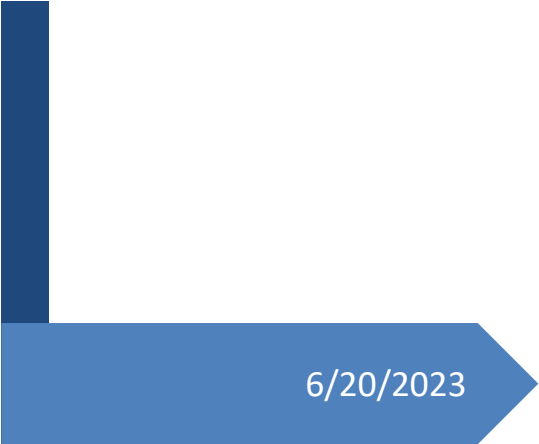
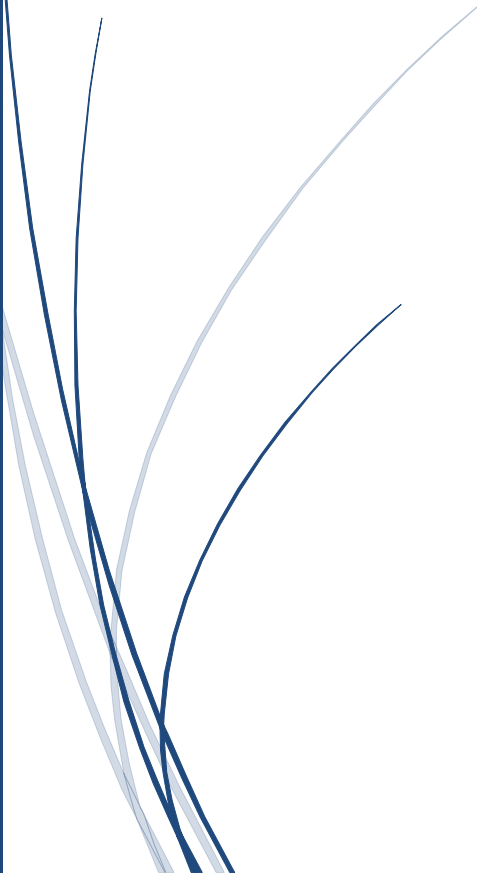


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6/20/2023

Quality Assurance Project Plan

Groundwater refugia for eelgrass restoration



Quality Assurance Project Plan (QAPP)

Groundwater refugia for eelgrass restoration

RAE/EPA Grant #: 84044301

Lead Organization: Stony Brook University & Peconic Estuary Partnership

Partner Organization: Old Dominion University

June 20, 2023



8/7/2023

Dr. Joyce Novak
Executive Director, Peconic Estuary Partnership
NEP PI Project Co-Manager

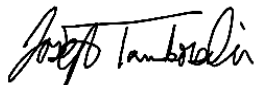
Date



8/7/2023

Dr. Bradley James Peterson
Professor, Stony Brook University
Lead Principle Investigator

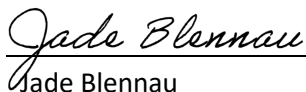
Date



8/7/2023

Dr. Joseph Tamborski
Assistant Professor, Old Dominion University
Co-Principle Investigator

Date



8/7/2023

Jade Blennau
Climate Adaptation and Community Coordinator
Peconic Estuary Partnership
NEP Outreach & Coordination

Date



8/7/2023

Dr. Phil Colarusso
EPA Quality Assurance
Quality Assurance Officer

Date



July 20, 2023

Suzanne Simon – Restore America’s Estuaries Grant Manager RAE Project Officer	Date
<i>Nancy Laurson</i>	7/20/23
Nancy Laurson – EPA Project Officer	Date
Brian Hulme EPA Region 2 Quality Assurance Officer	Date

Table of Contents

A3: Distribution List.....	5
Section A: Project Management	6
A4: Project Task/Organization	6
Peconic Estuary Partnership.....	6
Stony Brook University.....	6
Old Dominion University	6
Restore America’s Estuaries	6
EPA	6
A5: Problem Definition/Background	9
A6: Project Task Descriptions	11
Task 1: QAPP Development	12
Task 2: Initiation of team meetings	13
Task 3: Outreach.....	13
Task 4: Permit applications.....	14
Task 5: Identification of groundwater discharge.....	14
Task 6: Eelgrass seed collection.....	15
Task 7: Selection of restoration sites	16
Task 8: Test plantings and initial drone imagery	16
Task 9: Assessment of success metrics	17

Task 10: Large-scale restoration efforts	18
Task 11: Drone imagery post-restoration	18
A7: Quality Objectives and Criteria	18
Description of Data Acceptance	20
A8: Special Trainings/Certification	21
A9: Documentation and Records	21
Section B: Data Generation and Acquisition.....	22
B1: Sampling Process Design (Experimental Design)	22
B2: Sampling Methods.....	23
B3: Sample Handling and Custody.....	27
B4: Analytical Methods	33
B5: Quality Control	34
B6: Instrument/Equipment Testing, Inspection and Maintenance.....	39
B7: Instrument/Equipment Calibration and Frequency.....	37
B8: Inspection/Acceptance of Supplies and Consumables.....	39
B9: Non-Direct Measurements (i.e. secondary data)	39
B10: Data Management	39
Section C: Assessment and Oversight	41
C1: Assessments and Response Actions.....	41
C2: Reports to Management.....	41
Section D: Data Validation and Usability	42
D1: Data Review, Verification, and Validation.....	42
D2: Verification and Validation of Methods	43
D3: Reconciliation with User Requirements	43
References.....	1

List of Figures

Figure 1: Organizational chart showing the relationships and the lines of communication among project participants.....	7
Figure 2. Map of USGS simulated groundwater travel times to a receiving surface water body, including the Peconic Estuary. Adapted from Misut et al. (2021).	10
Figure 3. Map of Peconic Bay with proposed TIR overflight track for August 2023. The initial survey will encompass the perimeter of Flander’s Bay, Great Peconic Bay and Little Peconic Bay (~1800 – 2000 m altitude), before targeting the six shoreline regions of interest from the USGS model output (~1000 m altitude). The width of the red-dashed rectangle is approximately representative of the image swath at the proposed flight altitude of 2000 m.	14
Figure 4. US Geological Survey hydrogeologic model output for Peconic Bay, showing areas of predicted groundwater discharge (warm-colored pixels; adapted from Misut et al., 2021; Walter et al., 2020). Initial TIR and radon surveys in August 2023 will focus on the six areas of highest predicted discharge (red boxes).....	Error! Bookmark not defined.
Figure 5: Map of the Peconic and Shinnecock Bays to illustrate proximity of harvested eelgrass shoot location to the test sites in the Peconic Bays	16

Figure 6. Schematic of a single adult eelgrass shoot test plot layout. Each 1m ² quadrat will contain 50 transplanted adult eelgrass shoots woven into five burlap discs. Five test plots will be distributed across the foot print of each potential restoration site.	17
Figure 7. From Durrige Co. RAD7 RAD-AQUA default setup for the in-situ measurement of Rn-222 in water.	Error! Bookmark not defined.
Figure 8. Field log template for surface water radon sampling.	28
Figure 9. Adapted from Dugdale, 2016. An example of motion blur on a raw TIR image: (A) a “sharp” image and (B) a blurred image, over the same scene.	34
Figure 10. Adapted from Dugdale, 2016. An example of shadow cooling caused by bankside trees.	35
Figure 11. Adapted from Dugdale, 2016. An example of a boat wake producing an anomalous TIR surface signal.	36

Attachment A: Data Decision Tree

A3: Distribution List

Individuals listed here will receive a final copy of the Quality Assurance Project Plan.

Organization	Contact / Address	Email Address
Peconic Estuary Partnership	Joyce Novak , Executive Director Jade Blennau , Climate Adaptation and Community Coordinator PEP Program Office Riverhead County Center 300 Center Drive, Suite 250S Riverhead, NY 11901 (631) 852-2961	Joyce.Novak@stonybrook.edu jade.blennau@stonybrook.edu
Stony Brook University	Bradley Peterson , Professor Stony Brook University 239 Montauk Hwy Southampton, NY 11968 (631) 632-5044	Bradley.Peterson@stonybrook.edu
Old Dominion University	Joseph Tamborski , Assistant Professor Maira Taylor , Graduate Research Assistant Old Dominion University 4600 Elkhorn Avenue Norfolk, VA 23529 (631) 790-1579	jtambors@odu.edu mtayl059@odu.edu
Restore America's Estuaries	Suzanne Simon , Director 2300 Clarendon Blvd., Suite 603 Arlington, VA 22201 (401) 575-6109	ssimon@estuaries.org
Environmental Protection Agency	Phil Colarusso EPA Region 1 Office 5 Post Office Sq Boston, MA 02109 (617) 918-1506	colarusso.phil@epa.gov
Environmental Protection Agency	Nancy Laurson , Project Officer	laurson.nancy@epa.gov

Section A: Project Management

The following section provides information regarding the background of the *Groundwater refugia for eelgrass restoration* project, the tasks involved in completing the project, and the names and responsibilities of key project team members.

A4: Project Task/Organization

Peconic Estuary Partnership

Dr. Joyce Novak, PEP Director, will be responsible for overseeing this project for PEP, including technical review, participation in meetings and communication with the EPA.

Jade Blennau, PEP Coastal Adaptation and Community Coordinator, will be responsible for project outreach (Task 3) and permit coordination (Task 4).

Stony Brook University

Dr. Bradley Peterson of Stony Brook University will serve as the project leader and project QA/QC manager and be responsible for maintaining the official, approved QA Project Plan (Task 1). In addition, he will validate the data generated from this project, prior to the completion of the draft final report (Tasks 6 – 11). He will also plan all internal and external meetings and be primarily responsible for report generation.

Old Dominion University

Old Dominion University personnel Dr. Joseph Tamborski and Moira Taylor will initiate planning meetings with the US Geological Survey (Task 2) and will be responsible for project task 5 related to groundwater discharge identification.

Restore America's Estuaries

Restore America's Estuaries (RAE) has been selected by the Environmental Protection Agency (EPA) to manage the NEP Coastal Watersheds Grant Program. RAE will oversee fiscal and technical aspects of the grant project.

EPA

EPA is the grantor to RAE for the grant money that is being used for this project. The EPA is the Project Officer and will review and approve this Quality Assurance Project Plan (QAPP). EPA officers include Nancy Laurson, working to lead this project's grant management; Brian Hulme, EPA Region 2 Quality Assurance Officer, leading QAPP review and approval; and Phil Colarusso Ph.D. is leading the Eelgrass technical review.

Figure 1 is an organizational chart outlining communication between data users, manager, and coordinators. Table 1 has a list of the specific members from each organization and their primary responsibility.

Figure 1: Organizational chart showing the relationships and the lines of communication among project participants.

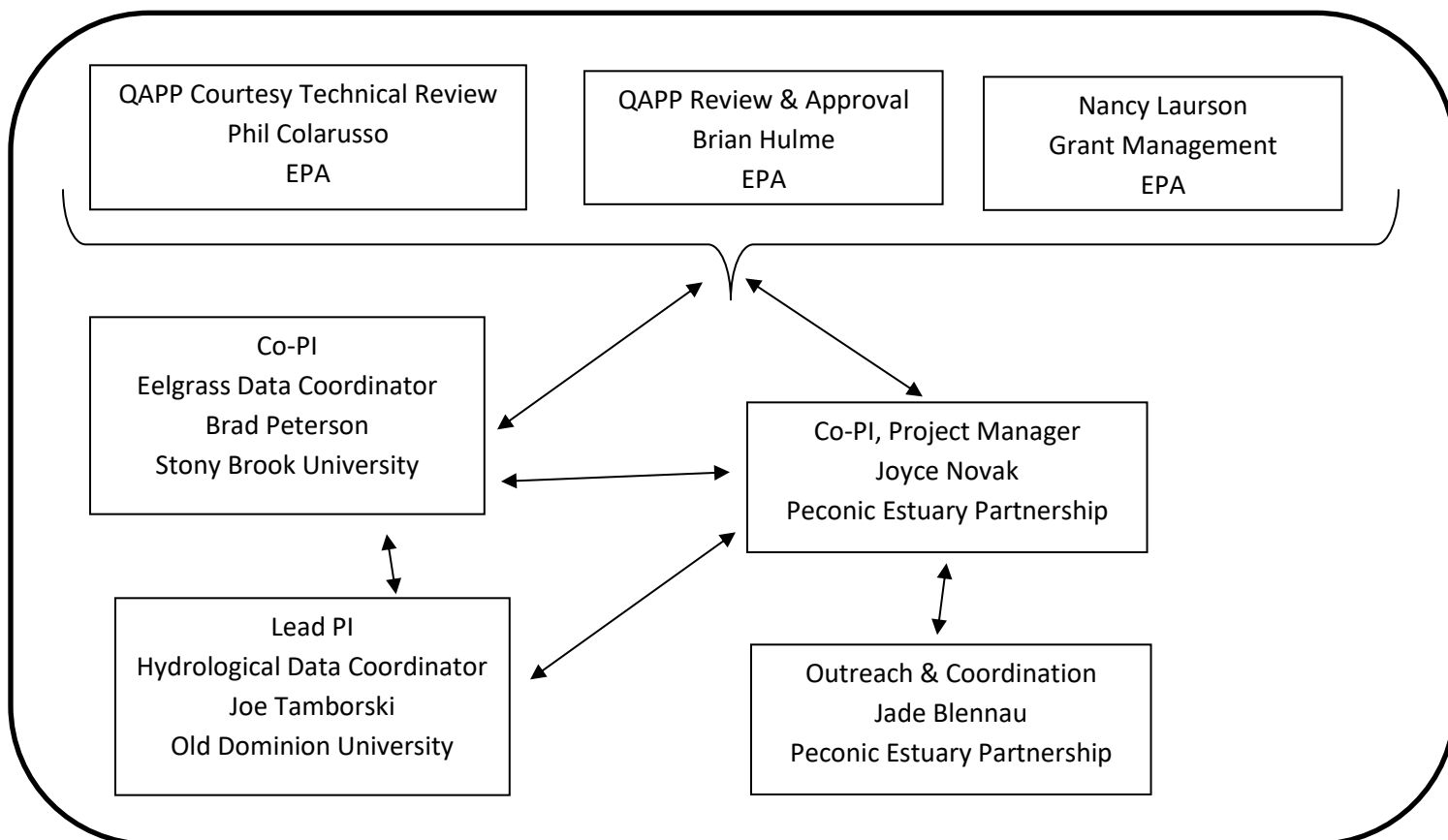


Table 1: Project Participants

Name	Title	Organization	Primary Responsibility
Joyce Novak, Ph.D.	Executive Director	Peconic Estuary Partnership	PI, Project manager
Jade Blennau	Coastal Adaptation and Community Coordinator	Peconic Estuary Partnership	Outreach and coordination
Bradley Peterson, Ph.D.	Professor	Stony Brook University	Co- PI, project management; eelgrass seed collection and restoration
Joseph Tamborski, Ph.D.	Assistant Professor	Old Dominion University	Lead PI, project management; groundwater identification
Moirra Taylor	Graduate Research Assistant	Old Dominion University	Groundwater identification
Suzanne Simon	Grant Manager	Restore America's Estuaries	Project oversight
Phil Colarusso, Ph.D.	EPA Quality Assurance	EPA	Courtesy QAPP Technical Review
Nancy Laurson	EPA Project Officer	EPA	Project oversight and QAPP review
Brian Hulme	EPA Quality Assurance	EPA	Final review and approval of QAPP

A5: Problem Definition/Background

This project addresses the priority outlined in the 2022 Restore America's Estuaries (RAE) Coastal Watershed Grant: loss of key habitats; aiming to make meaningful on-the-ground decisions regarding the impacts of climate change and warming waters on seagrass habitats. Climate change is altering the distribution of marine species worldwide. This migration is tied to significant changes in water temperatures which are not rising uniformly across the globe. Sea surface temperatures (SST) along the northwest Atlantic have risen at a rate nearly twice the global average (Kunkel et al., 2022). This accelerated temperature increase has had a significant impact on seagrasses, a foundational marine species, altering growth rates (Marsh et al. 1986), causing distribution shifts in coverage (Plaisted et al., 2022; Wilson and Lotze, 2019), and changes in patterns of sexual reproduction. The severity of increasing temperature on reproductive timing, seedling emergence, and survival will depend on the ability of the plant to adapt, which may be on timescales greater than allowed by the current temperature increases along the northeast coast of the US. Recent modeling predicts that under the current projections the southern extent of eelgrass will shift 6.5 degrees North by the end of the century, resulting in a virtual extirpation of eelgrass habitat from North Carolina to Long Island, New York (Wilson and Lotze, 2019). To minimize the extent of eelgrass extinction, new temperature mitigation strategies will need to be employed. In the northeast coastal region of the US, no other seagrass species can replace and offset the loss of *Zostera marina* (eelgrass) habitat and its associated ecosystem functions and services.

Of the National Estuary Programs on the US East Coast with seagrass habitats, all but one identified the need for more research surrounding groundwater discharge as a factor influencing these marine ecosystems (data taken from all East Coast National Estuary Program Comprehensive Conservation Management Plans). Specifically, northeast programs from Piscataqua region to Maryland Coastal Bays have identified groundwater discharge as an important contributor to seagrass health.

Recently developed hydrogeological models by the U.S. Geological Survey have predicted locations within the Peconic Estuary (NY) where groundwater discharge occurs with a coarse spatial resolution (Figure 2). This project seeks to develop a refined spatial dataset that will guide eelgrass restoration project sites by identifying the locations of cool groundwater temperature refugia during summer. In addition to cooler water temperatures, groundwater is also enriched in pCO₂ which may provide carbon enrichment to the belowground biomass, alleviating known metabolic deficiency (Peterson et al., 2012). We envision this novel use of groundwater temperature refugia for eelgrass restoration to serve as an example for other coastal embayment's along the east coast of the United States.

The conservation of coastal ecosystems depends on management and restoration practices that reinforce ecosystem resilience. In the short-term, this project will restore the loss of key habitat in the Peconic Estuary by identifying areas of cool groundwater discharge for targeted eelgrass restoration campaigns. Our long-term vision for this body of work is the development of a region-wide habitat restoration model in coastal areas where SST is buffered by the cooling influence of groundwater discharge, which broadly occurs along much of the continental US (Sawyer et al., 2016). Longer term data will be used by the network of National Estuary Programs, regional seagrass managers, specifically the East Coast Submerged Aquatic Vegetation Collaborative.

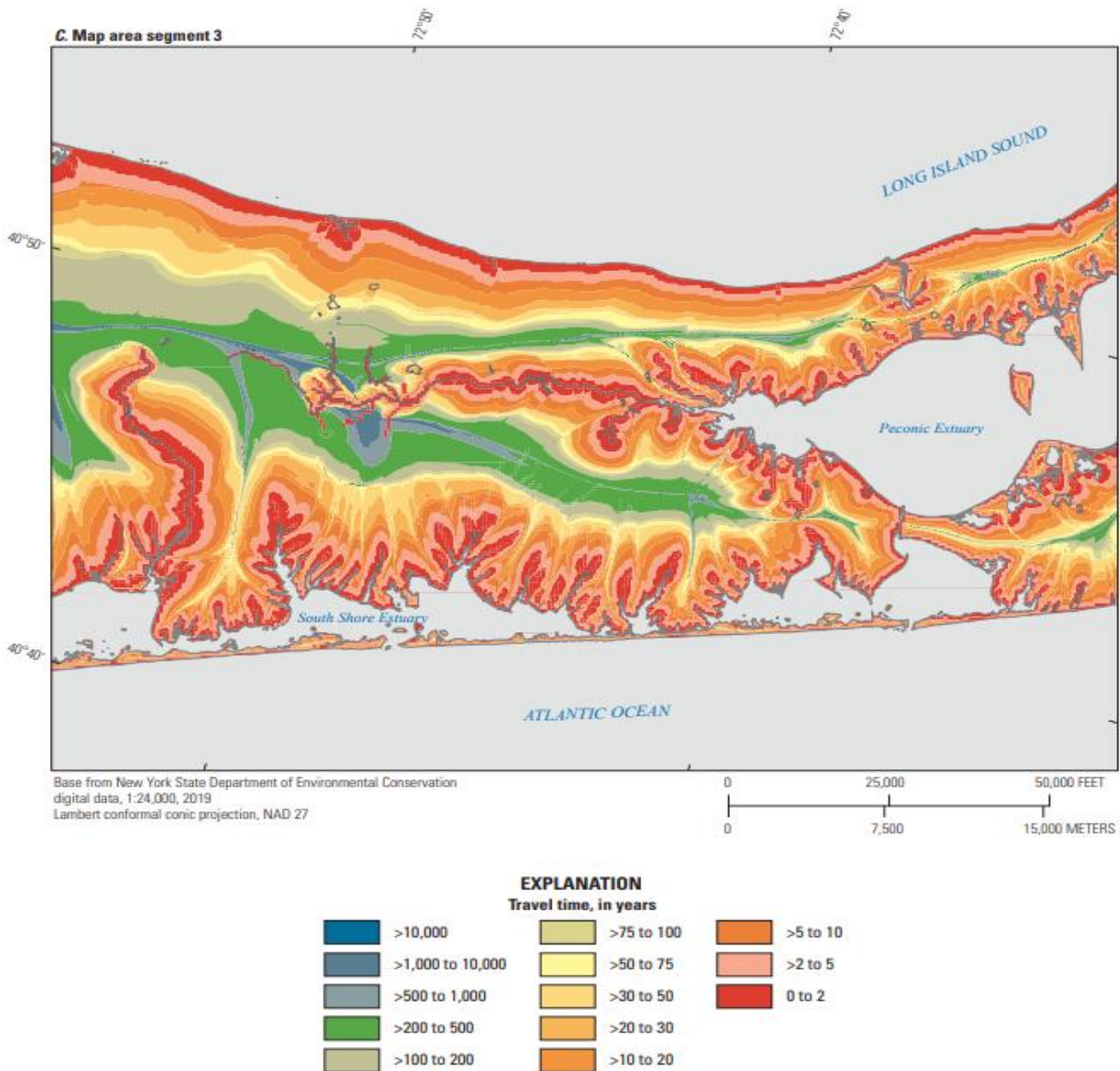


Figure 2. Map of USGS simulated groundwater travel times to a receiving surface water body, including the Peconic Estuary. Adapted from Misut et al. (2021).

A6: Project Task Descriptions

Table 2. Project Tasks and Schedule

Task	Deliverable	Timeline	Relevant Details/Comments
Task 1	QAPP development	March- June 2023	
Task 2	Initiate team meetings	April - June 2023	Project coordination and planning consulted with USGS New York Water Science Center
Task 3	Outreach	May 2023; June 2023; Jan 2024; Nov 2024; Jan 2025	Outreach with local chapter of SWMS; Story Map development; Seagrass workshop
Task 4	Permit applications	May – September 2023	NYS Department of Environmental Conservation, municipalities, and Trustees
Task 5	Identification of groundwater discharge	August 2023; December 2023	All data gathering will adhere to QA/QC checking as set forth in this QAPP.
Task 6	Eelgrass seed collection	June 2023	Collect eelgrass reproductive shoots in partnership with SWMS
Task 7	Selection of restoration sites	August 2023	Selection of 2 out of 6 surveyed areas for test plantings
Task 8	Test plantings and initial drone imagery	September - October 2023	Five plots within each site
Task 9	Assessment of success metrics	May 2024	Re-acquisition of drone imagery of two test plant sites
Task 10	Large-scale restoration efforts	June 2024	Collection of 25,000 reproductive eelgrass shoots and planting at final site

Task 11	Drone imagery post-restoration	October 2024	Success assessment for final planting site
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Task 1: QAPP Development

This QAPP describes the quality management system and procedures, as well as the roles and responsibilities of the Project Team. The QAPP provides an overview of the project and quality assurance related to data used for the project.

The Project Manager, Dr. Joyce Novak (Executive Director, Peconic Estuary Partnership (PEP)), will be responsible for maintenance and distribution of the approved QAPP. Dr. Novak will also act to coordinate QAPP approval with EPA - the QAPP will be provided electronically as needed.

Jade Blennau (Coastal Adaptation and Community Coordinator for PEP), will coordinate outreach activities locally in the Peconic Watershed as part of their established network. Additionally, PEP will facilitate coordination of eelgrass work throughout the New York Marine area using New York State partnerships. PEP will also lead the DEIJ initiative with the Society of Women in Marine Science (SWMS).

Dr. Bradley Peterson (Stony Brook) will have overall responsibility for the conduct of the project including direct supervision of the SBU graduate student. He will also have primary responsibility for QAPP and report preparation and documentation of the results. Peterson has spent the last twenty years in eelgrass community ecology and restoration. He is one of the founding members of the Shinnecock Bay Restoration Project (ShiRP) that has seen the restoration of over 100 acres of eelgrass and is currently chairing the steering committee of the “Building eelgrass resiliency along the mid-Atlantic and Southern New England Coast” working group. Dr. Peterson will assist the SBU graduate student in organizing volunteers in collecting the reproductive and adult eelgrass shoots. He will also lead the public events to weave the adult shoots into the burlap discs. Dr. Peterson also serves as the SBU Dive Safety Officer and will utilize the scientific diving classes to assist with the planting of the adult shoots and seed bags.

Dr. Joseph J. Tamborski (Old Dominion University) will design field sampling campaigns and oversee all project outputs related to groundwater discharge, including the airborne thermal infrared imagery and radon surveys. Dr. Tamborski has participated in several airborne thermal infrared overflights and radon surveys along the coasts of Long Island, and has studied submarine groundwater discharge to Long Island’s embayment’s since 2012. He will assist Dr. Peterson with QAPP development and report preparation. Dr. Tamborski will mentor a graduate student at ODU (Moir Taylor) who will be responsible for the processing of thermal infrared imagery and radon data. Both the student and Dr. Tamborski will collect environmental data in project year one. Both the student and Dr.

Tamborski will reduce data, create maps, prepare manuscripts and distribute results at local and national meetings in project year two.

Task 2: Initiation of team meetings

PEP, SBU and ODU project personnel will begin meetings to determine potential sampling locations and required permits (April – May 2023). Project coordination and planning is currently occurring with the USGS Program Development Specialist New York Water Science Center Dr. Christopher Schubert, Chief of Water-Resource Integrated Modeling Kris Masterson, physical scientist Kalle Jahn, and Groundwater modeling Specialist Don Walter. The USGS hydrogeological model will be used as a guide to select shoreline segments of suspected groundwater influence for further field investigation in Peconic Bay. A summary of the model is publicly available (<https://pubs.er.usgs.gov/publication/sir20205091>) (Walter et al., 2020) and includes links for model code and a pair of key datasets used in model development. No new data will be generated from this task.

Task 3: Outreach

3A: Outreach for community participation: PEP staff will participate in the local chapter of the Society for Women in Marine Science’s (SWMS) networking panel and share information on this project and details for organizing a restoration workshop (early May 2023). PEP team will engage with the local SWMS chapter to finalize logistics for participation in the eelgrass restoration field workshop (late May 2023), following up from the initial May meeting. No new data will be generated from this task.

3B: Story Map: Begin development of Story Map (January 2024). Project results will be incorporated into the Eelgrass Story Map currently being developed by PEP and Dr. Peterson to showcase the results of the recently completed PEP Eelgrass Habitat Suitability Model and will be shared with the public via the PEP website and presentations at completion. The Story Map will be finalized in November 2024. No new data will be generated from this task.

3C: Seagrass Workshop: PEP will facilitate a regional seagrass workshop to discuss results (January 2025) with EPA and other NEPs, the National Park Service, and other relevant stakeholders, and this project will be presented to these groups as well. No new data will be generated from this task.

3D: Wider Outreach: The Peconic Estuary Partnership (PEP) will disseminate information of this project via quarterly technical advisory committee meetings for the duration of the project. Final results will be disseminated to all NEPs and presented at the Fall 2024 NEP Tech Transfer in New York and the 2025 Fall NEP Tech Transfer in Alabama. No new data will be generated from this task.

Task 4: Permit applications

Project team submits permit applications after QAPP approval (May – September 2023). This will occur in two phases; phase 1: NYS Department of Environmental Conservation (June 2023); phase 2: local municipalities and trustees, following site-identification for restoration after field reconnaissance (September 2023). No new data will be generated from this task.

Task 5: Identification of groundwater discharge

We anticipate selecting six regions of high predicted groundwater discharge from USGS model outputs for monitoring in-situ during August 2023 (Task 5a; Figure 3 and Figure 4). Following Tamborski et al. (2015), a handheld thermal infrared (TIR) camera will be used aboard a helicopter to image coastal surface water temperatures at low tide to determine the spatial footprint of the discharge (August 2023). The whole bay will first be surveyed at an altitude of ~1800 – 2000 m (weather dependent; Figure 4). A second overpass will be conducted at a lower altitude (~1000 m) over the six shoreline areas of interest identified from the USGS model. We anticipate producing SST maps of the six regions identified from the USGS models, for August 2023. In December 2023, a follow-up flight will be coordinated over the two selected test restoration sites following the same procedure (Task 5b).



Figure 3. Map of Peconic Bay with proposed TIR overflight track for August 2023. The initial survey will be at ~2000 m altitude before targeting the six regions of interest from the USGS model output (~1000 m altitude). The width of the red-dashed rectangle is approximately representative of the image swath at 2000 m.

SST alone cannot identify groundwater discharging to an estuary. Continuous radon surveys will follow the TIR flights as dissolved radon-222 ($t_{1/2} = 3.83$ d) is naturally enriched in groundwater and depleted in seawater, making this an effective tracer of groundwater discharge (Adyasari et al. 2023). In-situ radon, temperature, salinity and pCO_2 will be mapped in near real-time by moving within the spatial footprint of the airborne thermal

infrared imagery and USGS model outputs (Figure 4) from a stationary or slowly moving boat during August 2023 and December 2023. Boats will be contracted from Suffolk County Department of Health Services and Stony Brook University's School of Marine and Atmospheric Sciences for a one-week period.

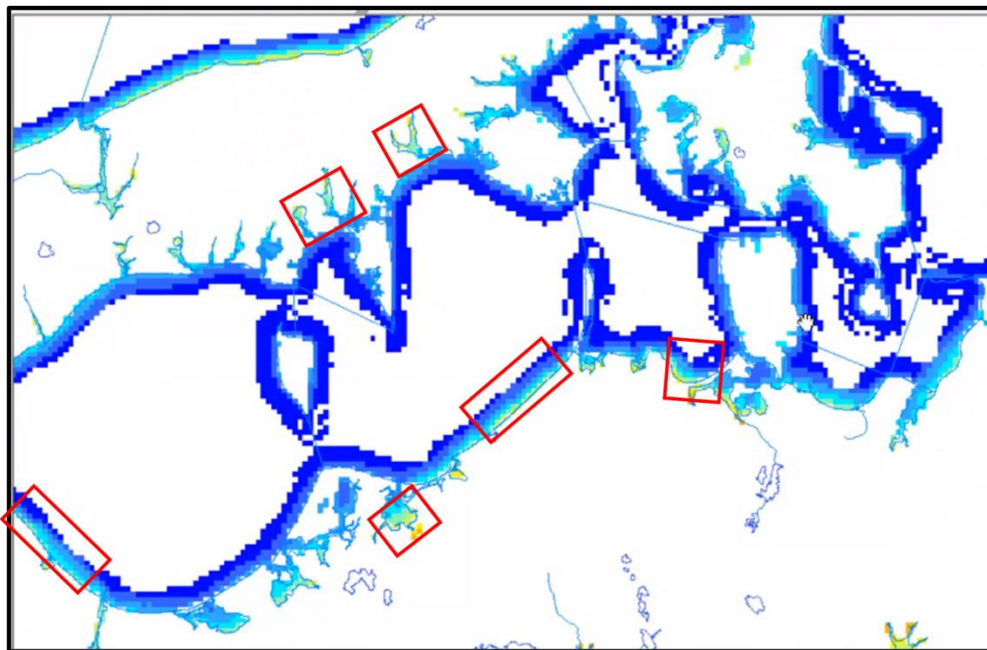


Figure 4. US Geological Survey hydrogeologic model output for Peconic Bay, showing areas of predicted groundwater discharge (warm-colored pixels; adapted from Misut et al., 2021; Walter et al., 2020). Initial TIR and radon surveys in August 2023 will focus on the six areas of highest predicted discharge (red boxes).

Task 6: Eelgrass seed collection

In June 2023, 500 eelgrass reproductive shoots (~20,000 seeds) will be collected by hand via SCUBA from a large and vibrant meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station (Figure 5). Harvested shoots will be stored indoors within flow-through seawater until all mature seeds are released from flowering shoots. Based on previous eelgrass seed-based restoration projects this will result in approximately 20,000 viable seeds (Gobler et al., 2022). This task includes SWMS participation in field work as part of these eelgrass restoration activities.



Figure 5: Map of the Peconic and Shinnecock Bays to illustrate proximity of harvested eelgrass shoot location to the test sites in the Peconic Bays

Task 7: Selection of restoration sites

The August 2023 temperature, salinity and radon maps will be used to select two of the six survey regions for test eelgrass plantings. This will occur immediately following site determination from the TIR and radon field surveys. The two regions with the greatest spatial footprint of bottom area receiving 22% surface light within the extent of the mapped cool water temperature and radon anomalies will be selected. At these two locations, paired temperature loggers will be placed at the sediment surface and 10 cm above across the spatial extent of the thermal footprint ($n=5$ pairs for each site). In addition, two self-wiping Photosynthetically Active Radiation (PAR) continuous loggers will be deployed to measure K_d and calculate H_{sat} at each site (August 2023).

Task 8: Test plantings and initial drone imagery

Eelgrass adult shoot test plantings will be conducted at five locations across the footprint of the two selected potential restorations sites based on the overflights and radon-222 surveys using the burlap disc method (DMF 2014; Figure 6). In September 2023, 2,500 adult shoots will be collected by hand via SCUBA from a vibrant eelgrass meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station. At the conclusion of harvesting, all adult shoots will then be woven into pre-cut and pre-holed burlap discs. Each disc will possess 10 adult shoots. All burlap-eelgrass discs will be transported to the field and 125 burlap discs will be planted at each of the two potential restoration sites in five 9m x 9m test planting plots.

In October, the eelgrass seeds will be deployed within the same 1m² test planting sites that the burlap discs were buried. The harvested seeds will be placed into 5 cm x 5 cm burlap bags and placed on the sediment surface between the buried burlap discs (n=4 per 1m²). This planting design has been successfully used in several restoration efforts (Davis and Short 1997, Kopp and Short 2001, Leschen et al. 2010). These ten test plantings sites will be distributed across the footprint of each restoration site. Initial drone visible-light imagery of each site will be acquired (September – October 2023).

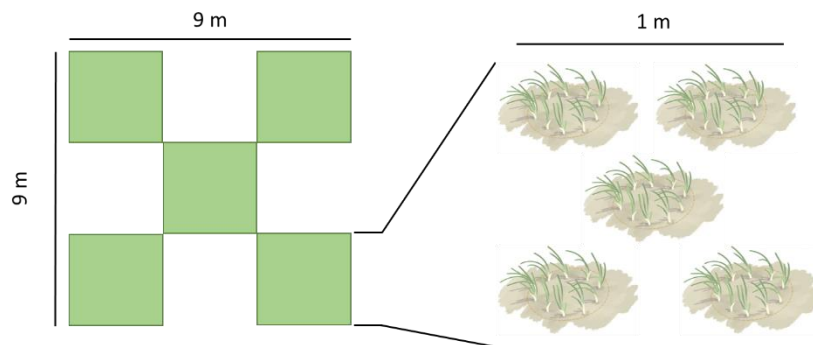


Figure 6. Schematic of a single adult eelgrass shoot test plot layout. Each 1m² quadrat will contain 50 transplanted adult eelgrass shoots woven into five burlap discs. Five test plots will be distributed across the footprint of each potential restoration site.

Task 9: Assessment of success metrics

Drone imagery will be acquired immediately after the eelgrass adult shoot transplanting in the test plots is completed (September). Imagery will be collected with a Phantom 4 DJI quadcopter. It is assumed that two flights will be necessary to cover the entire area. Once imagery is acquired, the individual images will be used to create a georeferenced mosaic in Pix4d. This initial image will serve as the baseline image for the change in eelgrass coverage in subsequent assessments (*i.e.*, post-restoration).

Test plots will be monitored in May 2024. Monitoring will consist of counting the planted squares, counting shoot density, measuring the area of the plot and assessing general health of plants and site conditions, including epiphytic coverage. Eelgrass survival of adult shoots will be quantified via changes in shoot counts from the initial plantings, growth of the areal coverage will be determined via re-captured drone imagery of each test plot comparing initial planting and eelgrass coverage in May 2024 and germination success will be assessed by conducting seedling counts from each of the burlap bags.

Task 10: Large-scale restoration efforts

In June 2024, 25,000 reproductive eelgrass shoots (~1,000,000 seeds) will be collected by hand via SCUBA from a vibrant eelgrass meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station. The test-planting site with the highest success metrics will be chosen for a final large-scale restoration effort. After the reproductive shoots are harvested, effort will shift to collecting 25,000 adult shoots. This will involve “sowing” adult eelgrass shoots into burlap discs and planting along transects by SCUBA divers. In October, the seeds will be deployed within the same 1m² planting sites that the burlap discs were buried.

Task 11: Drone imagery post-restoration

Drone imagery will be acquired immediately after the eelgrass adult shoot transplanting is completed (late August/early September). Imagery will be collected with a Phantom 4 DJI. All images will be taken with the camera facing down, to ensure camera position will be associated with the center of the image. It is assumed that two flights will be necessary to cover the entire area. Six brightly painted paving stones will be placed on the sediment surface across the footprint of the restoration area and geo-referenced with a handheld Trimble GPS for use as ground control points in the collected imagery. Once imagery is acquired, the individual images will be used to create a georeferenced mosaic in Pix4d. This initial image will serve as the baseline image for the change in eelgrass coverage in subsequent surveys.

A7: Quality Objectives and Criteria

The primary goal of this project is to determine water temperatures at locations of submarine groundwater discharge in the Peconic Bays with the aim of targeting areas for successful eelgrass restoration in the Peconic Estuary. By identifying these areas, the project team can create a model eelgrass restoration technique that can be replicated throughout the northeastern region of the United States. Identifying cool water refugia should result in an enhanced restoration protocol in the Peconic Estuary. Thus, quality objectives pertain to the measurements of:

1. Thermal infrared imagery used for identification of potential groundwater discharge locations (Task 5),
2. ²²²Rn monitoring in areas identified from USGS model and thermal infrared imagery for in-situ validation of groundwater discharge (Task 5),
3. In-situ monitoring of potential test-restoration sites, including in-situ temperature and PAR(Task 7). These will remain in the field from April thru September; and,

4. Assessment of eelgrass survivability based on change in aerial coverage, determined from drone surveys (Tasks 8 – 11).

Data Quality Objectives (DQOs) specify the quality of environmental data required to support decision-making processes. Specific DQO's are outlined below with a description of the Data Acceptance.

Precision: This project will collect disparate data that will have very different precision issues. The measurement of radon and conductivity in the ground water survey will require pre- and post-calibration of the instruments as listed in this document. The precision of these instruments are evaluated as measurements of standards. The light and temperature instruments are calibrated at the manufacturer and certified precision estimates will be understood to be valid unless inter-sensor calibrations reveal differences in between sensors. If this happens, then the deviating sensor will be returned to the manufacturer for re-calibration. The precision of the drone imagery will be assessed by the Pix4d software of the georeferenced imagery and will be documented for each image. In the field the germination success and shoot counts will be conducted by individuals but there will be one quadrat that will be counted by both field technicians and if there is more than a 10% difference in their shoot counts, all quadrats will be recounted.

Bias: As stated above, the use of reference materials will be used for the radon and conductivity calibrations prior to each field survey.

Representativeness: It is expected that the radon and conductivity surveys will create a map of values that "accurately and precisely" represent the spatial extent and degree of groundwater flow within the potential restoration areas. These values will be continuously recorded as water is pumped into the sensor package as the boat transits across the different sites. The continuous temperature and light loggers will be placed across (HOBO loggers) and within (LiCor sensors) the potential restoration sites in such a way as to expect "representative" temperature and light levels reaching the bottom at these sites. The design of the replicate burlap disk and seed bags planting scheme will promote replicate shoot counts and seed germination values which would be representative of each site.

Comparability: Care was taken to select both field survey and eelgrass monitoring methods that would be directly comparable to other previous studies. The radon and conductivity methods to be used to determine the groundwater footprint has been extensively used in other projects. The drone imagery, shoot counts and gemination counts are standard seagrass restoration metrics used to assess success and are directly transferable to previous restoration projects.

Completeness: This project has three tiers. First, identify the largest footprints of groundwater flow adjacent to shore using visual thermal cameras and verifying that these images are the result of groundwater via the radon and conductivity field surveys. These techniques will be sufficient to determine the extent of the groundwater footprint. Once this is completed, temperature and light instruments will be installed at two potential restorations sites as will adult shoot and seed test plantings. Drone imagery will be collected prior and after the test plantings and the following spring. In the spring, shoot counts and germinated seedlings will be counted. The direct counts of the seagrass shoots will allow the survival and growth of the seagrass to be assess as will the direct counts of the seed bags quantify the seed germination success. The drone imagery will quantify the change in seagrass coverage from the fall to the spring.

Sensitivity: The sensitivity of the instruments used in this project are provided. They are sufficient to determine the spatial extent of groundwater at each site, whether the summer water temperatures or light levels reaching the sediment surface are too stressful for the eelgrass to survive.

Description of Data Acceptance

Task 5: Thermal infrared flyover: The FLIR T640 camera has a pixel-to-pixel thermal accuracy of 0.1 K, an absolute accuracy of ~ 2 K, a wavelength range of 7.8–14 μm , and a lens field of view of $25^\circ \times 19^\circ$. At the proposed 1800 - 2000 m altitude flight track, each pixel field of view would cover approximately 1.2 m of sea surface. This field of view is sufficient to resolve sea surface temperature variations of ~ 1 m^2 , more than adequate to observe (relatively) large-scale thermal anomalies driven by groundwater discharge (Kelly et al. 2013; Tamborski et al. 2015).

Task 5: Radon Survey: Radon measurement precision with the RAD7 (DurrIDGE Co.) is a function of unit calibration and counting statistics (Poisson statistics). A factory calibrated RAD7 detector will be used for all radon measurements. Counting statistics will depend on the allotted counting time and activity of Rn-222 encountered in-situ. We will use two radon detectors to increase the Rn-222 measurement sensitivity (Dulaiova et al. 2005), with a minimum detectable activity (MDA) of approximately 10 Bq m^{-3} .

Task 7: Selection of Restoration Sites:

The LiCor LI-192 Underwater Quantum sensors are calibrated prior to delivery from the factory and recalibrated every 2 years after field deployment. Calibrations of quantum and photometric sensors at LI-COR are obtained using standard light sources that are traceable to NIST. Sensor spectral response conformity is measured using a computer-controlled spectrophotometer and reference silicon photodiodes. Sensors are cleaned prior to the calibration, inspected for diffuser and/or cable aberrations, and repaired as needed. The sensor's relative spectral response is measured to check its conformity to the ideal response. The sensor's actual response is then run through the spectral error routine which calculates the theoretical reading errors that would occur with a variety of light sources to check for acceptable limits.

The Onset HOBO Pendant Temperature logger has a temperature measurement range of -20° to 70°C . Based on factory specifications, the accuracy is $\pm 0.53^\circ\text{C}$ from 0° to 50°C , the resolution is 0.14°C at 25°C and the drift is less than $0.1^\circ\text{C} / \text{year}$.

Tasks 8 – 11 (drone imagery pre- and post-restoration):

The Phantom 4 quadcopter is equipped with a 1-inch 20MP CMOS sensor that has a manually adjustable aperture from F2.8 to F11. The camera is also outfitted with a polarizing lens. The individual images will be used to create a single orthomosaic using Pix4dmapper. The spatial resolution used to generate the orthomosaic is the same as the

resolution of the DSM which is set to 10 cm. Pix4d will generate a quality report that will provide metrics on the final orthomosaic.

A8: Special Trainings/Certification

All individuals involved in field sampling for eelgrass restoration on SCUBA will be certified scientific divers through the nationally recognized American Academy of Underwater Scientists (AAUS). Copies of their AAUS Letters of Verification of Training (VOT) will be kept on file with the QA/QC project leader. Familiarity with equipment used will be performed over several weeks of on-site field and laboratory training by the team leader. Bradley Peterson has been performing water quality under the National Park Service since 2007 and has trained the team following A Protocol for Monitoring Estuarine Nutrient Enrichment in Coastal Parks of the National Park Service Northeast Region using the equipment found in this document. All training and certification records are kept on the lab premises and can be verified. Peterson is also a certified UAS pilot (certification # 3991934) and has conducted hundreds of flights to acquire seagrass imagery in NY. He will be the Pilot-In-Charge for all drone flights conducted for this project. Thermal infrared overflights will be contracted out to Helicopter Flight Training Inc. and does not require any special trainings or certifications; Tamborski has worked with Helicopter Flight Training Inc. since 2013.

A9: Documentation and Records

The QA Project Plan will be distributed to all project personnel (PI's, students, technicians) prior to field sampling and periodically as updates are needed. The team currently shares files and data via Google Drive and will store an up-to-date version of the QA Project Plan for all authenticated users. Any updates to the QA Project Plan will be distributed to RAE and EPA personnel in a timely manner via PEP.

Data collected in the field will be recorded on prepared waterproof datasheets and later transcribed into digital files. These digital files will be reviewed after transcription by a third person to avoid transcription errors. These datasheets will include date, time of sampling, weather conditions, parameters sampled for, and crew names. Laboratory data will be recorded on prepared data sheets. Calibration of instruments will be recorded and stored in the laboratory file cabinet before being deposited electronically. Electronic and paper copies of the data will be kept by the project leader, and deposited in the Stony Brook Electronic Repository where they will be maintained for no less than five years after the completion of the project.

Section B: Data Generation and Acquisition

This QAPP was developed with guidance from the EPA Requirements for Quality Assurance Project Plans (QA/R-5).

B1: Sampling Process Design (Experimental Design)

This primary objective of this project is to restore eelgrass habitat along stretches of shoreline that are thermally influenced by groundwater discharge. To accomplish this, shoreline segments influenced by groundwater first need to be identified. The US Geological Survey will facilitate a knowledge transfer with project personnel based on existing hydrogeologic model outputs. This model output will be used to select six shoreline stretches for initial investigation (Figure 4). Verification of hydrogeologic model results will be performed via (1) airborne thermal infrared remote sensing and (2) in-situ radon-222 surveys. Following verification of airborne TIR and radon-222 data, two test planting sites will be selected (3). Pending success-metrics (4), one final site will be selected for a large-scale restoration effort (5).

- (1) For initial airborne overflights, the coastal zone of Flanders Bay, Great Peconic and Little Peconic Bay will be imaged in August 2023 (Figure 3). A second overpass will focus on the six shoreline segments identified by the US Geological Survey model output at a lower altitude (Figure 4). Repeat imagery will be collected in December 2023 along the shoreline of Peconic Bay and focused on two test restoration sites. Helicopter flights will be rescheduled in the event of inclement weather during the week of planned work. Thermal infrared data will vary with season and time of imaging; flights will be coordinated on cloud-free mornings around low tide, weather permitting.
- (2) In-situ radon-222 surveying will follow August and December 2023 thermal infrared overflights. The areal-footprint of the six shoreline areas of interest will be surveyed for the naturally occurring groundwater tracer, Rn-222, to confirm the in-situ presence of groundwater discharge. Final shoreline survey locations are to be determined after initial planning meetings with USGS personnel. All sites will be accessible via Suffolk County or Stony Brook University vessels. Rn-222 activity will vary with meteorological conditions and tides. Sampling will be limited to relatively calm weather conditions.
- (3) Test-plantings will be conducted at two sites that will be selected based on the airborne overflights and the in-situ radon-222 surveying. Within the footprint of these two sites, five 9m x9m test planting plots will be evenly spaced across the boundaries. Each of these five plots will have 250 adult shoots sewn into 25 burlap discs that will be buried as five discs in an "X" within alternating 1 m2 plots creating

a 9m x 9m checkerboard. To test for best restoration strategy, an additional ten 0.25 m² eelgrass sods will be transplanted to each site. In addition, in October each of these test planting plots will receive 2,500 eelgrass seeds. This will result in a total of 1,250 adult shoots transplanted to each of the two potential restoration sites selected based on the overflights and radon-222 surveys.

- (4) Assessment of the two test-planting sites will be conducted in May and June of 2024. The number of adult shoots, number of germinated seedlings and areal extent of the eelgrass (via drone imagery) at each of the five test planting plots in each of the two potential restoration areas will be determined.
- (5) Large-scale restoration will be conducted at the single site that has the greatest increase in areal coverage and shoot counts between the two test sites. In June of 2024, 25,000 reproductive shoots will be collected (~1,000,000 seeds). In August and July 2024, 25,000 adult shoots will be collected and woven into burlap discs and transplanted to the large restoration location in a similar alternating pattern as was used for the test planting sites.

B2: Sampling Methods

Thermal Infrared Flyover:

Low tide is the period of likely maximum groundwater discharge and thus presents the best timing opportunity for TIR image acquisition (Tamborski et al., 2015). Flights will be coordinated on cloud-free days, with a minimum of two overpasses at each site. Specifically, a FLIR Systems T640 TIR camera will be used at an altitude of 1800 – 2000 m (pixel-to-pixel thermal accuracy =0.1 K, absolute accuracy ~2 K, wavelength range of 7.8–14 µm, lens field of view =25° × 19°); each pixel field of view covers approximately 1.2 m of sea surface at 1800 m altitude. The infrared camera will be calibrated for atmospheric reflectivity and transmission prior to the flight following manufacturer protocols. Visible images are taken simultaneously (automatically) with thermal images using the FLIR camera. Images will be taken over the shore as close to nadir as possible to reduce image obliquity. During each survey, the camera will be deployed out the side of the helicopter door and operated by hand, with the lens at a minimum 150° angle from normal with an attempt to keep the frame as vertical as possible, following Tamborski et al. (2015). In the event of camera failure while surveying, a flight will be rescheduled once the failure issue has been corrected, either back in the laboratory by Tamborski or by the instrument manufacturer. No specific support facilities are needed.

In-situ parameters:

Surface water temperature, salinity, and depth will be measured in-situ during the August and December 2023 Rn-222 surveys. A Solinst 5 levellogger LTC will be calibrated for

temperature and conductivity using certified reference materials the day before field operations begin. This will be conducted by Dr. Tamborski and will be documented. A calibrated levellogger will be affixed with a lead-weight onto a rope attached to a cleat and towed along the starboard side of the vessel, approximately one meter depth. Measurements will either occur while anchored on-station, or while slowly moving (< 3 knots) within the spatial footprint of a shoreline region of interest. The LTC5 levellogger will be programmed to record data at one-minute intervals. At the end of each field day, data will be immediately downloaded and stored to an online data repository (ODU Microsoft OneDrive). Position will be monitored in real-time using a Garmin handheld GPS at 1-minute intervals. No specific support facilities are needed. In the event of instrument failure, temperature data will be taken from the RAD7 (internal temperature, for solubility correction) and depth will be derived from existing bathymetric maps of the Peconics.

Radon-222 survey:

A submersible pump (Proactive Mini-Monsoon 12V pump or similar product) will be used to draw surface waters into a gas-equilibrium chamber (DurrIDGE Co. RAD-AQUA) at a flow rate of >3 liters per minute (Figure 7). After 20 minutes, radon in-air and radon in-water will approach equilibrium (Santos et al. 2012), and surveying will commence. pCO₂ will be measured using a Sea-Bird Scientific SeapHOx V2 (Santos et al. 2012). Dissolved radon will be measured in-situ using two electronic radon-in-air analyzers (DurrIDGE Co.) operated in parallel (Dulaiova et al. 2005). Radon detectors will operate in “sniff” mode, with 10-minute counting intervals. The detectors will be offset by 5 minutes, thus providing spatiotemporally integrated radon measurements in 5-minute intervals. No specific support facilities are needed. In the event of instrument failure, a single backup device will be used while surveying underway.

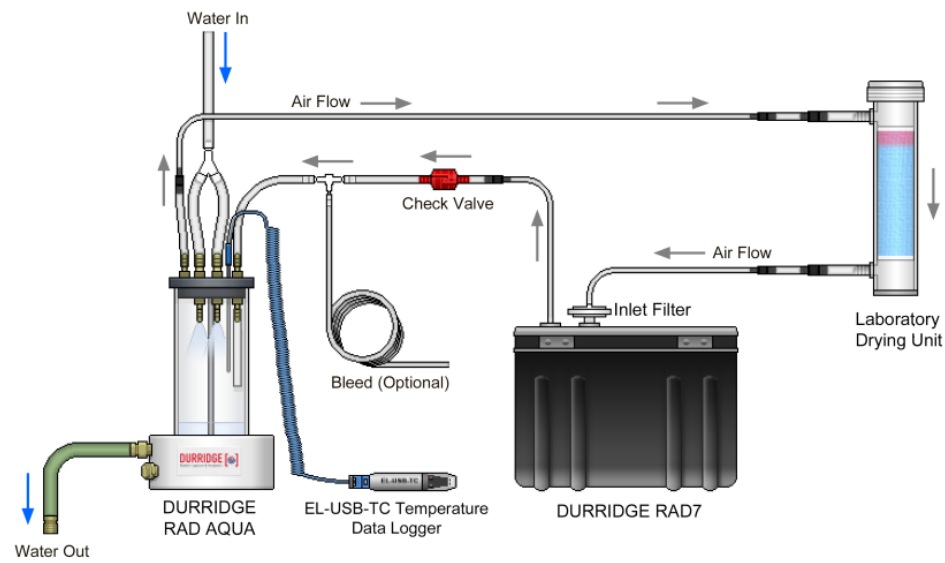


Figure 7. RAD7 RAD-AQUA default setup for the in-situ measurement of Rn-222 in water. From DurrIDGE Co.

Bottom Water Temperature

Paired Onset HOBO pendant temperature loggers will be attached to small screw anchors across the identified footprint of the potential restoration sites in a large “X” pattern (n=5 paired HOBO screw anchors). One logger of each pair will be located at the sediment water interface while the second will be attached to the screw anchor 5 cm below the surface of the sediment. Water temperature will be recorded every 15 minutes. No specific support facilities are needed and the utility of several loggers ensures redundancy in data collection should one logger fail. The Onset HOBO Pendant Temperature logger has a temperature measurement range of -20° to 70°C. Based on factory specifications, the accuracy is $\pm 0.53^{\circ}\text{C}$ from 0° to 50°C, the resolution is 0.14°C at 25°C and the drift is less than 0.1°C / year.

Light

Paired PME photosynthetically active continuous light loggers with wipers will be attached to a metal frame that positions the loggers 0.5 m apart vertically. These continuous light sensors positioned on the metal frame will be placed in the center of each potential restoration site and provide daily K_d values for each site. From these values H_{sat} will be calculated across the bathymetry of the potential restoration site’s footprint. No specific support facilities are needed and the utility of several loggers ensures redundancy in data collection should one logger fail. The LiCor PAR sensors have a sensitivity of 4 μA to 1 μA per 1,000 $\mu\text{mol s}^{-1} \text{m}^{-2}$. The absolute calibration is $\pm 5\%$ traceable to the U.S. National Institute of Standards and Technology (NIST).

Large-scale restoration efforts

Support facilities for seed harvesting is housed at the Stony Brook University Southampton Marine Station. Harvested shoots will be stored indoors within 14 upwellers placed inside a 3,500-L tank with flow-through seawater for approximately three weeks until all mature seeds are released from flowering shoots. Water flow will be adjusted to produce a full exchange of water in approximately 2 hours, and air lines along the bottom will vigorously aerate the tank contents. Individual rhipidium will be removed from the reproductive shoots and held within the upwellers. Each upweller will hold the rhipidia of 1,300–1,500 harvested shoots. The upwellers will be stirred daily to facilitate flushing of decomposing material, and to prevent establishment of anoxic zones on the upweller screen bottom.

We will use a multi-stage process to isolate seeds from the large volume of decomposing plant matter present after seed release, relying on the rapid sinking rate of viable, mature seeds (see below) to achieve separation without sieving. After three to four weeks the rhipidia will have released their seeds, allowing a portion of the floating grass material to be removed.

Upwellers will be vigorously stirred, and after allowing seeds to fall to the bottom for at least 10 seconds, vegetative fragments will be removed by dipping 1-cm mesh screens in the surface layer. This cycle will be repeated until little material appears on the screens. Seeds will be removed by draining the individual upwellers onto a 1-mm mesh screen.

We will assess viability using drop velocity of the seeds. In the absence of any rapid method to determine viability of large numbers of seeds without destroying the seeds (e.g. tetrazolium staining), we have traditionally assessed seed quality by individually examining seeds in subsamples and categorizing each seed as “good” (firm seeds resisting compression when squeezed lightly with forceps, having an intact seed coat, and sinking rapidly in seawater), or “bad” (soft, damaged, or slow-sinking). Fall velocity was subjectively assessed by dropping each seed in a watch glass filled with seawater. The assumption that “good” seeds are viable is supported by observations of >90% germination of these seeds planted in sediment in lab conditions (Orth, unpublished).

These viable seeds will be housed in high salinity (> 20 psu) and controlled temperatures (21-24°C) in a recirculating water system to prevent accumulation of organic matter (Marion and Orth 2010). These seeds will be held until the fall for the planting in the field during the lower water temperatures which reduces the metabolism of the dominant seed predators in the Peconic Estuary.

After the reproductive shoots are harvested, effort will shift to collecting 25,000 adult shoots. Adult eelgrass shoots will be collected by hand via SCUBA from a vibrant eelgrass meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine

Station. Eelgrass sods will be removed from the sediment and transported in coolers to the marine stations. It is estimated that 40 m² of eelgrass will be removed along the edges of the meadow in 0.25 m² sods to acquire this number of transplanted adult shoots. These sods will then be washed of sediment and individual shoots with at least 3 cm of rhizome material attached to the terminal shoot will be removed and placed within a flow through seawater tank. At the conclusion of two days of harvesting, all adult shoots will then be woven into pre-cut and pre-holed burlap discs. The plants will be kept cool, shaded and submerged in seawater in a tote while weaving plants at the Southampton Marine Station. Adult eelgrass shoots will be “sewn” into the burlap disc from one punched hole to another. The meristem must be exposed and at the top of the disc after it is woven to access oxygen and cannot be trapped under the disc when planted. Each disc will possess 10 adult shoots and be stacked on each other through a wire skewer in bundles of 10 disks. All discs will be transported to the restoration site on the third day and planted. Volunteers may weave plants on shore of the restoration site if shoots remain to be weaved.

Divers will mark the working line with a 50 m transect tape and lay the 1 m² quadrat at the 0 mark and flip the quadrat to move along the transect planting in 1 m, skipping 1 m and planting in the next to create a large checkerboard of plantings in the restoration area. At each 1m² planting location along the transect, divers will place 5 PVC rings in an “X” formation and push them 4-6 cm into the sediment. The top 4-6 cm of sediment is then excavated by hand and a burlap disc is removed from the wire skewer and placed within the ring with the leaves facing upward. The ring is filled with sediment until the burlap disc is fully buried. After checking that all leaves are vertical in the water column, the process is repeated until all five rings have been filled with burlap discs and covered with sediment. The rings are removed and the diver advances to the next 1m planting location along the transect.

In October, the seeds will be deployed within the same 1m² planting sites that the burlap discs were buried. The harvested seeds will be placed into 5 cm x 5 cm burlap bags to protect them from potential predation (Fishman and Orth 1996) and to minimize burial and/or lateral transport (Harwell and Orth 1999). At the restoration site, burlap bags will be soaked in seawater for several minutes to expand the fibers. Then, approximately 125 viable eelgrass seeds will be placed into a burlap bag with a handful of sediment from the site and tied close. These seed bags will be placed on the sediment surface between the buried burlap discs and buried to a depth of 2-3 cm and anchored with a U-shaped 10 cm staple.

B3: Sample Handling and Custody

Rn-222 survey:

All physiochemical and Rn-222 measurements are performed in situ and recorded on the data sheet in Figure 8.

Figure 8. Field log template for surface water radon sampling.

Eelgrass Seed Collection:

Surface Water Radon Sample Log

Site: _____

Personnel: _____

Date / Time: _____

Initial Wind Speed / Weather: _____

Purge Start / Purge Stop: _____ / _____

Mode & Cycle: _____

Page: _____

Sample ID	Rad-7 or Rad-8 S/N	Run #	Time	²²² Rn Activity (Bq m ⁻³)	Error (+/-) (Bq m ⁻³)	Wind Speed / Weather / Waypoint /Notes

Signature: _____ Date: _____

In June 2023, 500 eelgrass reproductive shoots (~20,000 seeds) will be collected by hand via SCUBA from a large and vibrant meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station. Harvested shoots will be stored indoors within 5 upwellers placed inside a 3,500-L tank with flow-through seawater for approximately three weeks until all mature seeds are released from flowering shoots. Water flow will be adjusted to produce a full exchange of water in approximately 2 hours, and air lines along

the bottom will vigorously aerate the tank contents. Individual rhipidium will be removed from the reproductive shoots and held within the upwellers. Each upweller will hold the rhipidia of 100 harvested shoots. The upwellers will be stirred daily to facilitate flushing of decomposing material, and to prevent establishment of anoxic zones on the upweller screen bottom.

We will use a multi-stage process to isolate seeds from the large volume of decomposing plant matter present after seed release, relying on the rapid sinking rate of viable, mature seeds (see below) to achieve separation without sieving. After three to four weeks the rhipidia will have released their seeds, allowing a portion of the floating grass material to be removed. Upwellers will be vigorously stirred, and after allowing seeds to fall to the bottom for at least 10 seconds, vegetative fragments will be removed by dipping 1-cm mesh screens in the surface layer. This cycle will be repeated until little material appears on the screens. Seeds will be removed by draining the individual upwellers onto a 1-mm mesh screen. We will assess viability using drop velocity of the seeds. In the absence of any rapid method to determine viability of large numbers of seeds without destroying the seeds (e.g. tetrazolium staining), we have traditionally assessed seed quality by individually examining seeds in subsamples and categorizing each seed as “good” (firm seeds resisting compression when squeezed lightly with forceps, having an intact seed coat, and sinking rapidly in seawater), or “bad” (soft, damaged, or slow-sinking). Fall velocity was subjectively assessed by dropping each seed in a watch glass filled with seawater. The assumption that “good” seeds are viable is supported by observations of >90% germination of these seeds planted in sediment in lab conditions (Orth, unpublished data). These viable seeds will be housed in high salinity (> 20 psu) and controlled temperatures (21-24°C) in a recirculating water system to prevent accumulation of organic matter (Marion and Orth 2010) within a single upweller until the fall 2023 for planting in the field during the lower water temperatures which reduces the metabolism of the dominant seed predators in the Peconic Estuary. Based on previous eelgrass seed-based restoration projects this will result in approximately 20,000 viable seeds (Gobler et al. 2022). This task includes SWMS participation in field work as part of these eelgrass restoration activities.

Test Plantings and Initial Drone Imagery:

Eelgrass adult shoot test plantings will be conducted at five locations across the footprint of the two selected potential restorations sites based on the overflights and radon-222 surveys using the burlap disc method (DMF 2014). In September 2023, 2,500 adult shoots will be collected by hand via SCUBA from a vibrant eelgrass meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station. Eelgrass sods will be removed from the sediment and transported in coolers to the marine stations. These sods will then be washed of sediment and individual shoots with at least 3 cm of rhizome material attached to the terminal shoot will be removed and placed within a flow through

seawater tank. At the conclusion of the two days of harvesting, all adult shoots will then be woven into pre-cut and pre-holed burlap discs. The plants will be kept cool, shaded and submerged in seawater in a tote while weaving plants at the Southampton Marine Station. Adult eelgrass shoots will be “sewn” into the burlap disc from one punched hole to another. The meristem must be exposed and at the top of the disc after it is woven to access oxygen and can not be trapped under the disc when planted. Each disc will possess 10 adult shoots and be stacked on each other through a wire skewer in bundles of 10 disks. All 250 discs will be transported to the field and 125 burlap discs will be planted at each of the two potential restoration sites in five 9m x 9m test planting plots on the third day. Volunteers may weave plants on shore of the restoration site if shoots remain to be weaved.

Divers will mark the boundary of each 9m x 9m test plot with screw anchors and using transect tape between two screw anchors at one side of the plot will lay the 1 m² quadrat at the corner and flip the quadrat to move along the transect planting in 1 m, skipping 1 m and planting in the next, then flip up and over to the middle of the test plant site and over and up to the final top row to create a large checkerboard of plantings in each of the five pilot test planting locations. At each 1m² planting location, divers will place 5 PVC rings in an “X” formation and push them 4-6 cm into the sediment. The top 4-6 cm of sediment is then excavated by hand and a burlap disc is removed from the wire skewer and placed within the ring with the leaves facing upward. The ring is filled with sediment until the burlap disc is fully buried. After checking that all leaves are vertical in the water column, the process is repeated until all five rings have been filled with burlap discs and covered with sediment. The rings are removed and the diver advances to the next 1m planting location along the transect. In October, the eelgrass seeds will be deployed within the same 1m² test planting sites that the burlap discs were buried. The harvested seeds will be placed into 5 cm x 5 cm burlap bags to protect them from potential predation (Fishman and Orth 1996) and to minimize burial and/or lateral transport (Harwell and Orth 1999). At the two potential restoration sites, burlap bags will be soaked in seawater for several minutes to expand the fibers. Then approximately, 125 viable eelgrass seeds will be placed into a burlap bag with a handful of sediment from the site and tied close. These seed bags will be placed on the sediment surface between the buried burlap discs (n=4 per 1m²) and buried to a depth of 2-3 cm and anchored with a U-shaped 10 cm staple. This checkered pattern allows for a larger planted area while requiring fewer shoots to be transplanted and incorporates space for growth and expansion. This planting design has been successfully used in several restoration efforts (Davis and Short 1997, Kopp and Short 2001, Leschen et al. 2010). These ten test plantings sites will be distributed across the footprint of each restoration site. Initial drone visible-light imagery of each site will be acquired (September – October 2023).

Drone Imagery:

Drone imagery will be acquired immediately after the eelgrass adult shoot transplanting in the test plots is completed (September). Imagery will be collected with a Phantom 4 DJI quadcopter flown in a boustrophedonic (lawn-mower) pattern with waypoints pre-programmed in Pix4D Capture (Pix4D), with the camera triggering automatically. The optical sensor is a 12.4 megapixel, 1/2.3" sensor camera attached to a 3-axis gimbal on the base of the drone. Flights will be undertaken at 80 m altitude in order to produce images of <5 cm per pixel over several hundred m². All hardware calibration steps will be undertaken on land before embarking to the survey site. Surveys will be undertaken late in the afternoon when the sun is lower on the horizon to reduce the influence of glare and glint on the images. No ground control points (GCPs) will be deployed. Instead, the UAV GPS will be used to georeference the mosaic, in a method known as direct georeferencing. Geographic data sets produced with direct referencing should be considered in context of the onboard GPS positioning accuracy, which for the DJI Phantom 4 is ± 1.5 m horizontally and ± 0.5 vertically according to the technical specifications from DJI. All images will be taken with the camera facing down, to ensure camera position will be associated with the center of the image. It is assumed that two flights will be necessary to cover the entire area. Once imagery is acquired, the individual images will be used to create a georeferenced mosaic in Pix4d with sub-meter resolution. This initial image will serve as the baseline image for the change in eelgrass coverage in subsequent years.

Test plots will be monitored in May 2024. Growth of the areal coverage will be determined via re-captured drone imagery of each test plot comparing initial planting and eelgrass coverage in May 2024.

Large Scale Restoration Activities:

In June 2024, 25,000 reproductive eelgrass shoots (~1,000,000 seeds) will be collected by hand via SCUBA from a vibrant eelgrass meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station. Harvested shoots will be stored indoors within 14 upwellers placed inside a 3,500-L tank with flow-through seawater for approximately three weeks until all mature seeds are released from flowering shoots. Water flow will be adjusted to produce a full exchange of water in approximately 2 hours, and air lines along the bottom will vigorously aerate the tank contents. Individual rhipidium will be removed from the reproductive shoots and held within the upwellers. Each upweller will hold the rhipidia of 1,300–1,500 harvested shoots. The upwellers will be stirred daily to facilitate flushing of decomposing material, and to prevent establishment of anoxic zones on the upweller screen bottom.

We will use a multi-stage process to isolate seeds from the large volume of decomposing plant matter present after seed release, relying on the rapid sinking rate of viable, mature seeds (see below) to achieve separation without sieving. After three to four weeks the

rhizoids will have released their seeds, allowing a portion of the floating grass material to be removed.

Upwellers will be vigorously stirred, and after allowing seeds to fall to the bottom for at least 10 seconds, vegetative fragments will be removed by dipping 1-cm mesh screens in the surface layer. This cycle will be repeated until little material appears on the screens. Seeds will be removed by draining the individual upwellers onto a 1-mm mesh screen.

We will assess viability using drop velocity of the seeds. In the absence of any rapid method to determine viability of large numbers of seeds without destroying the seeds (e.g. tetrazolium staining), we have traditionally assessed seed quality by individually examining seeds in subsamples and categorizing each seed as “good” (firm seeds resisting compression when squeezed lightly with forceps, having an intact seed coat, and sinking rapidly in seawater), or “bad” (soft, damaged, or slow-sinking). Fall velocity was subjectively assessed by dropping each seed in a watch glass filled with seawater. The assumption that “good” seeds are viable is supported by observations of >90% germination of these seeds planted in sediment in lab conditions (Orth, unpublished data).

These viable seeds will be housed in high salinity (> 20 psu) and controlled temperatures (21-24°C) in a recirculating water system to prevent accumulation of organic matter (Marion and Orth 2010). These seeds will be held until the fall for the planting in the field during the lower water temperatures which reduces the metabolism of the dominant seed predators in the Peconic Estuary.

After the reproductive shoots are harvested, effort will shift to collecting 25,000 adult shoots. Adult eelgrass shoots will be collected by hand via SCUBA from a vibrant eelgrass meadow in Shinnecock Bay, NY within close proximity to the Southampton Marine Station. Eelgrass sods will be removed from the sediment and transported in coolers to the marine stations. These sods will then be washed of sediment and individual shoots with at least 3 cm of rhizome material attached to the terminal shoot will be removed and placed within a flow through seawater tank. At the conclusion of two days of harvesting, all adult shoots will then be woven into pre-cut and pre-holed burlap discs. The plants will be kept cool, shaded and submerged in seawater in a tote while weaving plants at the Southampton Marine Station. Adult eelgrass shoots will be “sewn” into the burlap disc from one punched hole to another. The meristem must be exposed and at the top of the disc after it is woven to access oxygen and can not be trapped under the disc when planted. Each disc will possess 10 adult shoots and be stacked on each other through a wire skewer in bundles of 10 disks. All discs will be transported to the restoration site on the third day and planted. Volunteers may weave plants on shore of the restoration site if shoots remain to be weaved.

Divers will mark the working line with a 50 m transect tape and lay the 1 m² quadrat at the 0 mark and flip the quadrat to move along the transect planting in 1 m, skipping 1 m and planting in the next to create a large checkerboard of plantings in the restoration area. At each 1m² planting location along the transect, divers will place 5 PVC rings in an “X” formation and push them 4-6 cm into the sediment. The top 4-6 cm of sediment is then excavated by hand and a burlap disc is removed from the wire skewer and placed within the ring with the leaves facing upward. The ring is filled with sediment until the burlap disc is fully buried. After checking that all leaves are vertical in the water column, the process is repeated until all five rings have been filled with burlap discs and covered with sediment. The rings are removed and the diver advances to the next 1m planting location along the transect.

In October, the seeds will be deployed within the same 1m² planting sights that the burlap discs were buried. The harvested seeds will be placed into 5 cm x 5 cm burlap bags to protect them from potential predation (Fishman and Orth 1996) and to minimize burial and/or lateral transport (Harwell and Orth 1999). At the restoration site, burlap bags will be soaked in seawater for several minutes to expand the fibers. Then approximately, 125 viable eelgrass seeds will be placed into a burlap bag with a handful of sediment from the site and tied close. These seed bags will be placed on the sediment surface between the buried burlap discs and buried to a depth of 2-3 cm and anchored with a U-shaped 10 cm staple.

B4: Analytical Methods

Thermal Infrared Flyover:

Following quality control checks (section B5), raw thermal infrared images will be georectified using a Geographic Information System (*e.g.*, ENVI, ArcGIS Pro or similar software). Images will be georeferenced to current New York State orthomosaics (<http://www.orthos.dhSES.ny.gov/>) by manual selection of ground control points. Georectified imagery will be cropped to only include sea surface temperatures (excluding land) and overlain onto orthomosaic imagery to produce SST maps for regions identified by the USGS models (Tamborski et al. 2015).

Rn-222 Survey:

All physiochemical and Rn-222 measurements are performed in situ and recorded on the data sheet in Figure 8. Field in-situ Rn-222 measurements record radon-in-air concentrations. The manufacturer provided software *Capture* will be used to calculate radon-in-water concentrations via solubility corrections for measured water temperature and salinity (Schubert et al. 2012). Capture software will further be used for humidity corrections and B-to-A window spillover. Surface water Rn-222 concentrations, salinity

and temperature measurements will be overlain on top of georectified TIR imagery in a GIS to create maps of groundwater influence for regions identified by the USGS models.

B5: Quality Control

Personnel working on groundwater identification will be trained on all aspects of TIR/radon collection, processing and analysis by Joseph Tamborski.

Thermal Infrared Overflight:

Raw TIR images will initially be QC inspected based on (1) presence of land/structures and (2) motion blur. Shoreline and structures, including docks and piers, are necessary to place and geo-rectify the TIR image. Motion blur can be caused by wind gusts and/or vibration during flight and can be readily flagged by visual inspection (Dugdale, 2016; Figure 9). Raw TIR images flagged with either of these two parameters will not be used for subsequent analysis.

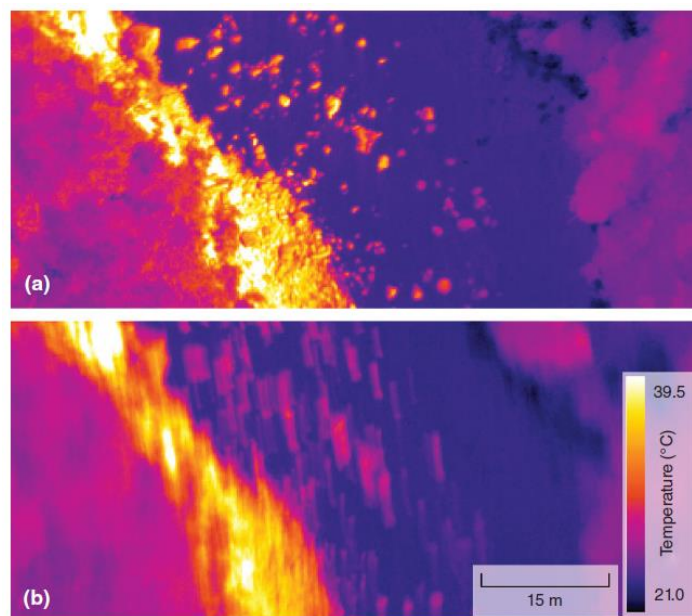


Figure 9. Adapted from Dugdale, 2016. An example of motion blur on a raw TIR image: (A) a “sharp” image and (B) a blurred image, over the same scene.

Thermal infrared imagery generated by the FLIR T640 is sufficiently precise to resolve *relative* temperatures differences within a single image frame, set by the pixel-to-pixel thermal accuracy of 0.1 K. Thermal data will vary from image-to-image due to the camera’s nonuniformity correction system (Dugdale, 2016). Given these considerations, we will only focus on relative thermal differences within a single image and will not make any quantitative correction to compare absolute temperature values between images or

to validate in-situ temperature (Karis-Allen et al. 2022). We will have a minimum of two overpasses at each site to minimize any gaps in TIR imagery along targeted shorelines. At 1800 m altitude, a single image will have a swath width of 1km or greater.

QC checked TIR images will be visually inspected to review for other sources of thermal uncertainty not caused by groundwater, following Dugdale (2016), including:

- Shadows cast by bankside objects (e.g., trees)
- Presence of foam on water surface
- Boat wakes
- Exposed rocks and sediments
- Shallow subsurface structures (e.g., drainage pipes)

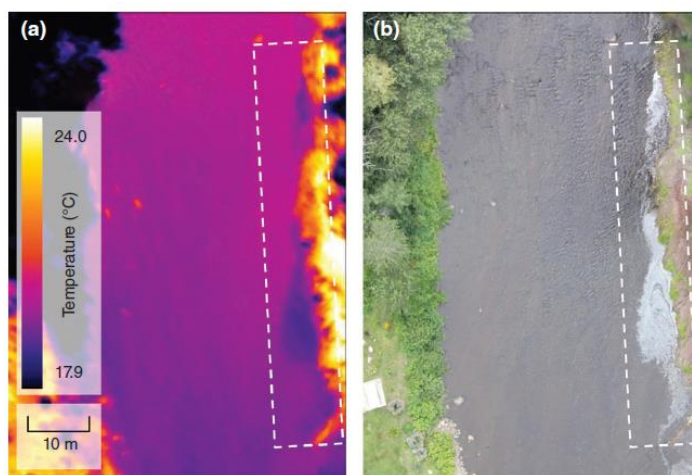


Figure 10. Adapted from Dugdale, 2016. An example of shadow cooling caused by bankside trees.

Each TIR image will be compared side-by-side with the simultaneously collected visible-light image (e.g., Figures 9 & 10). Each of the five checklist items will be reviewed, for each scene, to determine any TIR anomaly that is *not* caused by groundwater discharge.

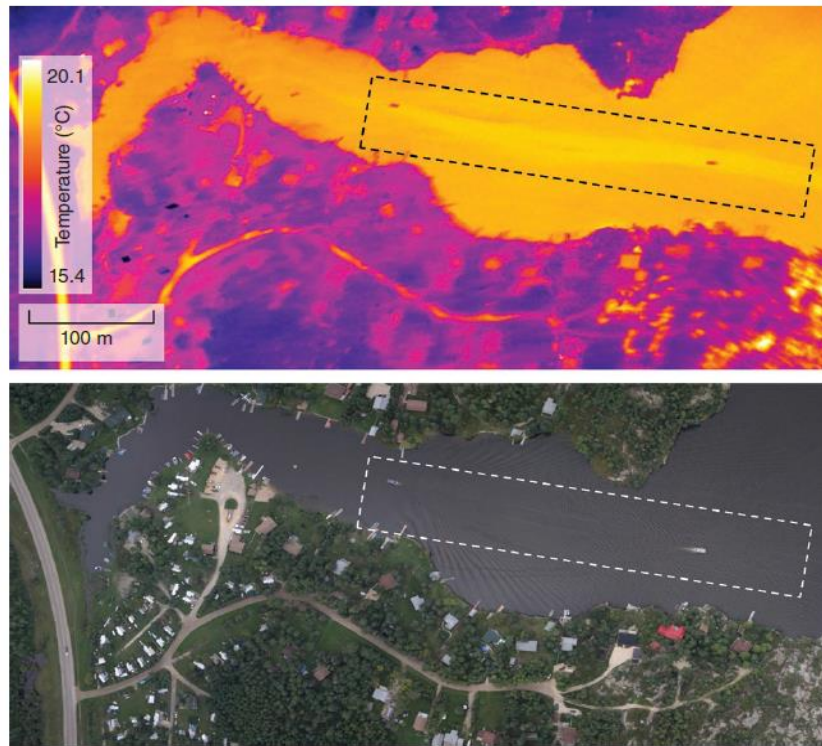


Figure 11. Adapted from Dugdale, 2016. An example of a boat wake producing an anomalous TIR surface signal.

Raw TIR images will be compared to visible light imagery and to a 1m contour bathymetry dataset (NOAA, 2007) to initially exclude temperature anomalies related to storm drain runoff, sewage outfall, and/or bathymetry (Kelly et al. 2013). Select thermal images over shoreline areas of interest, driven by USGS hydrologic model outputs, will be georeferenced to current New York State orthomosaics (0.25 m spatial resolution), available from New York State Orthos Online (www.orthos.dhSES.ny.gov). These final, ortho-rectified images will be used to produce the proposed mapping outputs.

Raw images (TIR, visible) and final map outputs (.jpegs) will be saved to the PEP Github server, and will be further saved on the ODU Microsoft OneDrive.

Radon survey and in-situ data:

Uncertainty in in-situ radon analysis is due a function of boat speed, sampling interval (count time) and activity (Dimova et al. 2013); uncertainty is approximately 10-15% without compromising the ability of the instrument to react to changes in radon activity.

Raw RAD7 data will be downloaded and processed using Capture software (Durrig Co.), where radon-in-water concentrations will be determined from radon-in-air measurements after solubility corrections for in-situ temperature and salinity, following

Schubert et al. (2012). Temperature and salinity data will be taken from the LTC5 levellogger by matching timestamps. Radon-in-water measurements will be corrected to the time and position of initial sampling (Schubert et al. 2019). Through this process, any anomalous radon data will be flagged based on the Capture software.

For the LTC5 levellogger, manufacturer standard operating procedures will be followed for data control, and can be found here:

<https://www.solinst.com/products/dataloggers-and-telemetry/3001-levellogger-series/operating-instructions/user-guide/7-data-control/7-data-control.php>

B7: Instrument/Equipment Calibration and Frequency

Thermal infrared overflight:

The infrared camera will be calibrated for atmospheric reflectivity and transmission prior to the flight following manufacturer protocols (<https://www.flir.com/support/products/t640/#Documents>).

In-situ parameters:

The Solinst LTC5 levellogger used for in-situ temperature and salinity measurements will be calibrated the day prior to field usage, for all campaigns. These calibrations will be performed by Dr. Tamborski and will be documented. A three-point conductivity calibration will be performed with manufacturer-provided conductivity standard reference materials within the range of anticipated conductivities (5,000, 12,880 and 80,000 $\mu\text{S}/\text{cm}$), using the manufacturer-provided software (Levellogger 4.6.1 or newer). Manufacturer guidelines can be found here:

<https://www.solinst.com/products/dataloggers-and-telemetry/3001-levellogger-series/operating-instructions/user-guide/6-conductivity-calibration/6-conductivity-calibration.php>

Radon survey:

From DurrIDGE Co: *"DurrIDGE calibrates all instruments to a set of four "master" instruments with a calibration precision of 1% or better. The master instruments have been calibrated by way of intercomparison with secondary standard radon chambers designed by the U.S. EPA... [DurrIDGE] determine[s] calibration factors by direct comparison to "master" radon monitors, which were themselves compared with EPA and DOE instruments, and which have participated in international inter-comparisons of radon instrumentation. The calibration accuracy is independently verified by direct determination of the radon chamber level from the calibrated activity and emission of the standard radon source... The U.S. EPA recommends that continuous radon monitors such as the RAD7[and RAD8] be calibrated at least once per year, and DurrIDGE agrees."*

We will use radon monitors that have been manufacturer calibrated within the one-year window recommended by US EPA and the manufacturer, following standard operating procedures.

Light:

The LiCor LI-192 Underwater Quantum sensors are calibrated prior to delivery from the factory and recalibrated every 2 years after field deployment. Calibrations of quantum and photometric sensors at LI-COR are obtained using standard light sources that are traceable to NIST. Sensor spectral response conformity is measured using a computer-controlled spectrophotometer and reference silicon photodiodes. Sensors are cleaned prior to the calibration, inspected for diffuser and/or cable aberrations, and repaired as needed. The sensor's relative spectral response is measured to check its conformity to the ideal response. The sensor's actual response is then run through the spectral error routine which calculates the theoretical reading errors that would occur with a variety of light sources to check for acceptable limits.

Following the instructions in the PME miniPAR User Manual the instrument will be set at a logging interval to 15 minutes. In addition, following the instructions in the PME miniWiper User Manual the wipe interval will be set to 30 minutes. Prior to deployment, the calibration LiCor sensor will be mounted with the PME miniPAR sensors to a bracket that will keep all three quantum sensors horizontal and placed in full sunlight within 2 hours of local apparent noon. At the end of the 1 hour logging period, the one hour average of the calibration logger will be used to compare with the miniPAR sensors. Small differences in sensor output can be corrected using this inter-calibration data, but if either underwater sensor differs from the air sensor by more than 20%, then it is very likely damaged and should be factory serviced. This inter-calibration will be conducted and documented by Dr. Peterson. On field sampling days, an independent measurement of light will be recorded adjacent to the miniPARs with the use of an LI-1400 LiCor logger with a PAR sensor held at the same depth as the bottom most miniPAR sensor.

Water Temperature

Onset HOBO pendent temperature loggers will be calibrated to known water temperature prior to deployment. All temperature loggers will be submerged in a water bath for a 1 hour period and each HOBO logger will be compared to the water bath temperature. Post calibration will be conducted the same way to insure data quality. This will be conducted by Dr. Peterson and documented.

B6: Instrument/Equipment Testing, Inspection and Maintenance

Field equipment is to be maintained according to the manufacturer's procedures. Equipment will be tested in the laboratory prior to field deployment. If the test fails the manufacturer's SOP, then a replacement unit will be used and/or the failed equipment will be returned for maintenance and repair. Each PI will perform the testing of their equipment and document this prior to each use.

B8: Inspection/Acceptance of Supplies and Consumables

Consumables are inspected/cleaned in the lab before being taken into the field. Laboratory consumables are inspected/cleaned in the lab and stored before use.

Supplies and consumables shall order through Stony Brook University and Old Dominion University from reputable sources and in line with procurement standard operating procedures for New York State and Virginia. All items will be inspected visually by Dr. Peterson and/or Dr. Tamborski prior to use. These inspections will be documented prior to each use.

B9: Non-Direct Measurements (i.e. secondary data)

The US Geological Survey's hydrogeologic model output will be used as a guide for initial field operations (**Figures 2, 4**). Six shoreline regions susceptible to groundwater discharge will be selected, based upon modeled absolute discharge and specific discharge rates. A summary of the model is publicly available (<https://pubs.er.usgs.gov/publication/sir20205091>) and includes links for model code and a pair of key datasets used in model development (Walter et al., 2020). No new data will be generated from this task.

B10: Data Management

Raw TIR and visible overflight imagery will be saved to the ODU Microsoft OneDrive, and to an external hard-drive specific to this project. QA/QC approved TIR images will be saved to the PEP Github. Radon survey data will be saved in a table format to the ODU Microsoft OneDrive and PEP Github (as Excel and CSV files); all map outputs (ArcGIS Pro or similar software, including raw .jpeg files) will be saved to the PEP Github. We anticipate producing in-situ salinity, temperature, pCO₂ and radon maps of the six regions of interest, for August 2023, and two maps for the test planting zones in December 2023. Maps will be produced in ArcGIS Pro or a similar software, and raw map outputs (.jpegs) will be saved to the PEP Github; all data will be saved to the ODU Microsoft OneDrive.

Records from the field will be kept on waterproof paper, formatted, and printed using a laser ink printer. The datasheets will be kept in an enclosed binder and taken out of the binder upon return to the laboratory and placed in a filing cabinet. The datasheets will then be entered by personnel, initials and date entered will be placed at the header when complete, these entries will then be cross-checked by Brad Peterson before analysis. The documents will be scanned and corresponding entered data will be uploaded to the Stony Brook University Electronic Repository (SBUER). Hard copies will be kept by Brad Peterson. HOBO datalogger files will be transferred to the computer with the Onset HOBOWare Underwater Shuttle (retrieved data from the dataloggers in the field) with HOBOWare Pro software and converted to .csv files. PMEminiPAR light records will be retrieved from the sensors. All files will be duplicated onto a USB drive and uploaded to the SBUER and PEP Github.

All electronic data will have corresponding dates, location, and parameter values in the same format and unit. Calibration datasheets will be kept with the field datasheets in a separate folder, scanned, and uploaded to the SBUER. All documentation and data files will be housed at Stony Brook University no less than five years after the completion of this project.

Section C: Assessment and Oversight

This section addresses the activities for assessing the effectiveness of the implementation of the quality assurance and quality control activities. The purpose of the assessment is to ensure that QAPP is implemented as described.

C1: Assessments and Response Actions

After field sampling, log sheets and raw data is checked to ensure that everything has been filled out properly, labeled, and put in the proper location. This will be conducted in the field on the day of sampling and all data sheets will be assessed at the end of the day prior to leaving the field. All data will be reviewed after analysis to be sure it meets QA/QC requirements. Any data entered into a Microsoft Excel will be checked to determine if it was properly entered within 15 days. Backup copies will be saved on a flashdrive/external hard drive every 30 days during the field season or active time of data collection. Bradley Peterson and Joseph Tamborski will oversee and provide regular checks including verifying field and laboratory procedures, both daily in the field and throughout the season overseeing data analysis. Regular check in with the PEP according to the QAPP and contract agreement will occur quarterly. If corrective action is needed, it will be reported to the Pls. Pls will investigate the issues, document the issue, retrain data collectors, and take appropriate corrective action within 30 days of issue arising.

C2: Reports to Management

Documentation of data and QA/QC will be available via request; all data will be kept on Microsoft Excel spreadsheets. Reports will be prepared by PEP, SBU and ODU personnel and distributed to RAE and EPA in a timely manner consistent with project reporting requirements.

Quarterly reports will be submitted, incorporating all of the sampling conducted to that point. Following the final quarterly report, a final report will be created that includes all of project data as well as spatial maps of SST and radon.

- Interim Progress Reports: quarterly reports will be provided to RAE and shall describe all of the sampling and analyses conducted to that point. The PEP Technical Advisory Committee (TAC) will be updated quarterly based on these reports.
- Final Report: a draft final report will be submitted for review to Restore America's Estuaries and the EPA. This report will include:
 - An executive summary
 - A summary of all methods used, analytical techniques and results.

- Implications of the work for comprehensive conservation and management plan implementation.
- Recommendations for new management actions or modifications to existing priority actions.
- Recommendations for future restoration and protection activities.
- Amend the draft final project report as necessary, in response to comments provided.
- Present a final report to the PEP Technical Advisory Committee and RAE.

The final report will be modified for publication in the primary scientific literature. Bradley Peterson will be responsible for all data reduction and data quality assurance related to eelgrass restoration, and Joseph Tamborski will be responsible for all data reduction and data quality assurance related to groundwater discharge. All data, after reduction and quality assurance, will be archived electronically and housed at the Geospatial Center Server for PEP at Stony Brook. In addition to the electronic data files, metadata for all spatial and non-spatial data describing the history of where, when and why the data were collected, who collected the data and the methods used to collect and process the data will be provided with the final report. The final report will also be presented to the PEP Management Conference for input and approval.

Section D: Data Validation and Usability

This section addresses the QA activities that occur after the data collection of the project has been completed. Implementation of these elements ensures that the data conform to the specified criteria and achieve the project objectives.

D1: Data Review, Verification, and Validation

Data collected in the field (on datasheets and handheld devices) will be reviewed during collection, upon return to the laboratory, and again after data has been input electronically to ensure consistency. Data will be input by trained staff and crosschecked prior to analysis. Inconsistent values will be removed before analysis, such as negative and otherwise impossible values. All data generated from field and lab work will be reviewed and analyzed by project personnel.

For the airborne TIR imagery and in-situ measurements (salinity, temperature, radon; Task 5), the QC procedure outlined in Section B5 will be used to accept or reject data in an objective and consistent manner.

For the field measurements of shoot counts, two divers will each conduct one QA/QC count on each 9x9 m² grid. If the counts are more than 10% off, 9x9m² grid will be

recounted. All HOB0 and miniPAR data will be post processed for values more than 2 standard deviations from the mean. If values exist, those records will be scrutinized to determine whether those values were possible.

D2: Verification and Validation of Methods

Data validation and verification will include checks on:

- Completion of all fields on data sheets; missing data sheets
- Completeness of sampling runs (e.g. number of sites visited/samples taken vs. number proposed, were all parameters sampled/analyzed)
- Completeness of QC checks (e.g. number and type of QC checks performed vs. number/type proposed)

QA/QC from instrument guidelines/SOPs will be followed to ensure that data is precise and accurate. Once data are generated, they will be examined to determine if there are any outliers that may indicate erroneous values (e.g., via graphing of data series to determine negative or otherwise impossible values). If there are outliers, the data will be studied to determine if it was a sampling/preparation error, an instrumentation error, or a calculation error. This will be recorded in the spreadsheet.

Thermal infrared, in-situ physiochemical and radon-222 measurements will be collected in the field. These data will remain with ODU project personnel, backed up to Microsoft OneDrive and an external hard-drive. Thus, the chain-of-custody for these raw data products rests solely with the generators (ODU). Final data outputs will be saved to the PEP Github and distributed to appropriate RAE and EPA personnel.

D3: Reconciliation with User Requirements

At the conclusion of the sampling season, after all in-season quality control checks, assessment actions, validation and verification checks and corrective actions have been taken, the resulting data set will be compared with the program's data quality objectives (DQOs). This review will include, for each parameter, calculation of the following:

- Completeness goals: overall % of samples passing QC tests vs. number proposed
- Percent of samples exceeding accuracy and precision limits
- Average departure from accuracy and precision targets

After reviewing these calculations, and taking into consideration such factors as clusters of unacceptable data (e.g. whether certain parameters, sites, dates, volunteer teams etc. produced poor results), the QA/QC Manager will evaluate overall program attainment of DQOs and determine what limitations to place on the use of the data, or if a revision of the DQOs is allowable.

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Attachment A – Decision Tree for Data Quality Evaluation

