optimization and biased the loss function toward high-magnitude regions.

The computational domain contained several hundred million grid nodes. This resolution was chosen to capture turbulent structures of interest while remaining computationally feasible. At this initial stage of this task, we attempted to investigate how neural networks trained under one boundary condition (BC) would generalize to an unseen one. The inlet specification determines the turbulence structures that develop downstream and therefore has a direct influence on the LES results which will be fed to the model as the training data. In this study, the LES simulations were performed using four BCs:

Table 1. First- and second-order variables available from the instantaneous and time-averaged LES datasets.

Dataset	Order	Variables
Instantaneous	First-order	U, V, W (velocity components)
	Second-order	– (not directly available)
Time-averaged	First-order	$\overline{U}, \overline{V}, \overline{W}$ (mean velocity components)
	Second-order	$\overline{uu}, \overline{vv}, \overline{ww}, \overline{uv}, \overline{vw}, \overline{uw}$ (Reynolds stresses)
	Derived	$k = \frac{1}{2}(\overline{uu} + \overline{vv} + \overline{ww})$ (turbulent kinetic energy)

- **Straight Channel:** considers a straight channel extending upstream from the inlet of the study area. A fully developed turbulent flow in the straight channel then was obtained using a periodic boundary conditions along the channel.
- **River Inflow:** Derived from a river flow simulations that included a mile long reach of the river just upstream of the study area.
- **Log-Law Profile:** generates a simple inlfow profile using log-law and imposed at the inlet of the river flow simulations.
- **ROMS-Driven Profile:** Time-varying boundary conditions derived from the Regional Ocean Modeling System (ROMS). The ROMS modeling effort was carried out by UNH team. The instantanous ROMS data for upstream river was interpolated into the relative fine grid system in our simulations.

Network Architecture and Training Details

The neural-network surrogate models in this study were designed to map instantaneous flow fields from the Piscataqua River LES database to their corresponding time-averaged quantities with the goal of eliminating the long temporal sampling period which is typically required to obtain statistically converged averages from high-fidelity simulations. Instead of running hundreds or thousands of LES timesteps and post-processing them into averages, the surrogate learns the relationship between a small number of instantaneous snapshots and their ensemble-mean representation.

Two complementary model configurations were developed to explore the effect of input dimensionality on predictive capability:

Single-variable input model (1-channel network). This architecture receives a single instantaneous scalar field, typically the streamwise velocity component u (x,y,z,t), and predicts its time-averaged counterpart mean u (x,y,z). The objective of this configuration is to evaluate whether the instantaneous spatial structures in one velocity component alone contain enough information for the network to infer the long-term mean flow. It provides a minimal, computationally inexpensive baseline.

Three-variable input model (3-channel network). In the second approach, the full instantaneous velocity vector (u,v,w) is supplied as a three-channel input tensor. This configuration allows the model to capture cross-component correlations, and the combined influence of streamwise, vertical, and lateral motions on the time-averaged field. Because the magnitudes of u, v, and w differ by more than an order of magnitude across the river domain, especially near bridge-induced wakes, a cube-root transformation was later applied to reduce this disparity before normalization.

Both models were implemented as compact 3-dimensional convolutional neural networks (3D CNNs) following an encoder–decoder or U-Net-like topology. Convolutions were performed in three spatial dimensions to preserve volumetric context within each data tile, ensuring that spatial continuity along the depth and cross-stream directions was maintained. The 1-channel and 3-channel variants share the same architectural backbone, differing only in the number of input channels and in the inclusion of the cube-root preprocessing step. The end goal of both models is to establish a scalable framework that is capable of learning the statistical imprint of turbulence from a limited set of instantaneous flow fields, and be served as a fast, data-driven surrogate for expensive long-duration LES averaging.

Backbone

Both surrogate models share an identical 3D convolutional encoder–decoder backbone. This architecture was chosen because it combines spatial feature extraction, dimensional compression, and upsampling within a single end-to-end trainable framework, which makes it well suited for mapping between volumetric flow fields of equal dimensions.

Encoder (Downsampling Path): The encoder progressively compresses the spatial domain while enhancing the feature representation of the flow. Each encoding stage consists of a 3D convolution followed by a nonlinear activation (Rectified Linear Unit, ReLU). The network begins with a small number of filters that increase with depth to capture features at multiple spatial scales:

$$C_{in} > 8 > 16 > 32 > 64$$

where Cin=1 is for the single-channel model and Cin =3 is for the three-channel model. Each convolution uses a kernel size of 5 by 5 by 5 with a stride of 3 . The fairly large kernel and stride allow the model to aggregate information across neighboring voxels while reducing spatial resolution, similar to a coarse-graining operation in turbulence modeling. The stride of 3 was empirically selected as a midpoint between preserving sufficient spatial detail (e.g., wake gradients) and maintaining GPU efficiency for 3D data. To maintain numerical stability, padding is applied so that the receptive fields overlap smoothly between layers. The ReLU activation introduces nonlinearity while maintaining positive gradients. It ensures fast convergence and avoids vanishing-gradient issues which is common in deeper 3D architectures. From a fluid-mechanics standpoint, the encoder operates like a hierarchy of low-pass filters: early layers detect fine-scale features such as shear and vortical edges, whereas deeper layers translate larger-scale structures like channel curvature or bridge-induced wakes.

Decoder (Upsampling Path): The decoder mirrors the encoder, using 3D transpose convolutions (also called deconvolutions) to upsample the compressed latent representation back to the original spatial resolution. The feature channels arrangement in reverse order:

$$64 > 32 > 16 > 8 > 1$$

Each transpose-convolution also uses a kernel of and stride , enabling smooth interpolation. ReLU activations are again applied except at the output layer, where a linear activation is used to produce continuous-valued predictions matching the physical target fields. This symmetric encoder–decoder arrangement ensures that the network sustains a balance between compression and reconstruction accuracy. Although it lacks direct skip connections (as in a full U-Net), the combination of wide kernels and overlapping receptive fields allows coarse and fine structures to coexist in the feature space.

Prediction Targets

Two target variables were selected for surrogate modeling:

- Streamwise Velocity (u): Physically interpretable and directly relevant to turbine performance. Contains sharp gradients and phase-sensitive information. *Dead end noted:* Direct prediction of instantaneous fields often led to unstable training and noisy outputs. Even averaged - field approximations proved difficult to obtain without heavy preprocessing.
- Turbulent Kinetic Energy (TKE): A scalar summarizing turbulence intensity. Less sensitive to phase shifts and more homogeneous across the domain. *Successful direction:* After applying cube-root scaling, TKE predictions stabilized, producing visually and physically reasonable maps. This became the preferred target for most later experiments.

Train/Test Splits and Experiment Design

The data were organized to test cross-boundary generalization explicitly. To cover different flow regimes and boundary conditions, we had to split the data not only into instantaneous and time-averaged, but also by boundary condition. Therefore, there were two main experimental approaches we took:

- Train on straight-channel: Test on river/log/ROMS inflows.
- Train on river flow: Test on straight channel/log/ROMS profile.

Additionally, splits were also done between instantaneous vs averaged fields to compare model stability. The reason is that instantaneous fields capture unsteady turbulence, while time-averaged fields capture mean flow and turbulence intensities; at the end, the model is expected to predict the time-averaged fields, given a few instantaneous fields as input. Averaged fields consistently yielded more stable training, while instantaneous fields exposed the model's difficulty in capturing high-frequency turbulence fluctuations.

Mean velocity field predictions

The surrogate model trained on the straight-channel boundary condition successfully reproduced the large-scale morphology of the mean velocity field across all test conditions. However, notable differences appeared in regions of strong shear and recirculation.

The predictions captured the general shape of the high-velocity core and the zones of reduced velocity near the channel banks and bridge wakes. However, compared to LES, the network underpredicted velocity magnitude in energetic regions downstream of the bridge piers, where shear layers and vortices dominate. This smoothing effect stems from the network's limited ability to infer the full temporal variability of these structures from a single instantaneous field.

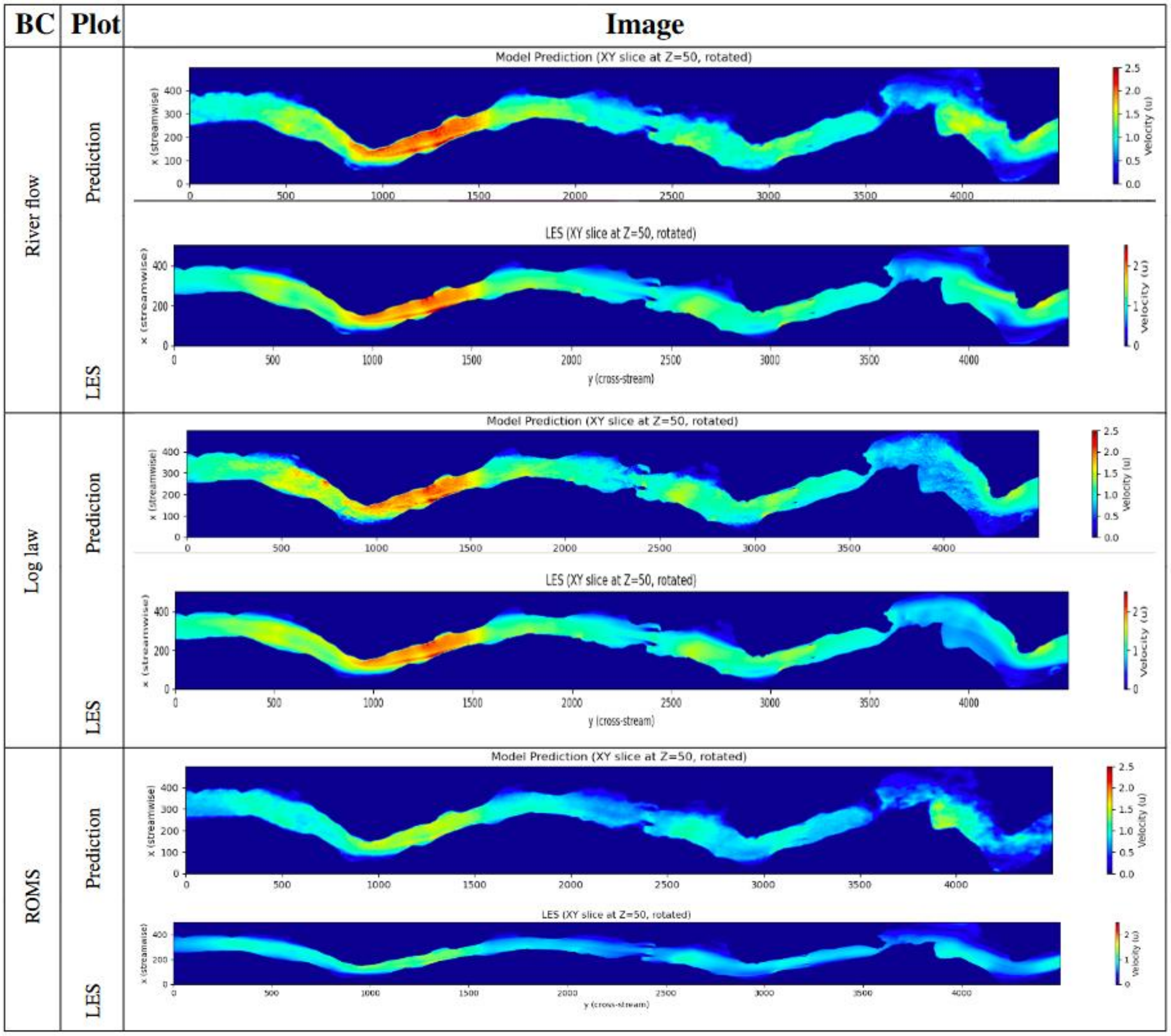


Figure 1. Case A: Trained on Straight Channel, given instantaneous U as input, predict average U as output. Each block shows Prediction (top) and LES (bottom).

The discrepancy was most pronounced in the ROMS-driven case, where inlet asymmetry and tide-induced unsteadiness shift the position of the high-velocity core. The model, trained on a steady, uniform inflow, struggled to replicate these phase-shifted structures, leading to slightly displaced low-velocity pockets and a shorter wake region. Overall, the model delivered realistic large-scale features but lacked sensitivity to local shear gradients, suggesting that additional temporal context or multi-variable inputs could improve its fidelity.

Predicting TKE

When trained on the river-flow boundary condition and provided with three instantaneous velocity components, the model reproduced the main TKE distribution but underestimated its magnitude in high-energy zones. The cube-root transform used for input normalization effectively stabilized training but also suppressed extreme values, leading to smoother predictions than the LES reference. Despite this leak of detailed information, the model accurately identified regions of elevated turbulence intensity, especially along channel bends and downstream of the Memorial and Sarah-Mildred Bridges. The comparison shows that the surrogate learned the qualitative spatial pattern of energy production and dissipation, though it failed to resolve localized TKE peaks where velocity fluctuations are most unsteady. Discrepancies were again exacerbated under ROMS-driven inflow, where the model failed to fully adapt to the changing turbulent structures inflicted by unsteady tidal forcing. This limitation highlights the model's sensitivity to domain shift and emphasizes the need for either domain adaptation or physics-informed loss functions in future work.

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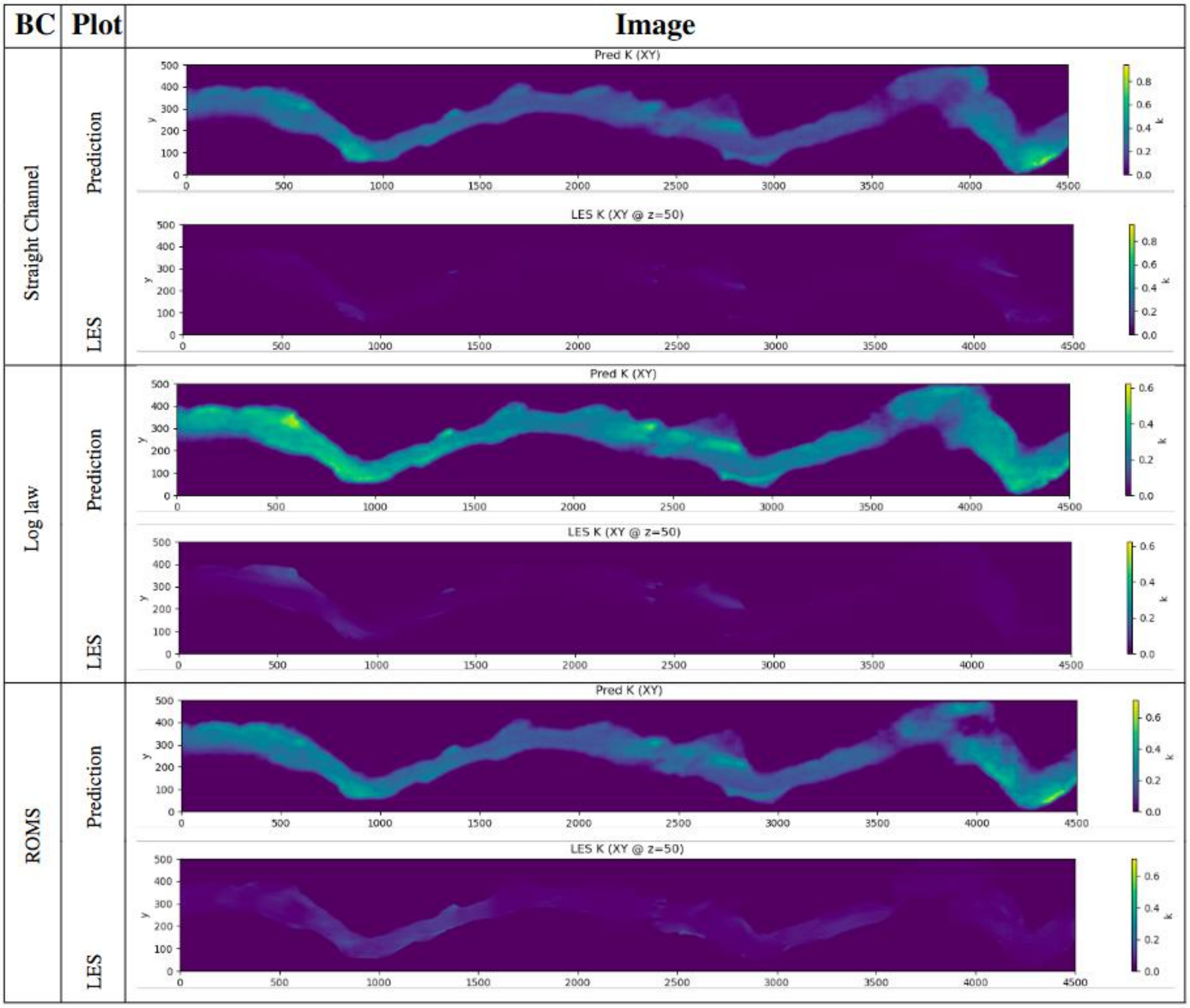


Figure 2. Case B: Trained on River flow, given instantaneous u,v,w as input, predict TKE as output. Each block shows Prediction (top) and LES (bottom).

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Not started yet – nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q3 FY2025 (April 1st – June 30th)
Not started yet.

Updates for Q4 FY2025 (July 1st – September 30th)
The task is in underway with a satisfactory speed.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q3 FY2025 (April 1st – June 30th)
Not started yet.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q3 FY2025 (April 1st – June 30th)
Not started yet.

Updates for Q4 FY2025 (July 1st – September 30th)
The SBU team will work with collaborators at UNH to extend the AI modeling to tidal arrays at the Piscataqua River.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q3 FY2025 (April 1st – June 30th)
Not started yet.

Updates for Q4 FY2025 (July 1st – September 30th)
A more comprehensive progress report is created in Overleaf. The initial AI algorithms and codes are prepared for archiving and reporting on PRIMER.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Not started yet.

Updates for Q3 FY2025 (April 1st – June 30th)
Not started yet.

Updates for Q4 FY2025 (July 1st – September 30th)
The speed of predictions using AI is amazing and could be soon the way to go for tidal farm optimizations. We are excited to push this effort forward.

Task 19: Decision Support Platform for Coastal Communities' Power Infrastructure Resilience

Major Project Goals and Objectives

Develop a simulation platform that allows analysts to predict the performance of coastal electric infrastructure systems and their ability to serve local communities during and after hurricane events.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
• Completed platform for global simulation of transmission network damage (to be used for subtasks 19.4 and 19.5).

• Variable classification, failure mode selection, design of experiment implementation, and random sampling implementation for parametric wind fragility models for monopole transmission towers.

Updates for Q1 FY2025 (October 1st – December 31st)
• Completed calculation of archetype fragility curves for steel monopole transmission towers.

• Completed calculation of parametric fragility curves for steel monopole transmission towers.

• Started preparation of journal manuscript for submission.

• Submitted abstract to 2025 Conference of the Engineering Mechanics Institute, entitled "Multi-dimensional Wind Fragility Curves for Steel Transmission Monopoles"

• Started industry engagement and survey preparation for recovery models.

Updates for Q2 FY2025 (January 1st – March 31st)
• Completed multiple focus group meetings with experts and stakeholders to discuss vulnerability models and recovery models

• One major feedback received was the need to include one additional failure mode for monopole structures, so we had to go back and resume the development of those fragility curves to include failure at mid-height.

• Completed development of expert survey for damage and recovery models, including several test-runs with experts in the field.

• Coordinated with IRB to have any requirement waived.

• Launched official survey data collection (currently in progress).

Updates for Q3 FY2025 (April 1st – June 30th)
• Advanced the development of monopole fragility curves, to account also for storm duration and, therefore, failures due to dynamic effects.

• Presented overall project and pole fragility curves computed by static analysis at the national conference of the Engineering Mechanics Institute, hosted by University of California, Irvine.

• Continued to work to expand participation of experts in the survey on powerline recovery. In particular, team members attended the Annual Lineworkers Benefit Rodeo and connected with experts and stakeholders there. Moreover, we set up a raffle to incentivize participation. https://nsujl.org/about-rodeo/

Updates for Q4 FY2025 (July 1st – September 30th)
• Continued work on dynamic fragility curve development for monopole structures and the preparation of the associated manuscript.

• Started development of testbeds for demonstration. In particular, we worked on wind-field model for three considered hurricanes.

• Started collection of storm surge fragilities.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
• Collected wind fragility curves available in the literature and assembled database:

- Electrical conductor cables
- Lattice steel towers
- Wood distribution poles
- Steel distribution poles (in progress)
- Reinforced concrete distribution poles (in progress)

• Compute new fragility curves for classes not available in the literature

- Monopole transmission towers, parametric (target: November)

Updates for Q1 FY2025 (October 1st – December 31st)
The student working on this project has progressed well, and in this quarter has been working also on her Doctoral Proposal (defended successfully in January 2025). We are slightly behind in terms of fragility curve development, because we realized that there is the need for more fragility curves than we anticipated, but we expect to be back on track by the end of Q3. We also started the industry engagement task and survey development/testing.

Updates for Q2 FY2025 (January 1st – March 31st)
This trimester has been mostly focused on industry engagement and preparation of the survey on power transmission support structures damage and recovery. We ran a few focus groups to test and refine the survey instrument. As part of that process, it emerged that one crucial assumption that we had made (i.e., monopoles fail at the groundline, where stresses are higher, therefore a static-equivalent analysis can be conducted) may be unrealistic for tall poles. For this type of structure, failures at mid-height are observed as well, probably due to stresses generated by the second mode of vibration. This required us to go back to the fragility models that we had developed and reopen that line of work. The survey is being administered right now, and while it is challenging to collect expert feedback, we are optimistic that we will get sufficient data.

Updates for Q3 FY2025 (April 1st – June 30th)
In this quarter we worked on developing a new set of fragility curves that includes storm duration and dynamic effects. These features are added in response to the feedback received by stakeholders. The research team has done good progress on this and is close to finalizing a manuscript for submission to a journal paper.

In addition, the team worked to expand expert participation in the survey for data collection. This proved to be more difficult than expected. In previous data collection efforts, we were able to collect feedback from dozens of experts. In this case, participation has progressed much more slowly, and the team addressed the issue by instituting a raffle and by participating in person to events where stakeholders and experts gather. This led to a substantial increase in the data collected, but still insufficient to calibrate some of the aspects of the model.

Updates for Q4 FY2025 (July 1st – September 30th)
We continued the analyses for the development of fragility curves. One full analysis takes about a week of computations in high-performance computing clusters (we used the NSF TACC resources and our local clusters at Lehigh). We had to do several iterations to refine the selection of the most relevant variables for parametrization, and this slowed us down. In parallel, we continued to work on the preparation of a journal paper on this topic.

The team also worked to start collecting data for testbed cases for demonstration. We selected 3 historical hurricanes that hit the US (Michael, Irma, and Ian), colleted data on the hurricane track geometry and intensity, developed a wind-field model, and calculated the corresponding wind fields over the affected regions.

Finally, we started collecting storm surge fragilities for electrical infrastructure and collecting it in a database.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report

Updates for Q1 FY2025 (October 1st – December 31st)
The literature review highlighted that there would be the need for the development of more fragility curves than we anticipated, also to support work planned under BIL tasks. We expect

that the surge fragilities will be faster to develop than the wind fragilities, and we will catch up then.

Updates for Q2 FY2025 (January 1st – March 31st)
The realization that we have to include an additional failure mode and perform dynamic analyses is a setback, which will cause some delays in our plan.

Updates for Q3 FY2025 (April 1st – June 30th)
The collection of data on powerline recovery has been very challenging. Now we have sufficient data on recovery of transmission poles, but the data on recovery of lattice towers is still scarce. We will soon have to move forward and proceed with the limited data available.

Updates for Q4 FY2025 (July 1st – September 30th)
In this quarter we faced several challenges on the computational side. We first started using TACC to run our analyses, but we soon run out of our computational allocation. Now we are using Lehigh's local cluster, but setting up an efficient way to run the analyses on two different systems has been a challenge.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Complete fragility curves archetype steel monopole towers

Updates for Q1 FY2025 (October 1st – December 31st)
• Submit paper on parametric fragility curves for steel monopole towers.

• Complete development of expert survey for recovery models and start administering it.

Updates for Q2 FY2025 (January 1st – March 31st)
• Complete survey data collection.

• Revise monopole fragility curves

• Present results at EMI conference

• Submit journal paper on monopole fragilities.

Updates for Q3 FY2025 (April 1st – June 30th)
• Submit journal paper on monopole fragilities, including storm duration effects.

• Submit journal paper on powerline recovery data.

Updates for Q4 FY2025 (July 1st – September 30th)
• Complete calculations in high-performance clusters.

• Advance/complete database with surge fragility.

• Submit journal paper on monopole fragilities, including storm duration effects.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Conference abstract under review.

Updates for Q2 FY2025 (January 1st – March 31st)
Survey tool now open and accessible online.

https://lehigh.co1.qualtrics.com/jfe/form/SV_5vaT6uzb3lPNMXA

Updates for Q3 FY2025 (April 1st – June 30th)
Presentation at EMI 2025 conference:

U. Otite & P. Bocchini. "Multi-dimensional Wind Fragility Curves for Steel Transmission Monopoles". Presented at the 2025 Conference of the Engineering Mechanics Institute, Anaheim, CA, May 27-30, 2025.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Task 20.0 Performance and design of foundations supporting marine energy devices

Major Project Goals and Objectives

Generate soil-foundation interaction cyclic test data and interface degradation models to develop design criteria for foundations supporting MHK systems.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

- During this quarter, the small-scale foundation test setup was improved to include confinement in all directions. The review of relevant studies on soil-foundation interaction for MHK systems was initiated. This effort is still going on. The MHK RM1 with three blades was also modeled in OpenFAST. This model focused on understanding applied loads and load transfer to the foundation elements. In this model the hydrodyn was utilized to include foundation stiffness. The team incorporated a soil stiffness matrix within the model. However, the dimensions of the scaled RM1 model are not realistic. Therefore, the effort currently focuses on: (1) data generated from scaled tests using the Tidal Turbulence

Test Facility to understand applied loads and load transfer to the foundation; (2) adjusting and scaling RM1 in OpenFAST to represent more realistic dimensions.

Updates for Q1 FY2025 (October 1st – December 31st)

- Analysis of Applied Loads and Scaling Effects

During Q1 FY2025, work focused on analyzing applied loads on marine hydrokinetic (MHK) turbine foundations.

Major Activities Included:

- Data collected and analyzed from the lab-scale turbine tests performed at a variety of rotor speeds at Lehigh university by professor Banerjee and his research group to assess torque and thrust measurements.
- Validation of hydrodynamic loads by comparing OpenFAST simulation outputs with test results with scaled lab test.
- Conducting scaling analysis of power coefficient (Cp) and thrust coefficient (Ct) to validate scaling to full-scale configurations.
- LPile- software was used to analyze the behavior of foundation under applied loads

Given that OpenFAST does not natively support soil modeling or soil-foundation interaction (assumes fixity at the mudline), additional effort focused on utilizing LPile simulations to:

Evaluate LPile results using forces calculated from OpenFAST simulations to understand the load transfer to the foundation and the response of the foundation under different operating conditions.

Identify refinement needs in boundary conditions and soil stiffness modeling that can provide a more realistic representation of foundation behavior.

Updates for Q2 FY2025 (January 1st – March 31st)

The OpenFAST RM1 MHK turbine is modeled with a fixity at the mudline in openFAST. To represent the soil-foundation system more realistically, flexibility at the mudline must be introduced. To achieve this, two approached were used: (1) modeling the soil-foundation system using LPile, applying the forces from the OpenFAST fixed base simulation to the LPile model, and then using superposition to add the resulting pile translations and rotations to the tower displacements calculated from openFAST using the RM1 model with fixity at the mudline; and (2) defining an External Platform (ExtPtfm) in OpenFAST to introduce a coupled spring model at the mudline, combined with BModes to modify the tower's mode shapes.

During Q2 FY2025, we focused on the latter approach. We implemented soil–foundation-structure interaction (SFSI) in the RM1 MHK turbine model using a workflow that combined LPile with OpenFAST. LPile modeled the foundation and surrounding soil, and a stiffness matrix was extracted at the mudline then the stiffness matrix used as an input in (ExtPtfm) in OpenFAST, capturing both translational and rotational responses. This implementation enabled more realistic, full system behavior of the marine hydrokinetic turbine, as opposed to a fixed base model.

OpenFAST simulations with SFSI integration provided time-varying mudline forces, moments, displacements, and rotations under realistic turbine operating conditions. These outputs are critical for identifying representative loading cases that give insight about the loading conditions of the upcoming experimental tests.

Updates for Q3 FY2025 (April 1st – June 30th)

During Q3, we investigated the impact of tower diameter variation (while keeping the tower thickness constant) on the structural performance of the MHK RM1 turbine under combined axial and bending loads at the mudline. This study aimed to identify an optimal tower cross-section that satisfies yield stress, local buckling, and fatigue under site operational and extreme loading conditions.

1-Mudline Stress Analysis

Using RM1 with tower and foundation diameter of 3.5 m and thickness of 39 mm, a parametric study was conducted to evaluate the impact of tower diameter on axial and bending stresses at the mudline. Soil condition of xx was assumed in this analysis. Several candidate diameters were tested while keeping wall thickness and material properties constant. Total stress was computed and compared to allowable yield limits using resistance factors of $\phi = 0.9$ for extreme conditions and $\phi = 0.5$ for operational conditions as part of a sensitivity analysis. The results confirmed that the 1D and 0.75D configurations satisfied the yield check, while the 0.5D and 0.25D cases exceeded allowable stress limits.

2- Local Buckling Check

We performed a local buckling analysis based on cross-sectional geometry and slenderness ratios. The results showed no major buckling issues, except when the diameter was reduced to 0.25D.

3- Fatigue Range Evaluation

Initial fatigue checks were performed using stress time histories obtained from OpenFAST. Stress ranges at the tower base were extracted and compared with S–N curves to assess fatigue life.

4- Extreme condition

Extreme conditions were examined in OpenFAST under two scenarios. The first involved a current spike, where the flow increased instantaneously above the operational level while the turbine operated normally with blades at 0° pitch. The second scenario involved a stalled turbine subjected to high current flow, with the blades feathered and the turbine not generating power.

As a result of this analysis, we found that the initial design of the three-bladed single-rotor MHK RM1 is overdesigned, and the outer diameter could be reduced by up to 25%.

Moreover, during Q3, we initiated monotonic testing on different piles (smooth and bio-inspired) to measure their uplift capacity. These tests were conducted under varying uniaxial and radial pressures. These results will serve as the baseline for comparison with the planned cyclic testing.

Updates for Q4 FY2025 (July 1st – September 30th)

During this quarter, foundation testing for the model piles was initiated. The testing phase began with evaluating different pile surface configurations including smooth piles and bio-inspired piles featuring asperities with two spacing-to-height (s/h) ratios, as shown in Figure 20.1

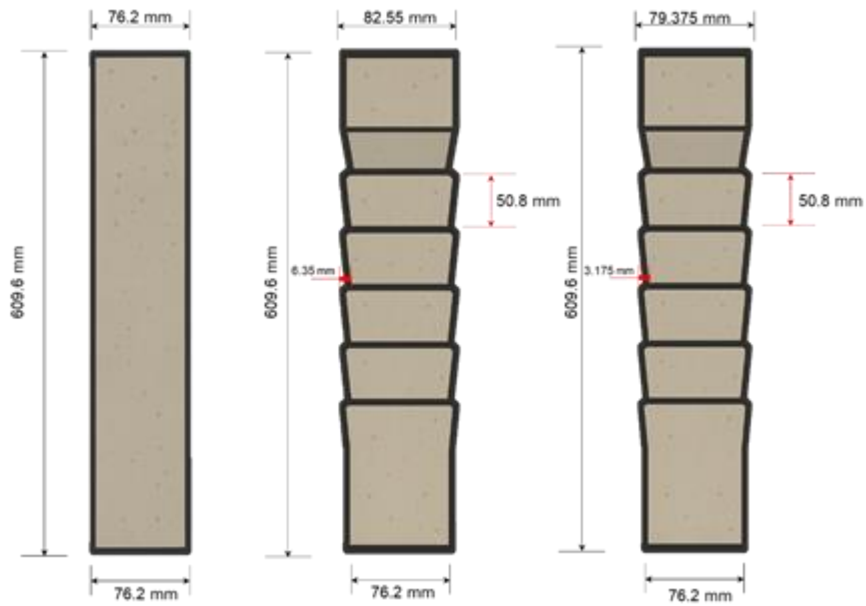


Figure 20.1: Pile designs with different surface configurations.

A series of initial tests were conducted using the small-scale soil tank specifically designed for this task. The test set up was designed to incorporate radial confinement, as illustrated in Figure 20.2, to provide realistic conditions. implementing confinement system allows achieving more representative pressure ratios in the range of 0.4 – 0.6 aligning better with field-scale conditions.

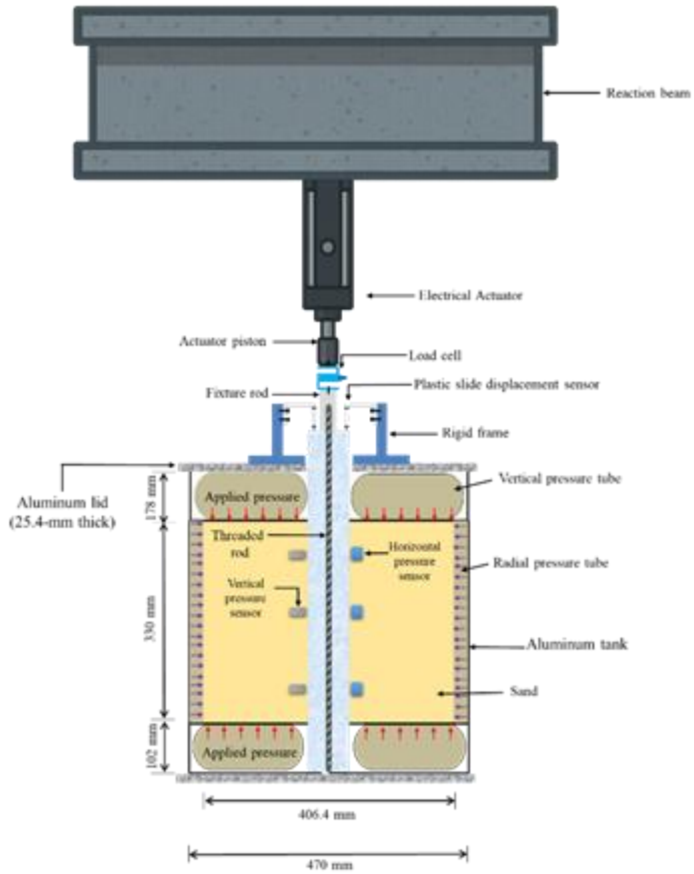


Figure 20.2: Soil box setup with inclusion of radial confinement.

Significant effort has been dedicated to assess the pressure distribution around the pile. The radial confinement system includes multiple components designed to achieve consistent and controllable pressure within the soil box. The system consists of stacked inflatable tubes positioned along the inner perimeter of the tank, which provide confinement from all directions. These tubes are interconnected through flexible hoses and connected to a central manifold to ensure equal pressure distribution along the length of the soil. The system is supplied with air through a pressure regulator and continuously monitored using a calibrated pressure gauge, allowing precise control and stability of the applied radial pressure throughout testing.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

More effort is still needed for understanding the applied loads and load transfer to the foundations before starting our testing program on foundation elements.

Updates for Q1 FY2025 (October 1st – December 31st)

- Progress is being made in the validation of the applied load models with physical test data and numerical simulations, keeping the project on track for its milestones.
- A soil-structure interaction module has been integrated with LPile, closing an important gap in OpenFAST's capabilities to tune foundation response

Updates for Q2 FY2025 (January 1st – March 31st)

- Successfully completed the integration of soil–foundation-structure interaction (SFSI) into the RM1 MHK turbine model using a coupled LPile–OpenFAST workflow.
- This progress keeps the project on track with its Q2 milestone and provides a crucial insight into the experimental planning in the next quarter

Updates for Q3 FY2025 (April 1st – June 30th)

Structural analysis of the RM1 tower confirmed that the current design is conservative and the tower diameter can be reduced by up to 25%. Extreme condition simulations under instantaneous current spike and stalled turbine condition were performed. Monotonic pile testing was initialized, establishing a baseline for upcoming cyclic tests. Overall, the project remains on track.

Updates for Q4 FY2025 (July 1st – September 30th)

- Progress is being made on finalizing sensor calibration, test setup, and the testing plan. Some of the challenges are controlling the stress conditions in the soil tank before performing the tests. This slowed the progress of our testing plan.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
No update.

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Continue efforts to model MHK systems to better understand applied loads and load transfer to foundation elements

Updates for Q1 FY2025 (October 1st – December 31st)

- Enhance models to accurately represent the load characteristics and load-deflection of the system.
- Addition of soil-foundation interaction modeling: To increase the accuracy of foundation response predictions, LPile simulations will be incorporated.

Updates for Q2 FY2025 (January 1st – March 31st)

- Parametric study to investigate representative loading cases for lab testing.
- Conduct detailed soil characterization.
- Initiate experimental setup and begin preliminary testing

Updates for Q3 FY2025 (April 1st – June 30th)

- Finalize monotonic testing of different piles under varying uniaxial and radial pressure conditions.
- Start cyclic testing of different piles under varying uniaxial and radial pressure conditions.

Updates for Q4 FY2025 (July 1st – September 30th)

- Start monotonic testing of different piles under varying soil stress condition.
- Start cyclic testing of different piles under varying soil stress condition.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

Nothing to report

Updates for Q1 FY2025 (October 1st – December 31st)

Nothing to report

Updates for Q2 FY2025 (January 1st – March 31st)

No update.

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2025 (July 1st – September 30th)

Nothing to report.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report

Updates for Q2 FY2025 (January 1st – March 31st)
No update.

Updates for Q3 FY2025 (April 1st – June 30th)
Noting to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report.

Task 21.0 Supply Chain Optimization

Major Project Goals and Objectives

Develop optimization models for (MREG and MREE) supply chains. Develop optimization models for two supply chains related to MRE: the supply chain of durable goods that enable MRE (MREG), and the supply chain of the energy itself produced by the MRE system (MREE). MREG supply chains may include the entities that manufacture, test, transport, install, and maintain MRE devices and supporting equipment and supplies. MREE supply chains may include electricity distribution networks, energy storage systems, and power consumption sites that are downstream from the MRE generation facilities.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
We developed a new approach for modeling uncertainty that can be tailored to address uncertainty MREE and MREG supply chain optimization problem.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

The work on this task was started on 7/1/2024. There is no significant progress to report at this time. We developed a new framework for modeling uncertainty that can be tailored to hedge against uncertainty in MREG and MREE supply chain optimization problems.

Updates for Q1 FY2025 (October 1st – December 31st)

Nothing to report

Updates for Q2 FY2025 (January 1st – March 31st)

We developed a new algorithmic approach for a stochastic capacitated fixed charge facility location problem (CFLP), which lies at the heart of many supply chain and other optimization problems.

Updates for Q3 FY2025 (April 1st – June 30th)

We are working on formulating a model for offshore Wind/Wave farm layout optimization under uncertainty

Updates for Q4 FY2025 (July 1st – September 30th)

We are continuing work on formulating a model for offshore Wind/Wave farm layout optimization under uncertainty

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2025 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2025 (April 1st – June 30th)

Nothing significant to report.

Updates for Q4 FY2025 (July 1st – September 30th)

Nothing to report

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report.

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Continue working on the proposed subtasks.

Updates for Q1 FY2025 (October 1st – December 31st)
Analyze offshore Wind/Wave farm layout optimization under uncertainty

Updates for Q2 FY2025 (January 1st – March 31st)
Finish the design and analysis of a new location model that involves various decisions relevant to the MREG and MREE supply chain. Formulate a model for offshore Wind/Wave farm layout optimization under uncertainty

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report

Updates for Q1 FY2025 (October 1st – December 31st)
Developed a new application-agnostic framework for modeling uncertainty in decision-making problems. This framework will be tailored to model uncertainty in supply chain optimization problems. A paper detailing the results (Man Yiu Tsang and Karmel S. Shehadeh.On the Trade-Off Between Distributional Belief and Ambiguity: Conservatism, Finite-Sample Guarantees, and Asymptotic Properties) was invited for revision in INFORMS Journal on Optimization (a top-tier journal). The same paper won second place in the 2024 YinzOR Student Conference Flash Talk Competition (by the student supported through this grant)

Updates for Q2 FY2025 (January 1st – March 31st)
The paper related to modeling uncertainty (Man Yiu Tsang and Karmel S. Shehadeh. On the Trade-Off Between Distributional Belief and Ambiguity: Conservatism, Finite-Sample Guarantees, and Asymptotic Properties) was accepted in INFORMS Journal in Optimization: https://doi.org/10.1287/ijoo.2024.0047.

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Impact

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Nothing to report

Updates for Q1 FY2025 (October 1st – December 31st)
Nothing to report

Updates for Q2 FY2025 (January 1st – March 31st)
Nothing to report

Updates for Q3 FY2025 (April 1st – June 30th)
Nothing to report

Updates for Q4 FY2025 (July 1st – September 30th)
Nothing to report

Task 22.0 Storage Integration across MRE – from Power Grid to Blue Economy Markets

Major Project Goals and Objectives

Grid connected MRE with integrated storage, additional objectives like market opportunities will be explored. AMEC's laboratory microgrids, including CSI's Green Energy Hub Microgrid deployed at Jennette's Pier, and the energy-water microgrid (EWM) at Shoals Marine Lab (energy storage in batteries and as desalinated potable water) will be evaluated as test case.

Project Activities Completed

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

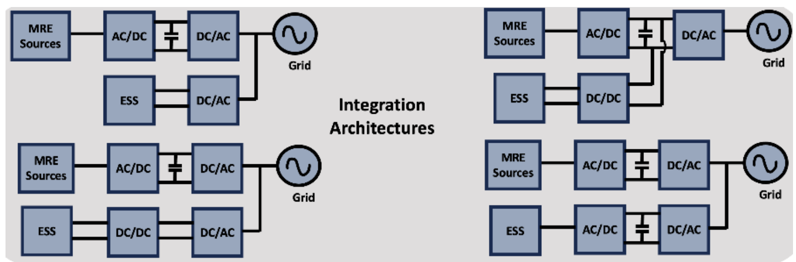
Updates for Q4 FY2024 (July 1st – September 30th)
Initiated comprehensive literature review focusing on MRE (Marine Renewable Energy) integration with energy storage systems.

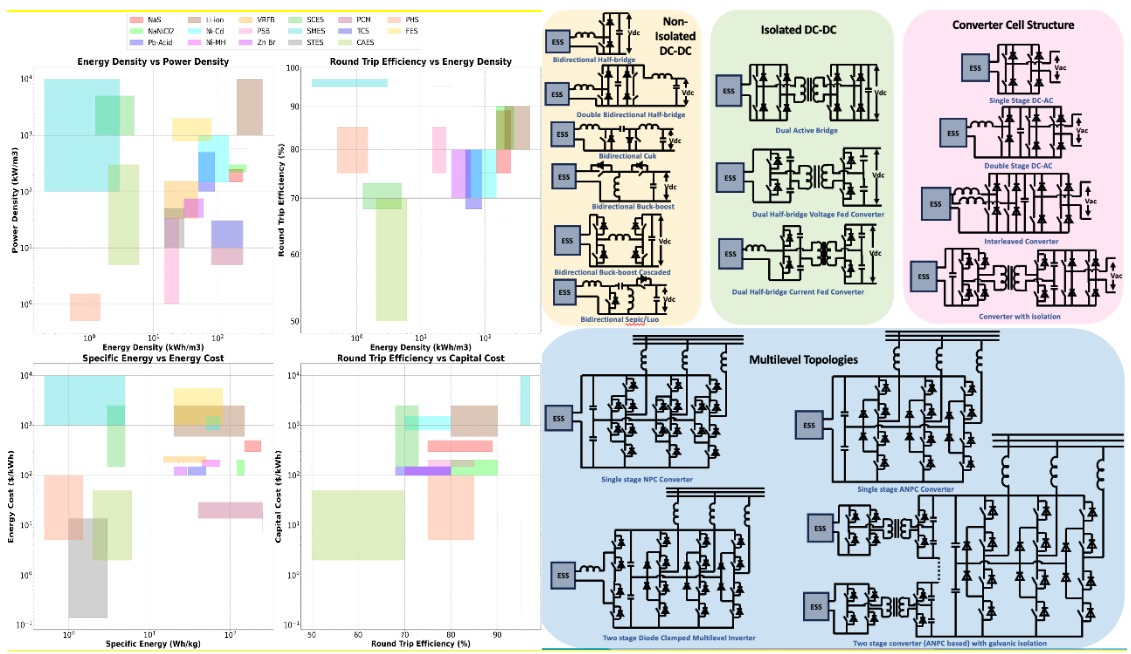
Collaborations established with team members from SBU, Lehigh, UNH, and NCSU to gather foundational knowledge and set up a test-bed at each location.

Preliminary analysis of existing energy storage models and power conversion designs, with a focus on DC-DC converters, inverters, and rectifiers suitable for MRE integration.

Published two papers in UMERC 2024:

- Enhancing Tidal Energy Integration: A Simulation-Based Comparative Study of Grid Following and Grid Forming Converters for Stability and Integration.
- Bridging the Seas: A Review on Integrating Energy Storage with MRE Sources.





The image illustrates various architectures for integrating energy storage systems (ESS) with MRE microgrids, the types of power electronics converters employed, and a comparative analysis of different energy storage technologies based on key performance parameters.

Updates for Q1 FY2025 (October 1st – December 31st)

Noteworthy accomplishments

➢ **Subtask 22.1: MRE Energy Storage Modeling**

- Developed and tested an economic dispatch model integrating MRE systems with a microgrid and desalination system, using site-specific electricity, water demand, and NOAA wave data.
- Formulated optimal dispatch with constraints for power, battery, and water balance, producing preliminary results on grid imports, water demand, tank levels, and RO production.

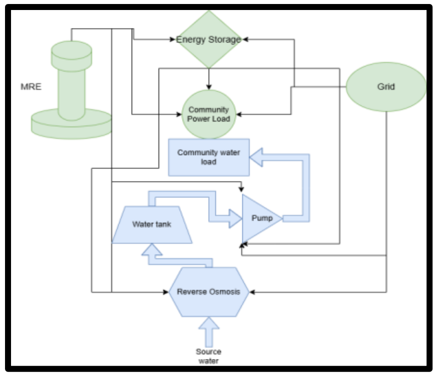


Figure 22.1.1. System Model for Economic Dispatch Analysis

Preliminary results

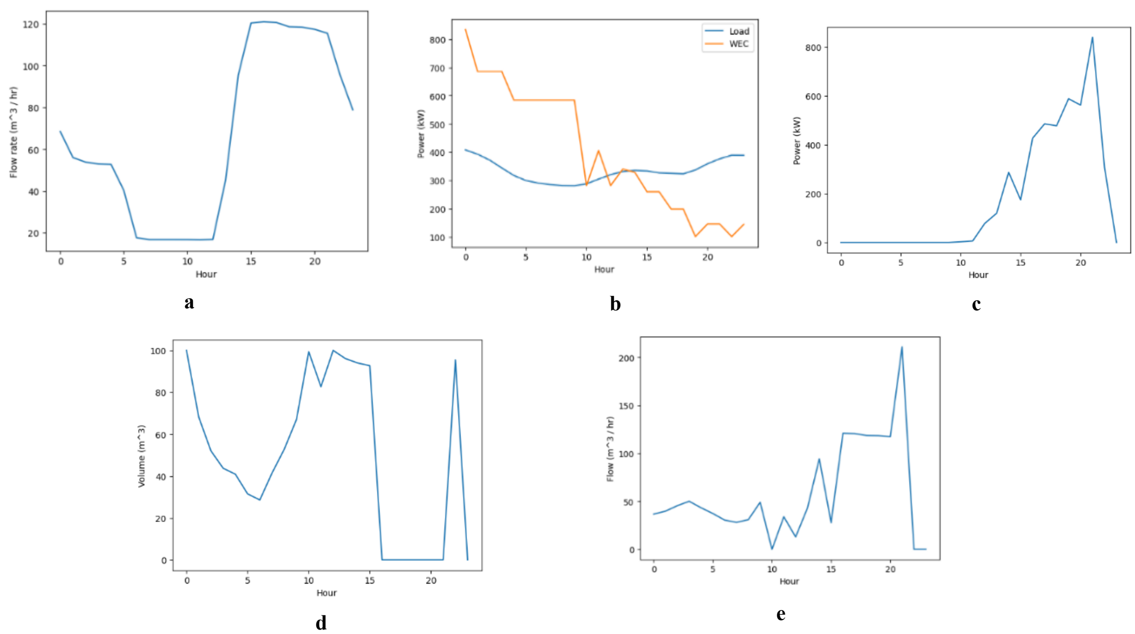


Figure 22.1.2. a. Community water demand **b.** The community electrical load vs the available WEC power for one day **c.** The power imported from the grid **d.** Water tank level **e.** RO production

- ➢ **Subtask 22.3: Resilient MRE Energy Storage Platforms**
- Integration of 339.2 V Battery with CE+T Stabiliti (Microgrid):
- The 339.2 V battery, acquired in 2023, has been thoroughly tested and is now ready for integration with the CE+T Stabiliti. The battery underwent operational testing using a resistive load, which verified its performance within the expected range.
- Additionally, the CAN communication of the Battery Management System (BMS) was successfully validated by connecting it to computer software via a CAN-to-

USB converter. The tests confirmed accurate monitoring and proper functionality of the BMS.

- With these positive results, the battery is fully prepared for integration with the microgrid.

➢ **Subtask 22.5: Establishment of Programmable Platforms for MRE Integration**

- Benchmarking MRE power conversion in MATLAB/Simulink for efficiency, reliability, and grid integration.
- **Hybrid energy system with tidal and battery is developed to understand:**
  - ❖ Source and Load Dynamics Impact.
  - ❖ Co-Existence of Different Loads.
  - ❖ Battery energy system leveraging SOC-based droop control to optimize power distribution and enhance operational resiliency under diverse dynamic conditions.

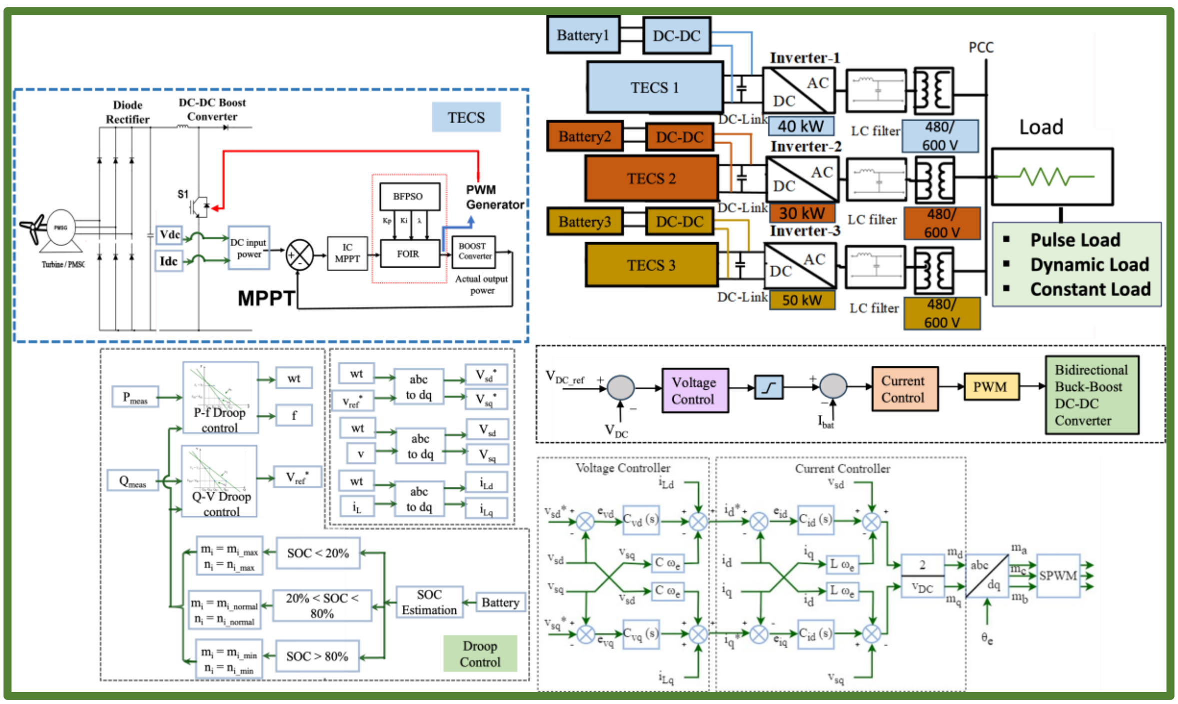
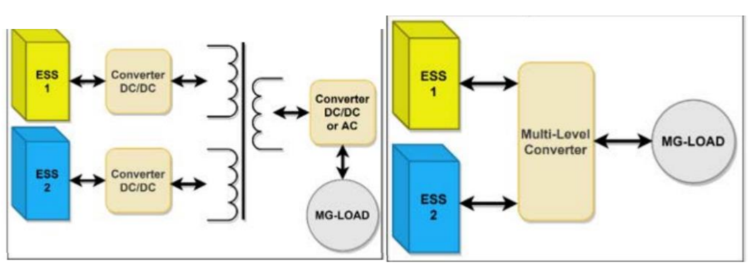


Figure 22.5.1. Hybrid system benchmarking with PMSG based tidal energy conversion system and battery with SoC-based Droop Control.

DC-DC Converter Topology

1. **Bidirectional Buck-Boost Converter**
2. DAB Converter
3. Multiport Converter/Multilevel



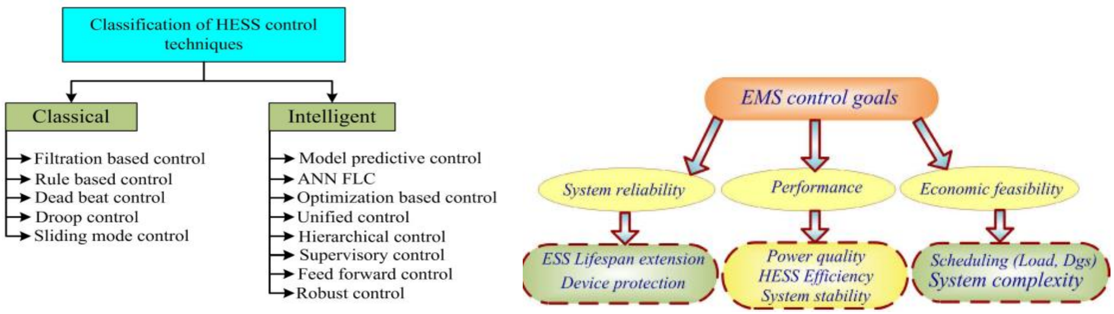
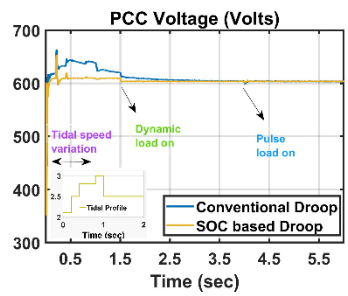


Figure 22.5.2. Converter topologies and architecture with EMS control techniques and goals.

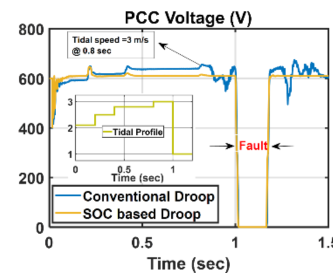
❖ Simulation Results:

Events	Dynamics	Rating	Duration (sec)
1	Constant Z Load	P=25 kW Q=5 kVAR	t_{on}=0
2	Constant Resistive Load	P=5 kW	t_{on}=0
3	Pulse Load	P=10 kW	t_{on}=4 t_{off}=4.05
4	Dynamic Load	P=10 kW Q=3 kVAR	t_{on}=1.5
5	Tidal speed variation	2.1 m/s - 3 m/s	t_{on}=0-1
5	Symmetrical Fault	-	t_{on}=1-1.167

(a)



(b)



(c)

Figure 22.5.3. (a). Load ratings with different dynamics **(b).** Comparison of Voltage at PCC under different Dynamics **(c).** Comparison of Voltage at PCC during Fault.

Updates for Q2 FY2025 (January 1st – March 31st)

Subtask 22.1: MRE Energy Storage Modeling

- Collected WEC, electric load, and water demand data over a month-long period to run a case study using the model
- Refined the optimization model to allow for the simultaneous optimal sizing of the energy storage system.
- Added pumped hydro storage and compressed air energy storage to the optimization formulation

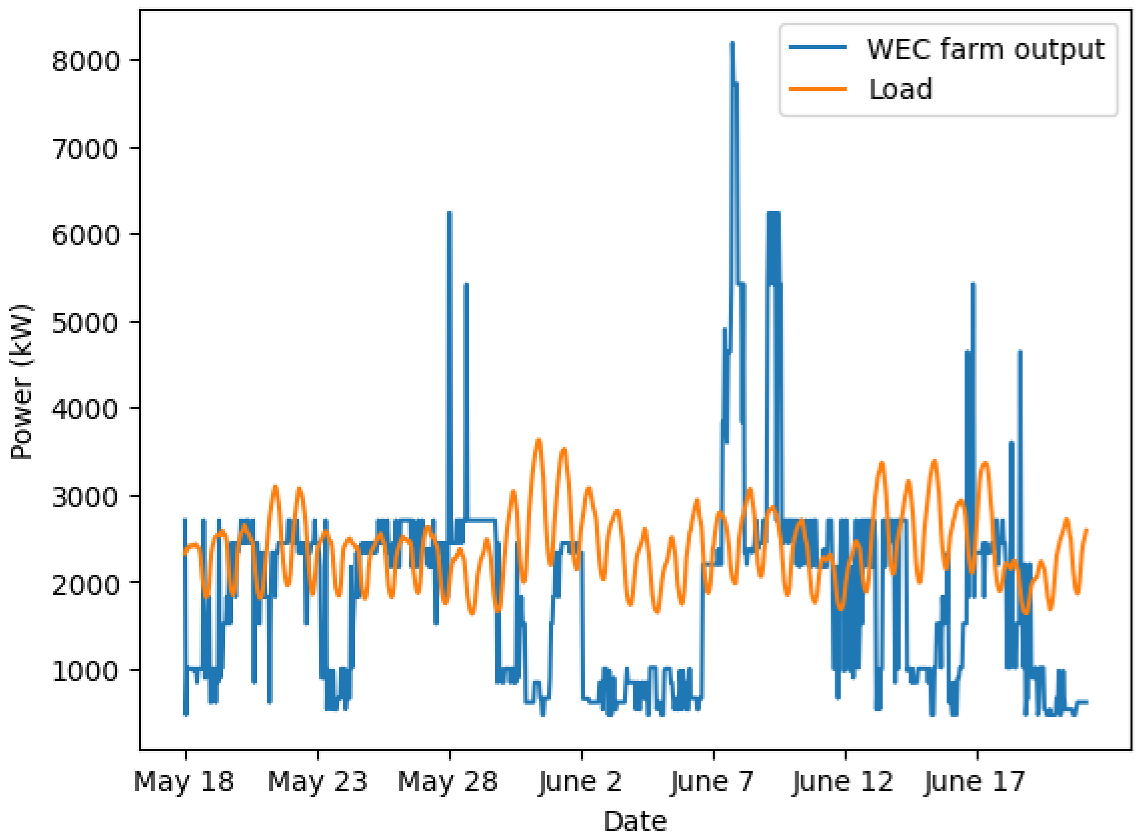


Figure 22.1.3. The WEC power output and electricity load for the case study period

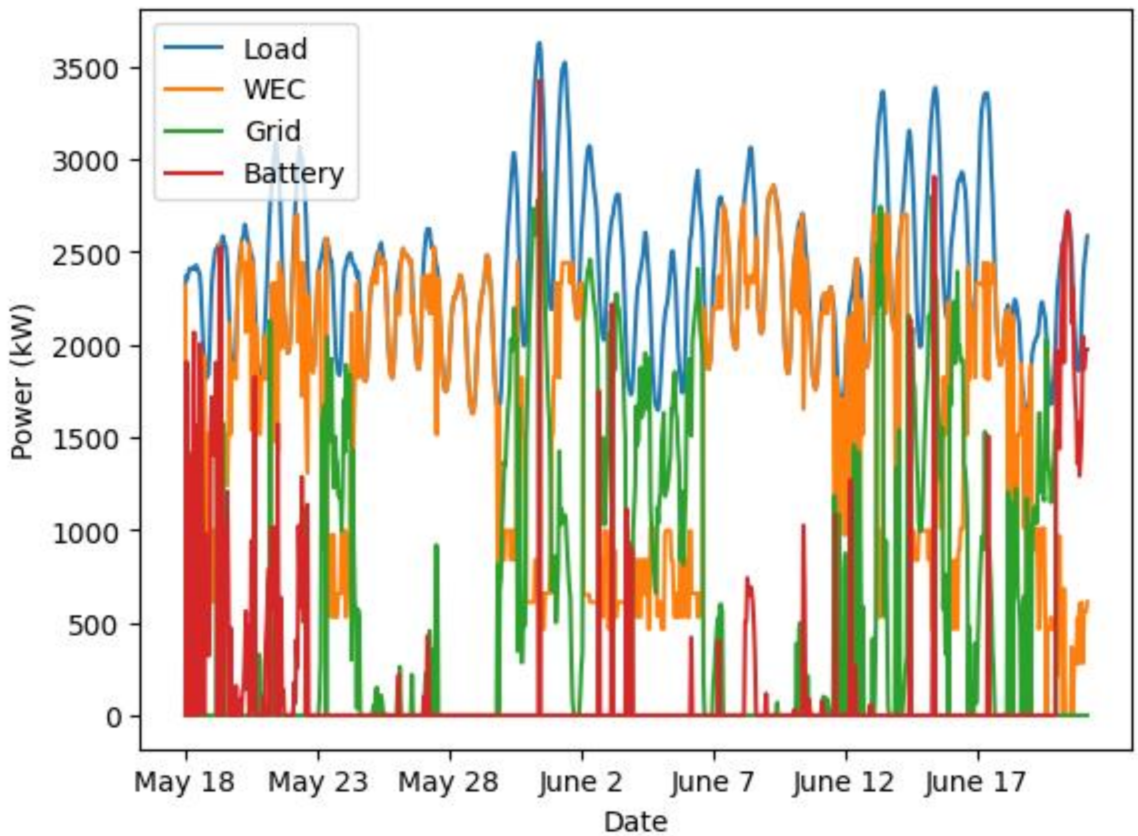


Figure 22.1.4. The optimal electricity dispatch during the same period

Subtask 22.3: Resilient MRE Energy Storage Platforms

- ✓ **Implementing and validating Constant-Current, Constant-Voltage (CC-CV) charging method for the 100Ah, 350 V battery using the CE+T Stabiliti (Microgrid):**

  - ➢ The 100Ah, 350V battery, previously validated through resistive load testing and CAN-based BMS communication, was successfully integrated with the CE+T Stabiliti Multiport Converter (2nd node of the AMEC microgrid).
  - ➢ Using the Constant-Current (CC) and Constant-Voltage (CV) charging method, the CE+T Stabiliti, configured in NET mode (it supplies all the power needed after the other supply in different ports), charged the battery.
  - ➢ During operation, all three ports of the Stabiliti were active: the PV port (DC3) supplied 1.5 kW, while the AC grid input (Port AC1, 480 V) supplied an additional 4.1 kW. A total of 5.5 kW was delivered to the battery connected to Port DC2.
  - ➢ This demonstrates successful coordination between PV and grid sources in charging the battery under real microgrid operating conditions.

Figure 22.3.1. Experimental results of battery charging (CE+T GUI).

<u>Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification</u>

✓ **Battery-Assisted Unified Power Quality Conditioner for Power Quality Improvement in Tidal-Driven microgrid**

- ➢ Implemented battery-assisted UPQC for a tidal-powered microgrid (Figure 22.5.1).
- ➢ Mitigated voltage and current disturbances via series–shunt compensation.
- ➢ Battery stabilizes the DC link during transients and generation variability (Figure 22.5.3.a and b).
- ➢ MATLAB/Simulink model confirms reduced harmonics and voltage deviations.
- ➢ Improved grid stability and ensured reliable power delivery.

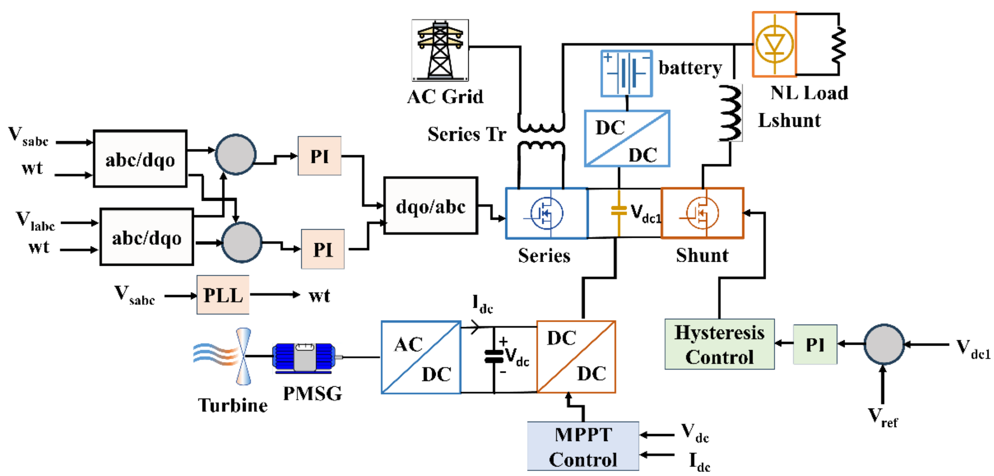


Figure 22.5.1. Power Conversion Architecture of Tidal Energy-based Microgrid with Control.

✓ **Preliminary Simulation for Grid-Tied Point-Absorption Wave Energy-based Energy System with Control Architecture using MATLAB/Simulink**

- ➢ Implemented a Point Absorber Wave Energy Converter (PAWEC) connected to the grid. (Figure 22.5.2)
- ➢ Diode rectifier is used for machine side converter and active Inverter is used for Grid side converter (with DC-link voltage and grid current control: Figure 22.5.3.c).

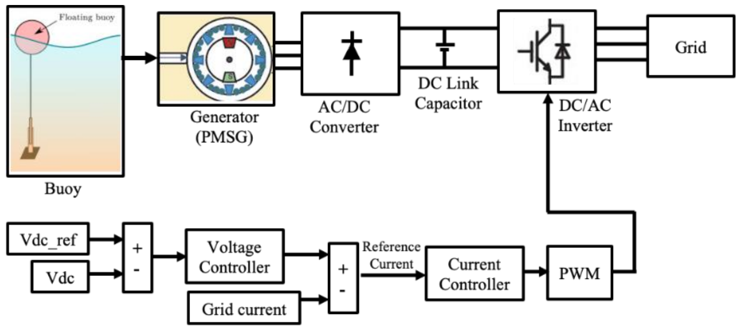


Figure 22.5.2. Preliminary Simulation for Grid-Tied Point-Absorption Wave Energy-based Energy System with Control Architecture.

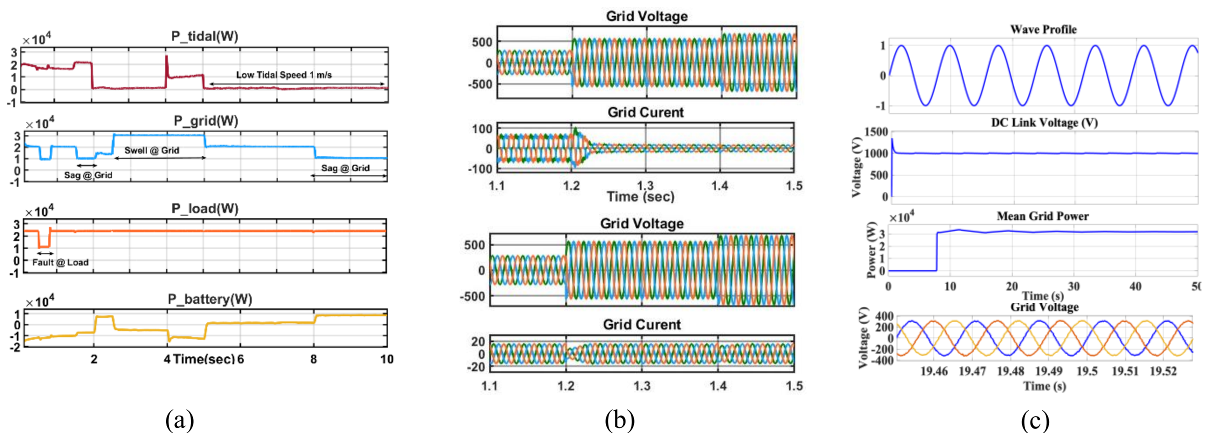


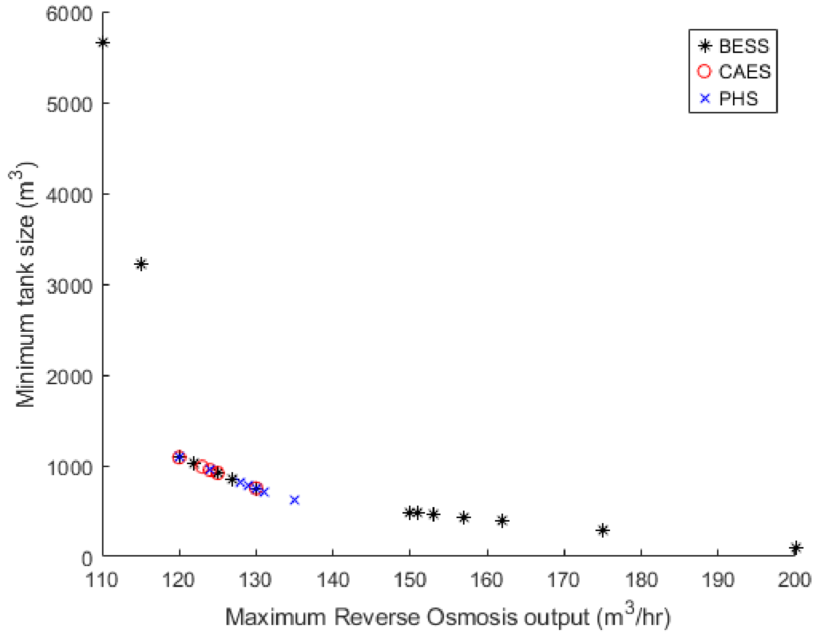
Figure 22.5.3.a: Active power profiles of system components under varying grid and load conditions. Figure 22.5.3.b: Grid Voltage and Current (a) Without Battery (b) With Battery. Figure 22.5.3.c: Preliminary results of grid tied WEC

Updates for Q3 FY2025 (April 1st – June 30th)

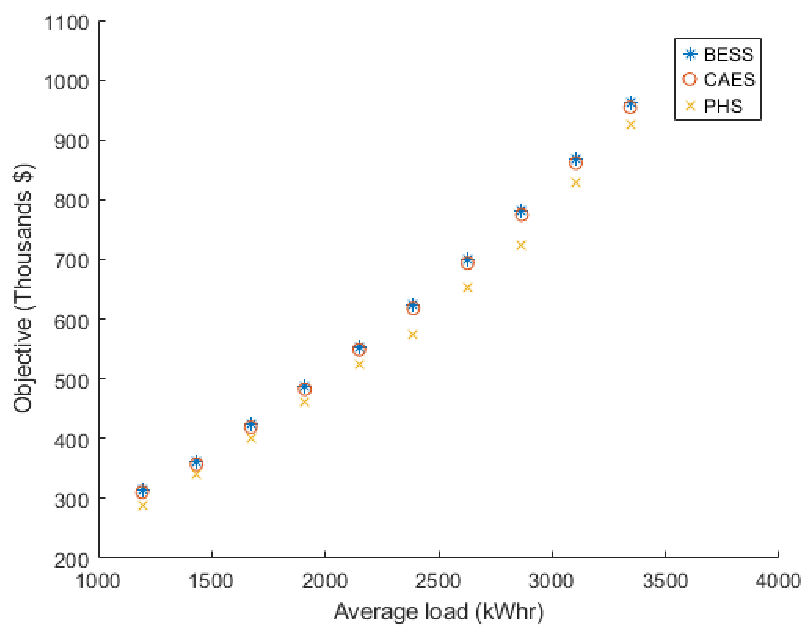
<u>Subtask 22.1: MRE Energy Storage Modeling</u>

<u>Subtask 22.3: Resilient MRE Energy Storage Platforms</u>

- Studied sizing of RO desalination system and water tank
- Performed sensitivity analysis on model. Varied:
- Cost of scheduling component power
- Amount of electrical load
- Amount of water load



The minimum possible tank size with different RO system outputs



The objective function value for the microgrid dispatch with three types of storage (battery energy storage system (BESS), compressed air energy storage (CAES), and pumped hydro storage (PHS)). The objective is reported for different mean electrical loads.

<u>RIAPS-Based Control of Node 1 and Node 2 in the AMEC Microgrid to charge the 100Ah, 350V BESS:</u>

The team successfully implemented RIAPS-based control for AMEC Node 1 (CE+T Stabiliti 2) and AMEC Node 2 (CE+T Stabiliti 1) in the marine DC microgrid. Leveraging the RIAPS platform, both CE+T Stabiliti units were controlled, enabling the charging of a 100Ah, 350V EV battery using solar power supplied through the DC port of CE+T Stabiliti 2 in AMEC Node 1.

Figure 22.3.1 illustrates the experimental setup used to test coordinated battery charging using power from both the PV array and the AC grid. The CE+T Stabiliti system effectively managed power flow across its ports to optimize energy distribution. In the setup, the PV array connected to port DC3_1 of CE+T Stabiliti 2 (AMEC Node 2) generated 3.5 kW. This power was transferred through the internal DC Bus shared between the DC ports of AMEC Node 1 and Node 2.

From the DC Bus, 2.4 kW was allocated to supply the 100Ah, 350V EV battery connected to DC2_2 of CE+T Stabiliti 1 (AMEC Node 1). The remaining power was either routed to other ports or lost as conversion inefficiencies. Specifically, port AC1_1 operated as a sink, drawing approximately 0.5 kW, with a small portion of energy lost in the AC conversion stage. The battery ultimately charged at a rate of 2.2 kW, indicating minor energy loss in the charging process. Despite these losses, the DC Bus consistently delivered 2.4 kW to the CE+T unit, confirming reliable and stable power transfer. This test demonstrated the system's ability to prioritize battery charging using PV energy under MPPT (Maximum Power Point Tracking) control while minimizing dependency on grid power. The setup successfully maintained port-level energy balance, confirming effective integration and coordination between AMEC Nodes 1 and 2 through the RIAPS framework.

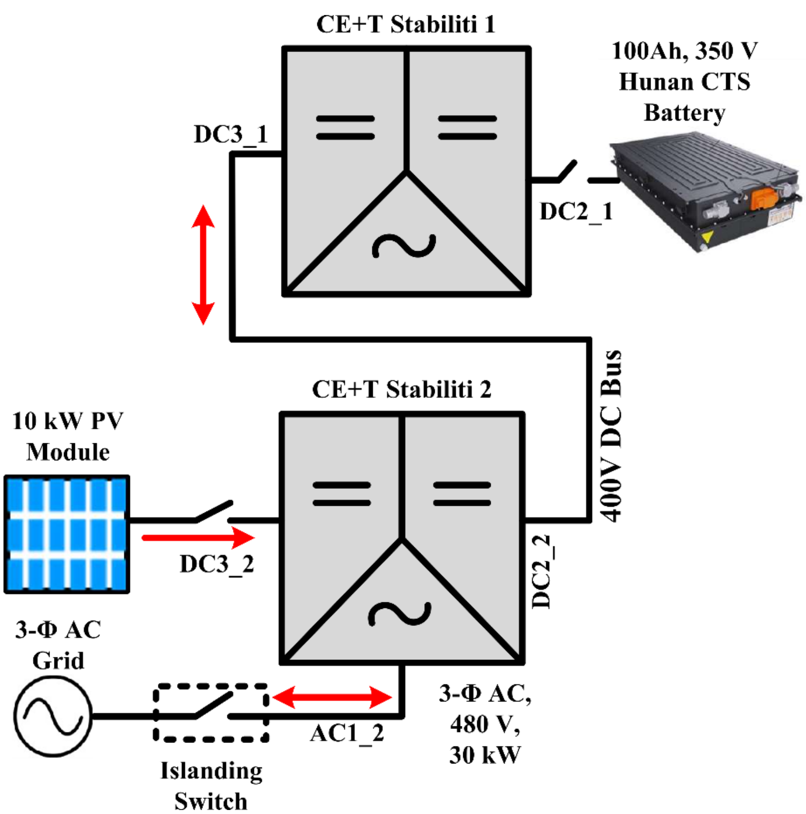


Fig. 22.3.1: Experimental Configuration of Operating two CE+T Stabiliti together to charge the battery using renewable energy (PV).

Fig. 22.3.2: GUI of both the CE+T Stabiliti, demonstrating the power flow to charge the battery.

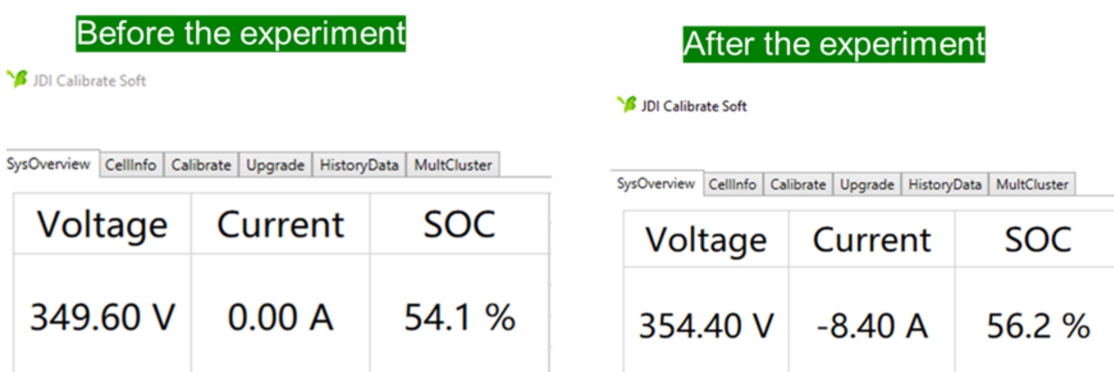


Fig. 22.3.3: BMS GUI of the 100Ah, 350V Battery before and after the test of operating both CE+T Stabiliti together.

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification

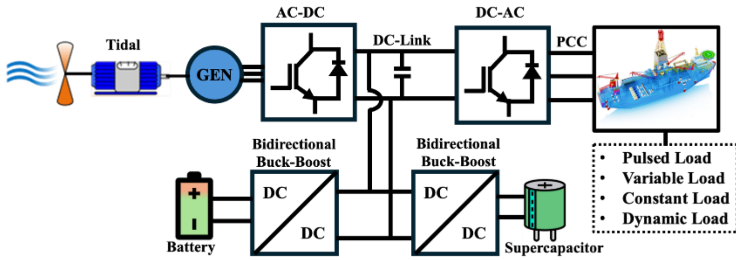


Figure. 22.5.1 : Integrated Tidal Energy System with Hybrid Energy Storage and Load

This study presents a coordinated control and energy management framework for a hybrid marine energy system integrating tidal energy converters with a Battery Energy Storage System (BESS) and a Supercapacitor Energy Storage System (SCESS). The proposed architecture exploits the complementary characteristics of individual resources. Tidal energy, with its cyclical and highly predictable nature, serves as the base contributor, ensuring consistent supply. To smooth input variability and ensure consistent delivery, the hybrid system employs a two-tier storage strategy: the BESS supports medium-duration balancing and steady-state loads, while the SCESS handles short-duration, high-frequency power fluctuations from load transients.

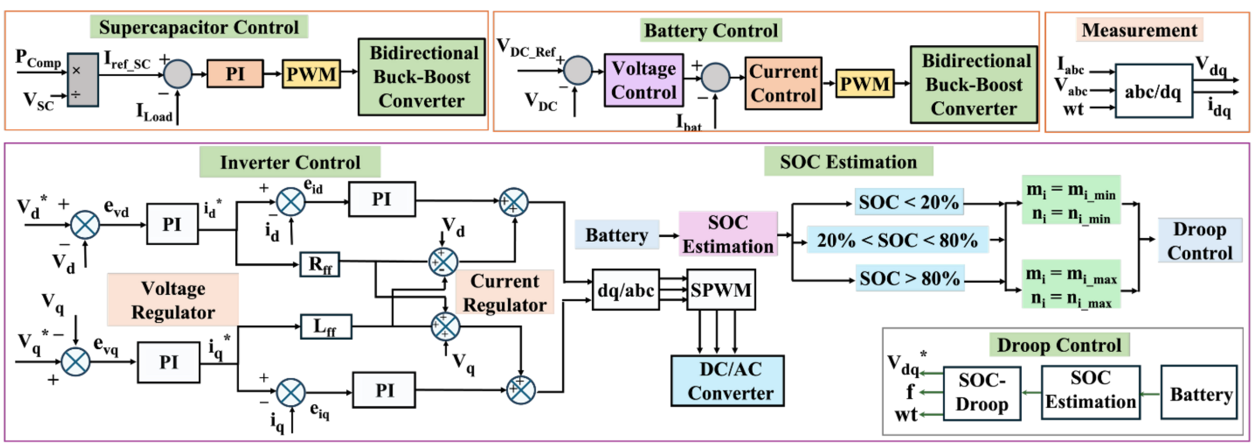


Figure. 22.5.2 : Coordinated Control Architecture Incorporating Droop Mechanism, Inverter Regulation, and Energy Management

A hierarchical coordinated control algorithm is developed, combining droop control principles with state-of-charge (SOC)-aware strategies for optimal energy sharing. Tidal converter operates under Maximum Power Point Tracking (MPPT) control to ensure optimal energy extraction under varying environmental conditions. The energy management system differentiates between long- and short-term power needs using a multi-time scale approach: the SCESS responds rapidly to sudden transients, while the BESS is engaged for sustained power support based on SOC levels and load forecasts. This coordinated response improves the dynamic performance of the system, reduces battery stress, and extends its operational lifespan by minimizing high-frequency cycling.

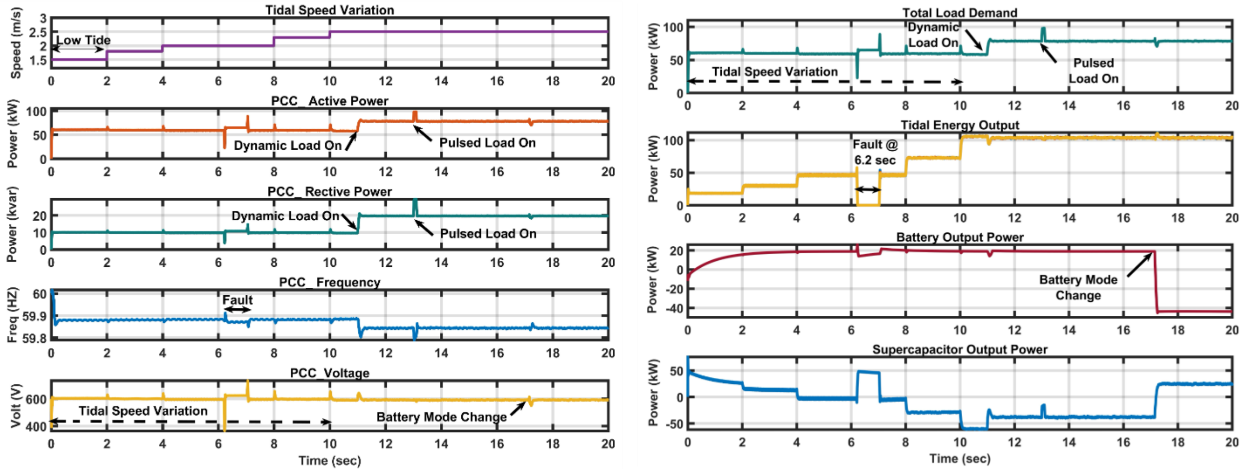


Figure. 22.5.3 : Dynamic Response of Tidal-HESS: Voltage, Frequency, and Power Coordination

The effectiveness of the proposed strategy is validated through a comprehensive simulation model developed in MATLAB/Simulink. The model includes realistic tidal input profiles, converter dynamics, and detailed storage system characteristics. Multiple operational scenarios are evaluated, including variable tidal speeds, sudden load changes, and combined disturbances. Simulation results demonstrate the capability of the hybrid system to deliver high-quality, stable power with reduced voltage and frequency deviations. The coordinated control mechanism ensures smooth transitions between power sources, efficient use of storage, and robust operation even under challenging marine conditions.

We observe that the tidal-based hybrid system maintained stable operation under variable load and fault conditions, with the supercapacitor effectively managing fast transients while the battery handled sustained energy balancing. The PCC voltage and frequency remained within acceptable limits during disturbances, and smooth mode transitions ensured reliable power delivery without instability, validating the system's suitability for autonomous marine microgrids with coordinated control.

Updates for Q4 FY2025 (July 1st – September 30th)

Subtask 22.1: MRE Energy Storage Modeling:

- Presented a poster at UMERC 2025 in Corvallis, Oregon, entitled: "Optimal selection of energy storage systems for an islanded community with desalination powered by wave energy."
- Worked on writing findings into a journal article.

Subtask 22.3: Resilient MRE Energy Storage Platforms

Development of Distributed Control for the AMEC Microgrid

As the AMEC marine DC microgrid grows to include multiple converters and renewable sources, centralized control becomes less practical and more failure-prone. A distributed control strategy is therefore adopted to enhance scalability, resilience, and autonomous coordination. Each node—equipped with its own multiport converter and BeagleBone RIAPS controller—acts as an intelligent agent that exchanges local data with neighbors to achieve system-level goals such as power sharing, bus stability, and fault tolerance. This approach follows FREEDM's modular, plug-and-play architecture, allowing each converter cluster to operate independently while sustaining a common 400 V DC bus.

The system comprises three nodes: **Node 1 (CE+T 1)** with PV and grid ports, **Node 2 (CE+T 2)** with battery and grid ports, and **Node 3 (10 kVA MPC)** hosting a DC/DC converter that regulates the 400 V bus and an AFE with split-phase inverter for AC loads and electrolyzer operation. The **primary layer** implements local droop control for voltage and current regulation, while the **secondary layer**—enabled through the RIAPS publish/subscribe network—uses a consensus algorithm to coordinate normalized power and balance the storage state of charge. Node 3 acts as the bus-forming unit, and the CE+T nodes follow droop-based current references corrected by distributed feedback.

Each RIAPS agent publishes local variables (power, current, voltage, and SoC) and subscribes to its neighbors' data to compute the consensus error

$$e_i = \sum_{j \in \mathcal{N}_i} (s_i - s_j), \quad s_i = \frac{P_i}{P_{i,\text{rated}}}$$

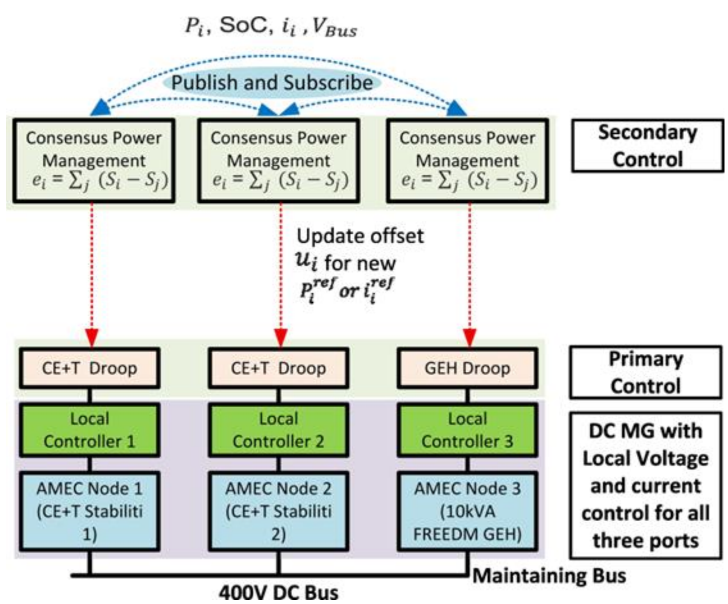


Fig. 22.3.1: Proposed distributed control structure for the AMEC Microgrid.

The resulting offset ui updates the droop coefficient or reference in the converter DSP, ensuring uniform normalized power across nodes. This distributed framework supports plug-and-play operation, maintains power balance under partial communication loss, and enables real-time coordination via RIAPS. Future stages will extend the framework to tertiary cooperative optimization for grid interaction and economic dispatch.

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification

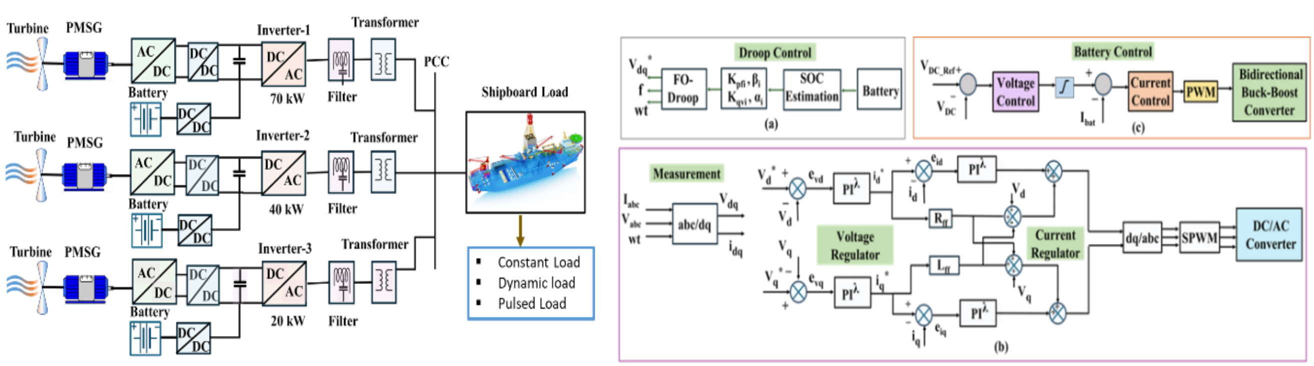
1. Development of Advanced FO-SoC Droop Control for Hybrid Tidal–Battery Systems

A Fractional-Order State-of-Charge (FO-SoC) droop control with Fractional-Order PI (FOPI) controller is proposed for hybrid tidal–battery systems to enhance power quality and resilience under tidal and load variations. The FO-SoC droop adaptively adjusts coefficients and fractional exponents (α, β) based on battery SoC for intelligent power sharing and stability, while the FOPI controller improves transient response and damping by accounting for both error magnitude and rate of change. Together, they ensure smooth dynamics, balanced battery usage, and stable operation under varying marine conditions. Figure 22.5.1 illustrates the simulated system and proposed control architecture.

- **FO-SoC Droop:** ***Energy-aware, nonlinearly scaled sharing***

$$V_{\text{out}} = V_{\text{ref}} - (K_{qv}^{\alpha})Q_{\text{meas}} \qquad f_{\text{out}} = f_{\text{ref}} + f_{\text{adjust}} - (K_{pf}^{\beta})P_{\text{meas}}$$

- **FO-Droop Coefficients (K_{qv}^{α} and K_{pf}^{β}) adapts based on SoC of batteries.**

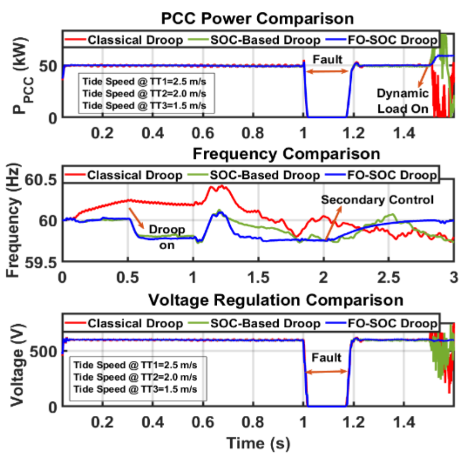


(a)

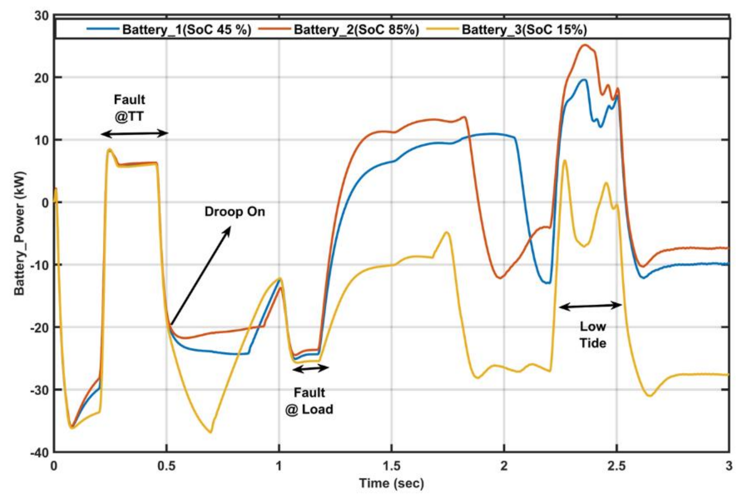
(b)

Figure. 22.5.1: (a) Simulated system architecture with multi-turbine generation, batteries and loads (b) Control Architectures: (a) Droop Control (b) Inverter Control (c) Battery Control

Simulations were conducted under various conditions, including constant, variable, and spatially varying tidal speeds, with identical (**45%**) and unequal initial SoCs (**45%, 85%, 15%**) under different dynamics including variation in load, tidal speed and faults. Figure 22.5.2 (a) shows simulation results under spatially varying tidal speed, where each tidal turbine operates under different tidal speed (varying between 1-3 m/s) and unequal SoCs under different events. The FO-SoC droop remains stable under tidal and SoC variations, whereas SoC-based and classical droop controls exhibit overshoot and instability under dynamic loading conditions. Figure 22.5.2 (b) shows FO-SoC droop adaptively adjusts battery output—high SoC batteries supply more during faults, while low SoC units conserve power, ensuring balanced response and longevity.



(a)



(b)

Figure. 22.5.2: (a) PCC Parameters at spatially varying tidal speed with unequal SoCs. (b) Battery power responses under a sequence of faults and tidal variations.

Performance Across Scenarios

- ❖ **Constant Tide**: FO-SoC → lowest voltage deviation; SoC-based → best frequency control; Classical → inefficient battery usage
- ❖ **Variable Tide**: FO-SoC remained stable; SoC-based and Classical → oscillations during low-tide
- ❖ **Spatially Varying Tides**: Only FO-SoC sustained stable operation under SoC imbalance and asynchronous inputs

2. CHIL Validation of Grid-Forming Control

The initial CHIL setup for validating grid-forming control of tidal energy conversion systems has been established using the Typhoon HIL platform. Preliminary tests with variable tidal speeds, load transients, and voltage/frequency disturbances have been initiated to assess system behavior. Early results indicate stable voltage and frequency regulation, smooth operational transitions, and effective droop control performance. Figure 22.5.3 illustrates the overall tidal energy conversion system architecture with droop-based control, the Typhoon HIL testbed at Stony Brook University, and corresponding SCADA interface. It includes system response plots under changing tidal speeds and load variations, demonstrating stable voltage, frequency regulation, and effective droop control during CHIL testing.

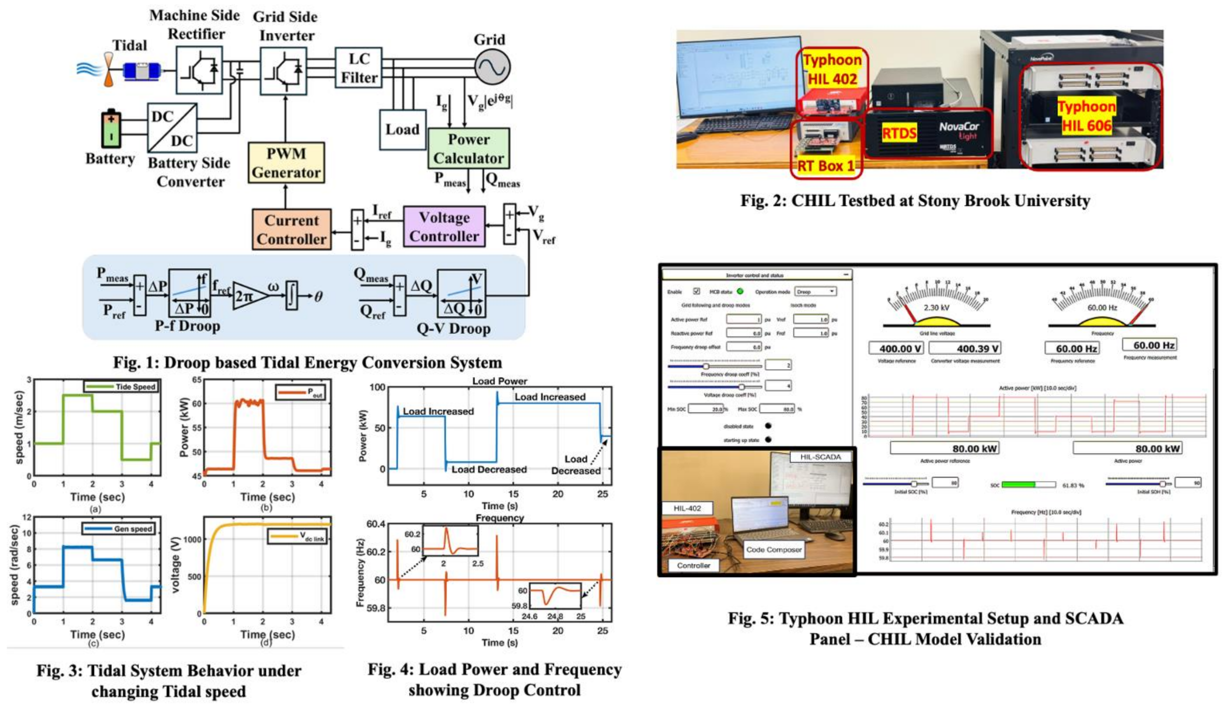


Figure. 22.5.3 CHIL setup for tidal energy grid-forming control.

Reflection on Progress

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

- Literature review and collaborations with partners have progressed smoothly.
- The project is on track for the November 2024 milestone for completing the literature review.
- Preliminary modeling and simulation work for MRE energy storage integration is to be started by December 2024.

Updates for Q1 FY2025 (October 1st – December 31st)

- **D22.1.1** – "Mathematical model": Modeling started: The subtask is on track.

- **D22.3.1** – "Resilient MRE Energy Storage Platforms": The subtask is on track.
- **M22.5.1** – "Power converter integrated programmable microgrid for resilient ESS and MRE integration": Benchmarking Started: The subtask is on track.

Updates for Q2 FY2025 (January 1st – March 31st)

Subtask 22.1: MRE Energy Storage Modeling - The model is completed, and a case study has been developed to test the model and compare energy storage methods for wave energy. The project is progressing.

M22.3 – "Resilient MRE Energy Storage Platforms": An ESS (Battery) was integrated and tested with one node of the AMEC marine DC microgrid. The subtask is on track.

M22.5.1 – "Power converter integrated programmable microgrid for resilient ESS and MRE integration": Power quality improvement strategies using ESS (Battery) and FACTS devices have been completed. Preliminary models for the integration of Wave Energy Converters (WEC) and supercapacitor-based hybrid energy storage systems are currently under development. The subtask is on track.

Updates for Q3 FY2025 (April 1st – June 30th)

Subtask 22.1: MRE Energy Storage Modeling:

The analysis that has been carried out provides insight into the performance of storage systems with MRE. This analysis will help in design and decision making for microgrids with MRE and storage.

M22.3 – "Resilient MRE Energy Storage Platforms": Two nodes of the AMEC marine DC microgrid were successfully tested together to charge the battery. The subtask is on track.

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification:

This research highlights a promising pathway toward resilient, efficient, and autonomous marine microgrids suitable for islanded or remote coastal applications. By leveraging the strengths of tidal in conjunction with advanced hybrid storage technologies, the system offers enhanced flexibility, reliability, and grid compatibility.

Updates for Q4 FY2025 (July 1st – September 30th)

Subtask 22.1: MRE Energy Storage Modeling

- The progress for this task is as expected.

Subtask 22.3: Resilient MRE Energy Storage Platforms

- The subtask is on track.

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification:

- The progress is on schedule.

Challenges, Risks, Mitigation, and Requests

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

Challenges: No major issues identified at this stage.

Updates for Q1 FY2025 (October 1st – December 31st)

- **Subtask 22.3:** The team is waiting for a manual service disconnect (MSD) fuse for the battery to integrate with the microgrid.
- No significant challenges have been identified for another subtasks.

Updates for Q2 FY2025 (January 1st – March 31st)

- No challenges for subtask 22.3 have been found.
- No significant challenges have been identified for subtask 22.5.
- Subtask 22.1: MRE Energy Storage Modeling - The difficulty in finding data for loads other than desalination may make it difficult to do a detailed analysis on other blue economy applications, such as aquaculture. Despite this difficulty, research is continuing into other blue economy scenarios to analyze.

Updates for Q3 FY2025 (April 1st – June 30th)

Subtask 22.1: Nothing to report

Subtask 22.3: No challenges for subtask 22.3 have been found.

Subtask 22.5: No significant challenges have been identified for subtask 22.5.

Updates for Q4 FY2025 (July 1st – September 30th)

Subtask 22.1: MRE Energy Storage Modeling

- Nothing to report

Subtask 22.3: Resilient MRE Energy Storage Platforms: Nothing to report

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification: No significant challenges have been identified for subtask 22.5.

Plans for Next Quarter

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
We will continue conducting the literature review on resilience in energy storage systems, focusing on operational reliability and fault tolerance.

Advance work on the evaluation of performance of the Shoals Marine Laboratory's (SML) Energy-Water microgrid under different load scenarios.

Start modeling and simulations of energy storage integration with marine energy sources.

Updates for Q1 FY2025 (October 1st – December 31st)
Subtask 22.1:

- Enhancing system formulation by integrating multiple water demands, optimizing pump operations, improving water system realism, and incorporating diverse storage types.

Subtask 22.3:

- The next task is implementing and validating the Constant-Current Constant-Voltage (CC-CV) charging method for the 350 V battery using the CE+T Stabiliti.

Subtask 22.5:

- Enhancing operational resiliency and power quality by refining energy storage-integrated FACTS devices through advanced control strategies, enabling adaptive response to dynamic grid challenges.
- Developing intelligent and unified control algorithms for HESS integration, incorporating batteries, supercapacitors, and hydrogen storage.
- Validating the approach using SML data from Sustainable SML.

Updates for Q2 FY2025 (January 1st – March 31st)
<u>Subtask 22.1: MRE Energy Storage Modeling</u>

- Organize results and begin writing a research article.
- Perform detailed sensitivity analysis on economic parameters
- Explore other blue economy applications

Subtask 22.3: Resilient MRE Energy Storage Platforms

- Completing the integration of all nodes of the AMEC marine DC microgrid.
- Operating all the nodes of the AMEC microgrid, which consists of two CE+T Stabiliti MPC and the FREEDM Multiport converter (MPC).

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification

Advanced Coordinated Control and Energy Management of Hybrid Marine Energy System

- Hybrid system includes: **Tidal + Wave Energy Converters + Battery + Supercapacitor**
- Developed coordinated control strategies for **efficient power flow and grid interaction**
- **Grid support functionalities** addressed across different dynamic timescales:
    - **Supercapacitor**: fast dynamics (transient voltage/frequency response)
    - **Battery**: medium and slow dynamics (load balancing, energy smoothing)

Updates for Q3 FY2025 (April 1st – June 30th)

Subtask 22.1: MRE Energy Storage Modeling

- Write a research article based on the results obtained so far.

Subtask 22.3: Resilient MRE Energy Storage Platforms

- Operating all the nodes of the AMEC microgrid, which consists of two CE+T Stabiliti MPC and the FREEDM Multiport converter (MPC).

  Future work will involve real-time validation through Typhoon HIL-based testing, integration of fault detection mechanisms, and exploration of adaptive control strategies using machine learning and predictive analytics.

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification:

Next Quarter Plan: Integrate tidal generation with wave energy systems and deploy a hybrid energy storage solution consisting of batteries and supercapacitors to enhance reliability and support higher renewable penetration.

Future work: Real-time validation through Typhoon HIL-based testing, integration of fault detection mechanisms, and exploration of adaptive control strategies

Updates for Q4 FY2025 (July 1st – September 30th)
Subtask 22.1: MRE Energy Storage Modeling

- Publish a journal article.

Subtask 22.3: Resilient MRE Energy Storage Platforms:

The future task for this part of the project is to develop the RIAPS network configuration for the AMEC node 3 or for the 10kVA FREEDM GEH. We need to develop a droop control algorithm for the 10kVA FREEDM GEH as well then, we will start making the distributed control for the AMEC node 1 and 2. After successful implementation of distributed control for two AMEC nodes, we will implement the distributed control for all three nodes.

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification

- CHIL and Real-time validation of HESS integrated with tidal and wave energy.
- Comparative techno-economic analysis of different power converter architectures.
- Utilize a co-simulation framework combining Typhoon HIL and RTDS platforms.

Outputs

Updates for Q1 FY2024 (October 1st – December 31st)
Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)
Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)
Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)
Discussed value of a future in-person meeting at one of the labs.

Literature survey findings focusing on dominating energy storage technologies and their comparative analysis.

Two academic papers presented in UMERC (2024).

Collaboration established for integrating programmable platforms and power conversion designs.

Updates for Q1 FY2025 (October 1st – December 31st)

- **Review Paper Drafting:** compiling a comprehensive review paper by integrating findings from the literature survey, incorporating identified research gaps, and structuring content to highlight key advancements and future research directions.
- **Collaborative Knowledge Exchange:** Conducting structured monthly discussions with teams from SBU, Lehigh, and NCSU to refine insights and assess test-bed infrastructure.

Updates for Q2 FY2025 (January 1st – March 31st)

Subtask 22.1: MRE Energy Storage Modeling

- **Abstract submitted and accepted to UMERC 2025**

Subtask 22.3: Resilient MRE Energy Storage Platforms

- **Two digests have been submitted to ECCE 2025 and are under review.**

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification

- **Two papers have been accepted for presentation at UMERC 2025.**
- **Two additional papers have been submitted to ESTS 2025 and are under review.**

Updates for Q3 FY2025 (April 1st – June 30th)

Subtask 22.1: Nothing to report

Subtask 22.3: Resilient MRE Energy Storage Platforms

- **One paper submitted to ECCE 2025.**

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification:

- **Two papers have been accepted for presentation at UMERC 2025.**
- **Two additional papers have been accepted at ESTS 2025 and will be presented in August 2025.**

Updates for Q4 FY2025 (July 1st – September 30th)

Subtask 22.1: MRE Energy Storage Modeling

Poster presented at UMERC 2025: "Optimal selection of energy storage systems for an islanded community with desalination powered by wave energy."

Subtask 22.3: Resilient MRE Energy Storage Platforms

One paper presented in the ECCE 2025

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification:

- Two papers have been presented at ESTS 2025 in August 2025.
- Successfully completed benchmarking of the hybrid MRE system with a coordinated control architecture.
- Achieved real-time control validation for BESS integration using Typhoon HIL.
- Completed CHIL-based validation of grid-forming and grid-following tidal energy conversion systems.
- Submitted one review paper to IEEE Access; preparation of a second review paper is in progress.
- Presented two conference papers at ESTS 2025 and two posters at UMERC 2025.

Impact

Updates for Q1 FY2024 (October 1st – December 31st)

Nothing to report.

Updates for Q2 FY2024 (January 1st – March 31st)

Nothing to report.

Updates for Q3 FY2024 (April 1st – June 30th)

Nothing to report.

Updates for Q4 FY2024 (July 1st – September 30th)

The collaboration between institutions has improved knowledge transfer and facilitated groundwork for future MRE integration projects.

Updates for Q1 FY2025 (October 1st – December 31st)

- Enhancing MRE energy storage solutions through collective research efforts, structured updates, and cross-institutional collaboration.

Updates for Q2 FY2025 (January 1st – March 31st)

- This subtask strengthens collaborative efforts in integrating advanced energy storage systems with marine renewable energy sources, enabling reliable, high-quality grid support through joint institutional innovation.

Updates for Q3 FY2025 (April 1st – June 30th)

Subtask 22.1: Nothing to report

Subtask 22.3: This subtask significantly advances resilient energy storage integration for marine applications, enabling reliable energy buffering and dispatch in hybrid microgrid systems.

Subtask 22.5: This research enables resilient autonomous marine microgrids for remote coasts, leveraging tidal and hybrid storage to deliver stable, efficient, and reliable power.

Updates for Q4 FY2025 (July 1st – September 30th)

Subtask 22.1: MRE Energy Storage Modeling

- Nothing to report

Subtask 22.3: Resilient MRE Energy Storage Platforms: This work will validate the use of a 350V 100Ah BESS with the RIAPS based distributed control

Subtask 22.5: Establishment of programmable platforms for MRE integration, power conversion design and formal verification:

This research enables stable voltage and frequency regulation, fast transient recovery, and reliable power sharing under variable tidal speeds, dynamic loads, and unequal SoCs—directly improving grid stability, fault resilience, and operational reliability in hybrid marine microgrids.

Participants and Collaborators

Brief description of contribution. Note: only list key project personnel involved as partners. This must include the Principal Investigator and any person who has worked at least 160 hours on the project during the reporting period. Refer to FARC Section I.A.4 for details.

Highlight new participants in yellow.

Individual(s)

Name:	Martin Wosnik	Location:	Durham, NH
Role:	Principal Investigator	Number of months worked:	1.5
Contribution			
Contributions on Tasks (all)			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Chelsea Kimball	Location:	Durham, NH
Role:	Research Assistant, Ph.D. student	Number of months worked:	1
Contribution			
Contributions on Task 9, 17			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Janggeun Choi	Location:	Durham, NH
Role:	Post-Doctoral Scholar	Number of months worked:	0.72
Contribution			
Contributions on Tasks 6, 7, 15, 16			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Andressa Gutierrez	Location:	Durham, NH
Role:	Program Manager	Number of months worked:	1.5
Contribution			
Contributions on Tasks (all)			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Stephen Pamboukes	Location:	Durham, NH
Role:	Engineer	Number of months worked:	1.5
Contribution			
Contributions on Tasks 4, 5, 9, 14			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Ali Khosronejad	Location:	Stony Brook, NY
Role:	P.I. at Subrecipient	Number of months worked:	1
Contribution			
Contributions on Tasks 1, 3, 4, 8, 15, 16, 18 (all)			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Mustafa Aksen	Location:	Stony Brook, NY
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 15, 16, 18			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Mehrshad Gholami Anjiraki	Location:	Stony Brook, NY
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 15, 16, 18			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Jonathan Craig	Location:	Stony Brook, NY
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 15			

Foreign travel this period?	No
Collaboration with foreign entities this period?	No
If applicable: Countries of foreign collaborators?	N/A

Name:	Gabriel Narh	Location:	Stony Brook, NY
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 16			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Samin Shapourmiandouab	Location:	Stony Brook, NY
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 18			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Hossein Seyedzadeh	Location:	Stony Brook, NY
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 18			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		N/A	

Name:	Arindam Banerjee	Location:	Bethlehem, PA
Role:	P.I. at Subrecipient	Number of months worked:	1.25
Contribution			
Contributions on Tasks 1, 2, 3, 4, 10, 11, 12, 13, 19-21, (all)			
Foreign travel this period?		No	
Collaboration with foreign entities this period?		No	
If applicable: Countries of foreign collaborators?		No	

Name:	Shalinee Kishore	Location:	Bethlehem, PA
Role:	Co-P.I. at Subrecipient	Number of months worked:	0.125
Contribution			
Contributions on Tasks 1, 2, 3, 4, 10, 11, 12, 13, 19-21, 22, (all)			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		
Name:	Mohd. Hanzla	Location:	Bethlehem, PA
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 4			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Cong Han	Location:	Bethlehem, PA
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 16			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Urinrin Otite	Location:	Bethlehem, PA
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 19			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Tareq Abu Agolah	Location:	Bethlehem, PA
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 20			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Man Yiu Tsang	Location:	Bethlehem, PA
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 21			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Kevin Wycoff	Location:	Bethlehem, PA
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Task 22			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	George Bonner	Location:	Wanchese, NC
Role:	P.I. at Subrecipient	Number of months worked:	1
Contribution			
Contributions on Tasks 1,2, 3,4, 5, 10, 11, 12, 13, 14, (all)			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Lindsay Dubbs	Location:	Wanchese, NC
Role:	Co-P.I. at Subrecipient	Number of months worked:	0.5
Contribution			
Contributions on Tasks 1,2, 3,4, 5, 10, 11, 12, 13, 14, (all)			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Linda D'Anna	Location:	Wanchese, NC
Role:	Co-P.I. at Subrecipient	Number of months worked:	0.5
Contribution			
Contributions on Tasks 1, 2, 10, 11			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Jillian Eller	Location:	Greenville, NC
Role:	Research Assistant, PhD student	Number of months worked:	3
Contribution			
Contributions on Tasks 10, 11			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Name:	Amy Thompson	Location:	Wanchese, NC
Role:	Environmental Specialist	Number of months worked:	3
Contribution			
Contributions on Tasks 10, 11, 12, 13, 14			
Foreign travel this period?	No		
Collaboration with foreign entities this period?	No		
If applicable: Countries of foreign collaborators?	N/A		

Organization(s)

Name:	University of New Hampshire
Location:	Durham, NH
Contribution	
Facilities, research, personnel, in-kind contributions as cost-shared academic year salary of PI and Co-PIs. Co-P.I.s M.R. Swift and T.C. Lippmann and post-doc J.G. Choi have contributed to AMEC tasks during the last quarter, but lower than the 160 hour threshold.	

Name:	Stony Brook University
Location:	Stony Brook, NY
Contribution	
SBU provided the computational resources of Zagros cluster at the Civil Engineering Department (Zagros cluster), and the Seawulf cluster at the Institute for Advanced Computational Science.	

Name:	Lehigh University
Location:	Bethlehem, PA
Contribution	
The co-PIs at Lehigh, Banerjee and Kishore are spending 6.3% and 3.5% of their AY time on the project. Banerjee attends weekly AMEC Directors meetings and has been coordinating with other investigators at Lehigh (Suleiman and Sause) to respond to the DOE-EQ1 questions. In addition, the Lehigh leadership team is also actively recruiting additional faculty members to work on the Blue Economy space and address energy-water interdependency problems. The Supply Chain and Energy Storage teams at Lehigh have also been working with partners at CSI on the Stakeholder Engagement subtask.	

Name:	Coastal Studies Institute
Location:	Wanchese, NC
Contribution	
AMEC reps attended NHA Clean Currents including an exhibit booth and technical presentations (CSI, UNH). Co-Director, George Bonner, participated in NHA Marine Energy Council strategic planning session in November 2021 to establish industry commercialization goals and objectives. • CSI Co-Directors been active in UMERC kick-off sessions. Co-Director, George Bonner, briefed stakeholders on AMEC including Outer Banks Chamber of Commerce (17 Nov 21), Marine Energy Forum sponsored by SoFar (14 Dec 21), Congressman Murphy, NC-03 (17 Dec 21), Dare County League of Women Voters (22 Jan 22). Research contributions to Task 2.	

Special Reporting Requirements

Nothing to report

Budgetary Information

Financial data has been provided in an updated RPPR2 and SF-425, both of which have been submitted separately.