Coastal Resilience Center of Excellence
Research Lead

based at

The University of North Carolina at Chapel Hill

YEAR 5 ANNUAL REPORT

Reporting Period:
July 1, 2019 – June 30, 2020
Award Number 2015-ST-061-ND0001-01

submitted to:

The Office of University Programs
Science & Technology Directorate
U.S. Department of Homeland Security

Coastal Resilience Center of Excellence
100 Europa Drive, Suite 540
Campus Box 7581
Chapel Hill, NC 27517
coastalresiliencecenter.unc.edu

July 30, 2020
Updated December 21, 2020

CRC YEAR 5 ANNUAL REPORT
TABLE OF CONTENTS

Theme 4: Education and Workforce Development

Appendices

I. INTRODUCTION AND CENTER OVERVIEW

This report provides a description of the activities and accomplishments of the Coastal Resilience Center of Excellence (CRC) that occurred during Year 5 of the Center's operations, covering the reporting period July 1, 2019, to June 30, 2020.

Report Structure

The first section of this annual performance report summarizes the administrative/management structure of the CRC, followed by a description of selected activities that were undertaken at the Center level during Year 5, including supplemental studies, tasks in support of the DHS S&T Centers of Excellence network, and ongoing program activity.

Following the summary is a section containing individual progress reports from each of the CRC PIs. The CRC provided a template to assist PIs describe in detail their research and education activities; progress in achieving project milestones; efforts towards transition of project outputs; interactions with end-users and stakeholders; and student activity. In addition, the template included a customized chart for each PI to report on project metrics for Years 1-5. These metrics are reported in the aggregate to DHS OUP each calendar year.

Finally, this report includes two appendices: Appendix A contains material submitted by PIs Berke and Ginis that supplements their respective reports. Appendix B contains a list of journal articles, conference papers, student dissertations and theses, and other documents produced by PIs and students with support from CRC.

CRC Project Composition

During Year 5 CRC managed a total of 16 projects carried out by partners from 12 universities and colleges and two private-sector firms located in eight U.S. states and one U.S. territory. Five projects focused on enhancing and institutionalizing education and workforce development programs at partner institutions; of these partners, four are classified as Minority Serving Institutions (MSIs). The remaining CRC projects focused primarily on research in coastal hazards modeling, planning, and social and behavioral sciences.

Delays in receiving full funding during Year 4 (including restrictions on 50% of the funding for ADCIRC-related projects) continued to impact the ability of several investigators to meet milestones on time, although most projects were able to catch up in Year 5. In addition, the Coronavirus pandemic (novel coronavirus-19) impacted the progress of some PIs due to necessary changes in normal operations, including implementation of on-line activities for remote teaching, learning, and research, as well as the impact of the virus on graduate students' research. However, despite the unexpected modifications of routine activities, PIs remained largely on track to meet Year 5 milestones.

Summary Statistics

Despite the unanticipated disruption of business as usual, CRC PI's made steady progress in their projects, as demonstrated by the following aggregated figures:

- PI’s reported teaching **38 courses** to **320 students** across five campuses, including class offerings in multiple categories, such as majors, minors, concentrations, certificate programs, seminars, and electives.

- Students were involved in **20 internships** related to Homeland Security.

- **51** students received **Homeland Security-related degrees**, nearly half of which were at the graduate level.

- **13** students secured **employment in Homeland Security**-related fields.

- **63** journal articles and other types of publications were submitted and/or published.

- PIs gave **147** project-related **presentations** in a variety of settings, including professional conferences, visiting lecture series, panel discussions and outreach events, among others.

- Center partners reported **more than $2.1 million in non-OUP funding**. Funding came from a variety of sources, such as government agencies, foundations and internal institutional programs.

CRC Administration and Management

The following organizational chart depicts the structure of CRC administration and management during Year 5. Executive Director Thomas Richardson, Education and Workforce Development Director Dr. Robert Whalin, and Administrative Assistant Ms. La Shon Lowe Austin operate from Jackson State University in Jackson, MS. Lead PI Rick Luettich and remaining CRC staff are located at the University of North Carolina at Chapel Hill. Despite the distance among team members, the workflow and decision-making processes of Center management are highly collaborative, facilitated by frequent communication via email, Zoom, phone, etc. This pre-existing relationship allowed for easy transition to working remotely due to Covid-19 beginning in March, 2020.

Figure 1: CRC organizational chart, July 1, 2019 – June 30, 2020

Internal Communications

Frequent communication continued to be an essential mechanism for ensuring coordination among members of the CRC management team during Year 5. As in prior years, weekly meetings were held every Monday morning with Center management and staff. A running chronological narrative for each issue and task was captured, listed, and assigned to a member of Center management for implementation. Monthly Center conference calls with PIs and Advisory Board members continue to be used to discuss business matters, plans and upcoming events, and to address questions and concerns. The CRC email listserv was used throughout Year 5 to send messages regarding important management issues, as well as information of general interest such as funding announcements, job postings, and student opportunities. Subscribers to the CRC listserv include PIs, Center management, and the DHS Program Manager and Project Coordinator. A separate listserv is used to communicate with Advisory Board members.

External Communications

Led by CRC Communications Manager, Josh Kastrinsky, CRC communicated information about its projects, events, successes and interactions with end users, stakeholders and the general public through the following media:

- News posts placed on the CRC website

- An informational website about the ADCIRC Prediction System™ (APS)
- Electronic newsletters issued 10 times a year
- Social media (Twitter and Facebook)
- Videos produced by CRC and in partnership with other groups, posted on YouTube, social media and the CRC website
- Media interviews about CRC projects and expertise regarding current hazard events
- Coordination of interviews and sharing of content through university and federal partners

Social media posts reach an audience of about 2,700 users across Twitter and Facebook, totaling about 50,000 impressions per month. The CRC website receives an average of about 1,900 unique visitors per month, while the CRC newsletter has about 1,500 recipients.

Chris Johns continues to serve as part-time Visual Communications/Digital Media Specialist to help guide, support, and execute the development and implementation of the CRC's graphic identity and visual media products. Mr. Johns creates and deploys print, digital and multimedia graphic products that tell the story of CRC work and that communicate the impacts and capabilities of Center products. In addition, Mr. Johns develops web graphics, informational graphics for projects, multimedia designs, animation and videography and has developed websites for CRC projects, managing both the technical and content elements.

During Year 5, CRC initiated the development of a new website for the ADCIRC Prediction System™ (APS™), highlighting the products offered by the software and providing a portal for public interaction with the developers. Work continues to expand the look and features of the website and to manage the site off of UNC servers to allow independent management beyond the life of the Center.

Unified Business Center

Essential support functions during Year 5 were provided by the Renaissance Computing Institute's Unified Business Center (UBC), including: assistance with grant management, financial administration, human resources, travel, event planning, purchasing, and other administrative functions. The UBC also continued to provide pre- and post-award administrative services, including developing, executing, and managing subcontracts. In addition, the UBC provides monthly reports on subcontractors' expenditure rates. These reports were formerly produced on a quarterly basis. The monthly expenditure reports are particularly useful to help CRC keep close track of projects that are lagging in their submission of invoices, allowing the management team to check on project progress, as well as encourage prompt invoicing as work is completed.

CRC Advisory Board

Many members of the CRC Advisory Board who served during Years 1-4 continued to be involved in the Center through Year 5 as well. Board members have helped the Center by reviewing and providing feedback on overall Center activities, evaluating current projects, and helping to place graduate students in internships and careers. Board members also help to identify transition partners, and to serve as subject matter experts as needed.

The primary mechanism for transmitting Board recommendations is the closed-door session immediately following the Center's Annual Meeting, as well as through communications with individual Board members.

The following members served on the CRC Advisory Board during Year 5:

- **Norma Anderson,** Founder, The William Averette Anderson Fund (BAF) for Hazard & Disaster Mitigation Education and Research
- **Doug Bellomo,** Lead for Flood Risk Management and Resilience Practice, AECOM
- **Chad Berginnis**, Executive Director, Association of State Floodplain Managers
- **Dr. John Cooper, Jr.,** Associate Professor of Practice, Landscape Architecture and Urban Planning Department, Texas A&M University
- **Dr. William Hooke,** Senior Policy Fellow and Director of Policy Programs, American Meteorological Society
- **Dr. Jae Park**, Associate Vice President, Risk Management & Resilience, AECOM
- **Dr. John Pine**, Director, Research Institute for Environment, Energy & Economics, Appalachian State University
- **Anthony Pratt,** Shoreline and Waterway Administrator, State of Delaware
- **Ellis Stanley**, Executive Vice President, Hammerman & Gainer International and former General Manager, City of Los Angeles Emergency Preparedness Department
- **Dr. Lee Weishar,** Senior Scientist, Woods Hole Group, Inc.

II. CENTER-LEVEL ACTIVITIES

Over the course of Year 5, the CRC administrative and management team carried out multiple activities on behalf of the Center, as summarized below. Additional information is found on the CRC website at coastalresiliencecenter.unc.edu.

CRC Annual Meeting

The fifth annual CRC meeting was held March 11-12, 2020 at the Center's main offices in Chapel Hill, NC. Originally planned as a two-and-a-half-day in-person event, due to the emergence of COVID-19 CRC leadership decided to cancel the final half day of the meeting. By condensing the final scheduled presentations and providing in-person attendees the option to continue their participation through Zoom, all of the items planned for the final day of the agenda, including the CRC advisory board meeting, were efficiently accomplished. Overall, 65 attendees participated in the event either in-person or remotely via Zoom, including CRC management and support team; Principal Investigators; CRC Advisory Board members; students; guest speakers; DHS personnel, OUP support staff, and members of the Federal Board of Directors.

During the meeting, each research PI made a detailed presentation about their project, including a summary of research methodology and findings, outcomes to date, milestone accomplishments, as well as an update on engagement with the project's end users. Education PIs focused on how their projects' course content is kept current, their level of engagement with HSE professionals, and plans for courses to continue post-CRC funding. In addition to discussing their project's progress during years 1-5, Research and Education PIs were given the opportunity to present their Year 6 proposals. The ADCIRC Year 6 proposals were presented by Lead PI Rick Luettich as a single portfolio in order to emphasize the cohesive nature of the ADCIRC projects.

The Federal Board of Directors prepared evaluations of each project's presentation. Results of these evaluations were received by the CRC and will be incorporated into project workplans during Year 6.

In addition to individual project presentations, updates about Center-level activities were also on the agenda, including the Flood Apex Project; RISE Conference; Joint Port Resilience Study, and the Coastal Probabilistic Hazard Assessment project. Guest speakers included a presentation by JCSU student William Case, who described his experience at the 2019 COE Summit; Dr. Olivia Scriven discussed her CRC-supported work with universities to provide recovery assistance to hurricane-impacted communities; Tia Maxwell stood in for Dr. Jessica Murphey to talk about the CRC-supported work of the JSU Center for Community Resilience; and presentations by teams who had participated in the DHS Summer Research Teams for Minority Serving Institutions program. Guest speakers included Benjamin Rance of FEMA who presented the Resilience Analysis and Planning Tool and Dr. Jessica Whitehead, NC Chief Resilience Officer.

ADCIRC Prediction System™ Business Plan

During Year 5, the CRC implemented a workplan to develop a business plan for making the ADCIRC Prediction System™ (APS) self-sustaining. A subcontract to lead this effort was let to Nancy Maron of BlueSky to BluePrint, LLC and a small advisory group formed to guide it and review results. The website https://adcircprediction.org/ was established, an electronic survey was developed and sent to the almost 700 registered users of the CERA web portal, a financial model was developed and populated with current information, and a number of one-on-one end user interviews were conducted.

ADCIRC Users Group Meeting and Boot Camp 2019

ADCIRC Week, originally planned to take place in Baton Rouge, went virtual this year. Led annually by CRC partner Seahorse Consulting, the 2020 ADCIRC Week consisted of a two-day Users Group Meeting and a three-day training event from March 30 to April 3, 2020. The event was held virtually via Zoom web conferencing in cooperation with Louisiana Sea Grant, Louisiana State University and The Water Institute.

Content during the Users Group Meeting included presentations and discussions on compound flooding in the ADCIRC context, model development, model applications, real-time forecasting using ADCIRC models and operational issues, and pre/post processing issues.

ADCIRC topics covered during the Boot Camp included comprehensive coverage of ADCIRC's fort. 15 file, nodal attributes file, output files, use of parametric vortex wind models for tropical cyclones, and other relevant topics.

The Virtual ADCIRC Group Meeting and Boot Camp in 2020 were a great success, with many new participants registering to participate after the change to a fully virtual format was announced. This increased the reach of the event considerably, as well as reducing the cost for all involved.

<u>2019 Hurricane Season</u>

The 2019 hurricane season was highlighted by hurricanes Barry and Dorian. CRC Lead PI Rick Luettich, PI Jason Fleming of Seahorse Coastal Consulting, PIs at Louisiana State University, and Brian Blanton at RENCI provided guidance to end users based on the ADCIRC Prediction System™:

- Prior to Dorian making landfall, the team worked directly with the U.S. Coast Guard and Deputy Assistant to the President, Homeland Security and Counterterrorism Advisor to provide regular updates on the storm's predicted impacts.
- On the state level, the team worked directly with the Risk Management Section of North Carolina Emergency Management, sending customized results from APS™ and "enhanced mapping products" to help guide their response on the North Carolina coast. The division compared APS™ water elevation and inundation predictions with the state's building footprint database to estimate potential damage to coastal structures.
- During Barry, work focused on the Louisiana Coastal Protection and Restoration Authority (CPRA) and the U.S. Army Corps of Engineers (USACE) to answer questions about APS™ outputs and relay decision-support needs to the computer engineering team for the next advisory. Data provided to USACE was shared with La. Gov. Jon Bel Edwards, Sen. John Kennedy (La.) and CPRA. APS™ data contributed to decisions on where to place National Guard resources in advance of the storm, and CERA was used to provide hydrographs of where and when the state could expect flooding.
- LSU's Louisiana Optical Network Initiative (LONI) and the LSU High Performance Computing provided supercomputing resources to run the ADCIRC model and produce guidance data during Barry. At RENCI, the Hatteras supercomputing cluster provided high-performance computing power as a backup to the LONI system at LSU. This backup allowed for a seamless transition in case the Baton Rouge-based supercomputing cluster was taken offline.
- Researchers at UNC-CH were able to successfully use the CRC-supported ASGS. This tool allows APS™ component users to track CPU usage across the country in real time, improving the efficiency of producing surge predictions and data for end users. The RENCI team also performed modeling runs of the national coastal mesh and compared it to runs of the regional meshes for Louisiana and Texas to validate predictions.

Over the course of the season, CRC researchers appeared in more than 20 publications, including The Weather Channel, CNBC, Newsweek and PBS NewsHour. Visit the CRC website for details on media interactions about the 2019 hurricane season.

DHS Flood Apex Program

Research Review Board

The multidisciplinary Flood Apex Research Review Board was established formally in November 2015 by the CRC with 13 members from academia, DHS subject matter experts (e.g., FEMA), other federal, regional, state and local experts, professional organizations, and the private sector. The Research Review Board serves as an expert panel whose responsibilities include:

- Help the DHS Flood Apex Program Manager refine the concept, requirements, and target users of the Program;
- Provide input on existing and developing systems, methods, and data sources;
- Provide advice on gaps in knowledge, data, and technology;
- Review draft products and publications;
- Identify transition pathways to help ensure end-products are useable for target users, particularly as they may have differing levels of capability and capacity

The Board first met informally via webinar in September 2015. Through Year 5, it has met 15 times (8 via webinar and 7 in person). During Year 5, the CRC organized and managed the following meetings:

- October 22, 2019 – virtual meeting by webinar
- January 22-23, 2020 – in-person meeting, Washington, DC

Joint Port Resilience Assessment Project

During Year 5, CRC entered the Joint Port Resilience Assessment Project, conducted by the DHS Cybersecurity and Infrastructure Security Agency (CISA) and the US Army Corps of Engineers' Engineer Research and Development Center (ERDC). The project will develop a Port Resilience Assessment and Decision Guide to provide a holistic understanding of port operations, the infrastructure systems that support these operations, and analysis methods that can be utilized to understand function resilience and support investment and other decisions, and that should be able to be used by a variety of stakeholders and end users.

The CRC effort is structured in coordination with CISA and ERDC to complement and add value to the research plan and execution. Additional participants subcontracted to CRC include WaterWonks, LLC, Vanderbilt University, and University of Rhode Island. Partner activities include technical review and advice, inland waterway case study, guide chapter on lessons learned from implementing resilience assessments, and a guide review workshop. The period of performance is April 15, 2020 to June 30, 2021.

Integrating Colleges and Universities in FEMA Disaster Recovery Field Operations and Steady State Preparedness

With funding from FEMA, CRC is supporting a new project titled "*Hurricane Michael as a Case Study for Integrating Colleges and Universities in FEMA Disaster Recovery Field Operations and Steady State Preparedness.*"

The project applies a mixed-methods approach to assess the use of colleges and universities in FEMA long-term disaster recovery operations in the aftermath of Hurricane Michael from the period November 2018 through October 2019. Examining data from field reports, a close-ended, short-answer survey, and 30-minute one-on-one interviews, the study explores operational processes to identify, engage and leverage technical assistance from institutions of higher education to advance the recovery mission and stakeholder perceptions about those processes. Study findings will be used to provide FEMA's National Disaster Recovery Support cadre with actionable recommendations to inform standard operating procedures for the rapid engagement of colleges and universities in field operations and as part of steady state preparedness. Delays in receiving IRB approval for the project have caused a later than expected start date.

Jackson State University Community Resilience Project

With support from the CRC, Dr. Jessica Murphey at the Center for Community Resilience (CCR) at Jackson State University lead a project to carry out the vision of the CCR to equip Mississippi's underserved communities with up-to-date skills for better preparedness for natural disasters to minimize loss of life and property, thus building resilient communities. By providing contemporary emergency management/disaster management and preparedness education and training related to natural disasters, the Center aims to mitigate losses, while also building a pipeline from middle school to higher education that develops future Emergency/Disaster Management Professionals and Atmospheric Scientists.

The following report describes the activities undertaken from June 1, 2020 to June 30, 2020 by Dr. Murphy and her team:

Description, Procedure, and End User:

- Mississippi underserved (rural) communities near the Jackson Metro area (i.e. Hinds Madison, Rankin, etc.—community training and outreach)
    - Collaborate with National Weather Service to provide weather safety information (virtual events).
    - Provide virtual activities to local area to inform students about weather preparedness and careers in Emergency Management, Meteorology, Journalism, and Psychology.
    - Develop and conduct survey to solicit community input regarding weather preparedness.
    - Host virtual community meeting and/or virtual information session/video on weather preparedness—featuring tornadoes, hurricanes, and flooding.
- Emergency academic program promotion to community - Generation Next: Discipline Awareness and Workforce Development (developing next generation of Emergency Management specialists, Meteorologists/Atmospheric Scientists, and Psychologists and Social Scientists Psychology (focusing on Disaster Mental Preparedness)
    - Develop short video(s) to explain the disciplines, degree and professional requirements, career paths, etc.
    - Host "virtual" meeting with a sample of area community members to discuss emergency preparedness for community entities such as schools.

Project Activity:

The CR Leadership Project Team at Jackson State University (Drs. Jessica Murphy, Dawn McLin, Elayne Hayes Anthony, April Tanner and Professor Don Spann and Collaborators: Bill Parker &

Latrice Maxie (National Weather Service) and Investigator Michael Ivy (JSU Public Safety)) met in May and June to prepare for June activities (e.g. outline promotional video, draft weather preparedness survey, and plan for 2 virtual town hall meetings) and complete IRB Application. The IRB Application was submitted the first of June and approved by mid-June 2020. For this pilot phase of the CR project, the aim was to recruit 150 participants. There were 58 participants who completed the survey and 43 to participate in the virtual town hall meetings. The town hall meetings where hosted on the Google Meet platform without difficulty. The following provide additional milestones from the CR Project:

1) Developed two short video promos that were televised on JSU TV.
2) Developed and made available survey for community.
3) Marketed program through JSU TV, Radios, JSU Blast, and other community networks (overall recruitment of participants).
4) Conducted in-person interviews (voice and video) with participants impacted by weather events (specifically the Easter 2020 Tornado in south MS).

RISE Conference

In 2019, CRC sponsored five students from the University of North Carolina at Chapel Hill and Duke University to travel to New York for the University at Albany's 2019 RISE conference. The conference's theme centered on university engagement in pre- and post-disaster environments, specifically in the context of Hurricane María in Puerto Rico.

Several CRC members participated as speakers and panelists during the conference, including Phil Berke, Rick Luettich, Ismael Pagan-Trinidad, Ricardo Lopez, and Tom Richardson. Students attended panels and plenary talks on preparedness, response and recovery, while networking with practitioners and researchers.

2020 Spring Speakers Series

The CRC, in partnership with the Department of City and Regional Planning at UNC, co-sponsored a graduate certificate program in the study of Natural Hazards Resilience. As part of this course, Dr. Shaleen Miller hosted a series of talks open to the public during the Spring 2020 semester on various topics related to natural hazards. Beginning in March, 2020, the speakers' series shifted to online presentations; recordings were posted to the CRC website.

Featured speakers included Adam Long, Greenhouse Gas Specialist along with Amy Armbruster, Research and Outreach Manager at UNC Three Zeros Environmental Initiative, who led a campus sustainability tour. Other speakers included Amanda Martin, Deputy Chief Resilience Officer at NC Office of Resilience and Recovery (and former CRC-supported student); Albert George, Director of Conservation at the SC Aquarium who spoke of resilience efforts through the Gullah Geechee Corridor; Julie Rosati, US Army Corps of Engineers Coastal and Hydraulics Lab; and more.

Following each speaker, students enrolled in the class prepared a blog about their learning experience. A complete list of speakers and their topics, as well as blog posts from students can be found on the CRC website.

DHS Summer Research Team Program for Minority Serving Institutions

During the summer of 2020, CRC hosted three teams of faculty and students through the DHS S&T Summer Research Team (SRT) Program for Minority Serving Institutions. Due to COVID-19, all research and interactions of the three teams was conducted virtually.

Rick Luettich at UNC-CH served as mentor for the team lead by NC A&T faculty, Dr. Liping Liu. Their project was titled "Combined Atmospheric-Storm Surge Modeling of Recent Hurricanes Landfalling on the East Coast of the U.S." Dr. Liu included two graduate students, Jackson Wiles and Tiana Johnson in the project.

Dr. Robert Whalin and Tom Richardson at Jackson State University virtually hosted Dr. Mauricio Cabrera Rios and two students, PhD candidate Deiver Suarez Gomez and Masters student Veronica Diaz from the University of Puerto Rico-Mayaguez. Their collaborative research was titled "Individual Emergency Response and Recovery: a learning experience from Puerto Rico's encounter with Hurricane Maria."

Dr. Brian Blanton of UNC-CH/Renci virtually hosted Dr. Sambit Bhattacharya and students Raymond Kimble and Grace Vincent from Fayetteville State University (NC) on a project titled "Hybrid Methods in Artificial Intelligence for Storm Surge Prediction."

Final reports and presentations by the three teams are expected in late summer/early fall, 2020.

Career Development and Workforce Development Grant Alumni

With funding from the DHS Office of University Programs, CRC and its predecessor, the CHC, have fully sponsored a total of five fellowships at UNC-CH through the DHS Career Development Grant (CDG) and the Science and Engineering Workforce Development Grant (WFD). The following update shows where these former students are now.

The first CDG recipient, Lea Sabbag, graduated with a Master's in City and Regional Planning from UNC-CH in Spring 2016. Following graduation, she served at the NC Division of Emergency Management (NCEM) as the Housing Operations Manager for NCEM's Recovery Section for Hurricane Matthew. She then went on to work as the Housing Manager for the Community Development Block Grant - Disaster Recovery (CDBG-DR). Ms. Sabbag worked for North Carolina Emergency Management until 2019. She is currently a consultant with Case Consultants International.

Ms. Ashton Rohmer completed the requirements for the CDG program upon graduating from UNC-CH with a Master's in City and Regional Planning in the Spring of 2017. After working with ASI Government as a consultant in support of the National Flood Insurance Program. Ms. Rohmer is currently and urban planner for AECOM in Washington, D.C.

With funding from the DHS OUP Science and Engineering Workforce Development grant, two students from UNC-CH - Colleen Durfee and Darien Williams – graduated with master's degrees in City and Regional Planning in Spring, 2018, while a third student – Jessamin Straub – graduated in August of 2019 with a graduate degree in Marine Science.

Mr. Williams is continuing his resilience studies by pursuing a Ph.D. in Urban Studies and Planning at the Massachusetts Institute of Technology. His research focuses on disaster resilience in underserved communities. After working as the Planning and Zoning Administrator for the City of University City, Missouri for a year, Ms. Durfee secured a position as Planner II for Lochmueller Group, where she performs transportation planning studies focused on improving the reliability and resilience of the city's transit systems and infrastructure. She also participates in multi-disciplinary teams involved in comprehensive planning, economic resilience planning, community equity, and sustainability.

Jessamin Straub was awarded a 2020 Knauss Fellowship, a highly prestigious appointment conferred through Sea Grant. The program provides a year of funding and job placement for graduate students working in areas focusing on national ocean and coastal policies. She is currently a Knauss Fellow and R&D advisor at the U.S. Army Corps of Engineers Research and Development Center in the Washington, D.C. Metro area.

Carolina Hazards and Resilience Planners

Carolina Hazards and Resilience Planners (CHRP) is a student group started by DCRP graduate students in 2016. CHRP's vision is to prepare DCRP students interested in hazards and resilience to be leaders in their field through professional development and service opportunities. CHRP provides guidance and support to students pursuing the CRC-supported Natural Hazards Resilience Certificate and connects students to professors, practitioners, and other students with shared interests and experience in the field of natural hazards and resilience planning.

For the 2019/2020 academic year, CHRP focused on planning for the Climate Change and Resilience Symposium in collaboration with the Institute for the Environment, Carolina Seminars, and Carolina Climate Scientists. The event was held virtually due to COVID-19.

In addition to the symposium, CHRP held several virtual networking events for students and continues to keep members up-to-date on news and opportunities through its listserv. CHRP members have explored options for a potential local (North Carolina) disaster response service trip, should the need arise. Since summer 2019, CHRP members have been communicating with the newly-formed student group at North Carolina State University in Raleigh called HazNerds. The two groups have discussed opportunities for collaboration, including symposium planning, combined networking events, and community service opportunities.

NSF PIRE Program

During year 5, CRC partners had students complete their NSF PIRE summer research projects with a report and a Poster presentation submitted to Texas A&M University, Galveston (TAMUG) in August 2019. The two-week research trip to The Netherlands was taken in May 2019 during year 4. The National Science Foundation (NSF) Partnerships for International Research and Education program (PIRE) sponsored the research through an award to Texas

A&M University, Galveston (TAMUG) entitled Coastal Flood Reduction. The Dutch participant is Delft Technical University. The TAMUG partners are Jackson State University (and University of Puerto Rico, Mayaguez), Rice and TAMU, College Station. Mr. Akil Muhammad, a coastal engineering master's student from Jackson State University submitted a report entitled "Comparing Dredging and Disposal Methods in Galveston Bay and the Western Scheldt Estuary". Mr. Muhammad graduated with a MS Engineering [Coastal Engineering concentration] degree in May 2020 and is now employed by the US Army Corps of Engineers Vicksburg District. Ms. Sofia N. Rivera Soto, a senior undergraduate Chemical Engineering student at University of Puerto Rico, Mayaguez submitted a research report entitled "Assessing Changes in pH, Temperature and Salinity in the Eastern Scheldt Estuary". During year 5, the competition for 2020 summer research experiences in The Netherlands took place from November 2019 to February 2020. Jackson State University and University of Puerto Rico, Mayaguez each had a student selected for the 2020 summer research experience. Unfortunately, the 2020 research trip to The Netherlands was canceled in March 2020 due to the pandemic. Students selected may have the opportunity to make the trip in summer 2021 (if they are still available and pandemic allowing) along with students selected from a new competition in late 2020 and early 2021. Jackson State University has had six graduate students participate in NSF PIRE sponsored summer research experiences in The Netherlands through year 5. All six have earned advanced degrees [5 MS and 1 PhD] and 5 of the six are working in the greater Homeland Security Enterprise. The University of Puerto Rico, Mayaguez has had two students selected to participate in the program, one each in 2018 and 2019.

COE Summit

Staff at CRC engaged in intense planning, organizing and coordinating with eight fellow DHS OUP Centers of Excellence to execute the CoE Summit, held on July 31-August 1, 2019 at George Mason University in Arlington, VA, home of the CINA CoE. The theme of the second annual Summit was "Homeland Security Challenges: Evolving Threats and Dynamic Solutions." CRC's role in preparing for the Summit included coordinating a panel led by CRC Executive Director Tom Richardson titled "Community, Collaboration and Homeland Security Research - Maximizing Impacts and Outcomes." Other Summit activities included the Innovation Showcase to demonstrate CoEs' recent research products. CRC demonstrated the ADCIRC Prediction System™ as well as the Plan Integration for Resilience Scorecard tool.

In addition to Keynote speeches from DHS S&T leaders and panel discussions led by CoE members, the Summit also featured multiple student activities, including a judged poster session, a "Grand Challenge" event, a student breakfast with human capital specialists from DHS component agencies, and other opportunities for CoE students to network with federal agency personnel and with each other.

Representing CRC, Maurice Hanns and William Case, students from CRC partner Johnson C. Smith University, participated on separate teams for the Grand Challenge, a core student activity at the Summit. The Grand Challenge was a "hackathon"-style contest where teams of students developed innovative solutions in response to an emerging DHS challenge. The challenge, "Identify an emerging threat to homeland security posed by Unmanned Aerial

Systems (UAS) and develop a strategy to counter it," gave students 36 hours to present a strategy to solve the problem. Case's team won the Grand Challenge second-place prize.

III. PROJECT REPORTS

The CRC research projects span three themes: 1) The Coastal Infrastructure Resilience project focuses on ways to improve damage prediction and loss estimates due to coastal hazards and develop a framework for new design methodologies for near-coast structures (one project); 2) The three projects in the Building Resilient Communities theme respectively focus on: developing tools to help communities integrate hazard resilience into local planning efforts; developing effective ways to communicate risk to motivate individuals to take preparedness action; and developing ways to integrate flood exposure and damage modeling techniques to improve planning in coastal communities. 3)The Coastal Hazards Modeling-themed projects emphasize advancing computer modeling capabilities for predicting storm surge, waves, and flooding associated with severe weather events along the U.S. East and Gulf Coasts and communicating the results of these predictions to improve coastal resilience (seven projects).

Through the fourth theme, CRC addresses education and workforce development by formulating and delivering resilience-oriented undergraduate and graduate courses, concentrations, minors, certificates, and training, with strong emphasis on Minority Serving Institutions. Focus areas in education include coastal and computational engineering, computer science and engineering, social science, coastal infrastructure, disaster science, and natural hazards resilience (five projects, including four conducted by faculty at Minority Serving Institutions).

Performance reports for each CRC project are in the section that follows, organized by theme. All of the PIs were encouraged to take a retrospective look back to activities undertaken and milestones achieved during Year 5, with a focus on the cumulative progress made to date. Delays in receiving project funding, compounded by difficulties caused by the Coronavirus pandemic, resulted in a shift to several projects' schedules over the course of Year 5. However, CRC provided PIs the opportunity to revise their milestone target dates and/or provide additional details on the schedule where necessary.

Theme: Coastal Infrastructure Resilience

Cox; van de Lindt: *Experimental and Numerical Study to Improve Damage and Loss Estimation due to Overland Wave and Surge Hazards on Near-Coast Structures*

Theme: Building Resilient Communities

Berke: *Application of the Plan Integration for Resilience Scorecard (PIRS) to Practice*

Prochaska: *Communicating risk to motivate individual action*

Twilley: *Integrating CERA-Planning Software to support DHS Modeling and Planning Efforts for more Resilient Communities*

Theme: Coastal Hazards Modeling: The ADCIRC Portfolio

Luettich: *ADCIRC Prediction System™ Development Coordination and Improved Connectivity with Hydrologic Models*

Fleming: *The ADCIRC Surge Guidance System as a Conduit for Innovation*

Blanton: *Operational Awareness Dashboard for ADCIRC Surge Guidance System*

Dietrich/Dawson: *Improving the Efficiency of Flooding Predictions via Adaptive Mesh Resolution*

Hagen/Medeiros/Bilskie: *Development of an optimized tide and hurricane storm surge model for the west coast of FL for use with the ADCIRC Surge Guidance System*

Ginis/Huang: *Modeling the combined coastal and inland hazards from high-impact hurricanes*

Resio: *Development and Validation of Efficient and Accurate Methods for Coupling ADCIRC to Hydrologic Models*

Richardson: *ADCIRC Prediction System™ Business Plan Development*

Theme: Education

Faik: *Preparing Tomorrow's Minority Task Force in Coastal Resilience through Interdisciplinary Education, Research, and Curriculum Development*

Laiju: *Multidisciplinary Certificate: Disaster and Coastal Studies (DCS)*

Pagan-Trinidad: *Education for Improving Resiliency of Coastal Infrastructure*

Smith: *Continuation of the Natural Hazards Resilience Certificate Program and Assistance to FEMA*

Whalin: *PhD in Engineering (Coastal/Computational) at an HBCU - Jackson State University*

Theme 1

Coastal Infrastructure Resilience

Cox: OSU
van de Lindt: CSU

DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title:

Experimental and Numerical Study to Improve Damage and Loss Estimation due to Overland Wave and Surge Hazards on Near-Coast Structures

Principal Investigators:

Dr. Daniel Cox, (PI) Professor, Oregon State University
Dr. John van de Lindt (Co-PI), Professor, Colorado State University

Additional Research Participants/Partners:
NHRAP/Hazus Program Manager, FEMA DHS
Regional Flood Map Geospatial Lead, FEMA DHS
Geospatial Risk Analyst, FEMA DHS
Federal Emergency Management Agency's Deputy Assistant Administrator for Mitigation, FEMA, DHS
Federal Insurance and Mitigation, Risk Management | Engineering Resources Branch, FEMA
Doug Bausch, NiyamIT Inc.
Jordan Burns, NiyamIT Inc.

Short Project Description ("elevator speech"):

This project will apply the wave-surge fragility method developed in years 1-3 of the project to determine damage to several additional building types. A Hazus analysis over a region of the Texas shoreline will be conducted using (1) the existing Hazus methodology, and (2) the new fragilities developed herein. This will require utilizing the ADCIRC work of others within the Center of Excellence as input. Depth-damage functions were requested by the Hazus team to align with their current software structure, so these will be started by mapping the fragility methodology to depth-damage functions. The investigators will work with DHS FEMA Hazus and their consultants at NiyamIT Inc. to lay out the steps needed to implement the depth-damage functions in Hazus

II. PROJECT NARRATIVE

1. Project overview:

This project focuses on Theme 1 – Coastal Infrastructure Resilience; Topic 1a – Coastal Infrastructure Planning and Design. As building stakeholders seek to mitigate damage, risk to property and structure loss it is becoming apparent that exiting design methodologies such as those outlined in the FEMA Coastal Construction Manual are inadequate to incorporate the range of building types, storm conditions, and potential for resulting damage. More effective decision support tools such as FEMA's Hazus-MH rely on a framework of multi- hazard fragility curves to relate the hazard and affected buildings to compute/predict an expected level of damage and subsequent losses. Hazus-MH is a software package that allows the user to determine the damage and financial losses over a region of interest using embedded databases and fragility functions. The fragility functions are based on past work and expert elicitation during the software development phase. Hazus-MH will be updated over the next decade, so the project described herein is occurring at an ideal time to contribute to its body of knowledge through technology transfer of the science created over the first three years. Although there have been significant advances in this correlation for wind and earthquake loading and some preliminary work for tsunamis, the coastal surge and wave response of structures remains poorly defined, primarily due to a lack of large-scale data and the complexity of the fluid/structure interaction modeling. This data was generated in the first three years of this project and served to validate a new fragility type for combined surge and waves. The investigators have worked with Hazus management to lay out the steps needed to release the new fragilities, and incorporate matching/similar depth-damage functions into Hazus. The overall goal of this project is to develop accurate fragilities for near-coastal structures against overland surge and wave forces and corresponding depth-damage functions for input to Hazus-MH to improve damage and loss estimation.

We outline these specific objectives to be completed in two years in order to provide (1) improved accuracy for wave and surge analysis in Hazus-MH; and (2) innovative advances in risk-informed design methodologies to enhance coastal infrastructure resilience:

- ***Objective 1:*** Develop additional fragilities based on input from Hazus-MH management, i.e. based on most needed, such that a basic loss analysis can be performed.
- ***Objective 2:*** Demonstrate Hazus-MH loss analysis for a portion of the New Jersey shoreline, including working to procure FEMA data to validate the loss modeling, documenting gaps that likely result as a function of the current approach.
- ***Objective 3:*** Demonstrate the surge and wave fragilities for the same location as in Objective 2, showing improved accuracy to actual loss values.

This project will have a direct impact on estimating probable damage and loss of existing coastal infrastructure by providing improved load-response relationships to Hazus-MH for surge and wave and develop a risk-informed framework for estimating loss avoidance and benefit analysis for mitigation. While beyond the scope of this study, the results could also help improve the potential designs associated with the retrofit of existing structures funded through FEMA hazard mitigation grant programs and the implementation of improved coastal building codes.

2. **Results:**

Fragilities were developed for five building archetypes at three different elevations above grade, i.e. elevated coastal structures. These represent four types of single-family dwelling and one multi-family apartment/condominium style building. This suite of buildings provides a (albeit small) suite of archetypes to populate the community selected along the Texas coastline.

3. **End users:**

Hazus personnel and related consultants all provided feedback on several on-line meetings throughout the year. This included planning for the remainder of year 5, the conversion from fragilities to depth-to-damage functions and instructions on the hindcasting process. The latter included outlining and helping to formulate the formal data request from FEMA-DHS which may contain personally identifiable data.

4. **Transition:**

The project team worked with FEMA-DHS and their consultant to outline a plan for hindcasting to ensure the results align with actual damage estimates at the community level. This involved a formal data request and direction on the process that FEMA goes through to release data on Github.

5. **Project Impact:**

The depth-damage relationships for Hazus-MH were initially developed for riverine flooding. To use Hazus-MH in the coastal environment where wave and surge loads are expected to have a significant impact on the building damage, it is necessary to (1) develop new damage functions that can account for wave and surge and then to (2) demonstrate their validity using hindcast data from recent storms. The impact of this project is that damage estimates for coastal damage will be more accurate in Hazus and therefore enable better community planning and mitigation efforts, of ten funded by FEMA and other federal agencies, e.g. HUD and USDA.

6. Unanticipated Problems:

The work in the latter part of Year 5 was numerical/computer-based in nature, so the project team has not had any direct impact to the project as a result of COVID-19.

7. Student Involvement and Awards:

a) Students involved in research:

At OSU:

- Sean Duncan, MS student, was supported in Year 5 to conducted test for surge/wave forces and progressive damage of elevated structure and analyze data.
- Caileen Yu, Summer Undergraduate Research Student, analysis of LiDAR images of progressive damage to on-grade and elevated structures

b) Student Demographics

- S Duncan – Grad – Male, white, non-Hispanic
- Robert Lewis – Ugrad – Male, Hispanic
- Ihan-Jarek T. Acevedo – Ugrad – Male, Hispanic
- Caileen Yu – Ugrad – Female, Asian

c) Degrees Attained

- MS obtained by S Duncan (OSU) June, 2020. Civil Engineering.

d) Student Awards

N/A

8. **Interactions with CRC education projects:**
   - In summer 2019, we had two SUMREX students from the University of Puerto Rico Mayaguez (Robert Lewis; Ihan-Jarek T. Acevedo)

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% complete	Explanation of why activity/milestone was not completed
RA3: Hazus-MH analysis using RA1 fragilities. Two sets of analyses will be performed for comparison: (1) Hazus analysis as it is currently performed; and (2) the new analysis developed during the first several years of this project within the CRC. These two damage and loss estimates will be compared to quantify the level by which Hazus under predicts damage and loss in coastal areas without inclusion of waves and surge using the building damage and loss data collected by FEMA	4/15/21	50%	There was a delay in obtaining the data from FEMA. As a result the analysis results will be provided to FEMA and they have agreed to do a detailed comparison of the analysis versus documented damage and loss.
RA4: Comparison of the RA2 and RA3 analyses. Comparison will show the benefit of the new fragilities for damage and loss estimation	5/15/21	50%	Same as above. However, we were asked by FEMA to modify the fragilities to depth-to-damage functions for incorporation into Hazus, so have focused on this effort while the data negotiations are on-going. The change to depth-to-damage function is not trivial

			and requires extensive computer/computational efforts. This has been completed for archetype 1 and the other four archetypes are underway.
Research Milestone			
RA3: Documentation of RA4 as a peer-reviewed journal paper submission *(J. of Natural Hazards Review)*	6/1/2020	0%	The analysis is underway and will be completed with collaboration from FEMA in early 2021 as indicated above.

2. Year 5 Transition Activities and Milestone Achievements:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
TA3: Webex meeting. Continue periodic webex meetings with project team and End Users for project update and feedback	Held every other month	100%	We have consistently held meetings with the project team and end users.
TA4: Documentation of fragility methodology. Prepare technical report with details of tools and methods used to develop building fragilities subjected to surge and waves for review by End User team	4/15/2020	25%	This is started, but will require completion of the analysis for the four remaining archetypes. The change from fragilities to depth-to-damage functions, as requested by FEMA, added significant analysis.
TA5: Detailed outline of Hazus hindcast. Prepare detailed outline of Hazus hindcast for review by End User team	4/01/2021	0%	The team is currently building the inventory profile for the hindcast area building by building.
TA6: Final report of Hazus-MH hindcast and prepare manuscript for peer reviewed journal paper.	5/01/2021	0%	Cannot be completed until all the work is finished.
Transition Milestone			
TM3: Technical report of fragility development provided to end user team	9/01/19	100%	This was done as a PowerPoint presentation on-line.

TM6: Final report submitted to end user team for review and develop manuscript for peer reviewed publication.	6/01/2021	0%	All work needs to be completed before the report can be written and completed.

3. **Research Project Product Delivery.** N/A

IV. PUBLICATIONS AND METRICS

1. Publications:

a) Journal Papers

- Park, H., Tomiczek, T., **Cox, D.T., van de Lindt, J.W.**, Lomonaco, P. (2017) "Experimental Modeling of Horizontal and Vertical Wave Forces on an Elevated Coastal Structure," *Coastal Engineering*, 128, 58-74. DOI: 10.1016/j.coastaleng.2017.08.001
- Do, Trung, **van de Lindt, J., Cox, D.T.** (2016) "Performance-Based Design Methodology for Inundated Elevated Coastal Structures Subjected to Wave Load Engineering Structures," *Engineering Structures*, 117, 250 – 262. DOI: 10.1016/j.engstruct.2016.02.046
- Park, H., Do, T., Tomiczek, T., Cox, D.T., van de Lindt, J.W. (2018) "Numerical Modeling of Non-breaking, Impulsive Breaking, and Broken Wave Interaction with Elevated Coastal Structures: Laboratory Validation and Inter-Model Comparisons," *Ocean Engineering*, 158, 15, 78-98. DOI: 10.1016/j.oceaneng.2018.03.088
- Tomiczek, T, A Wyman, H Park, DT Cox (2019) "Modified Goda Equations to Predict Pressure Distribution and Horizontal Forces for Design of Elevated Coastal Structures," *J. Waterway Port Coastal and Ocean Engineering* 145, 6, doi.org: 10.1061/(ASCE)WW.1943-5460.0000527.
- Do, T, JW van de Lindt, DT Cox (2019) "Hurricane Surge-Wave Building Fragility Methodology for Use in Damage, Loss, and Resilience Analysis," *J. Structural Engineering* 146(1), 04019177, doi.org: 10.1061/(ASCE)ST.1943-541X.0002472.

b) Conference Papers

- Do, T., Tomiczek, T., **van de Lindt, J. Cox, D.** (2017) "Development of Physics-Based Building Fragility Surfaces for Near-Coast Community Modeling," *International Conference on Coastal and Ocean Engineering*, Osaka, Japan.
- Lomonaco, P., P. Arduino, A. Barbosa, D. Cox, T. Do, M. Eberhard, M. Motley, K. Shekhar, T. Tomiczek, H. Park, J. W. van de Lindt, A. Winter (2018) "Experimental Modeling of Wave Forces and Hydrodynamics on Elevated Coastal Structures Subject to Waves, Surge or Tsunamis: The Effect of Breaking, Shielding and Debris, *International Conference on Coastal Engineering*, ASCE.
- Park, H., Do, T., Tomiczek, T., **Cox, D., van de Lindt, J.W.** (2018) "Laboratory Validation and Inter-Model Comparisons of Non-breaking, Impulsive Breaking, and

Broken Wave Interaction with Elevated Coastal Structures using IHFOAM and FLUENT," *International Conference on Coastal Engineering*, ASCE.

- Tomiczek, T., Wyman, A., Park, H., **Cox, D.T.** (2018) "Application and modification of Goda Formulae for Non-impulsive Wave Forces on Elevated Coastal Structures," *International Conference on Coastal Engineering*, ASCE.
- Tomiczek, T., Park, H., **Cox, D.T.**, Lomonaco, P., **van de Lindt, J.W.** (2018) "Application and modification of Design Formulae for Impulsive Wave Forces on Elevated Coastal Structures," *International Conference on the Application of Physical Modelling in Coastal and Port Engineering and Science (Coastlab18)*, IAHR.
- Do, T, JW van de Lindt W, DT Cox (2018) "Physic-Based Component Fragility Model for Near-Coast Residential Wood Building Subjected to Hurricane Wave and Surge" Engineering Mechanics Institute Conference 2018, Cambridge MA.

c. Thesis/Dissertation and Reports

- Trung Q. Do. *Fragility Approach for Performance-Based Design in Fluid-Structure Interaction Problems, Part I: Wind and Wind Turbines; Part II: Waves and Elevated Coastal Structures*, (2016), Ph.D. Dissertation, Colorado State University.
- William Short. *A laboratory study of horizontal and vertical regular wave forces on an elevated structure*. (2016). MS Thesis, Oregon State University.
- Benjamin Hunter. *Exceedance Probabilities of Hurricane Wave Forces on Elevated Structures*. (2016). MS Thesis, Oregon State University.
- Jason Burke. *Design and Structural Testing of a 1:6 Scaled, Light-frame Construction, Near-coastal, Residential Structure*. (2018). MS Thesis, Oregon State University.
- Matt Karney. *Hydrodynamic Testing on a 1:6 Scale, Wood Framed Near-Coast Residential Structure*. (2018). MS Thesis, Oregon State University.
- Duncan, S. *Physical Modeling of Progressive Damage and Failure of Wood Framed Coastal Residential Structures Due to Waves and Surge Forces,* (2020), MS Thesis, Oregon State University

2. Performance Metrics

Cox/van de Lindt: Performance Metrics:

Metric	Year 1 (7/1/15-6/30/16)	Year 2 (7/1/16-6/30/17)	Year 3 (7/1/17-6/30/18)	Year 4 (7/1/18-6/30/19)	Year 5 (7/1/19-6/30/20)
HS-related internships (number)					0
Undergraduates provided tuition/fee support (number)	0	0	0	0	0
Undergraduate students provided stipends (number)	0	0	0	0	0
Graduate students provided tuition/fee support (number)	2	2	2	1	1
Graduate students provided stipends (number)	0	2	2	1	1
Undergraduates who received HS-related degrees (number)	0	0	0	0	0
Graduate students who received HS-related degrees (number)	0	0	0	0	0
Graduates who obtained HS-related employment (number)	0	0	0	0	0
SUMREX program students hosted (number)	2	2	2	2	0
Lectures/presentations/seminars at Center partners (number)	0	3	0	1	0
DHS MSI Summer Research Teams hosted (number)	0	0	0	0	0
Journal articles submitted (number)	0	2	2	2	1
Journal articles published (number)	0	2	0	2	1
Conference presentations made (number)	0	1	2	2	0
Other presentations, interviews, etc. (number)	0	0	2	2	3
Patent applications filed (number)	0	0	0	0	0
Patents awarded (number)	0	0	0	0	0
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	0	0	0	0	0
Requests for assistance/advice from other agencies or governments (number)	0	0	0	0	0
Dollar amount of external funding	$355,000	$355,000	$0	0	$20,000
Total milestones for reporting	4	5	4	4	4
Accomplished fully (research activity/milestone)	0	2	3	2	2
Accomplished partially (research activity/milestone)	4	3	1	1	1
Not accomplished (research activity/milestone)	0	0	0	1	1

Theme 2

Building Resilient Communities

BERKE: UNC-CH
MASTERSON: TAMU
DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/14/2020)

I. INTRODUCTION

Project Title: Application of the Plan Integration for Resilience Scorecard™ (PIRS) to Practice

Principal Investigator Name/Institution: Phil Berke, University of NC at Chapel Hill

Additional Research Participants/Partners: Jaimie Masterson, Texas A&M University

Short Project Description ("elevator speech"):

We develop the *Plan Integration for Resilience Scorecard™* (PIRS) to assist local practitioners to assess the degree to which networks of local plans target geographic areas most prone to hazards and evaluate the coordination of local plans. Our research tested PIRS™ in six coastal communities and found that plans are not fully consistent and do not always address the areas in a community most vulnerable to floods or sea level risks; moreover, some plans actually increase physical and social vulnerability to hazards. For this project, our primary goal is to work directly with 4 to 5 local communities to refine the PIRS™ guidebook, training materials and plan scoring tool to ensure that they meet requirements of different communities that vary in capacity to anticipate and plan for future risks. Using a participatory action research methodology, we will document the strengths and weaknesses of PIRS based on end-user comprehension of PIRS™ concepts and tasks, and recommendations on how best to encourage use of PIRS™ by a broad range of local practitioners. We will develop metrics (quantitative and qualitative) to track outcomes of the PIRS application process across different communities. A top priority throughout the project is to continue our ongoing collaboration with federal agencies (FEMA, NIST), state agencies (New York Rising, Texas Sea Grant), and professional practice organizations to demonstrate how PIRS™ can best support their local mitigation and resilience planning programs.

II. PROJECT NARRATIVE

1. Project overview:

Communities adopt multiple interdependent plans that significantly affect future community vulnerability to hazards and climate change. The plans are almost always independently prepared by distinct government agencies and interest groups. It is not surprising that the plans are often in conflict and can actually increase physical and social vulnerability to hazards. We develop a resilience scorecard that allows local planners, emergency managers and other officials to assess the degree to which the network of local plans integrate mitigation and recognize and respond to the physical and social vulnerabilities of geographic areas most prone to hazards. The information generated by the scorecard is used to create strategies to resolve conflicts across plans and identify missed opportunities to improve community resilience.

Success story - Rockport, a small city (population 10,000) on the southern Gulf coast of Texas, applied PIRS^{TM} as the central tool for producing information to guide development of a new comprehensive plan in a post-disaster recovery context. Rockport officials considered the comprehensive plan to be the essential policy instrument to integrate resilience and guide community rebuilding across multiple urban sectors. To facilitate application of the scorecard, Rockport requested and received additional funding from a local non-profit organization, The Harte Research Institute for Gulf of Mexico Studies. The additional support was used to employ a part-time planning expert from the Texas Sea Grant Program to lead in the evaluation of the network of plans. The city planner participated on regular tele-conference meetings with the Texas Sea Grant planner and university experts between January 2019 and September 2019.

PIRS^{TM} process in Rockport includes organizing a core team, often the city planner, emergency manager, floodplain manager, etc. Then we conduct a webinar or in-person training and exercise with the core team using guidebook. We facilitate monthly calls to check in on the core team progress (pulling policies, mapping district-hazard zones, scoring policies). Finally, in collaboration with local government staff, we assisted in coordinating a series of meetings to discuss the results with staff in various departments, agencies, entities applicable within community. Figure 1 illustrates the sequence of the planning process and role of PIRS^{TM} used in Rockport.

The PIRS^{TM} team worked with the City at the start of the comprehensive planning process one year after Hurricane Harvey to determine the optimal time to conduct the PIRS^{TM} analysis. The city planner stated, “it’s important for us to look at how we want our community to grow in the next 20 years, especially with that memory so fresh in our minds.” The PIRS^{TM} team shadowed the 10 planning meetings which ranged from 15-200+ participants. Goals, objectives, and policies were drafted from the community feedback. Additionally, the City with assistance from the research team applied for the American Planning Association’s Recovery Planning Assistance Team grant, to further build planning capacity. The City was awarded this grant which resulted in a downtown study focused on hazard mitigation. The research team used this study, along with the six other plans, and the draft comprehensive plan policies in the PIRS^{TM} analysis. The comprehensive plan included a total of 170 final policies, 40 of which were edited and based on PIRS^{TM} , 73 policies are integrated with the network of plans. Figure 3 shows the composite policy scores by district hazard zone.

The research team developed two innovations within the comprehensive to visualize the benefit of PIRS^{TM}. First, reading through the recommendations the reader can find icons with acronyms that are associated with specific plans within the network of plans. There are call-out boxes throughout that describe how each recommendation and associated policy connects to other existing plans in the community. Second, the final chapter includes the compilation of all policies within the plan as the implementation table. A new column was added to this table to indicate which plans are integrated with each policy. The implementation table is used by city staff and city council to monitor progress. By including this column, it reminds staff and officials the consensus and greater impact of the policy ensuring future implementation.

One resident described the importance of having a plan that encompasses the entire city. While there had been two city-wide comprehensive plans and a downtown plan in the past, the new one "includes more factors" that were identified by the entire community, which helped to expand the scope of the project as compared to the original plan. Several residents noted that it was a benefit to have a replacement plan for the one developed years earlier and were pleased that the new plan is "well-integrated" because of PIRS^{TM}. Specifically, the connection to the county hazard mitigation plan and long-term recovery plan was important to the City. One resident, after reading through the comprehensive plan said, "I was involved with the Long-term Recovery Plan and I see it discussed here. Everything we worked on in that is not lost and is built on." Because of the planning process and recovery efforts, the City of Rockport received a Silver Achievement Award in Resiliency Planning from the Texas Chapter of the American Planning Association in November 2019. Figure 2 shows pictures of residents actively involved in applying PIRS^{TM} and a comment by the Rockport planner.

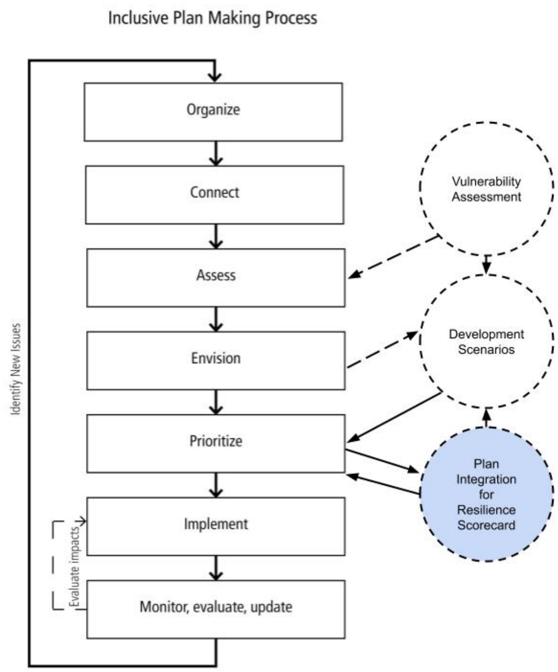


Fig. 1: Expanding the Inclusive Plan-Making Model for new plans (Masterson et al 2014). PIRS™ can be used in the development of new plans. As communities begin prioritizing goals, objectives, actions, and policies, PIRS™ can be used to understand the range of policies across the network of plans, identifying opportunities to fold other plan's policies into the new plan, and pinpoint additional policy opportunities to be embedded into the new plan.

Community Task Force: Rockport, Texas

Figure 2: Task Force and Comment by Lead Planner

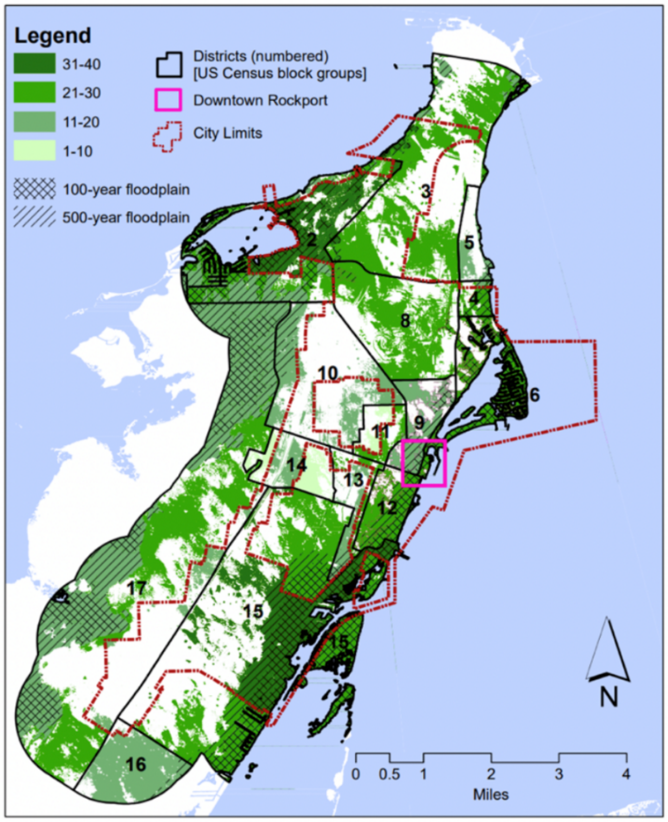


Figure 3: Composite Plan Policy Scores for All Plans by District Hazard Zone*
*Shaded areas outside of 100-year and 500-year floodplain indicate inundation by Hurricane Harvey

2. <u>Results:</u>

- Working with Rockport, TX in post-disaster recovery. The Harvey inundation area was used as the primary hazard zone for scoring plans. Rockport applied the scorecard to guide preparation of the city's new comprehensive plan to assure alignment of multiple post-Harvey recovery initiatives in the city with the vision and strategies included in the plan.
- Working with the Port of Corpus Christi- The Port of Corpus Christi Authority is collaborating with communities that experience growth related to port expansion in applying the resilience scorecard in order to better coordinate plans to reduce hazard vulnerability.
- Working with a community-based organization (CBO) in poor minority neighborhoods in Houston that is using the scorecard to track how well county, city and neighborhood plans (stormwater, housing, transportation, mitigation) meet needs after Hurricane Harvey.
- Finalized maps that display results from PIRS evaluation for Nashua, NH
- Nashua's Integrated Crosswalk for Resilience Planning: PIRS™ + NIST + FEMA
- We are using the TM icon to estable a trademark of PIRS™.
- Conducted a series of trainings and outreach

    - Sept 5, 2019- Malecha, M. & Masterson, J. "Integrating Resilience into Networks of Plans" Resilience Rising Symposium, College Station, TX
    - Oct 17, 2019- Scheduled meeting with NY State NY Rising
    - Nov 7, 2019- Masterson, J., Thapa, J., Bennis, A., Barret, C., Miller, K. "Big Storms, Even Bigger Challenges" APA TX Chapter Conference.
    - Apr 2, 2020- Jaimie Masterson visiting lecturer at University of North Carolina at Chapel Hill
    - Apr 27, 2020- Masterson, Jaimie, J. Thapa, A. Torres, A. "How Post-Disaster Data Can Inform Planning." American Planning Association, National Planning Conference 2020, NPC20@Home.
- Invited Lectures
    - Berke, P. Application of the Plan Integration for Resilience Scorecard to Practice, DHS Science & Technology Directorate Showcase Summit, July 11, 2019, George Mason University, Washington D.C.
    - Berke, P. City Planning for Resilience: Networking Across Planning, Infrastructure and Social Domains, September 6, 2019, Keynote Talk, Hunan University, Changsha, China
    - Berke, P. Characteristics, Causes and Outcomes of Plans: A Review a Decade of DHS Supported Research on and Actions of Mitigation Planning, Presentation to the FEMA Planning Effectiveness Committee (PEC), Nov. 7, 2019, Washington, D.C.
    - Berke, P. Real World Results: A Guidebook + A Scorecard = An Integrative Framework for Community Resilience Planning, Panel presentation RISE 2019: Transforming University Engagement in Pre- and Post-disaster Environments, Nov.18, 2019, State University of New York-Albany, Albany, NY
    - Berke, P. Application of a Plan Integration for Resilience Scorecard: Lessons from Local Practice. Flood Apex Review Board, Jan. 22-23, Washington, D.C.
- Proposals Funded
    - NC State Historic Preservation Office $25,000, 2020-21
    - NSF CRISP, $2 million, 2019-2023
    - One Gulf Program (Harte Foundation), $70,000, 2018-2020

3. End users:

- American Planning Association (APA): We are collaborating with APA to co-develop communication, outreach and training programs in year 6. We just had a roundtable panel (5/29/20) discussion with experienced proactioners representing floodplain mangagement and public works, emergency management, and urban planning. The panel reviewed the strengths and capabilities of PIRS^{TM}, and offered suggestions on developing training materials.
- National Institute of Science and Technology (NIST): We are partnering with NIST in assisting staff of the City of Nashua, NH in applying the Resilience Scorecard and NIST Resilience Planning Guide.
- FEMA: FEMA has assisted NIST and the Texas A&M group in facilitating potential work with NY Rising. While the project has not been initiated to date, we have had numerous contacts with FEMA and appreciate their efforts. We also met staff with Sullivan County that will likely take on the PIRS process with state funding.

- Texas Sea Grant of Texas A&M: We continued to work with and engage three coastal planning specialists employed by Sea Grant. They worked in collaboration with our group in three Texas communities, including Rockport, Corpus Christi and Houston. City of Norfolk, VA: We completed our project with Norfolk, VA in Spring 2018. This year, we interviewed city staff in to prepare the lessons learned report (Berke et al. 2020. *Applying a Plan Integration for Resilience Scorecard to Practice*).
- Nashua, NH: In year 5, we had continual contact and provided technical assistance to city staff in applying the Resilience Scorecard. Nashua completed application of the scorecard in September 2019. Our team assisted them to finalize the set of maps after their GIS lead staff retired. We also interviewed city staff in to prepare the lessons learned report (Berke et al. 2020. *Applying a Plan Integration for Resilience Scorecard to Practice)*.
- Rockport, TX: We initiated a new project with the Rockport staff in January 2019, expected completion date about September 2019. Rockport is devastated by Hurricane Harvey. We also interviewed city staff in to prepare the lessons learned report (Berke et al. 2020. *Applying a Plan Integration for Resilience Scorecard to Pract*ice). The core team included the city planner/floodplain manager, additional city staff, TX Sea Grant extension agent, comprehensive planning project manager. The following includes the community interactions:
    - *[May 2018- Comprehensive Planning process began]*
    - May 2019- PIRS introductory meetings
    - June- Initial training
    - July- Check in discussion
    - August- Results and comments back on policies
    - September- Policy adjustments
    - October- Staff approval
    - January- Plan finalized
    - March- Anticipated adoption
- Port of Corpus Christi Authority, TX: We initiated a new project with the port staff in May 2019. We completed the project in February 2020.
- Charity Productions: In spring 2019, we initiated a partnership with this community-based organization (CBO) to apply the scorecard in three poor minority neighborhoods in Houston that experienced significant damages from Hurricane Harvey. This CBO represents neighborhoods internal to the city with little or no formal power, but with intimate knowledge about how their neighborhoods are affected by hazards and the appropriateness of risk mitigation policy interventions that reflect the needs of socially vulnerable groups.

4. **Transition**:

- American Planning Association (APA) – Our primary transition goal this year was to integrate PIRS with APA. We had numerous discussions with senior staff at the APA to focus on how we might co-develop communication, outreach and training programs. We are happy to report that APA will work extensively in year 6 to translate the scorecard to practice in working through utilization of its extensive resources and outreach to 44,000 members and networks with allied professions.

- Advising FL Sea Grant on their funded proposal: "Quantifying the Effectiveness of Resilience Planning for Affordable Housing," funded by National Sea Grant Program;
- Texas General Land Office to include PIRS language into local hazard mitigation planning requirements.
- North Carolina State Historic Preservation Office (2020-21) to fund a training program for communities by PIRS™ staff on how to integrate hazard mitigation planning with historic and cultural resource planning. The office received funding from federal funding because of the extensive damage to the state from multiple recent hurricanes.

5. Project Impact: Describe the real-world impact of your project that you accomplished or worked toward during Year 5. Include information about how your project's outcomes advanced current technologies or capabilities, especially with regard to DHS component agencies (e.g., saves lives, saves money and/or property, increases operational efficiency)

    - We produced a report that examines the changes that resulted from the PIRS™ application in three pilot cities. Details about the findings and data collection methods are discussed in Berke and Masterson et al. (2020), *Applying a Plan Integration for Resilience Scorecard™: Experiences of Nashua NH, Norfolk VA, and Rockport TX*). To guide our assessment of change, we developed a logic model to track changes. A logic model is a graphic depiction that presents the relationships among *inputs* (resources, training), *outputs* (change in organizational capacity to plan), and *outcomes* including changes in policy (plans, development standards, incentives and investments) and vulnerability (housing units relocated from hazard area, acreas of hazard area conserved as open space). Figures 4, 5 and 6 (below) summarize outputs and outcomes from PIRS™ that occurred in the three pilot cities after the project was completed in each location.
    - Nashua emergency management staff scussessfuly integrated PIRS™ with the NIST Resilience Planning Guide. The city demsonstrated how both tools working together can significantly build local capacity to anticipate, plan for, and recover from an extreme event and build back better.
    - As demonstrated in the figures below, we believe that a range of local hazard mitigation planning and implementation practices supported by FEMA are directly connected to PIRS™ and can substantially improve community capacity and outcomes linked to better resilience.

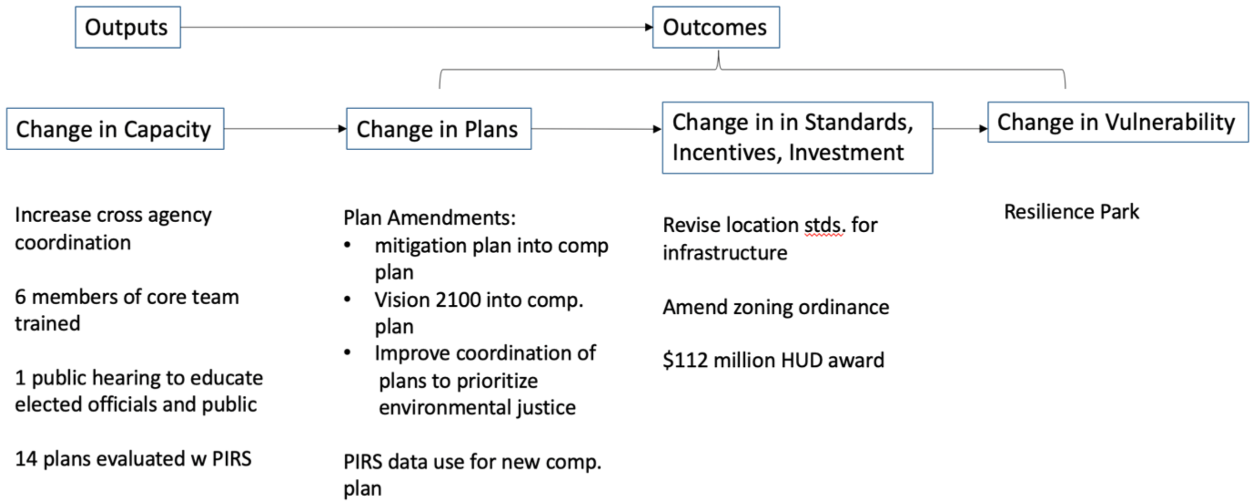


Figure 4: Changes Related to PIRS™ in Norfolk
After Project Completion (March 2018)

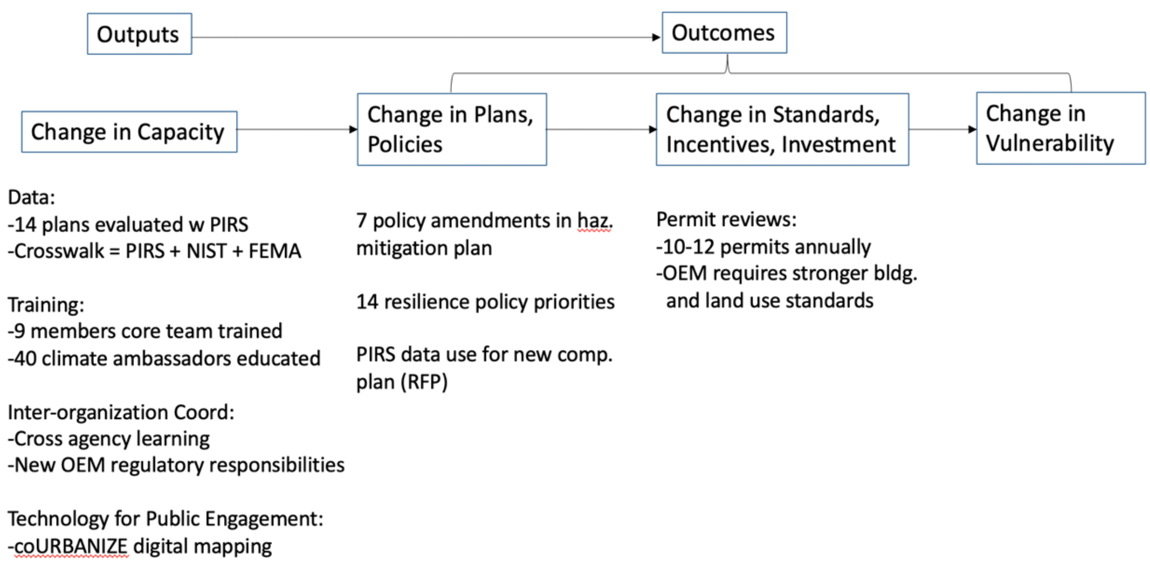


Figure 5: Changes Related to PIRS™ in Nashua
After Project Completion (July 2019)

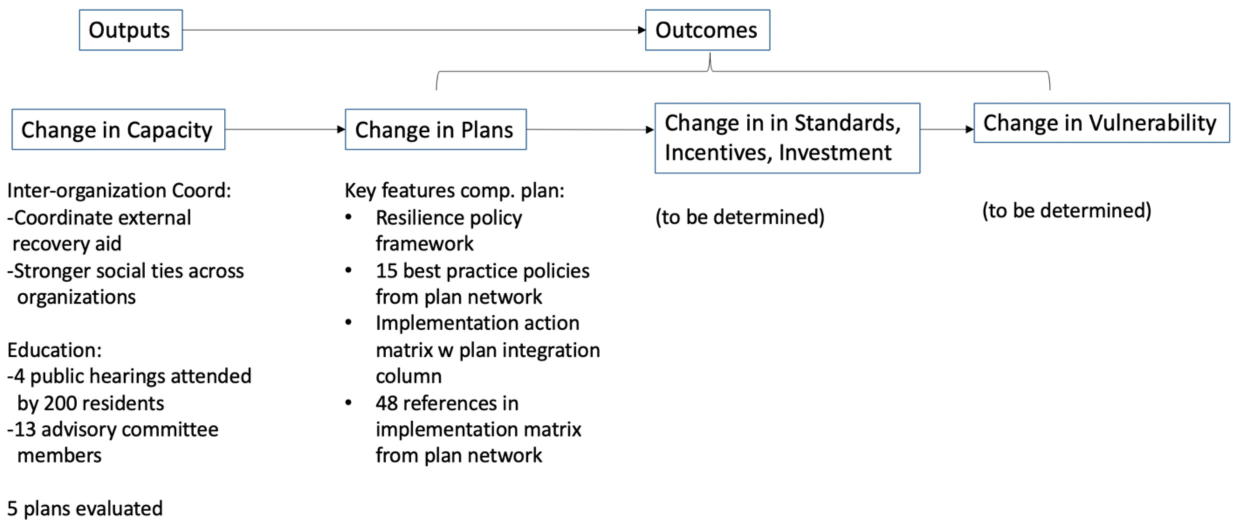


Figure 6: Changes Related to PIRS™ in Rockport
After Project Completion (March 2020)

6. Unanticipated Problems:

-COVID-19 has a significant negative affect on team interactions and communications with communities.
-Shifting PI's status to Masterson was a challenge. It took a long time getting funding sorted out. Masterson had to go through a lot of hoops because she is not faculty.

7. Student Involvement and Awards:

a) Student involvement in research

-One doctoral student supported by CRC funding.

-One masters student supported by CRC fundng.

b) Student Demographics

-Two International doctoral students: China and India

-One white non-Hispanic masters student.

c) Degrees Attained.

- Zito, Francesca, Master City & Regional Planning, University of North Carolina
- Siyu Yu, PhD, Urban & Regional Science, Texas A&M University
- Matt Malecha, PhD, Urban & Regional Science, Texas A&M University

d) Student Awards

- Zito, Francesca, Best Student Award by the American Planning Association, Master City & Regional Planning, University of North Carolina

8. Interactions with CRC education projects:
N/A

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Continue to document the process in which PIRS is applied to the communities under the NIST/Texas A&M partnership, and for each community recovering from a disaster.	3/30/2020	100%	
Research Milestone			
Complete 3-page research summaries for communities that applied PIRS since 6/30/19. As noted, research summaries are effective conveying research results focused on the experiences in use of PIRS among end-users to mitigation practitioners and policy makers.	4/15/2020	100%	We completed a report that documents the experiences of the three pilot communities. In collaboration with APA, we will be using this report to include in the the guidebook 3.0 and post on the APA website.
Produce a manuscript that describes application of PIRS during Years 3-5. The manuscript will document local official experiences in using the PIRS tool, how the information generation by application of the tool informs the planning process, actual outcomes, and highlights the important lessons learned. The manuscript will be submitted for peer review to a high impact publication outlet.	6/30/2020	100%	

2. **<u>Year 5 Transition Activities and Milestone Achievements</u>:**

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
<u>Transition Activity</u>	<u>Proposed Completion Date</u>	<u>% Complete</u>	<u>Explanation of why activity/milestone was not completed</u>
Work with 1-2 additional communities to apply the PIRS tool and integrate PIRS with NIST resilience planning guide.	3/30/2020	100%	
Conduct multiple training webinars (tbd). The primary intended audience is community officials that work in local government agencies (e.g., emergency management, planning, economic development, housing, transportation, stormwater utilities, city/county management) and non-profit organizations (e.g., conservation trusts and housing trusts) charged with creating and implementing plans that influence a wide range of land use and development activities in areas exposed to hazards. A second audience includes officials of state agencies (emergency management, community development, conservation) who could learn how PIRS works and become able to advocate and work with local jurisdictions in applying PIRS. A third audience includes Sea Grant coastal extension specialists that each coastal state and NOAA jointly support to assist land and marine resource management activities of coastal communities. Every land grant university in the U.S. with a coastline is designated as a Sea Grant university.	6/30/2020	100%	
Establish a partnership with Texas Sea Grant called the Community Resilience Collaborative to undertake multiple joint activities, including training extension specialists on how to assist communities in applying PIRS (i.e., train-the-trainers), tracking outcomes, and updating the PIRS Guidebook. The CRC will be hiring (about July 2019) one of our doctoral students as a permanent full-time extension specialist whose primary responsibilities are to train other extension specialists on use of PIRS, assist Texas coastal communities in applying PIRS in local planning efforts, and disseminate PIRS throughout the national network of state Sea Grant programs.	6/30/2020	100%	
<u>Transition Milestone</u>			

Finalize PIRS guidebook and related training materials. A final set of updates will be incorporated into the guidebook and related training materials. Investigators will document ways to improve the PIRS work based on local officials' comprehension of resilience planning concepts, experience in organizing local staff that supports inclusive engagement and efficiency in carrying out technical analyses. Successful aspects of our collaboration with NIST in conducting application of PIRS and the NIST resilience planning guidebook will be incorporated into the PIRS training materials. The primary aim is to improve the PIRS in ways that encourage use by key organizations that operate at the local level, and are influential in land use and development planning and decision making (local government agencies, non-profit organizations). Other target organizations include state agencies, professional practice organizations, and Sea Grant coastal land and marine resource management specialists.	6/30/2020	50%	We continue to work with American Planning Association (APA) to update the PIRS Guidebook – 3.0. We will integrate pilot community experiences, and APA contributions during year 6.
Finalize website that will house PIRS (mitigationguide.org). The updated website will significantly facilitate use by end-users based on lessons learned from real world applications of the guidebook, plan evaluation tool, and associated training materials during year-5. The investigators will work with engagement staff of the Institute for Sustainable Communities to include the updates on the website. The final version of the website will be designed to be user-friendly and made available to a wide array of practitioners. The website will include materials that will help local officials undertake a self-evaluation of their community's local network of plans, as well as educational materials that enable training by professional practice organizations, state agency staff, and Sea Grant specialists.	6/30/2020	50%	We made some changes to the current website [mitigationgudie.org], including inclusion of pilot community experneces, and research publications. Significant changes still need to be made based on the work with APA.
Present final version of the PIRS tool and examples of demonstration communities at one national conference linked to mitigation planning practice (e.g., APA conference, ICMA conference, ASFM conference, National Hurricane Center Conference), or FEMA workshop	6/30/2020	100%	We presented version 2.0 of the PIRS guidebook, and the Rockport case study at NPC20@Home. Ideally we would have liked a longer more in-depth training, but COVID-19 limited our outreach.
Transfer PIRS website and related training materials with the Community Resilience Collaborative (CRC) of Texas Sea Grant. CRC will maintain and update the website as real world applications by communities yield new knowledge and best practices	6/30/2020	0%	We decided against making the transfer to Texas Sea Grant. Rather, we are working with APA to develop an advanced version of a

that need to be incorporated into the guidebook and related training materials, and new sources of hazards exposure and vulnerability data become available. In addition, the investigators will request various professional practice organizations (e.g., American Planning Association, National Hazards Mitigation Association, Association of State Floodplain Managers), FEMA, state emergency management and planning agencies, and others to post links to the PIRS website. We also will work with NIST, FEMA and New York Rising to maintain and update the PIRS website with the intent of integrating PIRS into ongoing resilience planning programs of these organizations.			website to house PIRS guidebook and training materials.

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
Plan Integration of Resilience Guidebook™ – Version 2.0	Local government guidebook for evaluating networks of plans.	Fall 2019	-FEMA and NIST -Local governemnt practioners charged with planning in different urban sectors (e.g., planning, emergency management, floodplain management, historic preservation)
A*pplying a Plan Integration for Resilience Scorecard to Practice: Experiences of Nashua, NH, Norfolk, VA, Rockport, TX.* pp. 40.	Report that documents experiences and outcomes generated by application of PIRS™ by local officials in three pilot communities.	May 28, 2020	Same as above.

IV. PUBLICATIONS AND METRICS

1. Publications:

a) Publications

Year 5 Publications

Berke, P, M Malecha, S Yu, J Lee and J Masterson. 2019. Plan Integration for Resilience Scorecard: Evaluating Networks of Plans in Six US Coastal Cities, *Journal of Environmental Planning and Management*. 62(5): 901-92. DOI: /full/10.1080/09640568.2018.1453354 (published)

Berke, P., S Yu, M Malecha, J Cooper. 2020. Plans that Disrupt Development: Equity Policies and Social Vulnerability in Six Coastal Cities. *Journal of Planning Education and Research* doi.org/10.1177/0739456X19861144 (published online).

Other Publications

Berke, P., J Masterson, M Malecha, Matt, S Yu. 2020. Evaluation of Networks of Plans to Hazards and Climate Change: Application of Plan Integration for Resilience Scorecard™ in Norfolk, VA, *Carolina Planning Journal* (forthcoming).

Berke, P., J Masterson, M Malecha, Matt, S Yu. 2020. A*pplying a Plan Integration for Resilience Scorecard to Practice: Experiences of Nashua, NH, Norfolk, VA, Rockport, TX*. pp. 40.

Year 4 Publications

Newman, Galen, Malecha, Matt, Yu, Si, Qipao, Z., Horney, Jen, Lee, Daemyung, Kim, Young., Lee, R.J., & Berke, Philip**.** 2019. Integrating a Resilience Scorecard and Landscape Performance Tools into a Geodesign Process. *Landscape Research*. DOI: 10.1080/01426397.2019.1569219 (2020 Certificate of Research Excellence, Environmental Design Research Association)

Publications Prior to Year-4

Berke, P., Lee, J., Newman, G., Combs, T. Kolosna, C., Salvesen, D. 2015. Evaluation of Networks of Plans and Vulnerability to Hazards and Climate Change: A Resilience Scorecard, *Journal of the American Planning Association* 81(4): 287-302. DOI: 1080/01944363.2015.1093954

Berke P., Malecha M., Yu S., Lee J., Masterson J. (2018). Plan Integration Scorecard for Resilience: Evaluating Networks of Plans in Six US Coastal Cities, Journal of Environmental Planning and Management, DOI:10.1080/09640568.2018.1453354.

Malecha, M., Brand, A., & Berke, P. (2018). Spatially evaluating a network of plans and flood vulnerability using a Plan Integration for Resilience Scorecard: A case study in Feijenoord District, Rotterdam, the Netherlands. Land Use Policy, 78, 147-157. DOI: 10.1016/j.landusepol.201

Masterson, J., Berke, P., Malecha, M., Yu, S., Lee, J., & Thapa, J. (2017) Plan integration for resilience scorecard: How to spatially evaluate networks of plans to reduce hazard vulnerability.

College Station, Texas: Institute for Sustainable Communities, College of Architecture, Texas A&M. http://mitigationguide.org/wpcontent/uploads/2013/01/Scorecard_3Oct2017.pdf

b) Student theses and dissertations

Zito, Fracesca. 2020. *Applying the Plan Intehgration for Resilience Scorecard*^{TM}*: New Bern, NC.* Master City & Regional Planning, University of North Carolina-Chapel Hill. Primary Advisor: Philip Berke

Malecha, Matt. 2019-December. *Enahncing Communiy Resilience to Flooding through the Spatial Evaluation of Plans, Policies, & Regulation*. PhD, Urban and Regional Science, Texas A&M University. Primary Advisor: Philip Berke

Yu, Siyu. 2019-August. *The Influence of Plan Integration on Community Vulnerability and Ecological Resilience to Natural Hazards*. PhD, Urban and Regional Science, Texas A&M University. Primary Advisor: Philip Berke

Kim., You Jung. 2019-May. *Advancing Scenario Planning to Prepare for Uncertain Climate Change: Future Urban Growth Prediction and Flood Vulnerability*. PhD, Urban and Regional Science, Texas A&M University. Primary Advisor: Dr. Galen Newman, Committee Member, Philip Berke

2. Performance Metrics

Berke: Performance Metrics:

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17-6/30/18)	Year 4 (7/1/18-6/30/19)	Year 5 (7/1/19-6/30/20)
HS-related internships (number)	0	0	0	0	0
Undergraduates provided tuition/fee support (number)	0	0	0	0	0
Undergraduate students provided stipends (number)	0	0	0	0	0
Graduate students provided tuition/fee support (number)	2	2	2	2	1
Graduate students provided stipends (number)	3	3	3	0	2
Undergraduates who received HS-related degrees (number)	0	0	0	0	0
Graduate students who received HS-related degrees (number)	0		0	2	0
Graduates who obtained HS-related employment (number)	0		0	1	1
SUMREX program students hosted (number)	0	0	0	0	0
Lectures/presentations/seminars at Center partners (number)	0	3		8	0
DHS MSI Summer Research Teams hosted (number)	0	0		0	0
Journal articles submitted (number)	0	2	2	2	2
Journal articles published (number)	0	0	2	2	3
Conference presentations made (number)	3	5	2	4	9
Other presentations, interviews, etc. (number), webinars	1	6	2	1	3
Patent applications filed (number)	0	0	0	0	0
Patents awarded (number)	0	0	0	0	0
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number) (FEMA, NIST)	0	1	2	2	2
Requests for assistance/advice from other agencies or governments (number)	0	9	3	8	10
Dollar amount of external funding	$200,000	$250,000	$2,490,000	0	$175,000
Total milestones for reporting period (number)	2	2		5	7
Accomplished fully (number)	2	1	4	3	3
Accomplished partially (number)		1	1	2	3
Not accomplished (number)	0	0	0	0	1

PROCHASKA, URI
DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Communicating risks to motivate individual action

Principal Investigator Name/Institution: James O. Prochaska, Ph.D., University of Rhode Island

Additional Research Participants/Partners:

Andrea L. Paiva, Ph.D., Pam Rubinoff, and Karin Oatley; University of Rhode Island

Short Project Description ("elevator speech"):

Our research path will complete the validation or Proof of Concept (initiated in year 3) for changing storm preparedness behavior (Get a Kit, Make a Plan, Be Informed), using our Transtheoretical Model (TTM). This TTM tailored online approach for interventions included the added feature of delivering complementary stage-matched feedback via texting to each enrolled participant. Recruitment and intervention used a population based sample of 491 at-risk participants in Rhode Island over a 6-month period. Our targeted end-user transition path included outreach, needs assessment, recruitment, and implementation with organization(s); protocol development addresses the key elements including participant time demands, organizational costs, intellectual property issues and supporting technologies for program delivery. Our end-user recruitment plan targeted organizations that are committed to having their employee or customer populations be adequately prepared for natural disasters.

II. PROJECT NARRATIVE

1. Project overview:

This project has supported DHS in improving its national mission to safeguard people, infrastructure, and economies from catastrophic coastal natural disasters. This research met DHS priorities by strengthening national preparedness and improving the resilience of coastal communities in the face of coastal storm hazards; consistent with NOAA's coastal missions and programs as well. As such, this research addresses Presidential Policy Directive 8, which calls for increasing our level of National Preparedness by preventing, mitigating, responding to, and recovering from the hazards that pose the greatest risk. This project is specifically tied to strategic priority 1 of the 2014-2018 DHS strategic plan. More specifically we are responding to objective 1.3 aimed at increasing disaster awareness and action. Additionally, this project addresses QHSR Mission 5 (Strengthen National Preparedness and Resilience), which helps develop tools to enhance citizen preparedness, specifically Goal 5.1, Enhance National Preparedness supports efforts to "Empower individuals and communities to strengthen and sustain their own preparedness…build a collective understanding of their risks, the resources available to assist their preparations, and their roles and responsibilities in the event of a disaster." Hurricanes account for 10 of the top 15 most expensive natural disasters in the United States, including the top 3 (NOAA, 2014).

2. Results:

Our team has had success in our outreach efforts to end-user organizations which culminated in engaging 491 individuals to participate in our program. As mentioned in the workplan, we considered completing a demonstration study in Year 4 & 5 with a transition partner (e.g. health-related organization) instead of a new survey company. We have decades of experience in study recruitment for longitudinal intervention research. We know that recruitment is time-consuming and often times disappointing when we encounter organizations who acknowledge the need for the intervention but anticipate feeling burdened by involvement in a longitudinal study. For this project, we were more than surprised as this has not been the case. Every organization that we have approached about our computer tailored intervention (CTI) has shown genuine interest and enthusiasm. As would be expected, each end-user organization has its individual needs, time constraints, and suggestions regarding optimal protocol for recruitment and intervention for their *individual* end-user.

As we began our recruitment efforts it became clear that a tiered approach involving multiple phases was necessary. The initial phase would involve presentations to leaders within organizations who would benefit from the program's implementation (phase 1- tier 1). Once the organization's leader buys-into, or endorses the program's use, recruitment may pass to an additional entity that falls under the umbrella of the original organization that was presented to initially (phase 1 - tier 2). Once this level of recruitment is successful and an agreement is signed, the final recruitment phase is reached. During the final phase, the individual end-user is recruited (phase 2). End-user organizations determine the recruitment methods used to enhance individuals' awareness and opportunity to participate in the CTI. We have learned this detail is key in successful implementation as the invitation to participate is delivered by email and very often solicitation by this method goes unnoticed. Incentives and other methods may be used by the organization to enhance participation numbers.

Our team secured an end user umbrella organization, RI Department of Health, who then put us in touch with emergency preparation leaders from each organization. Our team worked closely with each organization and developed recruitment tools that were sent out through senior leadership in each organization. It was the responsibility of the senior leaders in each organization to recruit employees through their listserv for individual participation. Data was collected from 491 employees of health care facilities in Rhode Island (hospitals, nursing homes, in home hospice centers, dialysis centers). By working together with stakeholders, the leaders within various agencies that fall under the umbrella of the Rhode Island Department of Health, we were able to launch a demonstration study using a real-world sample rather than the initially proposed study which would have recruited participants from a survey company; those recruits regularly participate in survey research for survey companies who incentivize them in some way. By securing our sample from recruitment efforts with leaders and stakeholders who value our intervention due to the perception of possible return on investment or workforce resilience benefits, we produced a more valued sample; one in which we gain insight to generalize our findings to apply in future real-world dissemination. detail in the unanticipated events section of this report.

Guidance and resources were produced with future dissemination of program in mind. These are noted below and submitted in an addendum to this report.

Table 1 shows that the baseline stage distribution of the 491 baseline participants.

Table 1. Baseline Stage of Change and 3 month outcomes (N=491)			
Baseline Stage of Change	**n**	**%**	**% in A/M at 3mo**
Precontemplation (PC)	68	13.85	
Contemplation (C)	152	30.96	27.60%
Preparation (PR)	102	20.77	
Action (A)	78	15.89	89.50%
Maintenance (M)	91	18.53	

All participants were followed up for a 3-month intervention. Participants were not incentivized to return for the follow-up session although they were entered into a drawing for one of 20 $100 Amazon gift cards to help bolster participation and retention. The retention rate at 3-months was 31.4% (N=154) and participants from each baseline stage of change were represented in the 3-month data. We were able to analyze the data from both those participants who were in the pre-action stages (PC, C, PR – not yet prepared) at baseline (N=116) and those who were prepared at baseline (in Action or Maintenance) (N=38).

Pre-action at baseline sample results: Among this sample, 27.6% of participants moved to the Action or Maintenance stages. In our original proposal, we predicted that our tailored intervention would produce results at least 10 times greater than the national secular trends of 2% action taken per year and in a previous study within this project, 17% of New England participants moved to the Action or Maintenance stages.

Action/Maintenance at baseline sample results: Our hope is that our tailored interventions keep participants prepared. We found that 89.5% of these participants remained in the Action/Maintenance stages at the 3-month follow-up.

3. End users:

Organizational end-users: Rhode Island Department of Health (RIDOH), was recruited as a main collaborator who helped strategize and promote our program with the end-user organizations. In total we secured 1 end-user organizations out of a potential total of 18 agencies falling under the umbrella the Center for Emergency Medical Services at RIDOH. Those who are participating and have expressed interest and support of our program include the Healthcare Coalition of Rhode Island (HCRI), co-chaired by RIDOH and the Hospital Association of Rhode Island (HARI). Activities of HCRI are funded by a contract that RIDOH provides to HARI with federal funds received through the US Department of Health and Human Service, Assistant Secretary for Preparedness and Response, Hospital Preparedness Program. The employees of the following organizations have participants in our program:

- Women and Infants Hospital
- Westerly Hospital
- Landmark Medical Center
- Providence Veteran's Administration Medical Center
- Newport Hospital
- Kent Hospital
- Fatima Hospital
- Elenore Slater Hospital
- Bradley Hospital
- RI Home Hospice Centers
- RI Nursing Homes
- RI Assisted Living Centers

Individual end-users: 491 individuals were recruited by means of a recruitment invitation email sent from their employer through that organization's list serve. Thirteen healthcare agencies located in Rhode Island with employees in Rhode Island, Connecticut and nearby Massachusetts agreed to offer participation to their employees.

One community organization also participated by sending email invitations to individual members by list serve and social media platforms.

In total, we were successful in securing thirteen end-user organizations to utilize our computer-tailored preparedness program. Additionally, Rhode Island emergency management agencies expressed interest in possible future use of the program. With this in mind, we allowed access to utilization of the program while the demonstration trial was on-going as a means of demonstrating the program in real-time to RIEMA senior leaders, in the hope of increasing the likelihood of future engagement. Follow-up feedback with end-user organizations will occur post-Year 5 in order to allow appropriate time for all involved to recover from the COVID-19 pandemic.

4. <u>Transition:</u>

Through our demonstration to engage end users we developed a set of tools and resources to ease dissemination of the program. The following deliverables have been created during the course of this DHS funded project and were used in the implementation and roll-out of the demonstration study. By utilizing these tools and guides the project can easily transition from research to real-world dissemination of an advanced digital means of educating and preparing individuals to take action in taking the steps necessary to become more prepared. Another concern regarding transition was alleviated after discussion with a member of the university's legal team. We gained assurance that the intellectual property rights will permit use of this CTI program to agencies who receive federal funding related to natural hazard preparedness.

The following tools provide guidance and resources for future dissemination of the CTI.

Digital programs:

- Computer-tailored intervention program for preparedness including tailored text messaging. Use of digital technology with texting being tailored to the stage of each participant. This digital technology is housed at the University of Rhode Island.

Recruitment Tools:

- General Guidance for Dissemination – "how to guide" in narrative form
- Promotional Video for use in phase one & two of recruitment
- Fact Sheet with Frequently Asked Questions (FAQ) Template – use of program cost will change over time
- Customizable PowerPoint TEMPLATE for use in phase one of recruitment (phase 1 = organizational stakeholders and phase 2 = individual end-user)
- Organizational Timeline TEMPLATE– provides general overview/flow of participation for use with Organizations and Individuals
- End-Product Cost Statement including breakdown of cost options for levels of technology/customizability including statement of intellectual rights
- Sample Letter of Commitment for use in securing end-user organization
- Recruitment Letter Sample for use in phase 2 recruitment of individual end-user

Products to Disseminate:

- White Paper entitled "Are Rhode Islanders Ready – Assessing Individual Climate Change Preparedness", Rubin, Rubinoff, Ginis, et al
- Webinar featuring Dr. James Prochaska discussing the need and benefits of a CTI for increasing individual preparedness for natural disasters
- Book Chapter - "Resilience and Thriving in Spite of Disasters", Mundorf, et al

5. Project Impact: The impact of our project is reflected in all of the technology, tools, guides and data we have generated throughout the project and adopted during Year 05. This includes the first digital technology that can tailor communications to segments of the population who are ready, getting ready, or not ready to become prepared for coping effectively with hurricanes and other severe storms. One of the biggest challenges for behavior changes, like risk reducing actions, is to engage individuals and organizations in our evidence-based programs. Our engagement and dissemination tools include: A promotional video for use in phase one & two of recruitment (phase 1 = organizational stakeholders and phase 2 = individual end-user); a customizable PowerPoint template for use in phase one of recruitment; a sample letter of commitment for use in securing end-user organization; a recruitment letter sample for use in phase 2 recruitment of individual end-user; General Guidance for Dissemination Outline – "how to guide" in narrative form; and an organizational timeline template that provides general overview/flow of participation for use with organizations and individuals.

The data we have generated this year along with data from previous years will provide the evidence for producing at least one high impact peer reviewed publication in Year 06. The publication will introduce readers to the innovative and integrative program that has helped drive our data.

6. Unanticipated Problems:

We encountered three unanticipated problems, the first being the issues we became aware of in utilizing the survey recruitment company that has a strong history of retention in past projects. For several months we waited while various university departments engaged in discussion of how to move forward in allow us to use this company that was not an equal opportunity employer which, we then learned, is a university policy. We also learned that there exist certain circumstances were it can be done but as we began pursuing these options we realized the time involved made it prohibitive. Luckily, we had already begun recruitment talks with several organizations who we thought might be interested in hearing about our program and set out to gauge their interest in the possibility of future engagement. These talks quickly became the source of our real-world sample of participants and the recruitment company was no longer needed.

Our second unanticipated problem effects our baseline data collection sample and occurred when we were in the process of expanding our recruitment beyond the 491 participants to include another large recruitment site when COVID-19 ramifications began to impact us on or around March 16, 2020. As readiness and preparedness will be impacted by COVID-19, it would have been problematic to recruit more baseline participants at that time. In addition, the 491 participants is a solid study size especially as they are all from one region.

Lastly, consideration should be given to the results data we will collect at the 6-month time point (April-June). The timing of the pandemic may have an effect on people's behavior change, likely we may find individuals being more prepared (in the Action stage) due to external influences to prepare for this pandemic. For example, individuals are stocking up more on food during the pandemic, which will be beneficial for a natural disaster. However, people may not respond to the 6-month check in given the situation, and the fact that many of them are health care staff occupied by the pandemic. Our focus will rely more on the data collected at the 3-month time point as those were collected prior to RI shutting down for the pandemic.

7. Student Involvement and Awards:

Lauren Hanna, a graduate student/fellow majoring in Environmental Management was involved in the text messaging refinements and testing as well as in the production of the promotional video. Her funding was leveraged from the NOAA Sea Grant funding. Undergraduates Sarah Angeloni, Joe Franco and Joshua Hastings, from the university's Harrington School of Communication and Media were involved in the production of our promotional video. They were supervised teaching professor, Keith Brown, MFA.

8. **Interactions with CRC education projects:** N/A

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Proof of Concept - implement T1 assessment; begin sending text intervention	10/1/19	100%	
Proof of Concept - Analyze baseline assessment	1/30/20	100%	
Proof of Concept - Text messages sent to participants for 6 months	6/1/20	100%	
Proof of Concept - Reassess participants for longitudinal study	1/15/20 and 4/15/20	100% 100%	
Proof of Concept - Analyze follow-up data	6/15/20	100%	6-month data collection still underway but likely affected by COVID
Review/revise text messages based on meetings and discussions with end users.	8/1/19	100%	
Research Milestone			
Proof of Concept - Text messages completed and longitudinal assessment implemented	1/15/20	100%	
Proof of Concept – Analysis completed; reported to/discussed with CRC/DHS; webinar #2	6/30/21	*	To be completed during anticipated no cost extension period.
Develop a final report documenting the project and its findings/outcomes from beginning to end. Clearly identify which elements are validated and able to be applied in practice.	6/30/21	*	Now part of Y06 workplan

2. **Year 5 Transition Activities and Milestone Achievements**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Summarize the sample that was collected at T1including region, demographics, stage of change, time spent on the program/assessment, and how many participants opt into the text messaging feature. This summary will indicate that we were able to recruit the sample needed for our proof of concept.	6/30/21	*	Will be included in journal article to be produced in Y6
Engage end-users in Webinars • Opportunities and Protocols for adoption by end-users. Integration Proof of concept with transition on recruiting and implementation	9/19, 1/20	100%	* Intent of this activity was completed - was done in-person as opposed to webinars
Update fact sheet based on results from Proof of Concept such as changes in expected results, changes in costs to end users.	2/28/21	*	To be completed during anticipated no cost extension period.
Close on at least one Letter of Agreement with an end user to move onto the next end user	4/20	100%	We secured agreements with 12 end-user organizations to participate in our trial – post grant recruitment was negatively impacted by the pandemic.
Engage at least 6 additional candidates in meetings for program adoption	4/1/20	100%	Same as above *The current COVID-19 pandemic prevents outreach for post-grant engagement at this time since recruitment efforts will involve healthcare providers, emergency management personnel and healthcare organizations, all of which are frontline response organizations.

Completing protocol and guidance for effective implementation end-users.	4/30/20	100%	
Make the updated fact sheet available via an online website	6/30/21	*	To be completed during no cost extension period.
<u>Transition Milestone</u>			
Summarize meetings with at least 3 additional potential end users. This will highlight the pros and cons of adopting a behavior that end users have identified during our meetings. This will help CRC/DHS better understand updates and customizations that would be ideal	6/30/21	50%	Possible post-grant organizations remain interested in future use of the program; however, the current pandemic prevents follow-up outreach at this time since recruitment efforts will involve frontline response organizations.
Our goal is to close on at least one additional agreement with an end user for implementation post-project.	6/30/21		Same as above
Close on at least one Letter of Agreement with an end user to move onto the next end user	6/30/2021		Same as above
Provide a report to DHS on the validated project outcomes in the form of a "how-to" guide. The report should include the method and how to implement the method.	6/30/2021		Add stage explanation in guide
Webinar or other presentation at FEMA on how to apply the method and/or findings to date	6/30/2020	100%	Preliminary engagement with FEMA state (5/19), reginal (12/19) and national (5/19)

3. Research Project Product Delivery.

Table: Research Project Product Delivery

Product Name and Function	Brief Product Description, including type (e.g., software, algorithm, guidance document, knowledge product)	Date Delivered (or projected date of delivery	Recipient or End User(s)
Digital Programs	Digital technology software program for promoting emergency preparedness - including corresponding algorithms and stage-matched text messages	6/2020	End user organizations

White Paper	"Are Rhode Islanders Ready: Assessing Individual Climate Change Preparedness", Rubin, Rubinoff, Ginis, et al	6/2020	Professionals, scientists, senior leaders interested in the program
Book Chapter	Mundorf, N., Redding, C.A., Prochaska, J.O., Paiva, A.L., & **Rubinoff, P**. (2018). Resilience and Thriving in Spite of Disasters: A Stages of Change Approach. In A. Fekete & F. Fiedrich (Eds.), *Urban disaster resilience and security: Addressing risks in societies* (pp. 383–396). Springer International Publishing. doi: 10.1007/978-3-319-68606-6_22	6/2020	Professionals, scientists, senior leaders interested in the program
Customizable PowerPoint Template	For use in phase 1 of recruitment (phase 1 = organizational stakeholders)	6/2020	Umbrella organizations interested in disseminating to their organizations
Sample Letter of Commitment	for use in phase 1 – securing end-user organization	6/2020	URI for signing on end users
Promotional Video	For use in phase 1 (org level) & phase 2 (individual level) of recruitment	6/2020	URI for engaging end user organizations or end user organizations to recruit participants
Recruitment Letter Sample	For use in phase 2 recruitment of individual end-user	6/2020	End user organizations
Fact Sheet Template	Includes facts and Frequently Asked Questions (FAQ) Template – use of program cost will change over time	6/2020	URI for engaging end user organizations
General Guidance for Dissemination Outline – "how to guide"	Describes recruitment phases	6/2020	End user organizations
Organizational Timeline Template	Provides general overview/flow of participation for use with Orgs & Indiv.	6/2020	End user organizations
End-Product Cost Statement	Includes breakdown of cost options for levels of technology/customizability including statement of intellectual rights	6/2020	URI for engaging end user organizations
Branding Logo	"ARE YOU READY Waves of Change" Logo for use in branding materials for recruitment. Engagement tool	6/2020	URI for engaging end user organizations and end user organizations for the project recruitment or promotion of the project

IV. PUBLICATIONS AND METRICS

1. Publications: N/A

2. Performance Metrics

Prochaska: Performance Metrics

Metric	Year 1 (1/1/16 6/30/16)	Year 2 (7/1/16- 6/30/17)	Year 3 (7/1/17- 6/30/18)	Year 4 (7/1/18- 6/30/19)	Year 5 (7/1/19- 6/30/20)
HS-related internships (number)					
Undergraduates provided tuition/fee support (number)					
Undergraduate students provided stipends (number)					
Graduate students provided tuition/fee support (number)	1				
Graduate students provided stipends (number)					
Undergraduates who received HS-related degrees (number)					
Graduate students who received HS-related degrees (number)					
Graduates who obtained HS-related employment (number)					
SUMREX program students hosted (number)					
Lectures/presentations/seminars at Center partners (number)	2	2			
DHS MSI Summer Research Teams hosted (number)					
Journal articles submitted (number)					
Journal articles published (number)					
Conference presentations made (number)					
Other presentations, interviews, etc. (number)	2	2	2	2	2
Patent applications filed (number)					
Patents awarded (number)					
Trademarks/copyrights filed (number)					
Requests for assistance/advice from DHS agencies (number)	2	2		1	
Requests for assistance/advice from other agencies or governments (number)					
Dollar amount of external funding	$0	$100,000	$100,000		
Total milestones for reporting period (number)	4	5		3	
Accomplished fully (number)	4	3		3	
Accomplished partially (number)	4	2		0	
Not accomplished (number)				1	

TWILLEY / LSU
DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Integrating CERA-Planning Software to support DHS Modeling and Planning Efforts for more Resilient Communities

Principal Investigator Name/Institution: Robert R. Twilley, Louisiana Sea Grant/Oceanography & Coastal Science, LSU

Additional Research Participants/Partners:

Traci Birch, Coastal Sustainability Studio, LSU
Carola Kaiser, Center for Computation and Technology (CCT), LSU Brant Mitchell, Stephenson Disaster Management Institute (SDMI), LSU

Short Project Description ("elevator speech"):

We propose to investigate how some of the skills developed within CERA-Planning can be integrated into some of the flood exposure and damage modeling techniques that have been developed to evaluate impact of natural hazards to improve planning. The approach is to test whether some of the skills that have been developed within CERA/ASGS and incorporated into CERA-Planning to describe flood exposure and impacts can contribute to the existing flood consequence modeling within FEMA and NIST.

II. PROJECT NARRATIVE

1. **Project overview:** We propose that the skills developed within CERA-Planning can be used to link CRC work developing high resolution flood hazard data and visualization through CERA/ASGS with the damage calculating abilities of FEMA's Hazus Flood and Wind models. Integrating reliable, high resolution flood hazard data into the Hazus models may be valuable in producing higher quality mitigative design and planning approaches that target areas of repetitive loss by making engineering and computer sciences advances easily accessible to other disciplines in the risk reduction field. Having better knowledge of where it is flooding and how much that flooding is costing a community, decision makers would more easily be able to protect the vulnerable areas of the community. This real-time knowledge is needed for disaster planning and response. The techniques developed are also useful for accurate post-event evaluation to make land use and redevelopment decisions in recovery, as well as shape disaster plans to avoid future loss by maximizing risk reduction.

   The program is focused on exchanging data from CERA with data from Hazus to create reliable maps fitting within the objectives of the NIST Community Resilience programs.

Having produced a technique to integrate CERA/ASGS hazard data into the Hazus flood model to produce building damage maps, the program plans to focus on the following in the future: (1) perfecting this technique and exploring others suggested by end-users, (2) create more types of loss maps using Hazus results, (3) integrate these maps into the existing CERA Planning tool prototype.

2. **Results:** In the past, our focus has been on presenting results to emergency managers and, more recently, promoting the use of other DHS tools through our results. In the 4th year of this project, we focused on promoting the use of the Hazus Wind and Flood Models by creating a technique that successfully processes CERA provided APS storm surge results into a format that can be used by Hazus. To properly compute storm surge damages in Hazus, the user must first complete a run through the Hazus Wind Model, followed by a run in the Hazus Flood Model. The results from these runs are combined by Hazus in a Combined Wind and Flood Direct Losses run to simulate the results of a storm surge. For a Combined Wind and Flood style run, the user can use a historic storm that is provided through Hazus, or through a user defined storm. The storms provided through Hazus are a simplified SLOSH model resulting in hazards that are a lower resolution than both SLOSH and APS model outputs. For this reason, an accurate user-defined storm for either the SLOSH or APS model would give a much more accurate Hazus hazard scenario.

   Having previously established that APS is more accurate than SLOSH, this group focused on creating a user-defined scenario from APS outputs. This task has been previously complicated by the file format, netCDF, of APS outputs since this file format is not able to be read in the Hazus Flood Model. Furthermore, once the data in the netCDF file is accessed, it is difficult to process in ArcGis into an acceptable depth grid for Hazus, as APS meshes do not easily transfer to the Hazus required raster. However, it is possible and relatively simple using CERA/ASGS. The hazard outputs visualized in CERA are done automatically for each storm advisory produced by NHC. An output available for download on the CERA website is the inundation point shapefile for a storm. The shapefile can be loaded into ArcGis and interpolated into a raster which depicts the flood inundation levels. This raster is the ideal input for a user-defined storm in Hazus.

   Since our group has developed this method to easily and accurately integrate the APS results into Hazus, we are able to create Hazus scenarios with APS results that produce risk in dollars that are comparable to the historic losses for Hurricane Isaac in 2012. This type of Hazus run could be done in real time to predict the losses as a storm approached or during recovery and planning.

   We use this data to create maps that depict the risk associated with that high-resolution hazard data to aid in post-storm land-use planning. The map we have worked on shows simulated building damages in dollars per census tract. Variations of this map include damages due to wind, flood and combined. We plan to develop these maps further using other outputs of Hazus. This would make it possible to overlay these risks and identify the census tracts in a study region most susceptible to loss. Comparing these types of maps of multiple storms hitting the same study region would work well to identify the census tracts repeatedly effected by storm surges.

The team has also started to work on a CERA Planning prototype. This features the same mapping visualization available on CERA with inventory data added. The inventory data is provided by SDMI, as it is more accurate than the Hazus data and organized according to NIST guidelines. Right now, this is only available for Hurricane Isaac 2012 water levels, but could be useful in the future when a storm is approaching to determine what essential facilities are at risk of flooding.

3. **<u>End users:</u> FEMA** Hazus Program under the Risk Management Directorate of FEMA and the Risk Analysis Program of FEMA Hazus.

   During the annual CRC meeting in Chapel Hill, our team connected with FEMA Hazus Program including Risk Analysis Program Manager, Hazus Program Manager, Hazus Development Lead and several software engineers to discuss techniques and tools within the ADCIRC Prediction System (APS), including CERA-Planning that could support Hazus development. This led to discussion via email and zoom meeting with the FEMA Hazus Program team. The Hazus Program team found our technique to be a reasonable solution. However, the team would like to see more techniques using a netCDF to raster approach to hopefully cut down on processing time. While there is an experimental process for this, it is only for the state of North Carolina and has proved very difficult to process. We are looking into seeing how much a direct netCDF to raster approach is possible at a national scale, and, if it is possible, would it actually be more computationally efficient.

4. **<u>Transition:</u>** A member of the CERA Planning team learned how to use to use Hazus Flood and Wind Models.

   The team discussed and tested methods to process CERA outputs into a raster to successfully integrate the data into Hazus. In more recent months, this discussion has included members of the Hazus development team to try to better fit the technique into their needs.

5. **<u>Project Impact:</u>** Contact with Hazus development team to make the APS integration into Hazus technique widely available.

6. **<u>Unanticipated Problems:</u>** The original workplan for the CERA-Planning tool had three strategies: develop local team of regional planners to develop CERA-Planning tool to assist in mitigating repetitive losses in coastal Louisiana; work with NIST to modify CERA-planning tool that would support community resilience guidelines to coastal communities; develop CERA-Planning tools that would support Hazus damage assessment tools. As program evolved, the project focused primarily on working directly with FEMA Hazus Program team to incorporate APS tools into Hazus software. The CERA/Hazus planning was initiated in June 2019 with a follow up discussion remotely with FEMA Hazus Program team in January 2020. Follow up with Hazus developers at the March 2020 CRC all hands meeting initiated the planning for an in-person workshop as anniversary to our June 2019 meeting. COVID-19 prevented us from planning the follow up workshop to be held at FEMA in Washington DC. We have changed that strategy to inviting Hazus developers to participate on selected biweekly research team meetings of the CERA/Hazus group at LSU. We will continue to hold those remote discussions with the Hazus development team with the

LSU CERA/Hazus team in the next several months to compare results with different data transfer techniques.

7. **Student Involvement and Awards:**
   - Katherine Jones is a graduate student funded by the CRC as a research assistant in the Department of Civil and Environmental Engineering. Her work is focused on the CERA Planning project, and she plans to complete all requirements for a Masters of Science in Civil and Environmental Engineering in May 2021.

8. **Interactions with CRC education projects:**
   N/A

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Link CERA-Planning with Hazus FLOOD analysis to investigate what skills from CERA/ASGS flood exposure and communication capabilities would support FEMA consequence modeling	Dec. 2019	100%	
Research Milestone			
CERA-Planning simulations based on scenarios from Hurricane Isaac are implemented as data source used by Hazus FLOOD analysis with significant improvements based on hindcasting.	4/30/2020	100%	

2. **<u>Year 5 Transition Activities and Milestone Achievements</u>**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Develop a working group to develop ways that CERA Planning can augment technical capabilities of FEMA Hazus-FLOOD	Dec. 2019	100%	
Hold technical workshop with Hazus-FLOOD modelers and developers to identify how CERA-Planning tool can provide additional high-resolution input data on flood conditions during an event.	June 2020	80%	Smaller working group sessions have been held remotely with FEMA Hazus Program developers due to COVID-19 restrictions on travel and in person consultation.
Transition Milestone			
Incorporate output identified in the CERA-Planning/Hazus FLOOD workshop results into a simulation test of the Hazus FLOOD model.	March 2020	100%	
Compare Hazus-FLOOD model capabilities with and without the higher resolution input data on flood exposure	June 2020	80%	Smaller working group sessions have been held remotely with FEMA Hazus Program developers due to COVID-19 restrictions on travel and in person consultation.
Provide DHS a report and presentation on the method and findings resulting from this project that would enable them to be used/applied in practice.	June 2020	75%	Smaller working group sessions have been held remotely with FEMA Hazus Program developers due to COVID-19 restrictions on travel and in person consultation.

3. **<u>Research Project Product Delivery.</u>**
N/A

IV. PUBLICATIONS AND METRICS

1. <u>Publications:</u> N/A

2. Performance Metrics

Twilley: Performance Metrics

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17- 6/30/18)	Year 4 (7/1/18- 6/30/19)	Year 5 (7/1/19- 6/30/20)
HS-related internships (number)					
Undergraduates provided tuition/fee support (number)					
Undergraduate students provided stipends (number)	1	1	1	0	0
Graduate students provided tuition/fee support (number)	1	1	1	1	1
Graduate students provided stipends (number)	1	1	1	1	1
Undergraduates who received HS-related degrees (number)					
Graduate students who received HS-related degrees (number)					
Graduates who obtained HS-related employment (number)					
SUMREX program students hosted (number)					
Lectures/presentations/seminars at Center partners (number)	1	2	3	3	0
DHS MSI Summer Research Teams hosted (number)					
Journal articles submitted (number)					
Journal articles published (number)					
Conference presentations made (number)	5	3	3	4	1
Other presentations, interviews, etc. (number)	6	2	3	2	2
Patent applications filed (number)					
Patents awarded (number)					
Trademarks/copyrights filed (number)					
Requests for assistance/advice from DHS agencies (number)	7	6	11	18	
Requests for assistance/advice from other Federal agencies or state/local governments (number)	5	4	3	55,000*	3
Dollar amount of external funding	$650,243	$800,243	$575,243	$575,243	$575,243
Total milestones for reporting period (number)	8				
Accomplished fully (number)	3				
Accomplished partially (number)	5				
Not accomplished (number)	0				

* CERA users during 2018 hurricane season

Theme 3

Coastal Hazards Modeling

LUETTICH, UNC-CH
DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020

I. INTRODUCTION

Project Title: ADCIRC Prediction System Development Coordination and Improved Connectivity with Hydrologic Models

Principal Investigator Name/Institution: Rick Luettich, Professor, University of North Carolina at Chapel Hill
Additional Research Participants/Partners:
Brian Blanton, UNC-CH
Jason Fleming, Seahorse Consulting,
Casey Dietrich, NCSU
Clint Dawson, UT-Austin
Scott Hagen, LSU
Isaac Ginis, URI
Don Resio, UNF

Short Project Description (“elevator speech

A substantial portion of the Coastal Resilience Center’s research portfolio involves the development and application of new capabilities for the ADCIRC Prediction System (APS)^{TM} which is comprised of ADCIRC, the ADCIRC Surge Guidance System (ASGS) and the Coastal Emergency Risks Assessment (CERA) web portal. This project provides resources for the overarching coordination across the ADCIRC portfolio, from process improvements to transition.

Included in these activities are the development of:

- higher resolution regional grids for the US East and Gulf coasts that integrate with our current national scale Hurricane Surge on demand Forecast System (HSOFS) grid (with Dietrich, Dawson, Hagen, Ginis);
- software to efficiently track and manage multiple ADCIRC runs across different computer platforms including “the cloud” (with Blanton, Fleming);
- additional improvements in the wind model that is included in ADCIRC (with Ginis);
- better coupling to hydrology models that track the movement of fresh water across the land, into streams and rivers until it interacts with coastal waters (with Resio, Ginis, Huang);
- continued operation and maintenance of the ASGS and CERA to provide access to

ADCIRC predicted water levels and flooding during major storm events and water velocities 24x7x365 for US Coast Guard search and rescue operations (with Blanton, Fleming and Kaiser);

- enhanced documentation for ADCIRC via the development of an ADCIRC wiki; and
- development of a business plan and end-user outreach to support transition and self-sustainment (Tom Richardson and Jason Fleming)

This proposed project will contribute to and coordinate the suite of projects providing enhancements to the APS to increase the accuracy and power of this system; provide interpretation of APS results during major storm surge events to maximize the value of these results for end users; and develop improved documentation and testing via an updated website, wiki and test cases to better enable its use by the broader ADCIRC user community.

II. PROJECT NARRATIVE

1. Project overview:

   Significant development work has been and continues to be done to enhance the ADCIRC modeling system. This project is designed to direct and integrate this work for the benefit of ADCIRC-based forecasting system that comprises the ADCIRC Prediction System (APS). In addition, this project supports the expansion of ADCIRC information and documentation available to the user community and the development of improved couplings between inland and coastal flooding.

2. Results:

   Results are further detailed in the milestone tables below. Preeminent results include extensive forecasting efforts for 2019 hurricanes Barry and Dorian; substantial progress toward ADCIRC validation for 2018 hurricane Florence including improvements to the land interaction terms in the wind forcing model and the ability to model hydrologic flow in coastal areas; enhancements to APS capabilities including the continued development of the ASGS monitoring portal by Blanton; the development of a group of multiple individuals who are capable of operating the APS; and near completion of a business plan for the continuation of ADCIRC based forecasting after the end of the CRC.

3. End users:

   Hurricane Barry forecasts – The State of Louisiana Coastal Restoration and Protection Agency – while the Governor of Louisiana generously attributed these results to the Water Institute and LSU, APS results provided critical information used in making the decision not to evacuate the city of New Orleans in advance of this storm.

   Hurricane Dorian forecasts – These results were broadly used along the US south east coast as the storm approached and eventually move northward along the coast. During the storm I communicated with the State of Florida Emergency Command Center; Departments of Transportation in South Carolina, North Carolina and Maryland and the emergency command center in the While House. I also provided briefing material to DHS OUP for dissemination to DHS S&T leadership.

While not all end users access APS via CERA, we have a database of over 700 individuals who have registered for CERA login credentials over the past two hurricane seasons. These users were surveyed to solicit feedback on APS existing or desired products in January / February 2020 and the results are being used to develop the APS business plan (see Richardson report).

I am on the leadership team of the interagency Coastal Coupling Community of Practice (includes NOAA, USGS, USACE, FEMA, academia, others) which forms an important community of end users for advancements in the coastal hydrologic-storm surge work.

The broader ADCIRC user community comprises a significant group of end users who have benefited from the improved ADCIRC model documentation that is being provided on the ADCIRC wiki.

4. <u>Transition:</u>

During significant storm events I use twitter, email, video conferencing and phone to communicate results from the APS. The Coastal Coupling Community of Practice is an important network for facilitating transition of modeling advancement, and the coastal circulation listserve and professional meetings are important means for communicating model and documentation advancement. The APS business planning project is important for developing a long term sustainability plan for ADCIRC and APS.

5. <u>Project Impact:</u>

The results discussed above for Hurricanes Barry and Dorian are examples of the high impact of our work. While decisions are rarely the result of a single source of information, we know that our work during Barry guided closing gates in the hurricane protection system around greater New Orleans and influenced the decision not to evacuate the city in advance of the storm. The latter decision was contentious because independent predictions made by the USACE/NWS suggested that the storm surge added on top of the historically high river stage would produce overtopping of the river levees in New Orleans. ADCIRC model runs indicated that this was unlikely to happen. I do not have a similarly explicit example of ADCIRC's role in decisions during Dorian, however, my conversations with multiple state and federal agencies in the period leading up to the storm indicated they found our results to be valuable with the myriad of decisions they were faced with before and during the storm.

6. <u>Unanticipated Problems:</u>

The greatest unanticipated problem has been hiring technical help for this project. Due to the substantial funding delays in year 4, I was not able to hire significant technical assistance for this project. During year 5 I was able to identify, process and hire an outstanding individual with extensive ADCIRC development and application experience. However, delays in processing his visa (he is a Japanese citizen) delayed his arrival in the US until early 2020, after which all immigration was been shut down. I am currently looking for other help and hoping that he will be able to join our team in the US in the spring of 2021. These issues have delayed progress, particularly on the hydrologic / storm surge coupling research.

7. Student Involvement and Awards:

a) How did you involve students in your research during Year 5, including research assistants supported or partially supported by CRC funding? Did you include non-CRC students in your research?

Jessamine Straub, Marine Sciences MS student – studied accuracy of ADCIRC+SWAN water level and wave predictions for computing wave runup and dune erosion along different types of barrier island shore faces.

John Ratcliff, Marine Sciences MS student – studying the accuracy of ADCIRC+SWAN for predicting storm surge and flooding from Hurricane Florence

Taylor Asher, Marine Sciences PhD student – working on the ADCIRC wiki

Tiana Johnson - North Carolina A&T, undergraduate, MSI 2020 summer team – modeling Hurricane Florence using the WARF meteorological model

Jackson Wiles - North Carolina A&T, graduate, MSI 2020 summer team – modeling Hurricane Florence using the WARF meteorological model

b) Describe the demographics (esp. minority students) and student level (undergrad, graduate, etc.) involved in your research

Jessamine Straub – white, female, graduate

John Ratcliff – white, male, graduate

Tylor Asher – white, male, graduate

Tiana Johnson - African-American, undergraduate

Jackson Wiles - graduate

c) List any degrees attained by CRC-supported students during Year 5. Include student name and degree (BS, MS, Ph.D.) and major or field of study.

Jessamine Straub – awarded MS in Marine Sciences with a graduate Certificate in Natural Hazards Resilience.

d) List any awards/recognition students achieved during Year 5.

Jessamine Straub – awarded a Knauss Fellowship and is now working with the USACE (Julie Rosati and Mary Cialone) on coastal resilience.

8. <u>Interactions with CRC education projects:</u>

   My project did not directly interact with one of our CRC education partners.

9. <u>Interactions with CRC education projects:</u>

   My project is currently interacting with a summer MSI team from NC A&T University.

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. <u>Year 5 Research Activities and Milestone Achievements:</u>

Year 5 Research Activities and Milestones: Status as of 6/30/2020

Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Continue development of hydrologic model – ADCIRC coupling to include additional ways to represent interactions in rivers	06/2020	50%	This work has been delayed by the late funding received for the project during year 4 and the difficulties hiring an individual who is a Japanese citizen due to prolonged and now halted visa processing. We will continue to work on this during year 6 using funds carried over from year 5.
Evaluate performance of new ADCIRC river representations in hydrological model – ADCIRC coupling studies by Ginis/Huang (New England) and Resio (Northern Florida).	06/2020	0%	This work has been delayed by the late funding received for all of the projects involved during year 4 and the difficulties hiring an individual who is a Japanese citizen due to prolonged and now halted visa processing. We will reconsider the feasibility of this milestone during year 6.
Research Milestone			
Presentation of findings from research activities at national conference	1/2020	100%	Presentations drawing from this work during year 5 included:

			2020 Ocean Sciences, San Diego, CA 2020 American Meteorological Society Annual Meeting, Boston, MA RISE 2019 National Conference: Transforming University Engagement in Pre- and Post-Disaster Environments, Albany, NY 2019 Making Communities More Resilient to Extreme Flooding, Earth from Space Institute, Columbia, MD (keynote speaker) 2019 American Meteorological Society Summer Community Meeting, Albany, NY (invited)
Presentation of findings from research activities at ADCIRC Week	06/2020	100%	done by graduate student Taylor Asher
Submission of manuscript about hydrological model – ADCIRC coupling for peer review	06/2020	0%	to be done in year 6

2. **<u>Year 5 Transition Activities and Milestone Achievements</u>**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020

Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Modify ADCIRC / ASGS to interface with the URI HBL	06/2020	0%	This work has been delayed by both the late funding received by both the UNC and URI projects during year 4 and hiring difficulties. We will pursue this during year 6 using funds carried over from year 5.

Transfer of version 2 of high resolution regional grids into APS to include improved hydrologic coupling in rivers and to address improvements identified during testing and application of version 1 of these grids during 2019	06/2020	100%	5 regional grids have been transitioned for use in the APS forecast runs.
Test capability of ADCIRC / ASGS run monitoring portal	06/2020	100%	The APS run monitoring portal was tested and extensively utilized during the 2019 hurricane season.
Continued revision of ADCIRC website and documentation available online at adcirc.org to include an ADCIRC wiki page and additional test cases for the benefit of the ADCIRC user community.	06/2020	100%	Extensive progress has been made revising the ADCIRC documentation via the ADCIRC wiki and the inclusion of additional ADCIRC test cases.
Transition Milestone			
Inclusion of URI HBL wind model in ADCIRC / ASGS Version 2 of high resolution grids included in APS	06/2020	50%	This work has been delayed by both the late funding received by both the UNC and URI projects during year 4 and hiring difficulties. We will pursue this during year 6 using funds carried over from year 5.
Version 2 of ADCIRC / ASGS run monitoring portal is operational	06/2020	100%	
Version 2 of revised ADCIRC website and documentation available online at adcirc.org	06/2020	100%	

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function	Brief Product Description, including type (e.g., software, algorithm, guidance document, knowledge product)	Date Delivered (or projected date of delivery)	Recipient or End User(s)
ADCIRC version 54	software	Spring 2020	ADCIRC User Community
http://wiki.adcirc.org	Wiki documentation	Summer 2020	ADCIRC User Community

IV. PUBLICATIONS AND METRICS

1. Publications:

a)

2020 Luettich, R.A. and D.R. Corbett, "Sea Level Rise and Coastal Water Levels", chapter 4 in Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K. Dello, J. Dissen, G.M. Lackman, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, A.J. Terando, 2020: North Carolina Climate Science Report. North Carolina Institute for Climate Studies, 232 pp. https://ncics.org/nccsr.

2020 Straub, J.A., A.B. Rodrigueq, R.A. Luettich, L.J. Moore, M. Itzkin, J.T. Ridge, A.C. Seymour, D.W. Johnston, E.J. Theuerkauf, "The role of beach state and the timing of pre-storm surveys in determining the accuracy of storm impact assessments", Marine Geology 425(2020), https://doi.org/10.1016/j.margeo.2020.106201.

2020 Gharagozlou, A., J.C. Dietrich, A. Karanci, R. Luettich, M.F. Overton, "Storm-Driven Erosion and Inundation of Barrier Islands from Dune- to Region-Scales", *Coastal Engineering*, 158(2020), https://doi.org/10.1016/j.coastaleng.2020.103674.

2019 Asher, T.G., R.A. Luettich Jr., J. Fleming, B.O. Blanton, "Low frequency water level correction in storm surge models using data assimilation", *Ocean Modelling*, 144(2019): 101483. https://doi.org/10.1016/j.ocemod.2019.10148

2019 Paerl, H.W., N.S. Hall, A.G. Hounshell, R.A. Luettich, Jr., K.L. Rossignol, C.L. Osburn, J. Bales, "Recent increase in catastrophic tropical cyclone flooding in coastal North Carolina, USA: Long-term observations suggest a regime shift", *Nature Scientific Reports*, (2019) 9:10620, https://doi.org/10.1038/s41598-019-46928-9

2019 Thomas, A., J.C. Dietrich, T.G. Asher, M. Bell, B.O. Blanton, J.H. Copeland, A.T. Cox, C.N. Dawson, J.G. Fleming, R.A. Luettich, "Influence of Storm Timing and Forward

Speed on Tides and Storm Surge during Hurricane Matthew", *Ocean Modeling*, v137, May 2019:1-19, doi.org/10.1016/j.ocemod.2019.03.004.

2018 Gao, J., On the Surface Wind Stress for Storm Surge Modeling, PhD Dissertation Department of Marine Sciences, UNC Chapel Hill, 12/2018, primary advisor – R. Luettich.

b)

2019 Straub, J.A., Predicting Dune Erosion at Dissipative, Intermediate and Reflective Beaches, MS Thesis, Department of Marine Sciences, UNC Chapel Hill, 7/2019, primary advisor – A. Rodriguez.

2. Performance Metrics

N/A

RESIO, UNF
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020

I. INTRODUCTION

Project Title: Development and Validation of Efficient and Accurate Methods for Coupling ADCIRC to Hydrologic Models

Principal Investigator Name/Institution: Donald Resio, Professor, University of North Florida

Additional Research Participants/Partners: John Atkinson, ARCADIS

Short Project Description ("elevator speech"):

Today, the ability of coastal communities to sustain health and prosperity is being threatened by rising sea level and increased development in areas vulnerable to flooding. Recent storms such as Isaac, Harvey, and Irma have shown that a somewhat previously overlooked threat, the omission of hydrologic contributions (rainfall, runoff, and river flow) during storm surge events, can produce significant under-predicted flood risks in coastal areas. This project will develop and evaluate methods to couple hydrologic and surge models for the quantification of flood risk. In terms of coastal resilience, this change is critical to the accurate estimates of flooding for real-time evacuation planning, supporting long-term resiliency planning, as well as accurate hazard predictions in coastal areas. Products derived from this research mission will be of immediate utility to DHS and their mission to define existing risk and proposed risk reduction activities for United States coastal communities. The project will also develop a set of metrics that include accuracy, computer resource requirements (primarily execution time) and the flexibility of the system to function effectively and accurately over a range of conditions.

II. PROJECT NARRATIVE

1. Project overview:
    a) Year 5 research focused on the evaluation of three methods for estimating the computational feasibility and system accuracy of three different methods for calculating inland flood stages due to combined storm surge and storm-related hydrologic processes that lead to increased flooding in the Lower Saint Johns River Basin. It also investigated various means to convert the prediction system from execution in a deterministic mode to execution in a probabilistic mode, i.e. a Joint-Probability-Method – Optimal- Sampling (JPM-OS) execution. This is an important initial step toward developing a methodology that can be used by FEMA to quantify hazards and risks in coastal areas around the United Stated in order to improve coastal resilience. This information is also key to enabling local and state governments to recognize additional threats to their lives and livelihood that have been previously neglected.

2. Results:
    a) In year 5, the UNF team re-formulated response functions for flooding along open coasts and in estuarine and riverine environments where hydrologic forcing is also important. This new methodology allows us to quantify the potential effects of local and broad-scale variations in coastal/riverine configuration.
    b) We also found that the degrees in freedom needed to include at least the discharge at the upper boundary (or boundaries) of the modeled area and sufficient parameters to describe the space-time varying rainfall over the entire modeled area is quite large However, discharge at the downstream location of these systems did not significantly affect water levels at points slightly removed (offshore), allowing a de-coupling of the surge models from the discharge rate.
    c) Treatment of input from small tributaries into a main channel can be represented for all basins along the St Johns River within a parametric model that includes rainfall, backwater effects, and drainage rates will be explained in the final report.
    d) Rainfall rates within the ADCIRC model can be estimated by the IPET extension of the Parametric Hurricane Rainfall Model (PHRAM) (IPET, 2008), with some regional empirical adjustments.
    e) It was also determined, consistent with previous JPM effort, that it is essential to include organized deviations from the mean rain field and uncertainty in all factors involved in probabilistic model outputs.
    f) It was determined that about 350 discharge-rainfall variations will be needed to estimate the hydrologic runoff/backwater flooding effects in a study area such as the Lower St Johns River Basin.
    g) Three options have been evaluated as part of this effort:
        i. Execution of a single pass ADCIRC model to all combinations of forcing;
        ii. Executing independent ADCIRC simulations using a "slightly off-coast water level boundary at one end and the discharge boundary at the upstream end of the model domain;
        iii. Executing a simple one-dimensional finite-difference model using similar boundary conditions as those described in ii (the ADCIRC independent executions).
    h) Option "i" would require an increase of over two orders of magnitude in run-time for the JPM-OS simulations, so it does not appear feasible in a JPM-type application.
    i) Option "ii" appears to be the most advantageous, since it is already used in FEMA studies and training in the use of an ADCIRC river model to an ADCIRC surge model should build on existing capabilities.
    j) Option "iii" would require new training tools, testing, and would not initially include be able to include wind and wave forcing in areas where they might be important.
    k) Choice for final coupled system St Johns River testing:
        i. Option 2 is now in its stage of beginning production runs for option 2 as part of the Arcadis effort
        ii. The Arcadis and UNF groups have jointly developed the methodology for combining small-basin drainage and rainfall into the ADIRC model to retain stability.

3. End users:

    a) FEMA State Emergency Management, in conjunction with Florida Atlantic University are working on a statewide plan to evaluated coastal and inland hazards. Other universities are expected to join this team later.

    b) Discussions with City of St. Augustine on coastal and hydrologic hazards facing the city and threats to its historic landmarks and economic losses to flooding ranging from “nuisance-flooding” to major surge events in underway.

4. Transition:

    a) At this point, our emphasis has been on minimizing impacts on FEMA FloodMap operational methods, while still enabling the incorporation of combined hydrologic effects into the results used for the mapping.
    b) We believe the system developed through this effort will not significantly impact the overall time of computing in these studies, so their adoption would be very straightforward.

5. Project Impact:

    a) Since inland flooding in tropical cyclones is a major contributor to loss of life, damages and societal impact in many previous cases within the United States, the ability to include all major processes that contribute to risks in these areas, the incorporation of inland rainfall and rain fall in an accurate, efficient manner is essential to reaching this goal.
    b) The new system should very minimally affect the current computational burdens in FEMA studies in two fundamental ways:
        i. The hydrologic component of the computations is developed to be applied in a statistical context. This allows random errors to be included within a joint probability integral, which can be incorporated into the results within a context that does not require that details of every reach within the stream network be modeled exactly. Inside the integral this uncertainty is included via error term (typically Normally distributed around any bias).
        ii. In recent testing, many instabilities within ADCIRC ocean-to-river modeling system have arisen. By separating the ADCIRC runs into two components 1) computationally expensive offshore/nearshore regions and 2) computationally inexpensive hydrologic simulations of ADCIRC, coupled with a simple runoff model and rainfall over this area, by separating these two components in ADCIRC executions, problems with stability should be minimized.
        iii. Since our results suggest that there will be as many degrees of freedom in the hydrologic region as there are in the surge-modeling region, run time required for simulations in that form would increase the computational burdens by at least at factor of 300, since these degrees of freedom control the number of computer runs necessary for FEMA RiskMap studies)

6. Unanticipated Problems:

    a) Problems in the coupling of ADCIRC and hydrologic simulations were encountered in terms of instabilities in the ADCIRC model. The Arcadis group has made great progress in solving these problems, so we are now almost ready to begin some final runs in full system.

    b) The analysis of rainfall patterns coincident with hurricanes was much more difficult that the UNF group thought it would be; however, we have finalized our methodology and will present it in our final report.

7. Student Involvement and Awards:

    a. Students involved in research

a) William (Paul) Chilton (MS Student) has been instrumental in developing new techniques for quantifying coastal surge response, both along the coast and inland, and for the objective quantification of potential errors in interpolations between points in the JPM-OS matrix. Paul has been accepted at Virginia Tech into their Coastal Resilience Program as a PhD student.

b) Student Demographics

b) Paul Chilton (male, Caucasian) was funded by this program for two years.

    a. Degrees Attained

c) Paul Chilton will receive a M.S. degree at the end of June.

d) Student Awards

    d) Paul Chilton received the Ditzenberger Scholarship from the Ditznberger Foundation in Year 5.

8. Interactions with CRC education projects:
    N/A

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Finalize ADCIRC-Hydrologic grids	May 2020	100%	
Down-select models for final testing, based on metrics (such as computational efficiency and overall accuracy) that will be developed in year one of the project.	May 2020	100%	
Research Milestone			
Documentation of performance and computational costs for final options tested. For top performing hydrologic + ADCIRC model combinations, we will document the performance (i.e., run time, accuracy) and computational costs (i.e., number of HPC units required).	June 3, 2020	60%	Due to medical problems from Jun through early December of this year, this task will be finished in January

2. **Year 5 Transition Activities and Milestone Achievements**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Meetings with local officials to hold discussions on 1) the distributions of the flooding during Irma compared to previous flooding events and 2) provide information of the degree of potentially critical differences to the likelihood to flooding in areas along the St Johns River.	June 2020	80%	We have met with several groups but are waiting until we have our final results to give a full presentation to Jacksonville and St. Augustine. Due to medical issues this has been delayed until Febuary.
Cooperative efforts with other CRC groups to determine how to best transition emerging capabilities to planning agencies with the City of Jacksonville. It is expected that the City will	June 2020	80%	This will be completed in Febuary.

consider developing a commercial application of this system for urban planning along the River corridor.			
Transition Milestone			
Demonstration of system capabilities using different options for Hurricanes Matthew and Irma to federal (NOAA, USACE, FEMA), state (Florida Department of Environmental Protection, Water Management Districts) and local (Jacksonville Planning Commission). These demonstrations provide critical information on value of the improvements in prediction capabilities related to the need coupled system for end users and internal staff. The end-users could be motivated to ingest this information into their planning and the internal staff can identify the potential value of additional research in specific modeling components.	June 2020	80%	We have only completed Irma simulations to date, but will finish Matthew for our final report in February.
Report on "final" system capabilities and preliminary results of model boundary placement as a function of distance up the river (for example: at the river mouth or upriver).and implementation of different systems in conjunction with ADCIRC. This information could be of extreme value to FEMA RiskMap applications and to USACE design and planning applications, since such applications always involve decisions related to the value of different methodologies verses the cost of their application.	June 2020	50%	We have part of the report completed on our model selection; however, the "final" system is just coming online now. We expect to finish the final report in February.

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function .	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
System for full JPM modeling of combined surge-hydrologic modeling	Set of software codes that allow Joint Probability Model applications to areas where this is a	June 30	Possible End Users for part or all of the system: FEMA USACE State of Florida

	discernible issue in flood levels.		
Documentation of model and system application	Use guides for applying models and utilizing outputs in JPM type studies	June 30	Potential User Groups: FEMA USACE State of Florida
Journal Article describing the system, its application in studies, its accuracy in the two storms simulated and suggestions for future improvements’	Published article will provide a good peer review of the methodology and its suitability to real-world studies.		Universities and other educations groups.

IV. PUBLICATIONS AND METRICS

1. <u>Publications:</u>

Student Theses and Dissertations

a) A dissertation by Amanda Tritinger was completed last June. She was supported by CRC funding for her entire dissertation and is now employed at the USACE ERDC. Her dissertation title is: The Influence of Vertical Structure on Open-Coast Surges and its Incorporation into Depth Averaged Models.

2. Performance Metrics

Resio Performance Metrics:

Metric	**Year 1** (1/1/16 6/30/16)	**Year 2** (7/1/16-6/30/17)	**Year 3** (7/1/17-6/30/18)	**Year 4** (7/1/18-6/30/19)	**Year 5** (7/1/19-6/30/20)
HS-related internships (number)					
Undergraduates provided tuition/fee support (number)				2	1
Undergraduate students provided stipends (number)					1
Graduate students provided tuition/fee support (number)	1			1	1
Graduate students provided stipends (number)	1	2	1		1
Undergraduates who received HS-related degrees (number)					
Graduate students who received HS-related degrees (number)				1	1
Graduates who obtained HS-related employment (number)	2			1	
SUMREX program students hosted (number)		1			
Lectures/presentations/seminars at Center partners (number)	1	1	1		2
DHS MSI Summer Research Teams hosted (number)					
Journal articles submitted (number)	1	1	1	1	
Journal articles published and Book Chapters (number)	1	1			
Conference presentations made (number)		1	1		
Other presentations, interviews, etc. (number)	1		1		1
Patent applications filed (number)					
Patents awarded (number)					
Trademarks/copyrights filed (number)					
Requests for assistance/advice from DHS agencies (number)	1	1		1	
Requests for assistance/advice from other agencies or governments (number)	1	1		2	1
Dollar amount of external funding	$40,000	$187,000	$150,000	$125,000	$75,000
Total milestones for reporting period (number)	3	2	2	7	7
Accomplished fully (number)	1	5	1	2	2
Accomplished partially (number)	2	6	1	5	5
Not accomplished (number)					0

BLANTON, UNC-CH
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Operational Awareness Dashboard for ADCIRC Surge Guidance System

Principal Investigator Name/Institution: Brian Blanton, UNC-CH (RENCI)

Additional Research Participants/Partners:
Lisa Stillwell (RENCI)
Phil Owen (RENCI)

Short Project Description:

This project is developing a web-based *operational awareness dashboard* (OAD) for monitoring ADCIRC Surge Guidance System (ASGS) prediction activities being conducted at several HPC sites. This dashboard provides a real-time view of ASGS simulations during tropical cyclone events, and displays multiple, concurrent ASGS instances on different HPC resources. This continuation of CRC Y4 activities will elevate ADCIRC/ASGS prediction activities to a new level of robustness, reliability, confidence and availability by showing all ASGS activities in one web-based application. This new capability also advances ASGS/ADCIRC operational activities as we position for long-term sustainability beyond the lifespan of the CRC.

II. PROJECT NARRATIVE

1. Project overview: Recent tropical cyclones (TC) that threatened the eastern US and Gulf of Mexico coasts have demonstrated that storm surge and wave predictions from the ADCIRC Prediction System (APS) have substantial demand and value to end-users, such as emergency managers, the US Coast Guard, NOAA, DHS/FEMA, and companies. To meet this demand, the core APS operations community (DHS/CRC, RENCI, UT, NCSU, Seahorse Coastal Consulting, etc) relies on high performance computing (HPC) assets to compute and deliver real-time storm surge guidance information to end-users. While the primary APS components, ADCIRC and ASGS, have proven to be robust, efficient, and accurate, it remains challenging for APS operators to have an awareness of the entire suite of activities and simulations being conducted during a TC event, since each ASGS instance is run independently and with several different human operators. This presents a significant challenge when it is critical for operators and real-time guidance experts to know what is being computed, in what stage is any given simulation, and (particularly) when updated results can be expected.

   To summarize the previous work and progress on this project, we proposed at the start of year 4 to ***develop an operational awareness dashboard*** that monitors multiple, concurrent

ASGS instances on different HPC resources and provides a real-time, web-based visualization of the ASGS workflow, progress, and status. We designed, implemented, tested, and deployed the OAD, using modern and production-ready software components to send/receive internet-based messages and display status information in a webpage. Development of the infrastructure was rapid, due to the expertise of the project's software engineering personnel (L. Stillwell and P. Owen).

The resulting OAD (see example in Figure 1) alerts APS operators to runtime warning and errors that occur, substantially decreasing downtime and facilitating debugging of ASGS input/output and operational issues. The OAD also shows important information in the top-level banner. From left to right, the NCEP inset graphic shows the continental-scale synoptic weather (clicking on the thumbnail brings up a larger version); the current NCEP cycle date/time and local time, and the current tropical situation from NHC. This level of awareness has been critical for APS operators as we headed into the 2019 Atlantic hurricane season.

2. <u>Results:</u> During year 5, we continued to refine the OAD's user-facing layout, and in particular reorganized the main way in which the information is presented. We based these changes on feedback of the first (Y4) version during the 2019 hurricane season, which includes the first part of this reporting period. The improved layout is shown in Figure 1. This layout is easier to read and will (in the next project year) be more configurable by operators. This screen capture was taken during the third named storm of the 2020 Atlantic hurricane season, Tropical Storm Cristobal. The OAD shows that 10 different ASGS/ADCIRC configurations were operating, on three different HPC platforms (TACC, RENCI, and LSU (Queenbee)), and in various stages of completion (Step and % complete columns).

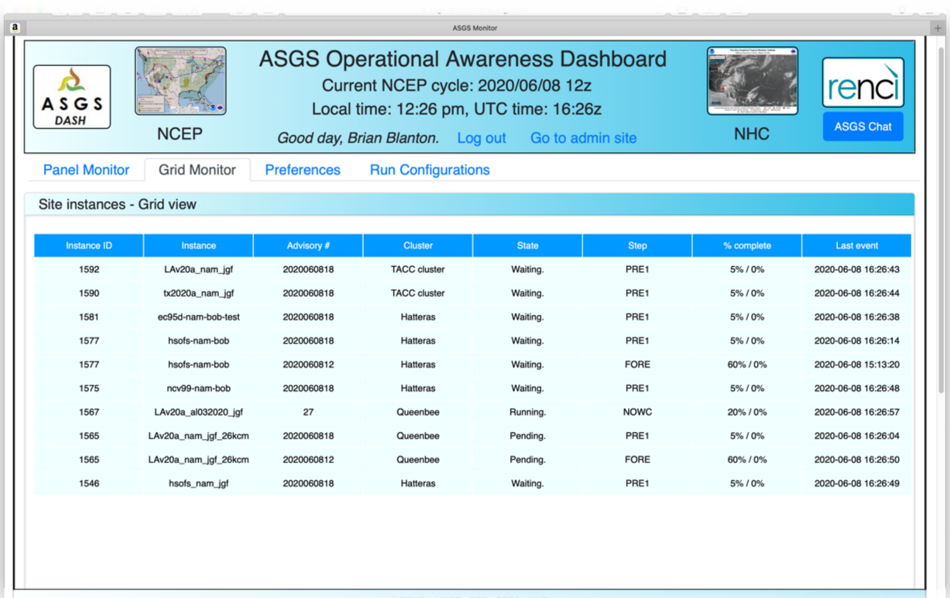


Figure 1 (above): Grid/table information layout implemented in Y5 of the OAD project.

3. <u>End users:</u> End users of the APS OAD are the APS operators and those communicating directly with end-users. As noted above, the OAD does not provide the actual APS prediction/simulation output, but rather on simulation status information. Current APS operators and product communicators include Jason Fleming (Seahorse Coastal Consulting), Rick Luettich, Brian Blanton, Matt Bilskie (LSU), Nathan Dill (Ransom Consulting), and This group of users must maintain an "operational awareness" of all concurrent ASGS computing activities in a fast and easily understandable format, in order to optimally communicate hazard information to their respective end-users and "clients", anticipate delivery of new information, and react to system warnings and errors that delay product computation and delivery.

4. <u>Transition:</u> Transition of the project outcome (the OAD itself) is done through the website that hosts the OAD, https://asgs-monitor.renci.org/index. All APS operators have an account on this website and can view all currently running ASGS instances.

5. <u>Project Impact:</u> The primary impact of the OAD is through the operators that are running the ASGS/ADCIRC system on multiple HPC sites, with different ASGS/ADCIRC configurations, and potentially for different but concurrent tropical events. It provides a unified view of all ASGS instances, thus facilitating more effective communication between operators maintaining and running the systems. This impacts the broader end-users that the operators increasing the timeliness and robustness of operations.

6. <u>Unanticipated Problems:</u> Other than typical software development issues, there have been no unanticipated problems, due to the expertise of the software development/engineering personnel on the project. The design, implementation, and maintenance of the OAD has been efficient, streamlined, and rapid. No students were involved in this project, because of the need for robustness, on-time delivery, and deep understanding of web technologies.

7. <u>Student Involvement and Awards</u>: None

8. <u>Interactions with CRC education projects:</u> None

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Incorporate design changes into OAD	7/1/2019	100	
Update OAD user interface as needed	12/31/2019	100	
Assess OAD functionality during 2019 ASGS season	3/31/2020	100	
Research Milestone			
Deploy year 2 version of OAD	5/1/2020	100	
Maintenance and updating of the OAD system. This includes addressing software bugs and failures and updating the required software components on the computers that host the RabbitMQ messaging system, the message database, and the website itself. Any substantial software update will be documented. Without maintenance of the software system, existing functionality may be degraded and new features impossible to implement.	6/30/2020	100	

2. **Year 5 Transition Activities and Milestone Achievements**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Delivery of updated OAD, with functionality improvements based on end-user participation in the design process and previous testing and evaluation.	3/01/2020	100	
Maintenance and updating of the OAD system. This includes addressing software bugs and	6/30/2020	100	

failures and updating the required software components on the computers that host the RabbitMQ messaging system, the message database, and the website itself. Any substantial software update will be documented. Without maintenance of the software system, existing functionality may be degraded and new features impossible to implement.			
Transition Milestone			
Host a virtual meeting with ASGS operators and communicators to train them on new features and functionality of the OAD website.	6/15/2020	100	This has been accomplished through a series of shorter Zoom/Slack meetings where capabilities were demonstrated, user questioned answered, and suggestions for improvements were recorded.

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
OAD website	software	3/01/2020	APS/ASGS operators

IV. PUBLICATIONS AND METRICS

1. Publications: N/A

2. Performance Metrics

BLANTON PERFORMANCE METRICS

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17-6/30/18)	Year 4 (7/1/18-6/30/19)	Year 5 (7/1/19-6/30/20)
HS-related internships (number)	0	0	0	0	0
Undergraduates provided tuition/fee support (number)	0	0	0	0	0
Undergraduate students provided stipends (number)	0	0	0	0	0
Graduate students provided tuition/fee support (number)	1	1	1	0	0
Graduate students provided stipends (number)	1	1	1	0	0
Undergraduates who received HS-related degrees (number)	0	0	0	0	0
Graduate students who received HS-related degrees (number)	0	0	1	0	0
Graduates who obtained HS-related employment (number)	0	0	0	0	0
SUMREX program students hosted (number)	0	1	0	0	0
Lectures/presentations/seminars at Center partners (number)	1	0	1	0	0
DHS MSI Summer Research Teams hosted (number)	1	0	0	0	0
Journal articles submitted (number)	0	0	0	0	0
Journal articles published (number)	0	0	0	0	0
Conference presentations made (number)	2	2	2	0	0
Other presentations, interviews, etc. (number)	0	2	4	0	0
Patent applications filed (number)	0	0	0	0	0
Patents awarded (number)	0	0	0	0	0
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	0	0	0	0	0
Requests for assistance/advice from other agencies or governments (number)	0	0	0	0	0
Dollar amount of external funding	0	0	$935,000	0	0
Total milestones for reporting period (number)	7	7	5	5	8
Accomplished fully (number)	2	2	5	4	8
Accomplished partially (number)	3	3	0	1	0
Not accomplished (number)	2	2	0	0	1

HAGEN, LSU
MEIDEROS, ERAU
BILSKIE, LSU
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/21/2020)

I. INTRODUCTION

Project Title: Development of an optimized tide and hurricane storm surge model for the west coast of FL for use with the ADCIRC Surge Guidance System.

Principal Investigator Name/Institution:
Scott C. Hagen, Professor - Louisiana State University, Department of Civil & Environmental Engineering / Center for Computation & Technology, Director - Center for Coastal Resiliency

Additional Research Participants/Partners:

Stephen C. Medeiros, Assistant Professor, Embry-Riddle Aeronautical University, Department of Civil Engineering.

Matthew Bilskie, Research Scientist, Louisiana State University, Center for Coastal Resiliency.

Short Project Description ("elevator speech"):

This project will simplify an existing high-definition research-grade tide, wind-wave, and hurricane storm surge model of the west coast of Florida for use in the ADCIRC (Advanced Circulation) Surge Guidance System (ASGS). The goal is to enable the model to complete a 5-day simulation forecast in less than 1 hour, while retaining water surface elevations that are within 10-percent of the original research-grade model. Achieving this goal reduces model run times (from several hours to 1 hour) so that end-users will have model forecast guidance in a timelier fashion.

II. PROJECT NARRATIVE

1. Project overview: Using and improving upon the techniques developed in years 1 through 4 of the project, we optimized a FEMA ADCIRC mesh for the west coast of Florida to reduce wall -clock simulation time. We also finished a comparative analysis of two surface roughness parameterization techniques: the traditional one based on published land cover / land use maps and an innovative one based on 3-dimensional lidar point clouds. Both of these components contribute to the body of knowledge in storm surge prediction which directly impacts evacuation, pre and post storm logistics, and recovery.

2. Results: The primary results were academic journal papers, a Master's thesis, and a working model incorporated into APS.

    1. Bilskie, M.V., S.C. Hagen, S.C. Medeiros (2019) "Unstructured Finite Element Mesh Decimation for Real-Time Hurricane Storm Surge Forecasting," Coastal Engineering, 156. https://doi.org/10.1016/j.coastaleng.2019.103622.

    2. White, S.C., S.C. Medeiros, M.V. Bilskie, S.C. Hagen (2020) "Comparison of surface roughness parameterization methods for a storm surge simulation of Hurricane Michael (2018) in the Florida Panhandle," Coastal Engineering, In preparation.

    3. White, S.C. (2020) "Comparison of surface roughness parameterization methods for a storm surge simulation of Hurricane Michael (2018) in the Florida Panhandle," Embry-Riddle Aeronautical University, College of Engineering, Department of Civil Engineering, MS Thesis.

    4. Florida West Coast Model EGOM-RT_v20b delivered to ADCIRC Prediction Service Team (Luettich, Twilley, Fleming, Kaiser) on 08 May 2020.

3. End users:

- NOAA Northern Gulf of Mexico Sentinel Site Cooperative (NGOMSSC)
    - Director, NOAA NOS NCCOS Competitive Research Program
    - NGOM Sentinel Site Cooperative Coordinator/Coastal Climate Resilience Specialist, Mississippi-Alabama Sea Grant
    - Output from NGOM_RT was shared with the NGOMSSC throughout the 2019 hurricane season.
- FEMA Region IV
    - Provided Florida West Coast FEMA mesh in October 2018 and kept informed of mesh decimation / optimization process
- South Florida Water Management District (SFWMD)
    - Jason Godin – Section Leader, Systems Modeling Unit,
    - Matahel Ansar, Tibebe Dessalegne, Jie Zheng, Joe Iudicello
    - Conducted a webinar on CERA interface for SFWMD staff (5 participants) on 12 July 2019
    - SFWMD provided API schema for adding their gages into schema.
    - Expressed interested in doing their own modeling, perhaps with CRC models / tools
- Florida Department of Transportation
    - Dr. Medeiros held a 90-minute workshop in the FDOT District 5 EOC (DeLand, FL) for employees with EM responsibility from maintenance, structures, and safety groups on 18 June 2019 (5 participants including John Hatfield, PE - District 5 Maintenance Engineer)
    - Dr. Medeiros presented coastal resilience research efforts to Kevin Thibault (Secretary of the FDOT) and Jared Perdue (Interim Secretary of District 5) on

Thursday 13 February 2020 at ERAU MicaPlex, including CRC efforts to develop a real time capable mesh for FL West Coast.

- State of Florida
    - Former Florida State Chief Resilience Officer, now Homeland Security Advisor in Trump Administration
    - Presented coastal resilience research efforts on 27 August 2019 at ERAU College of Engineering and followed up at UCF Sustainability conference mixer at Orlando City Hall

4. Transition: The primary transition activity was delivering the Florida West Coast Model EGOM-RT_v20b to ADCIRC Prediction Service Team (Luettich, Twilley, Fleming, Kaiser) on 08 May 2020.

5. Project Impact: The results of this project expanded the high-resolution modeling capability of APS to the west coast of Florida, getting it one step closer to complete coverage of the Gulf/east coast of the United States. The work on surface roughness parameters will lead to more accurate prediction of the behavior of storm surge in the coastal floodplain. The techniques developed and published advanced the state of the art for storm surge prediction which directly saves lives and enhances the nations resilience to coastal hazards.

6. Unanticipated Problems: There were two unanticipated problems during this reporting period. First, Dr. Medeiros moved from the University of Central Florida to Embry-Riddle Aeronautical University. This necessitated the issuance of a new subaward which took longer than expected. Dr. Medeiros leveraged his start-up funds to support his graduate student and undergraduate research assistant until the funding was released. The second unanticipated problem was the COVID-19 travel restrictions resulting from state and national stay at home guidance. This prevented Dr. Medeiros from traveling to LSU to work with Drs. Bilskie and Hagen in person. However, the team continued to meet via video conference and was able to complete research and transition milestones.

7. Student Involvement and Awards:
    a) Dr. Medeiros supported one MS student and one undergraduate research assistant using funds from the project.
    b) Both of Dr. Medeiros' students, Sky White and Joelle Bobinsky, are female, a traditionally underrepresented group in engineering.
    c) Sky White, MS in Civil Engineering from Embry-Riddle Aeronautical University, Summer 2020.
    d) Sky White, Outstanding Graduate Student in Civil Engineering, AY 2019-2020, Embry-Riddle Aeronautical University.

8. Interactions with CRC education projects: Minimal during this time period due to earthquake recovery in Puerto Rico and subsequent COVID-19 travel restrictions.

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Re-mesh FL West Coast model as necessary in response to end user local knowledge	12/31/2019	100	
The real-time FL West Coast model will be combined and refactored with the existing northern Gulf of Mexico real-time model (NGOM_RT) to create two separate models. Model 1 will focus on the Louisiana, Mississippi, and Alabama coast and Model 2 will focus on the Alabama, Florida panhandle, and western Florida coast. The overlapping region will reside in Alabama, specifically Mobile Bay. This refactoring will reduce the number of models for this region from three to two.	03/31/2020	100	As a research team, we modified this task to include two APS ADCIRC models for the Gulf coast; (1) NGOM-RT (Years 1-4) and (2) EGOM-RT (Years 4-5). The NGOM-RT mesh is focused on MS, AL, and FL panhandle and EGOM-RT is focused on the Florida Big Bend region, down to the Everglades.
Run test simulations of the refactor models within the ASGS framework. Simulations will be performed across the LSU and LONI systems.	04/30/2020	100	
Perform simulations on the UCF STOKES HPC system and confirm redundancy.	04/30/2020	0	Dr. Medeiros leaving UCF negated this milestone.
Research Milestone			
The real-time Northwestern Gulf of Mexico real-time (NWNGOM_RT) and Northeastern Gulf of Mexico (NENGOM_RT) models will be fully connected to CERA. Model testing, evaluation, and validation will be complete.	06/01/2020	100	
Submission of manuscript on final model system validation to a peer-reviewed journal.	06/30/2020	50	In preparation, target submission date June 2021.

2. **<u>Year 5 Transition Activities and Milestone Achievements</u>**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Provide CERA training to all identified end users (please refer to Section 6 for identified end users). Stephen Medeiros will lead the identification of end users.	06/01/2020	100	All identified end users with operational needs were presented with CERA
Technical presentations on model development for end users with local knowledge of the geographical/water management assets in the targeted area.	12/31/2019	100	SWFWMD presentation accomplished this milestone
Organize and share feedback from CERA trainings with the CERA research team. This information will include the affiliations of those who took the training, suggestions on CERA improvements, and items in CERA that were well-liked. This will benefit the CERA team by allowing the end-users to provide information on how the CERA platform is useful and ways it may be improved and optimized for their user experience. The feedback will be shared via a video conference call.	03/31/2020	100	Emails written to Rick Luettich, Jason Fleming, and Carola Kaiser provided detailed feedback on what end users from SWFWMD and FDOT stated during presentations.
Transition Milestone			
CERA training complete for 10/10 (100%) of identified end users. End users will be proficient in operating the CERA online platform.	06/01/2020	100	
Integration of the final real-time (RT) forecast-grade mesh of the northern Gulf of Mexico and eastern Gulf of Mexico into the ASGS. During an impending tropical cyclone event with potential impacts to the region results from the ASGS will be delivered to the CERA online visualization platform.	06/01/2020	100	
Completion of a table-top emergency management exercise with at least one end user	06/01/2020	0	Milestone was not achieved due to funding delays and travel restrictions.

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
EGOM-RT_v20b	Real time storm surge model for FL west coast	08 May 2020	ADCIRC Prediction Service (APS) Team: Luettich, Twilley, Fleming, Kaiser

IV. PUBLICATIONS AND METRICS

1. Publications:

- Bilskie, M.V., S.C. Hagen, S.C. Medeiros (2019), "Unstructured Finite Element Mesh Decimation for Real-Time Hurricane Storm Surge Forecasting," *Coastal Engineering*, 156. https://doi.org/10.1016/j.coastaleng.2019.103622.

- Santiago-Collazo, F.L., Bilskie, M.V., Hagen, S.C. (2019) "A comprehensive review of compound inundation models," *Environmental Modelling & Software*, 119, pp. 166-181. https://doi.org/10.1016/j.envsoft.2019.06.002.

- Bilskie, M.V., Asher, T.G., Fleming, J.G., Hagen, S.C., Kaiser, C., Luettich Ur., R.A., Twilley, R. (2020) "Real-time storm surge predictions during Hurricane Michael," *Weather and Forecasting*, In Progress (Previously submitted to *Geophysical Research Letters* and being revised).

- White, S.C., S.C. Medeiros, M.V. Bilskie, S.C. Hagen (2020) "Comparison of surface roughness parameterization methods for a storm surge simulation of Hurricane Michael (2018) in the Florida Panhandle," *Coastal Engineering*, In preparation.

2. Performance Metrics

Hagen Performance Metrics:

Metric	**Year 1** (1/1/16 – 6/30/16)	**Year 2** (7/1/16 – 6/30/17)	**Year 3** (7/1/17- 6/30/18)	**Year 4** (7/1/18- 6/30/19)	**Year 5** (7/1/19- 6/30/20)
HS-related internships (number)					
Undergraduates provided tuition/fee support (number)					
Undergraduate students provided stipends (number)		1	1	1	1
Graduate students provided tuition/fee support (number)	1	1			1
Graduate students provided stipends (number)	1	1			1
Undergraduates who received HS-related degrees (number)					
Graduate students who received HS-related degrees (number)					1
Graduates who obtained HS-related employment (number)					
SUMREX program students hosted (number)	1	2			
Lectures/presentations/seminars at Center partners (number)					
DHS MSI Summer Research Teams hosted (number)					
Journal articles submitted (number)				2	2
Journal articles published (number)	1	1		1	1
Conference presentations made (number)			1	1	1
Other presentations, interviews, etc. (number)	8	10	1	3	
Patent applications filed (number)					
Patents awarded (number)					
Trademarks/copyrights filed (number)					
Requests for assistance/advice from DHS agencies (number)		1			1
Requests for assistance/advice from other agencies or governments (number)		2		1	1
Dollar amount of external funding	$0	$0	$0		
Total milestones for reporting period (number)	3	4		4	12
Accomplished fully (number)	0	5	3	1	9
Accomplished partially (number)	3	2	3	1	1
Not accomplished (number)	0			2	2

DIETRICH – NCSU
DAWSON – UT-AUSTIN
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title:

Improving the Efficiency of Flooding Predictions via Adaptive Mesh Resolution

Principal Investigator Name/Institution:

Joel Casey Dietrich, Associate Professor, North Carolina State University

Additional Research Participants/Partners:

Clint Dawson, Professor, The University of Texas at Austin

Short Project Description:

Coastal communities rely on predictions of flooding caused by storms. Computational models are essential for making these predictions, but a typical prediction can require hundreds or even thousands of computational cores in a supercomputer and several hours of wall-clock time. In this project, we will improve the performance and accuracy of a widely-used, predictive model for coastal flooding. Its representation of the coastal environment will adapt during the storm, to better utilize the computing resources and ultimately provide a faster prediction.

II. PROJECT NARRATIVE

1. Project Overview:

The goal of this research project is to speed up the ADvanced CIRCulation (ADCIRC) modeling system, which is used extensively by DHS and its constituent agencies for the prediction of storm-induced flooding. We are improving the efficiency of the modeling system, and thus reducing its computational cost. This work is relevant to the DHS mission to ensure resilience to disasters, as articulated in its Strategic Plan and Quadrennial Review, specifically its Goals 5.1 (Objectives 5.1.1 and 5.1.2) to reduce vulnerability and mitigate risks associated with natural hazards, and its Goal 5.3 (Objective 5.3.1) to provide timely and accurate information during a storm event. The efficiency improvements in this project will allow for more model simulations in ensemble-based design applications, which will increase the accuracy of flood risk products used in building design and the establishment of flood insurance rates, and thus lessen the impact of a disaster. The efficiency improvements in this project will also allow for faster simulations in time-sensitive applications such as operational forecasting, and thus improve the communication and understanding of potential hazards.

This project will benefit DHS and the Homeland Security Enterprise in two ways: a more-efficient ADCIRC model will allow for more model runs in ensemble-based design application, and for faster simulations in time-sensitive applications such as operational forecasting. In its development of Flood Insurance Rate Maps (FIRMs), FEMA will benefit because the probabilistic framework requires a large number of simulations, which will now require fewer computational resources, and thus the studies can be completed in a shorter time and/or consider a larger suite of storms. We are working with FEMA engineers, with whom we are sharing research progress and receiving feedback on future directions. In their use of flood predictions provided in real-time by the ADCIRC community, state-level emergency managers will benefit because by now having more time to consider the forecast guidance in their decision-making. We are working with partners at the Texas State Operations Center and NC Emergency Management. We also have partners in the USACE, NOAA, and academia, as described below.

2. Results:

During Year 4, our research was focused on three related topics: (A) the continued development and testing of technologies for a coarse-grain mesh adaptivity, (B) the continued development and testing of dynamic load balancing, and (C) the refinement of techniques for downscaling and visualizing the forecast guidance as a post-processing step. We discuss our results for each of these topics:

Adaptive mesh techniques: The idea behind this approach is simple on the surface: use a less refined mesh when the storm is still far from land and/or the track is still uncertain, then, at some intermediate point of the calculation, stop the run, interpolate the solution onto a higher resolution mesh, and finish the simulation on this mesh. The outcomes of the research include the software ADCIRpolate, which uses many of the interpolation routines in the open-source Earth System Modeling Framework (ESMF). ADCIRpolate reads an ADCIRC hotstart file generated on one mesh (call it Mesh 1) and interpolates it onto another mesh (call it Mesh 2). If Mesh 1 and Mesh 2 cover the exact same domains, this process is straightforward. The difficulty in our project is that Mesh 1 and Mesh 2 may differ substantially, especially in floodplain areas. This required developing some extensions of the ESMF software to handle extrapolation and wetting and drying, and to make some modifications to the hotstart capability of ADCIRC, which historically has been based on simply hot-starting a calculation on the same mesh/domain. We also note that ESMF operates in parallel, thus the interpolation from one mesh to the next can be done very efficiently.

During Year 5, we are nearing completion of this technology, after a final round of rigorous testing. At NC State, we developed a mesh for the southeast U.S. coast with high-resolution of the coastal region from Florida through North Carolina. The overall mesh has about 5.6 million vertices. It was constructed with the state-scale meshes from the FEMA flood risk mapping studies for the coastal region along the South Atlantic Bight (SAB), and so we are calling it the FEMA-SAB mesh. This mesh can be used for high-resolution simulations of any storm that threatens this long coastline. We have worked with Hurricanes Matthew (2016) and Florence (2018), which affected the coast in different ways. Matthew had a shore-parallel track, and it raised water levels throughout the entire region. Florence had a shore-normal track, and its effects were focused in North Carolina.

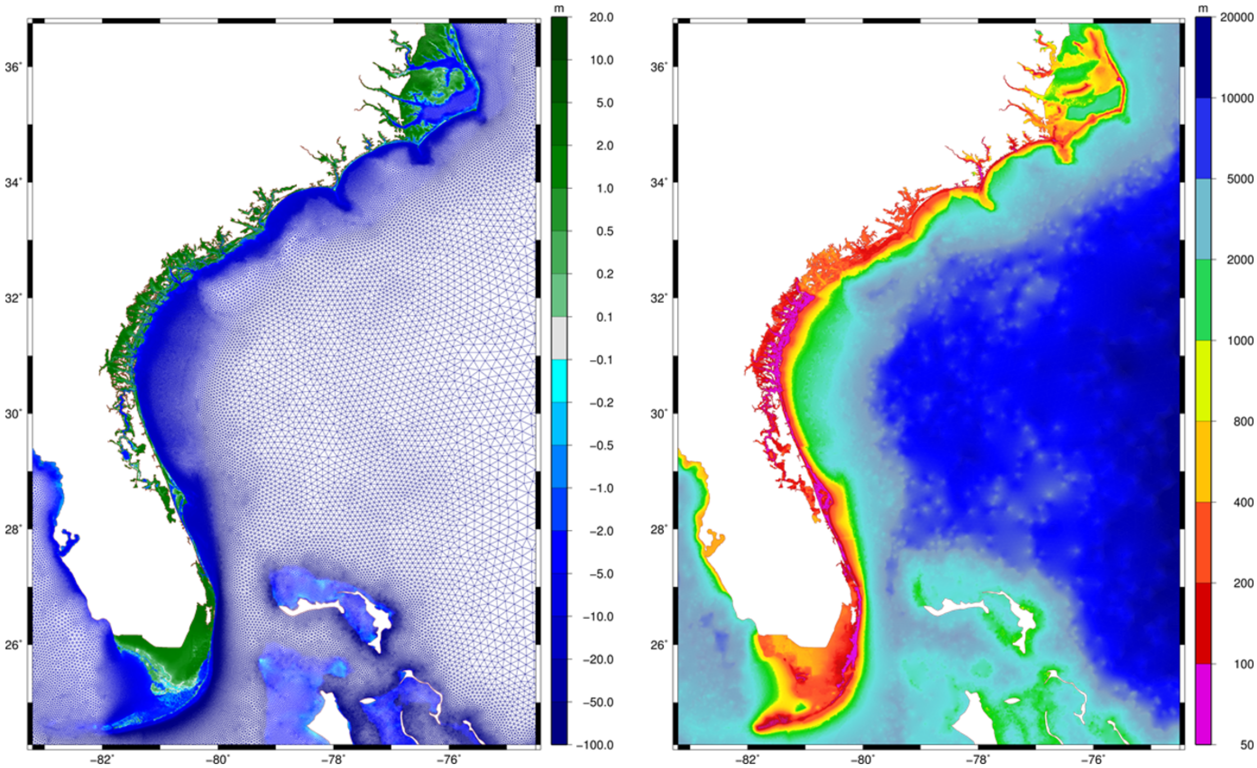


Figure: (left) bathymetry and topography (m, relative to NAVD88), and (right) resolution (m) in the new FEMA-SAB mesh for the southeast U.S. coast.

For example, we have tested the adaptive meshing technologies for simulations like what may be seen in an operational setting. For both storms, we did a full simulation on the high-resolution FEMA-SAB mesh; we denote these as the “Fine” simulations. And again for both storms, we started the simulation on the relatively-coarse HSOFS mesh and then switched onto the high-resolution FEMA-SAB mesh as the storm approached the coast; we denote these as the “Mixed” simulations. The table below gives a summary of these simulations, their accuracy relative to observed peak water levels during the storms, and their efficiency in wall-clock time. The Mixed simulations give a speed-up of 23-33 percent, which is a significant gain in efficiency. But the root-mean-square errors for the peak water levels are not changed significantly. This is encouraging, as it shows the coarse-grain adaptivity can improve the efficiency of operational forecasts without a loss in accuracy.

Table: Summary of "Fine" and "Mixed" simulations for Hurricanes Matthew (2016) and Florence (2018). Note the decrease in wall-clock times for the Mixed simulations, which maintain the accurate predictions of the peak water levels during the storms.

		Matthew (2016)		Florence (2018)	
		Fine	Mixed	Fine	Mixed
Mesh	Coarse (HSOFS)		Oct 2 - 6/12 4.5 days		Sep 7 - 11/12 4.5 days
	Fine (FEMA-SAB)	Oct 2-11 9 days	Oct 6/12 - 11 4.5 days	Sep 7 - 16 9 days	Sep 11/12 - 16 4.5 days
Accuracy	Peak WLs	580	580	190	190
	RMSE	**0.29 m**	**0.29 m**	**0.22 m**	**0.26 m**
Efficiency	Coarse		29 min		19 min
	Adcirpolate		12 min		12 min
	Fine	393 min	222 min	380 min	259 min
	Total	**393 min**	**263 min**	**380 min**	**290 min**

In a similar way, Hurricane Ike (2008) and Hurricane Harvey (2017) were simulated using the adaptive mesh technique. The same HSOFS mesh as mentioned above was used as the 'coarse' mesh but since these two storms made landfall along the Texas coast, a mesh (referred to as the 'Texas Mesh') with much higher refinement specifically around the Texas coast was utilized for the 'fine' mesh. The HSOFS mesh contains around 1.8 million nodes while the Texas mesh contains around 3.3 million. The speedup, depending on when the interpolation from 'coarse' mesh to 'fine' mesh was performed gave a speedup between 10-25 percent. In both the simulation of Ike and Harvey, the differences in inundation pattern and maximum water levels between running with the HSOFS mesh and the Texas Mesh are significant enough to be visible upon inspection.

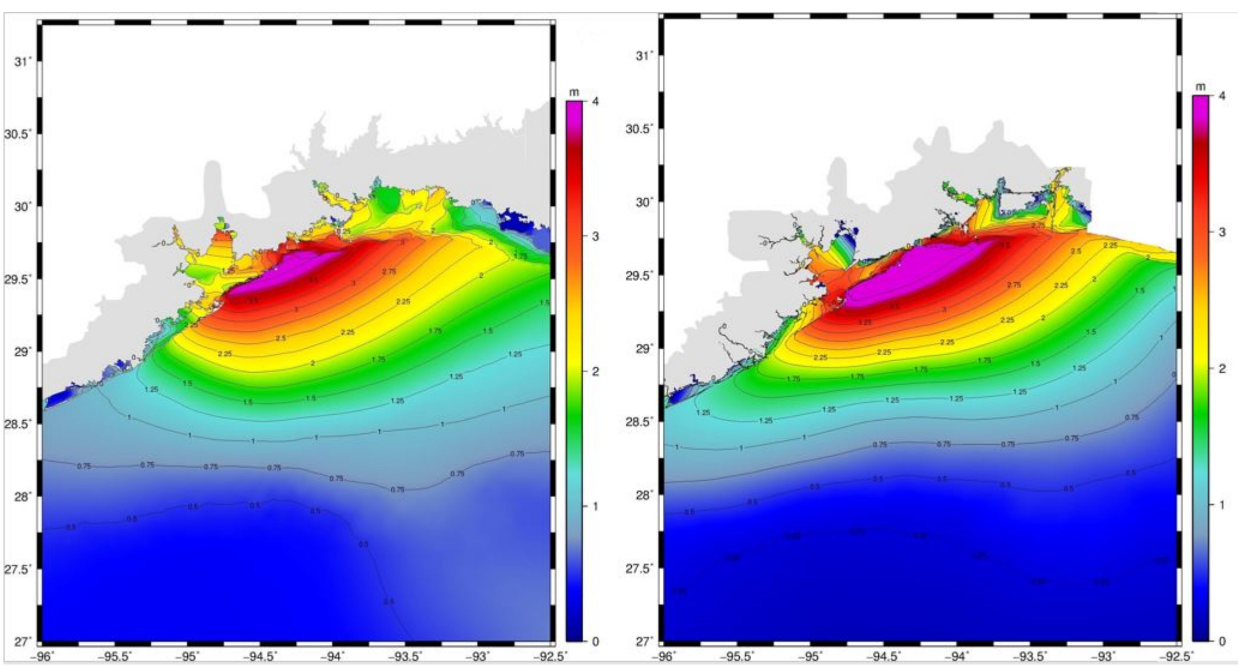


Figure above: (left) maximum water surface elevation (m, relative to NAVD88) of Hurricane Ike using HSOFS mesh, and (right) maximum water surface elevation (m) using the new adaptive meshing technique to interpolate onto Texas mesh.

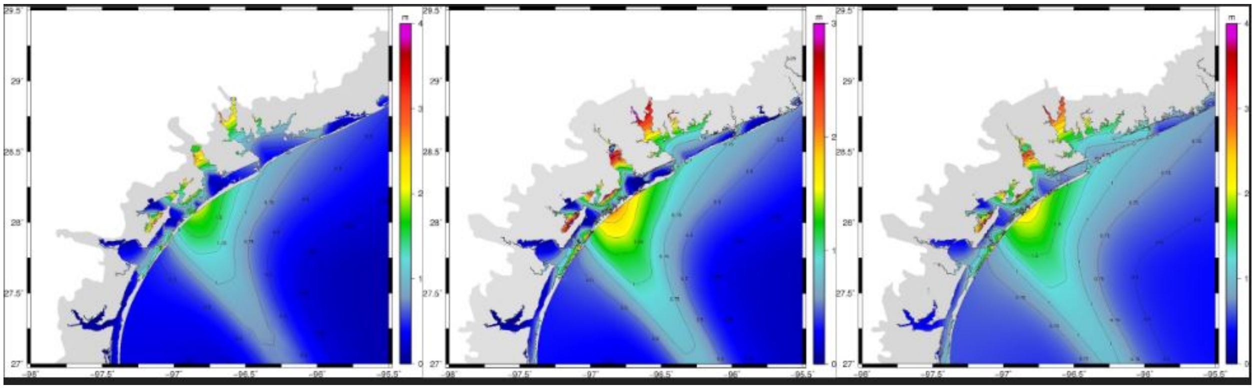


Figure: (left) maximum water surface elevation (m, relative to NAVD88) of Hurricane Harvey using HSOFS mesh, (middle) maximum water surface elevation (m) using the adaptive mesh technique and (right) maximum water surface elevation (m) using the new adaptive meshing technique to interpolate onto Texas mesh.

Dynamic load balancing: Another component of this research project has been the treatment of dry regions within our high-resolution meshes. The idea behind this research is to better distribute the dry regions, so that they are contained on only a few cores. Then more of the cores will be available to compute the flooding in wet regions. This technology will adapt during the storm, as regions become wet and then dry again. By better distributing the workload over the cores, ADCIRC will become more efficient for simulations of flooding into overland regions. Working with collaborators at Notre Dame, we rewrote the dynamic load balancing routine to use the Zoltan library for adaptive domain decomposition. This library can control how computational points are migrated between neighboring sub-domains, instead of starting each decomposition from scratch. This implementation has provided further speed-ups in the wall-clock time.

During Year 5, we are nearing completion of this technology, via a set of final tests and the writing of a manuscript. For storms on realistic domains, the dynamic load balancing is allowing for significant speed-ups over a base simulation. In the figure below, we show the scaling curves and speed-ups for the dynamic load balancing for several storms and unstructured meshes. In all cases, the dynamic load balancing is allowing for a significant decrease in the wall-clock times, and the speed-ups are between 10-20 percent. And as with the coarse-grain adaptivity, there is no trade-off in the model accuracy: the solution is unchanged. Thus the dynamic load balancing will be a significant benefit to the larger ADCIRC community, and it will lead to faster forecasts to support the mission of DHS.

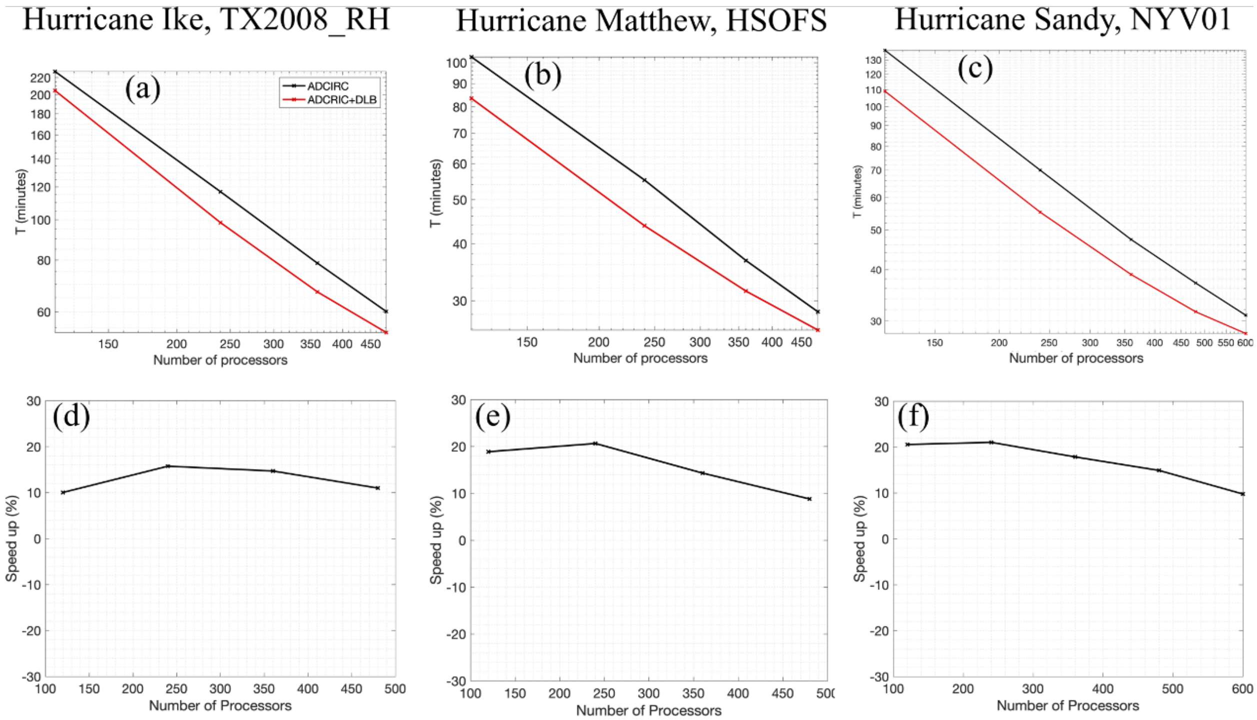


Figure: (top) scaling curves and (bottom) speed-ups for the dynamic load balancing. In the top row, the black lines are the wall-clock times for the existing ADCIRC with a static domain decomposition, while the red lines are the wall-clock times for the new ADCIRC with the dynamic load balancing. In the bottom row, the percent speed-ups are shown to be between 10-20 percent.

Downscaling and visualization of forecast guidance: When the flooding forecast guidance is shared with stakeholders, it is shared typically in an online mapping system (CERA) or via GIS shapefiles. The advantage of the GIS shapefiles is that they can then be integrated within the workflows of our stakeholders, who may want to combine them with other datasets for flooding forecasts or critical infrastructure. Although the GIS shapefiles have infinite resolution, in the sense that they are vector-based representations of the ADCIRC results, they are still limited by the mesh resolution used by ADCIRC. This mesh resolution may vary downward to 10-20 m in specific small-scale channels, but more typically the mesh resolution is 100-500 m throughout the coastal zone. This resolution can prevent the representation by ADCIRC of smaller-scale infrastructure, including roadways and buildings, which are critical for decision-makers. We have developed a technology to downscale ADCIRC guidance to a finer resolution in a DEM, and then extrapolate the water levels to where they should intersect with the topography.

During Year 5, we added two new downscaling methods: slopes, which uses the slope of the water surface as predicted by ADCIRC in the extrapolation of the flood extents; and head loss, which uses land cover data to compute frictional losses as the water surface is extrapolated. We found that the slopes method does not change significantly the flood extents, but the head loss method is a significant improvement. In the figure below, we compare the flooding predictions from the downscaling methods to a high-resolution “truth” simulation (shown in red). The base ADCIRC simulation is an under-prediction, as its wet regions do not extend to the shoreline of this estuary. If the water surface is extrapolated as a flat surface (in a static method, shown in light blue), then the flood extents are over-predicted. But if the extrapolation does include head losses due to friction, then the flood extents are a good overall match to the truth. This is an improvement to the downscaling technology, and it will allow for better forecasts for our partners.

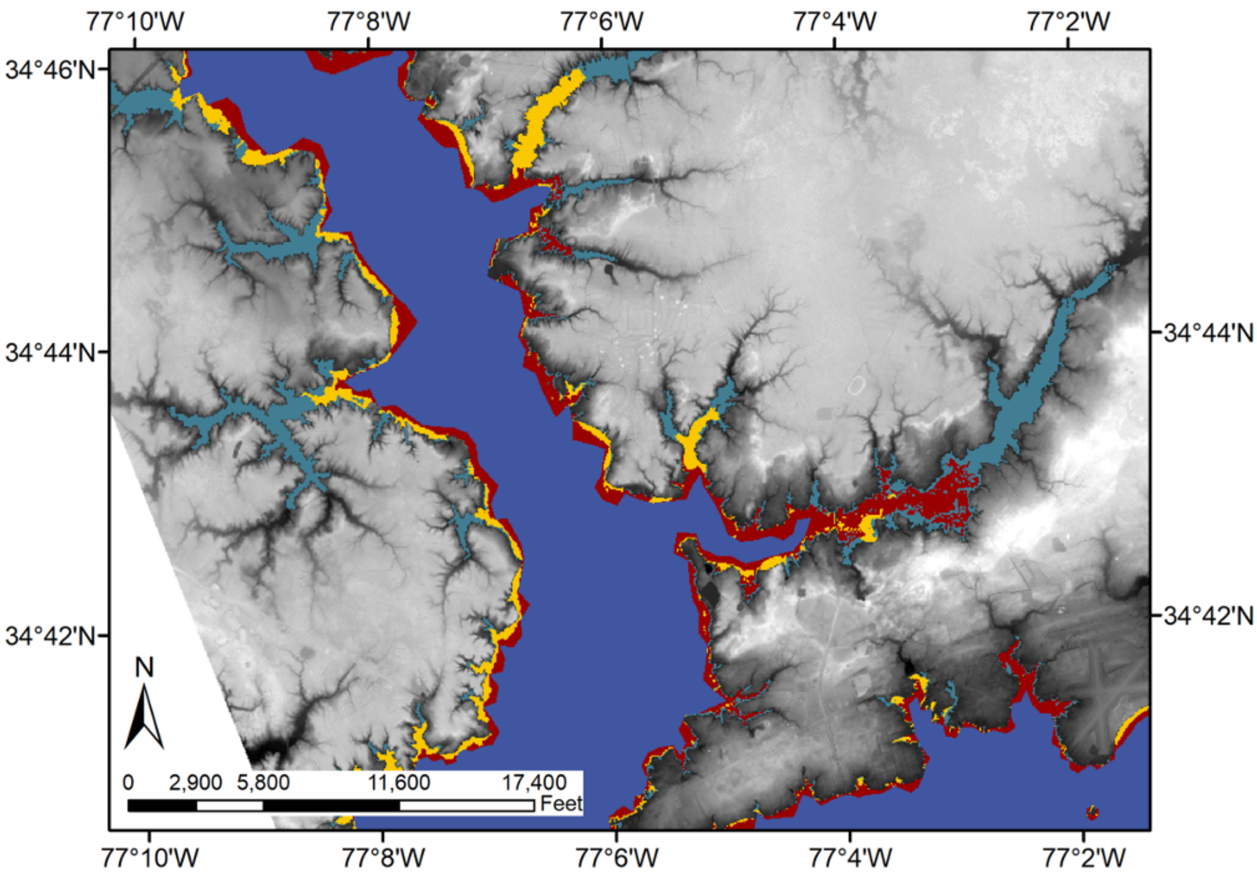


Figure: Validation of downscaling methods for an estuary in Carteret County, North Carolina, and a simulation of Hurricane Florence (2018). The water levels are shown for: (dark blue) the base ADCIRC predictions, (light blue) static extrapolation as a horizontal surface, (yellow) dynamic extrapolation to include head loss due to friction, and (red) a higher-resolution ADCIRC simulation as "truth." Note the head loss method is a better overall match to the true flood extents.

3. <u>End Users:</u>

The proposed enhancements to efficiency will benefit all model users, including several DHS agencies with missions related to coastal flooding. In its development of Flood Insurance Rate Maps (FIRMs), FEMA will benefit because the probabilistic guidance requires a large number of deterministic simulations, and the approach described in this project will require fewer computational resources. For example, if a flood mapping study would see an efficiency gain of, say, 10 percent, then the study could be completed in a shorter time. Alternatively, that efficiency gain could be reinvested into increasing the mesh resolution and/or considering a larger suite of storms, and thus increasing the accuracy of the model results. At FEMA, **coastal**

engineers are participating as transition partners. The project will also help to speed the delivery of projected flood inundation levels associated with coastal storms, thereby assisting FEMA as well as state and local emergency managers to plan for coastal evacuations and deployment of resources and personnel. In addition, the Coast Guard will benefit from faster guidance about waves and surge and therefore be able to make operational decisions about the possible relocation of assets in advance of an oncoming storm. The project personnel will continue to work with the transition team to identify additional end-users in these and other DHS constituent agencies.

With the Texas State Operations Center, the project personnel are working with **decision makers** to transition the analysis products that are used for guidance by the emergency management leadership. [REDACTED] has worked with forecast guidance for the Texas coastline in previous seasons and is supportive of the proposed work. This partnership is important because it connects the products with end users at the state and local levels.

The proposed work will also benefit ADCIRC model users at other federal agencies. With the USACE Engineer Research and Development Center, + are participating as transition partners. For partners who are focused on operational modeling with ADCIRC, these activities are taking the form of guidance about development with the goal of transitioning products to their work in the long term.

The project personnel also work closely to transition the project outcomes to the ADCIRC modeling community. These transition activities are connected with Jason Fleming and Carola Kaiser, ADCIRC forecasters, who are key members of the Coastal Emergency Risks Assessment (CERA) group. They operate the forecasting systems for regions along the U.S. Gulf and Atlantic coasts, and they visualize and communicate the forecast guidance via a Google Maps application. Dr. Fleming also manages the software repository for the development of ADCIRC. The project personnel are working with these partners to ensure that the new modeling technologies can be incorporated within the forecasting system and the release version of ADCIRC.

4. Transition:

The project team has transitioned the research results, both in real-time during storm events, as well as in activities to benefit the community in the longer-term.

During storms, the project team continues to support the ADCIRC real-time forecasting activities, which have a direct benefit to DHS constituent agencies and other emergency managers. At UT Austin, the team continued to work with Jason Fleming and Carola Kaiser to update the ASGS on supercomputers at the Texas Advanced Computing Center (TACC) and provide support for the CERA and the Texas State Operations Center during the 2019 hurricane season. TACC facilities were utilized during Hurricanes Barry and Dorian. We are currently preparing for the 2020 hurricane season. The UT Austin team will be working with Jason Fleming and Brett Estrade to provide operational ASGS support for storms that threaten the Texas coast.

At NC State, the project team also supported real-time forecasting during Dorian, specifically by using the downscaling technologies to provide guidance products to collaborators at FEMA and NC Emergency Management (NCEM). For every forecast advisory, we sent products to NCEM to show the maximum water levels at higher-resolution in coastal NC. On 9 September 2019, we received the following feedback from an end user at FEMA:

> *Thank you for generating a hindcast above ground level that we can use for analytics! This is really helpful.*

And on 12 September 2019, we received the following feedback from Tom Langan, the engineering supervisor for the North Carolina Floodplain Mapping Program:

> *Just wanted to say thank you to you and Carter for providing the enhanced mapping products for NC during Hurricane Dorian. We ran the water surface elevation rasters against our building footprints to estimate coastal damages and depth in structures for the advisory and hindcast runs.*

At NC State, we have released the downscaling technologies as open-source software with a full documentation. They can be downloaded from this site (https://ccht.ccee.ncsu.edu/downscaling-flooding-inundation-extents-using-kalpana/), which provides examples for using the technology, including input files and commands. These technologies have already been adopted by partners in the ADCIRC community, including at George Mason University and Taylor Engineering.

5. Project Impact:

This project is developing technologies to improve the efficiencies of the ADCIRC modeling system in parallel computing environments. It is developing automated routines for an adaptive, multi-resolution approach to employ high-resolution, unstructured meshes for storm surge applications, and it is developing automated routines for the efficient re-balancing of the computational workload via parallelized domain decomposition.

The initial motivation for adaptive mesh refinement was to speed up the forecast capabilities of ADCIRC and improve the ASGS. We are working with Jason Fleming and other ASGS developers to incorporate ADCIRpolate into the ASGS as a beta version. The adaptive capability has also motivated future ADCIRC-related projects within the CRC. We are working to develop capability to interpolate HSOFS results onto a number of ADCIRC models of Texas, the Northern Gulf, the Carolinas, and the Northeast/New England. In addition, there are extensions of this work beyond hurricane forecasting. We are speeding up post-storm analysis and scenario analysis by allowing for the use of high-resolution meshes targeted to specific regions and specific locations, but also allowing for pre-storm tidal spin-up and storm initiation to be executed on a coarser mesh.

The capability for dynamic load balancing has the potential to benefit all ADCIRC simulations, including the real-time forecasting in the ASGS. These routines better utilize the available computing resources by ensuring that every core is busy during the entire simulation. One benefit of these new routines is that they will be blind to the user; the workload will be rebalanced automatically, without requiring input from the user. Thus it will not be necessary for users to know Zoltan or the other mechanics of the domain decomposition. The efficiency gains will be shared by all users. These new routines are being shared (with extensive documentation and examples) with the ADCIRC modeling community, including the ASGS.

6. Unanticipated Problems:

During Year 5, the only unanticipated problem was the novel coronavirus and its related disruptions to the academic calendar and work arrangements. Luckily, this research project is entirely computational, and so the project personnel can continue to make progress while working remotely. As we progress into a carryover and Year 6, we will continue to work around this problem, especially the impacts on research progress due to limits on in-person interactions.

7. Student Involvement and Awards:

a) Students involved in research

At UT Austin, this project supported:

- Graduate student **Mark Loveland**, who worked primarily on the implementation of the dynamic mesh software ADCIRpolate and the testing of the software on Hurricane Harvey and Hurricane Ike. He worked with NCSU students to train them on the use and installation of the software and the ESMF library.

At NC State, this project supported:

- Graduate student **Ajimon Thomas**, who worked primarily on testing the ADCIRpolate software for Hurricane Florence, as well as developing a mesh for the southeast U.S. coast.
- Graduate student **Carter Rucker**, who worked primarily on generalizing the downscaling technologies, including their release as open-source software with extensive documentation.
- Undergraduate student **Chloe Stokes**, who assisted Ajimon with mesh editing.
- Undergraduate student **Carter Howe**, who assisted with programming improvements for visualization software to support the project.
- Undergraduate student **Carter Day**, who assisted with re-calibrating the newest release version of SWAN to provide guidance to the ADCIRC community.

b) Student Demographics

- During Year 4, three graduate (Mark, Ajimon, Carter R.) and three undergraduate (Chloe, Carter H., Carter D.) students were supported on this project. Two undergraduate students (Chloe, Carter D.) are members of an under-represented group (women) in engineering.

c) Degrees Attained

- During Year 5, two of our graduate students attained their degrees. Carter Rucker defended his MS thesis in March 2020 and graduated during the Spring. Ajimon Thomas will defend his PhD dissertation and graduate during the Summer.

d) Student Awards.

N/A

8. Interactions with CRC Education Projects:

During previous years, our project personnel have been active in the SUMREX and RETALK activities, via interactions with education partners at Jackson State University and Johnson C. Smith University. However, we were not able to connect with them during Year 5. There was hope that we would host another group of students from Johnson C. Smith University to NC State (as in the summers of 2017 and 2019), but that visit was not pursued due to the novel coronavirus.

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020

Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not completed
Development of hybrid mesh capability for channels	06/2021	20%	We continue to pursue this milestone. Preliminary investigation of using quadrilateral type elements in ADCIRC (by connecting two triangles) was performed by Rick Luettich's group at UNC. Upon further investigation it was decided not to pursue this avenue but to focus on improving the advection scheme and mass conservation properties in ADCIRC specifically in channels.
Improved advection schemes in ADCIRC for channel flow: We will investigate methods for providing better "hooks" into ADCIRC for coupling ADCIRC with rainfall models such as the National Water Model. The goal is to improve the mass conservation and advective capabilities of ADCIRC within channels, and potentially use hybrid meshes that combine triangular and quadrilateral elements to improve resolution across channel widths with fewer degrees of freedom	06/2021	40%	We continue to pursue this milestone. We are investigating adding a discontinuous Galerkin capability for the continuity equation in ADCIRC to improve the handling of advection and mass conservation in channels. The UT team has begun this

			work. This involves substantial code modification and testing and will continue into Year 6 pending funding.
Inclusion of simple physics in enhanced-resolution technique. The interpolation routine for the downscaling and extrapolation of forecast guidance will be extended to include overland friction and surface gradients. In its current implementation, the routine extrapolates the maximum water levels as a flat surface, which can cause an overestimation of flooding extents. By considering some simple physics, we will improve the accuracy of these routines.	03/2020	100	
Research Milestone			
Presentation at national conference	09/2019	100	
Submission of peer-reviewed manuscript about dynamic load balancing	03/2021	90	We are collaborating with Keith Roberts, who graduated from Notre Dame in 2019 and has been working as a post-doc in Brazil. This manuscript has been submitted and reviewed favorably, and the revised manuscript will be submitted soon.
Presentation at ADCIRC week	04/2020	100	
Submission of peer-reviewed manuscript about downscaling and extrapolation	03/2021	90	Ajimon Thomas has written this manuscript as a chapter in his dissertation, and this manuscript has been submitted.
Submission of peer-reviewed manuscript about improved channel flow	06/2021		We continue to pursue this milestone. This manuscript will be developed in Year 6.

2. **Year 5 Transition Activities and Milestone Achievements**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020

Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not completed
Online documentation of new technologies. The project technologies will be documented via technical descriptions, user guides, and example files on a public Web site, either the to-be-revised ADCIRC homepage or the sites of the project PIs. (Dietrich's site already contains documentation for ADCIRC features and example files, and it is a common resource for ADCIRC users). This documentation will make it easier for all ADCIRC users to adopt and use the project technologies, thus ensuring an impact beyond the life of this project.	06/2021	50	We are nearing completion of the online documentation for the downscaling technology with head losses due to friction; this documentation has been posted online. The online documentation for the interpolation technology has been delayed as we finalize its performance.
Transfer of technologies to ADCIRC modeling community	06/2021	50	We continue to pursue this milestone. We are working with our partners to operationalize these technologies.
Integration of project software into release version of ADCIRC	06/2021	50	We continue to pursue this milestone. We are working with our partners to operationalize these technologies.
Transition Milestone			
Quarterly progress updates, feedback from transition partners. These updates are provided as videoconferences, in which Dietrich and Dawson share their research progress as short presentations, with an emphasis on what is novel since the previous update. Most of the update is a discussion about ongoing and future research directions, and we are careful to solicit feedback and suggestions from our partners. This feedback is then used to improve the utility of our technologies as we develop them during the project.		100	We are no longer having regular meetings with our full set of transition partners, because the technology is mature. Instead, we have targeted meetings with specific end users for each technology.

3. **Research Project Product Delivery**

Year 5 Research Project Product Delivery

Product Name and Function	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
Downscaled forecast guidance during Hurricane Dorian	Shapefiles	09/2019	Tom Langan, NC Emergency Management
Downscaled hindcast guidance after Hurricane Dorian	Shapefiles and geo-referenced TIFFs	09/2019	FEMA

IV. PUBLICATIONS AND METRICS

1. Publications:

- A Gharagozlou*, JC Dietrich, A Karanci, RA Luettich, MF Overton (2020). "Storm-Driven Erosion and Inundation of Barrier Islands from Dune- to Region-Scales." *Coastal Engineering*, 158, 103674, DOI: 10.1016/j.coastaleng.2020.103674.

- A Thomas*, JC Dietrich, TG Asher, M Bell, BO Blanton, JH Copeland, AT Cox, CN Dawson, JG Fleming, RA Luettich (2019). "Influence of Storm Timing and Forward Speed on Tide-Surge Interactions during Hurricane Matthew." *Ocean Modelling*, 137, 1-19, DOI: 10.1016/j.ocemod.2019.03.004.

- R Cyriac*, JC Dietrich, JG Fleming, BO Blanton, C Kaiser, CN Dawson, RA Luettich (2018). "Variability in Coastal Flooding Predictions due to Forecast Errors during Hurricane Arthur." *Coastal Engineering*, 137(1), 59-78. DOI: 10.1016/j.coastaleng.2018.02.008.

Student Theses and Dissertations Completed in Year 5.

- Ajimon Thomas (2020). "Using a Multi-Resolution Approach to Improve the Accuracy and Efficiency of Flooding Predictions." PhD Dissertation, Department of Civil, Construction and Environmental Engineering, North Carolina State University, Raleigh, North Carolina, JC Dietrich (primary adviser).

- Carter Rucker (2020). "Improving the Accuracy of a Real-Time ADCIRC Storm Surge Downscaling Model." MS Thesis, Department of Civil, Construction and Environmental Engineering, North Carolina State University, Raleigh, North Carolina, JC Dietrich (primary adviser).

2. Performance Metrics

Dietrich-Dawson Performance Metrics:

Metric	Year 1 (1/1/16-6/30/16)	Year 2 (7/1/16-6/30/17)	Year 3 (7/1/17-6/30/18)	Year 4 (7/1/18-6/30/19)	Year 5 (7/1/19-6/30/20)
HS-related internships (number)	0	0	0	0	0
Undergraduates provided tuition/fee support (number)	0	0	0	0	0
Undergraduate students provided stipends (number)	0	0	0	2	3
Graduate students provided tuition/fee support (number)	3	2	2	3	3
Graduate students provided stipends (number)	3	2	2	3	3
Undergraduates who received HS-related degrees (number)	0	0	0	0	0
Graduate students who received HS-related degrees (number)	0	0	1	0	2
Graduates who obtained HS-related employment (number)	0	0	0	0	1
SUMREX program students hosted (number)	1	0	0	0	0
Lectures/presentations/seminars at Center partners (number)	1	1	0	0	0
DHS MSI Summer Research Teams hosted (number)	0	1	0	1	0
Journal articles submitted (number)	0	0	1	1	1
Journal articles published (number)	0	0	1	1	1
Conference presentations made (number)	2	4	3	3	2
Other presentations, interviews, etc. (number)	1	4	11	5	4
Patent applications filed (number)	0	0	0	0	0
Patents awarded (number)	0	0	0	0	0
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	0	1	0	2	1
Requests for assistance/advice from other agencies or governments (number)	0	1	3	2	1
Dollar amount of external funding	$0	$0	$0	$0	$0
Total milestones for reporting period (number)	6	7	8	10	6
Accomplished fully (number)	6	3	3	5	2
Accomplished partially (number)	0	2	5	5	4
Not accomplished (number)	0	2	0	0	0

GINIS, URI
HUANG - FSU
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Modeling the combined coastal and inland hazards from high-impact hurricanes

Principal Investigator Name/Institution: PI: Isaac Ginis, University of Rhode Island, Professor
Co-PIs:

- Tetsu Hara, University of Rhode Island, Professor
- David Ullman, University of Rhode Island, Marine Research Scientist
- Pam Rubinoff, University of Rhode Island, Coastal Resilience Specialist
- Austin Becker, University of Rhode Island, Associate Professor

Additional Research Participants/Partners:

Research Participant: Wenrui Huang, Florida State University, Professor

Other participants: Chris Damon (URI Environmental Data Center), Peter Stempel (RI School of Design), Sam Adams (Asst. Director of URI Public Safety, President of RI Association of Emergency Managers and MAF PhD student)

Short Project Description ("elevator speech"):

This project advances modeling capabilities that assess the potential impacts of landfalling hurricanes on critical infrastructure and communities and transition the developed advanced capabilities to the real-time ADCIRC-Surge Guidance System (ASGS) and Coastal Emergency Risks Assessment (CERA). The primary focus is on hurricanes in the Northeastern United States, combining multiple hazard impacts, including coastal flooding due to storm surge and inland flooding due to rainfall. We developed new capabilities for the ADCIRC modeling system, such as improved surface wind modeling during hurricane landfall, coupling of storm surge and waves, and inland flooding from rainfall. We developed a participatory methodology for capturing storm risk information in a format that is compatible for integration with high-resolution numerical storm models. Our "Consequence Threshold (CT)" approach provides end-users with real-time storm models that include a detailed understanding of a broad range of potential consequences resulting from infrastructure damage. CTs combine geospatial (location of critical facilities) and meteorological information (wind, surge, and flooding data) with qualitative storm damage information from critical facilities to model the cascading impacts of storm damage to lifeline infrastructure. CT data can then be integrated as storm model outputs and used to guide emergency response decision-making within an emergency operations center.

II. PROJECT NARRATIVE

1. Project overview:

The major goal of this project is to comprehensively investigate hazards and impacts in the focus regions through advancement of coupled hurricane, coastal ocean circulation/storm surge, wave, and hydrological models. This project contributes to improving the real-time ADCIRC-Surge Guidance System (ASGS) and Coastal Emergency Risks Assessment (CERA) to meet the requirements of their main users within federal agencies, including users within FEMA, USACE and NOAA NWS, and decision makers at state and municipal levels in New England. We developed and implemented new capabilities for the ADCIRC modeling system, such as improved surface wind modeling during hurricane landfall, coupling of storm surge and waves, and inland flooding from rainfall. Emergency managers need relevant, local-scale, information about potential consequences of extreme events in advance of a storm's landfall. We develop and implement in practice an innovative hazard impact methodology for collecting actionable and nuanced storm risk information from critical facility managers that is underpinned by participatory research theory, a key tenet of which is the convergence of multiple stakeholder perspectives. This allows end-users to better understand the consequences of coastal and inland hazards associated with high impact landfalling hurricanes and to better prepare coastal communities for future risks.

2. Results:

Building on work from years 1-4, our research activities in Year 5 continued to focus on advancing the capabilities and forecast skill of the ADCIRC modeling system in the Northeast and adding new capabilities, such as improved surface wind modeling during hurricane landfall, coupling of storm surge and waves, and inland flooding from rainfall. The following specific tasks were accomplished: 1) modification of the ADCIRC mesh in coastal New England and its evaluation with river inflows during historic extreme weather events; 2) evaluation and implementation of the sea state dependent drag coefficient into ADCIRC; 3) expanding coupled inland and coastal flood modeling to many Southern New England rivers; and 4) advancing the URI Hurricane Boundary Layer model applications to any location in the U.S. coastal region. A detailed description of our modeling efforts is included in the Year 5 Report Appendix.

We also continued developing innovative hazard impact analysis and infrastructure visualization methods. A new ESRI GIS dashboard system was developed that allows end-users to filter and view the potential consequences using a simulated storm. The dashboard system integrates the "consequence thresholds database" with ADCIRC model outputs and leverages the existing technologies currently in use at the Emergency Operations Center at the Rhode Island Emergency Management Agency. The dashboard system showcases the capabilities of the system using a simulated storm and data collected for the City of Providence. We further advanced 3D Visualization infrastructure coupled with ADCIRC model outputs in Rhode Island for the towns of Newport and Portsmouth. This infrastructure has been utilized to display storm surge outputs and to create visualizations useful in conjunction with the developed elicitation methods to facilitate the expansion of the project to representing additional areas. A detailed description of our hazard impact analysis and infrastructure visualization efforts is included in the Year 5 Report Appendix.

3. End users:

Key partners who provided regular input and guidance during Year 5 include: NOAA NWS: Hydrologist in Charge, Norton, MA; NOAA NCEP/EMC: Ocean Task Lead; US Coast Guard: Marine Transportation Recovery Specialist, Sector Southeast New England; RIEMA: Operations Section Chief/Crisis Information Management; Software Coordinator; Critical Infrastructure/Key Resources Coordinator; RI Dept of Health: Chief and Deputy Chief and Program Support Specialist, Center for Emergency Preparedness and Response; Providence Emergency Management Agency: Director and Deputy Director; Providence Department of Public Property: Public Property Coordinator; RIDEM Office of Water Resources: Engineering Manager; New England National Grid: Senior Coordinator/Community Investment & Economic Development; Providence Water Supply Board: Director of Engineering; RI Infrastructure Bank: Chief Resilience Officer; City of Providence: Division of Capital Asset Management & Maintenance. The project has established a Steering Committee with 15 end-user organization/agency participants that provides guidance on the development of training materials tailored to the needs of the critical lifeline sectors. The steering committee consists of the following partners: Rhode Island Emergency Management Agency (RIEMA), RI Department of Health (RIDOH), Providence Emergency Management Agency (PEMA), Department of Homeland Security (DHS), Providence Department of Public Property, RI Department of Environmental Management (RIDEM), Narragansett Bay Commission, US Coast Guard, North East National Grid, Providence Water Supply, RI Infrastructure Bank, and the City of Providence. "Buy-in" and trust from infrastructure facility managers is a critical component of this project, as they are the source of data that is integrated with storm model outputs. The established steering committee and key partners land the project credibility and build trust with the facility managers. We established close collaboration with the Rhode Island Association of Emergency Managers (RIAEM) which includes emergency managers (EM) from all 39 communities in the state, as well as EM from institutions, such as hospitals and universities. The collaboration with RIAEM provides an opportunity for the project team to reach out to the broader audience to get feedback on the approach and products, and build buy-in and capacity for future use of ADCIRC in real-time tool; feedback on the consequence threshold effort is also critical to determine the interest and ability to scale that effort beyond the pilot to statewide application. The president of the RIAEM (Sam Adams) also joined the team as a PhD student in Marine Affairs under the supervision of Dr. Becker.

4. Transition:

Efforts continued to engage our collaborators in the ADCIRC model development efforts. We held a meeting with the research staff and forecasters at the NOAA/NWS Northeast River Forecast Center on November 20, 2019 to discuss our work on inland and coastal flood coupled modeling in Southern New England and transitioning it to real-time forecast capabilities. We also held a meeting with the ocean and wave modeling group at the NOAA's Environmental Modeling Center in College Park, MA on January 22, 2020 to discuss our progress in developing sea-state dependent wind stress parameterization in shallow water to improve storm surge forecasting and develop plans for future collaboration with EMC scientists.

Efforts continued to engage end-users in a pilot project in Providence, Rhode Island focusing on evaluation the effectiveness of our "consequence threshold" risk analysis approach and participatory methodology for capturing storm risk information in a format that is compatible for integration with high-resolution numerical storm models. Key partners provided regular input and guidance, including direction with respect to the technical requirements of the database system and interface. RIEMA, RIDOH and PEMA are our prime partners to help scope and implement the effort, as they are the ones targeted to use the product for real time applications. A full list of meetings, interviews, and site visits, as well as testimonials from these key stakeholders can be found in the Year 5 Report Appendix.

To date, the primary focus on the end-user transition has been on the Rhode Island emergency management community, with the goal of getting their input and buy-in to 1) develop a pilot project that shows the capability of modeling storms and impacts; 2) gather critical infrastructure information to use in the model; 3) identify ways to share information for real time use at the Emergency Operations Center; 4) get feedback on visualizations, platforms, and modeling approaches that will be rolled out to New England stakeholders for the enhanced ADCIRC modeling initiative.

Our team continued to collect critical infrastructure information, thresholds, and concerns through site visits of all critical infrastructure facilities in the floodplain of Providence, RI, key informant interviews and focus groups of key infrastructure sector experts (detailed list of all end-user interactions can be found in the Year 5 Report Appendix). In sum, we collected 321 CTs for 137 critical infrastructure assets located within the Providence floodplain. The most common assets that were identified included entrances to buildings, generators, and HVAC systems.

The project Steering Committee met in the fall of 2019 (August and September) to share an update of data collection and discuss options to fill gaps in information. The team reached out to the RI Association of Emergency Managers to provide an overview of the project, both the ADCIRC modeling as well as the consequence thresholds. There was keen interest in learning how best to use the ADCIRC as another tool for emergency response and to better understand the potential to expand the consequence threshold component statewide. The focus of end-user engagement in Fall 2019 with our partners was to discuss user interface and platforms for delivering the information. This resulted in meetings (December 2019) with FEMA Region 1 and RIEMA leaders to discuss options and collaboration.

Additional details on the transition activities are provided in Year 5 Report supplemental material.

5. Project Impact:

Significant progress was made to further advance the capabilities and forecast skill of the ADCIRC modeling system in the Northeast, including a highly refined computational grid and new capabilities, such as improved surface wind modeling during hurricane landfall, coupling of storm surge and waves, and inland flooding from rainfall. All these advancements will make an important contribution to the DHS mission, because improving the accuracy of hurricane hazard and infrastructure impact modeling will enhance our ability to anticipate and better prepare for future hurricanes.

The new capabilities afforded by our "Consequence Threshold (CT)" approach provides end-users with real-time storm impact analysis that includes a detailed understanding of a broad range of potential consequences resulting from infrastructure damage. The CT methodology will inform emergency manager decision-making in the event of an extreme storm event to protect lives and increase operational efficiency in response to storms. Storm events are dynamic in nature and introduce economic, social, ecosystem, environmental, and supply chain impacts that vary temporally and spatially. Modeling specific impacts of critical infrastructure damage can be a time consuming and computationally intensive task for researchers. The CT approach provides a more efficient method of projecting potential storm consequences in a way that is custom tailored to the needs of the end user. The participatory nature of the process engages stakeholders and builds trust within the facility manager community.

6. Unanticipated Problems:

Because Year 5 funds arrived late in 2019 some of the tasks have been only partially completed. Engagement with end-users was severely impacted by the COVID-19 pandemic. Given that our key partners are first responders (RIEMA, RIDOH, and PEMA), it was not appropriate or feasible to engage them from March, 2020. The team continued to develop the interface for delivery of critical infrastructure consequences linked with the storm prediction models. Training material and web-based interactive software was developed for a virtual workshop in July, 2020.

On the data collection side, we faced challenges associated with the collection, handling, and dissemination of Protected Critical Infrastructure Information (PCII). We overcame this through adoption of a data sensitivity protocol built into our approach (with significant input from the steering committee), as well as by participating in PCII training for all members of the research team. Details of this are provided in Year 5 Report Appendix.

7. Student Involvement and Awards:

   a) Students involved in the research

      i. Xuanyu Chen, a PhD student at the Graduate School of Oceanography, worked on evaluation and improvements of the wave models WW3 and SWAN in hurricane conditions and investigated the sea state dependent drag coefficient in shallow waters during hurricane landfall. (Full CRC support).
      ii. Mansur Ali Jisan, a PhD student at the Graduate School of Oceanography, worked on advancing modeling of surface winds during hurricane landfall for predicting storm impacts. He also assisted in running the ADCIRC system for nor'easters. (Full CRC support).

iii. Ellis Kalaidijan, a MA student in the Department of Marine Affairs, worked with PIs and end-user partners to collect, aggregate, and synthesize data on critical infrastructure. (Partial CRC support).
iv. Noah Hallisey, a MS student in the Department of Biological and Environmental Sciences, worked with PIs and end-user partners to collect, aggregate, and synthesize data on critical infrastructure. (Partial CRC support).
v. Sam Radov, a BS student in Community Planning and Sociology, worked with PIs to collect data on critical infrastructure. (Partial CRC support).
vi. Joyce Pak, a MS student at Brown University, worked with PIs and end-user partners to collect data on critical infrastructure. Her involvement on the project was leveraged through our partnership with the RI Department of Health and Brown Public Health program. (No CRC support)
vii. Sam Adams, a PhD student at URI, is not directly assisted through CRC funding but is an active member of the team. Adams is also the Asst. Director of Public Safety for URI and president of the RIEAM. (No CRC support)
viii. Madison Russ, a MARCH student at RISD, is not directly assisted through CRC funding but is an active member of the team building visualization infrastructure for Newport. (No CRC support)
ix. Anya Drozd, a BARCH student at RISD, is not directly assisted through CRC funding but is an active member of the team building visualization infrastructure for Portsmouth. (No CRC support)

b) Student demographics

Our project involved five female and four male student researchers. Among them, seven were graduate students and two undergraduate students.

c) Student Degrees

- Peter Stempel was awarded his PhD in Marine Affairs in Y4.
- Bobby Witkop, Master's thesis in Marine Affairs in Y4.
- Xuanyu Chen, Ph.D. student is scheduled to defend her dissertation in July 2020.

d) Student Awards

- Peter Stempel was awarded the Graduate Scholarship Excellence Award in Y4.
- Xuanyu Chen was awarded the William E. Simmons Memorial Scholarship Award in Oceanography for research expected to be of real economic value in Y5 and the Marine Science Award, Thomas & Kathy J. McNiff Graduate Student Endowment in Y4.

8. Interactions with CRC education projects:

- Austin Becker gave a webinar presentation to Dan Cox's Engineering Course at Oregon State University on May 6, 2020.

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. <u>Year 5 Research Activities and Milestone Achievements:</u>

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Implement the Precipitation-Runoff Modeling System (PRMS) to simulate rainfall runoff in Massachusetts.	06/30/2020 New target date: 6/30/2021	80%	Due to the delay in ADCIRC team funding.
Complete coupling of waves and storm surge models in ADCIRC-SWAN system to include a sea state dependent drag coefficient, air-sea flux budgets, Coriolis-Stokes interactions, Stokes-vortex forces and Langmuir turbulence.	06/30/2020 New target date: 6/30/2021	80%	Due to the delay in ADCIRC team funding.
Evaluate the ADCIRC-PRMS modeling system for simulations of historic tropical cyclones in New England, such as hurricanes Irene (2011) and Sandy (2012), and four nor'easters affected the region in March 2018.	06/30/2020 New target date: 6/30/2021	70%	Due to the delay in ADCIRC team funding.
Apply the URI Hurricane Boundary Layer (HBL) model and conduct its validation against available observations in historic hurricanes that made landfall in the U.S.	06/30/2020 New target date: 6/30/2021	80%	Due to the delay in ADCIRC team funding.
Implement the URI Hurricane Boundary Layer (HBL) model into the ADCIRC real-time prediction system and evaluate its impact on the storm prediction skill. Transition the model to the operational ADCIRC-Surge Guidance System.	06/30/2020 New target date: 6/30/2021	30%	Due to the delay in ADCIRC team funding.
In collaboration with the ASGS and CERA developers implement technical capabilities for integrating the disaster consequence thresholds into the real-time system. This will benefit coastal emergency management and provide hazard impact information to the public through CERA.	06/30/2020	60%	Due to the delay in ADCIRC team funding. In consultation with end-users and our steering committee, we altered this task to leverage the existing technology in use at RIEMA. Thus, we no longer plan to integrate the disaster consequence thresholds with CERA at this stage. Instead, we are developing an ESRI

			mapping dashboard that is similar to the systems already in use at RIEMA.
Develop and implement technical capabilities for integrating 3D hazard visualization output compatible with the ASGS and CERA computational framework.	06/30/2020	60%	In consultation with end-users and our steering committee, we altered this task to leverage the existing technology in use at RIEMA. Thus, we no longer plan to utilize the 3D visualization outputs into CERA at this stage. Instead, it will be integrated into an ESRI mapping dashboard that is similar to the systems already in use at RIEMA.
Research Milestone			
Implemented the Precipitation-Runoff Modeling System (PRMS) to simulate rainfall runoff in Massachusetts.	06/30/2020 New target date: 6/30/2021	80%	Due to the delay in ADCIRC team funding.
Implemented the sea state dependent drag coefficient and other physics upgrades in ADCIRC-SWAN system.	06/30/2020 New target date: 6/30/2021	80%	Due to the delay in ADCIRC team funding.
Completed integration of the PRMS hydrological modeling in CT, RI, and MA into ADCIRC--Surge Guidance System.	06/30/2020 New target date: 6/30/2021	70%	Due to the delay in ADCIRC team funding.
Completed integration of the URI Hurricane Boundary Layer Model into the ADCIRC-Surge Guidance System.	06/30/2020 New target date: 6/30/2021	70%	Due to the delay in ADCIRC team funding.
Completed integration of the hazard impact and 3D visualization output into the ASGS and CERA computational framework.	06/30/2020	60%	In consultation with end-users and our steering committee, we altered this task to leverage the existing technology in use at RIEMA. Thus, we no longer plan to utilize the 3D visualization outputs or to integrate with CERA at this stage. Instead, we are developing an ESRI mapping dashboard that is similar to the systems already in use at RIEMA.

2. Year 5 Transition Activities and Milestone Achievements:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Reconvene core end-user group meeting to discuss model results. Reconfirm outreach strategy to local emergency managers.	06/30/2020 New target date: 6/30/2021	50%	Due to the delay in ADCIRC team funding. Some engagements with end-users was severely impacted by the COVID-19 pandemic.
Present model capabilities to end-users at strategic meetings, such as the FEMA regional meetings, State Emergency Manager Associations or State Floodplain Manager Annual meetings.	06/30/2020 New target date: 6/30/2021	50%	Some planned engagements with end-users were impacted by the COVID-19 pandemic.
Conduct questionnaires at the end of each training and workshop activity to determine progress and assess effectiveness of the developed hazard model improvements and impact output capabilities in improving risk assessment and emergency response.	06/30/2020 New target date: 6/30/2021	0%	This will be done during the workshop/webinar scheduled for July 2020. It was delayed due to the COVID-19 pandemic.
Design and conduct a webinar on model capabilities to reach out to additional end users.	06/30/2020 New target date: 6/30/2021	0%	Additional webinars will be conducted with one or more groups after the scheduled July workshop.
Participate and contribute to annual ADCIRC training courses for end-users.	06/30/2020	100%	
Transition Milestone			
Transition the completed coupling of wave and storm surge models to the operational ADCIRC-Surge Guidance System (ASGS).	06/30/2020 New target date: 6/30/2021	60%	Due to the delay in ADCIRC team funding.
Transition the completed Precipitation-Runoff Modeling System (PRMS) in CT, RI and MA to the operational ADCIRC-Surge Guidance System (ASGS).	06/30/2020 New target date: 6/30/2021	60%	Due to the delay in ADCIRC team funding.

Transition the URI Hurricane Boundary Layer Model (HBL) to the operational ADCIRC-Surge Guidance System (ASGS).	06/30/2020 New target date: 6/30/2021	70%	Due to the delay in ADCIRC team funding.
Transition the completed integration of the hazard impact and 3D visualization output into the ADCIRC-Surge Guidance System (ASGS) and the Coastal Emergency Risks Assessment (CERA).	06/30/2020	60%	In consultation with end-users and our steering committee, we altered this task to leverage the existing technology in use at RIEMA. Thus, we no longer plan to utilize the 3D visualization outputs or to integrate with CERA at this stage. Instead, we are developing an ESRI mapping dashboard that is similar to the systems already in use at RIEMA.

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
Hazard Consequence Modeling System (HCMS)	This real-time hazard and impact prediction system for hurricanes and nor'easters in Southern New England will run on existing ArcGIS systems typically in use at Emergency Operation Centers (EOCs) around the country. It integrates end-user knowledge and concerns as model inputs into the ADCIRC-Surge Guidance System. It provides predictions of cascading consequences of extreme weather (i.e., surge, wind, flooding, waves) impacting critical infrastructure (e.g., wastewater treatment facilities, sewer systems, airports, and seaports).	Demonstration product anticipated July 2020	Rhode Island Emergency Management Agency, Providence Emergency Management Agency, Rhode Island Dept. of Health, other state and federal agencies per Year 5 Report Appendix

IV. PUBLICATIONS AND METRICS

1. **Publications:**

Yr 4/5 Publications (Student authors are marked with an asterisk):

- Chen, X.*, T. Hara, and I. Ginis, 2020. Impact of Shoaling Ocean Surface Waves on Wind Stress and Drag Coefficient in Coastal Waters: Part I Uniform Wind, *J. Geophys. Res., In review.*
- Chen, X*., I. Ginis, and T. Hara, 2020: Impact of Shoaling Ocean Surface Waves on Wind Stress and Drag Coefficient in Coastal Waters: Part II Tropical Cyclones, *J. Geophys. Res., In press.*
- Huang, W., F Teng, I. Ginis, and D. Ullman, 2020. Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by International Journal of Structural and Civil Engineering Research (IJSCER), August V9N3.
- Stempel, P., Becker, A., 2020. Is it Scientific? Viewer perceptions of storm surge visualizations. *Cartographica (The Canadian Journal of Cartography). In Review*.
- Stempel, P., Becker, A., 2019. Visualizations out of context. Implications of using simulation-based 3d hazard visualizations. *ISPRS International Journal of Geo-Information*: Special issue on Natural Hazards and Geospatial Information. Vol 8, No 318; Doi:10.3390/ijgi8080318.
- Ullman D.S., I. Ginis, W.Huang, C. Nowakowski*, X. Chen*, and P. Stempel*, 2019: Assessing the Multiple Impacts of Extreme Hurricanes in Southern New England, USA, *Geosciences*, *9*(6), 265; https://doi.org/10.3390/geosciences9060265
- Witkop R.*, A. Becker, P. Stempel*, and I. Ginis, 2019: Developing Consequence Thresholds for Storm Models Through Participatory Processes: Case Study of Westerly Rhode Island. *Front. Earth Sci.* 7:133. doi: 10.3389/feart.2019.00133
- Bender, M.A., T. Marchok, R. E. Tuleya, I. Ginis, V. Tallapragada, and S. J. Lord, 2019: Hurricane model development at GFDL, 2019: A Collaborative success story from a historical perspective., *Bull. Amer. Met. Soc.*, September, https://doi.org/10.1175/BAMS-D-18-0197.1
- Wang, D.*, T. Kukulka, B. Reichl, T. Hara, I. Ginis, and W. Perrie, 2019: Wind-wave misalignment effects on Langmuir turbulence in tropical cyclones conditions, *J. Phys. Oceanogr*., https://doi.org/10.1175/JPO-D-19-0093.1
- Torres M.J.*, M. R. Hashemi, S. Hayward, M. Spaulding, I. Ginis, and S. T. Grilli, 2019: Role of hurricane wind models in accurate simulation of storm surge and waves. *Coastal, Ocean Eng.*, 2019, 145(1): 04018039. doi: 10.1061/(ASCE)WW.1943-5460.0000496

Previous Publications (student authors are marked with an asterisk)

- Gao K.*, and I. Ginis, 2018: On the characteristics of roll vortices under a moving hurricane boundary layer, *J. Atmos. Sci*., 75, 2589-2598. https://doi.org/10.1175/JAS-D-17-0363.1
- Chen*, X., I. Ginis, and T. Hara, 2018: Sensitivity of offshore tropical cyclone wave simulations to spatial resolution in wave models. J. Mar. Sci. Eng., 6, 116. http://www.mdpi.com/2077-1312/6/4/116/

- Jisan, M. A.*, Bao, S., & Pietrafesa, L. J. (2018). Ensemble projection of the sea level rise impact on storm surge and inundation at the coast of Bangladesh. Natural Hazards and Earth System Sciences, 18(1), 351. https://doi.org/10.5194/nhess-18-351-2018
- Stempel, P.*, Ginis, I., Ullman, D., Becker, A., Witkop, R.* (2018). Real-Time Chronological Hazard Impact Modeling. Journal of Marine Science and Engineering, Vol. 6, no. 134. doi:10.3390/jmse6040134.
- Teng, F., W. Huang, and I. Ginis, 2018. Hydrological modeling of storm-induced runoff and snowmelt in Taunton River Basin. Journal of Natural Hazards, 91, 179-199, https://doi.org/10.1007/s11069-017-3121-y
- *Liu, Q.*, L. M. Rothstein, and Y. Luo, 2017. A periodic freshwater patch detachment process from the Block Island Sound estuarine plume. J. Geophys. Res. Oceans, 122, 570–586, DOI:10.1002/2015JC011546
- Gao, K.*, I. Ginis, J.D. Doyle, Y. Jin, 2017: Effect of boundary layer roll vortices on the development of the axisymmetric tropical cyclone *J. Atmos. Sci*. DOI: 10.1175/JAS-D-16-0222.1
- Whitney, M. M., D. S. Ullman, and D. L. Codiga, 2016. Subtidal Exchange in Eastern Long Island Sound, . *J. Phys. Oceanogr*. 46, 2351-2371. DOI: 1175/JPO-D-15-0107.1
- Gao, K*. and I. Ginis, 2016: On the equilibrium-state roll vortices and their effect in the hurricane boundary layer. *J. Atmos. Sci.*, 1205- 1222. https://doi.org/10.1175/JAS-D-15-0089.1
- Liu, Q., L. M. Rothstein, Y. Luo, D. S. Ullman, and D. L. Codiga, 2016. Dynamics of the periphery current in Rhode Island Sound, *Ocean Modelling*, 105, 13-24. DOI: 10.1016/j.ocemod.2016.07.001
- Liu, Q., L. Rothstein, and Y. Luo, 2016. Dynamics of the Block Island Sound estuarine plume. J. Phys. Ocean., Accepted for publication. DOI: 10.1175/JPO-D-15-0099.1
- Reichl, B. G.*, D. Wang, T. Hara, I. Ginis, T. Kukulka, 2016: Langmuir turbulence parameterization in tropical cyclone conditions. *J. Phys. Oceanogr.,* 46, 863-886. DOI: 10.1175/JPO-D-15-0106.1
- Reichl, B. G.*, I. Ginis, T. Hara, B, Thomas, T. Kukulka, and D. Wang, 2016: Impact of sea-state dependent Langmuir turbulence of the ocean response to a tropical cyclone, *Mon. Wea. Rev*. DOI: 10.1175/MWR-D-16-0074.1
- Sun, Y., C. Chen, R. C. Beardsley, D. Ullman, B. Butman, and H. Lin, 2016. Surface Circulation in Block Island Sound and Adjacent Coastal and Shelf Regions: A FVCOM-CODAR comparison, *Progress in Oceanography*, 143, 26-45. DOI: 10.1016/j.pocean.2016.02.005
- Spaulding, M. L., Grilli, A., Damon, C., Crean, T., Fugate, G., Oakley, B., & Stempel, P.*, (2016). "Stormtools: Coastal Environmental Risk Index (CERI)." *Journal of Marine Science and Engineering*, 4(3). DOI: 10.3390/jmse4030054
- Fei, T., W. Huang, I. Ginis, Y. Cai, 2016. Characteristics of River Flood and Storm Surge Interactions in a Tidal River in Rhode Island, USA. Proceeding of IUTAM Symposium on Storm Surge Modelling and Forecasting, Oct 17-19, 2016, Shanghai, China

Conference papers, presentations:

Yr 4/5 presentations (student authors are marked with an asterisk):

- Becker, A., Rubinoff, P., Stempel, P., Ginis, I., Adams, S.*, Hallisey, N.*, Kalaidjian, E.*, (2020) Hazard Consequence Threshold Models for Emergency Management and Response Decision Making. Natural Hazards Center Researchers Meeting, Boulder, CO, July 15-16.
- Stempel, P., (2020). "Adaptation of low-lying neighborhoods in Portsmouth, RI. USA." International Geodesign Collaboration (IGC), Redlands, CA. February 22–24, 2020
- Chen, X.*, I. Ginis and T. Hara: Numerical Study of Wind Stress in Coastal Water Under a Tropical Cyclone, Ocean Sciences Meeting, Feb. 16-21, 2020, https://agu.confex.com/agu/osm20/meetingapp.cgi/Paper/644262
- Hara T., X. Chen* and I. Ginis: Impact of Shoaling Wind Waves on Drag Coefficient in Finite Depth, Ocean Sciences Meeting, Feb. 16-21, 2020, https://agu.confex.com/agu/osm20/meetingapp.cgi/Paper/646849
- Becker, A. (2019), "Coastal Hazard Impact Assessment." Climate Preparedness and Resilience Community of Practice Lead, CW Guidance Program US Army Corps of Engineers Headquarters, Washington, DC, Sept. 11.
- Becker, A. (2019), "Hazard Consequence Threshold Models for Emergency Management and Response Decision Making." CARIS (Climate Adaptation and Resilience Information Sharing Group, Sept. 13.
- Becker, A., Rubinoff, P., Ginis, I., Adams, S.* (2019) Hazard Consequence Threshold Models for Emergency Management and Response Decision Making. Presentation to FEMA Region 1, Dec. 18, Boston, MA.
- Stempel, P., (2019). "Rethinking model-driven realistic storm-surge graphics." Rhode Island Coastal Ecology, Assessment, Innovation, and Modeling (R C-AIM) Research Symposium 2019, Kingston RI. April 10.
- Ginis, I., and Il-K. Ma (2019): Impact of Warm-Core Ocean Eddies on Tropical Cyclone Intensification in the Northwest Pacific, International Workshop on Tropical Cyclone-Ocean Interaction in the Northwest Pacific, June 20, http://www.tcoi.co.kr/
- Ginis I. (2019): Advancing modeling capabilities to improve prediction of extreme weather events in the Northeastern United States, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, April 11.
- Ginis I. (2019): Improving Prediction of Extreme Weather and Its Impact in New England, RI Emergency Management Agency, Cranston RI, March 7.
- Ginis I. (2019): Modeling Combined Coastal and Inland Impacts from Extreme Storms, RI Department of Health, Providence RI, March 8.
- Becker, A, (2019). "Overcoming Barriers to Long-term Climate Adaptation," Lecture of Opportunity, US Naval War College, Newport, RI, April 29.
- Becker, A., (2019). "Climate risk adaptation for ports: Research for transformational thinking." UNCTAD Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future , Geneva, Switzerland, April 16-17.
- Stempel, P., Becker., A., Ginis, I., Ullman, D., Rubinoff., P., Overstrom, N. (2019). "Rethinking model-driven realistic storm-surge graphics." Rhode Island Coastal Ecology, Assessment, Innovation, and Modeling (RI C-AIM) Research Symposium, Kingston RI. April 10.
- Becker, A, Stempel, P.*, Menendez, J.* (2019). "Visualizing Risk: Dynamic 3d Models of Storm Impacts on Coastal Structures In Rhode Island." Poster presentation at the Infrastructure Climate Network Meeting, Portsmouth, NH, April 4-5.

- Huang, W., F Teng, I. Ginis, and D. Ullman (2019). Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by 8th International Conference on Civil Engineering (ICCEN 2019), November 19-20, Paris, France, 2019

Previous presentations (student authors are marked with an asterisk)

- Ginis I. (2018): Advances in Predicting Hurricane Path and Intensity, Jamestown Philomenian Library, Jamestown RI, September 24.
- Chen, X. *, I. Ginis and T. Hara (2018). "Sea-State Dependent Drag Coefficient in Shallow Waters Under Tropical Cyclones", 21st Conference on Air-Sea Interaction, June 18 https://ams.confex.com/ams/23BLT21ASI/meetingapp.cgi/Paper/345222
- Chen, X.*, T. Hara, and I. Ginis (2018). "Sea-state dependent air-sea momentum flux in a shallow water under a tropical cyclone", Ocean Sciences Meeting, February 14 https://agu.confex.com/agu/os18/meetingapp.cgi/Paper/303041
- Ginis, I., C. Nowakowski*, and K. Gao (2018). "A Hurricane Boundary Layer Model for Simulating Surface Winds during Hurricane Landfall", 33rd Conference on Hurricanes and Tropical Meteorology, April 18, https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339799.html
- Becker, A. (2018). "Stimulating Transformational Thinking for Long-Term Climate Resilience." University of Rhode Island Coastal Resiliency Symposium, Oct. 16, Narragansett, RI. (I)
- Ginis, I., D. Ullman, T. Hara, C. Kincaid, K. Rosa*, X. Chen*, B. Thomas, A. Becker, P. Stempel*, R. Witkop*, P. Rubinoff, W. Huang, M. Orr, R. Thomas, R. Thompson, M. Belk, P. Morey, and S. Conard (2018). "Advancing Modeling Capabilities and Impact Analysis Tools to Improve Preparedness for Major Hurricane Hazard Events", 98th AMS Annual Meeting, January 11, https://ams.confex.com/ams/98Annual/webprogram/Paper336049.html
- Nowakowski, C.* and Ginis I. (2018): Advancing modeling of surface winds during hurricane landfall for predicting storm impacts, DHS Centers of Excellence Summit, May 30-31, 2018 https://cina.gmu.edu/coe-summit-2018/
- Witkop, R.*, Becker, A., Stempel, P.*, (2018). "Incorporating facility manager knowledge into storm impact models: A case study of critical facilities in Westerly, Rhode Island," Rhode Island Floodplain Managers Association, Smithfield, RI, April 5.
- Rosa, K.*, Kincaid, **C.** (2018). "Transporting Nutrients Northward from Rhode Island Sound Bottom Water to the Upper Narragansett Bay Euphotic Zone", RI C-AIM/RI NSF EPSCoR Symposium. Kingston, RI, April 9.
- Rosa, K., Kincaid, C., Ullman, D., and Ginis, I. (2017). Hurricane Rhody: How does Rhode Island Fare Against Hypothetical Superstorm? URI Graduate Conference. Kingston, RI. 8 April.
- Rosa, K. *, Kincaid, C., Ullman, D., and Ginis, I. (2017). "Baroclinic Model of Narragansett Bay Post-Storm Shelf-Estuary Exchange", Estuary Research Workshop: Limiting Factors Beyond Nitrogen. Narragansett, RI. September 13.
- Ginis, I., D. Ullman, T. Hara, C. Kincaid, L. Rothstein, W. Hwang, B. Thomas, X. Chen*, K. Rosa*, A. Becker, P. Stempel*, R. Witkop*, P. Rubinoff (2017). "Developing a multi-model ensemble system for assessing hurricane hazards and impacts", URI Coastal Resilience Science and Engineering Workshop, December 4.

- Ullman, D., I. Ginis, W. Hwang, P. Stempel*, T. Hara, C. Kincaid, L. Rothstein, P. Rubinoff, B. Thomas, X. Chen*, K. Rosa* (2017). "Assessing the Mul-ple Impacts of Extreme Hurricanes in Southern New England", URI Coastal Resilience Science and Engineering Workshop, December 4.
- Witkop, R.*, Stempel, P.*, Becker, A., (2017). "Coupling local scale, high resolution, qualitative data to interface with numerical storm models", American Geophysical Union Annual Conference, New Orleans, LA. Dec. 12.
- Stempel, P.* (2016). "Data Driven Visualization", Estuarine and Coastal Modeling Conference 2016, Narragansett, RI, June 14-15.

Student Theses/Dissertations

- Bobby Witkop Master's thesis in Marine Affairs "Developing Consequence Thresholds for Storm Impact Models: Case Study of Westerly, Rhode Island", 2018, Primary advisor: Dr. Austin Becker, Committee member: Dr. Isaac Ginis
- Peter Stempel Ph.D. Dissertation in Marine Affairs: "Depicting consequences of storm surge, opportunities and ethics." 2018, Primary advisor: Dr. Austin Becker, Committee member: Dr. Isaac Ginis
- Xuanyu Chen Ph.D. Dissertation in Physical Oceanography: "Impacts of Shoaling Ocean Surface Waves on Wind Stress and Storm Surge" 2020, Primary advisors: Dr. Isaac Ginis and Dr. Tetsu Hara, Committee member: Dr. David Ullman

2. Performance Metrics

Ginis Performance Metrics:

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17-6/30/18)	Year 4 (7/1/18-6/30/19)	Year 5 (7/1/19-6/30/20)
HS-related internships (number)	0	0	0	0	0
Undergraduates provided tuition/fee support (number)	0	0	0	0	0
Undergraduate students provided stipends (number)	0	0	0	1	1
Graduate students provided tuition/fee support (number)	2	3	3	3	3
Graduate students provided stipends (number)	2	3	3	3	3
Undergraduates who received HS-related degrees (number)	0	0	0	0	0
Graduate students who received HS-related degrees (number)	0	0	0	0	2
Graduates who obtained HS-related employment (number)	0	0	0	0	2
SUMREX program students hosted (number)	0	2	2	0	0
Lectures/presentations/seminars at Center partners (number)	1	3	2	1	2
DHS MSI Summer Research Teams hosted (number)	0	0	0	0	0
Journal articles submitted (number)	2	7	6	3	4
Journal articles published (number)	7	8	9	7	10
Conference presentations made (number)	15	14	15	8	14
Other presentations, interviews, etc. (number)	12	22	17	23	18
Patent applications filed (number)	0	0	0	0	0
Patents awarded (number)	0	0	0	0	0
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	0	3	5	3	3
Requests for assistance/advice from other agencies or governments (number)	5	13	12	11	12
Dollar amount of external funding	$3,921,000	$3,660,000	[illegible]		
Total milestones for reporting period (number)	11	21	19	8	9
Accomplished fully (number)	9	17	19	1	0
Accomplished partially (number)	2	4	0	7	9
Not accomplished (number)	0	0	0	0	0

FLEMING, SEAHORSE CONSULTING
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/21/2020)

I. INTRODUCTION

Project Title: The ADCIRC Surge Guidance System as a Conduit for Innovation

Principal Investigator Name/Institution: Jason G. Fleming, Seahorse Coastal Consulting

Additional Research Participants/Partners: Brett Estrade, Coastal Computing Services, LLC; Sarah Lipuma, Duke University

Short Project Description ("elevator speech"):
We are positioning our ADCIRC Surge Guidance System software (ASGS) as a real time 24/7 delivery vehicle for the innovations developed at the CRC that have the best value proposition for our key stakeholders. We are also researching asset database driven products beyond storm surge that are more directly relevant to the needs of our transition targets. Finally, we are setting up outreach and training activities that will benefit new users as well as generate sales leads for sustainable funding going forward.

II. PROJECT NARRATIVE

1. Project overview: Over the years, CRC researchers have developed significant innovations to enhance coastal resilience and coastal hazard decision support. However, when it comes to transition, there is often no clear path for reliably delivering these new technologies into the hands of the people that need them.

It is difficult for Universities and their staff to deploy and support a technology with the round-the-clock reliability that is key for emergency operations. Furthermore, if the innovations developed at the CRC are transitioned to end user agencies piecemeal, each one may be not significant enough on its own to justify the ongoing expense of transition. And even if they do transition successfully in isolation from each other, the benefit of synergy between them is lost.

To address these challenges, we are positioning our technology, the ADCIRC Surge Guidance System (ASGS), as a conduit that runs 24/7/365 to deliver the innovations developed at the CRC to end user agencies. We also provide training and outreach to end users, and we collect O&M funding from end user agencies to sustain the innovation pipeline. As an added benefit, this approach breaks down the silos separating the CRC PIs by aggregating and integrating their research products into a common delivery vehicle, thus taking advantage of the synergies between them.

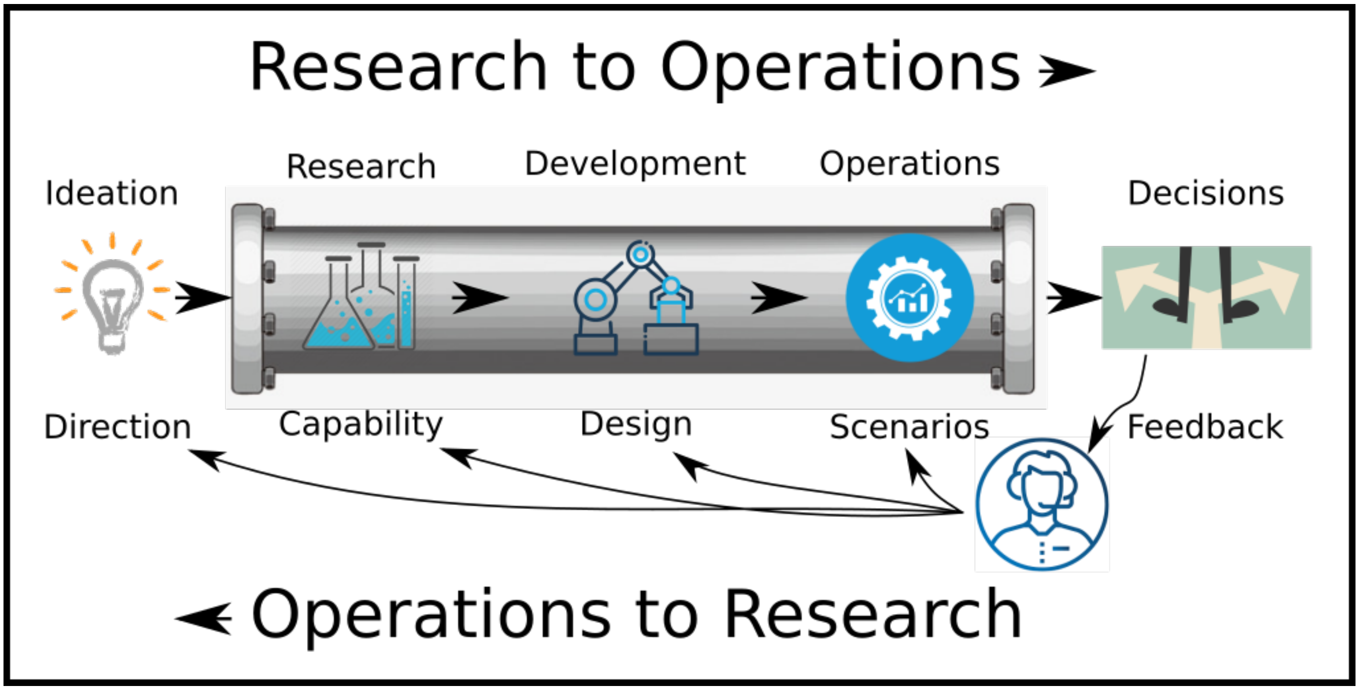


Figure 1 The Research-to-Operations pipeline is critical for advancing the state of the practice, while the Operations-to-Research feedback system continuously renews the vitality and relevance of the research enterprise. The construction and maintenance of this pipeline is a project in itself; it acts as a force multiplier for research spending.

Finally, this project also acknowledges the crucial importance of communication and raising the profile of the advancements funded by DHS OUP with significant emphasis on travel to stakeholder sites, presentations at meetings with National relevance, and on business development for sustainable funding streams.

2. Results: Our 24/7 hurricane decision support operations provided key support for life and property decisions for the US Coast Guard, FEMA, and other Federal agencies (including the US Army Corps of Engineers) as well as State agencies including the Louisiana Coastal Protection and Restoration Authority (LA CPRA) and the North Carolina Department of Transportation, among others.

During this Year 5, we were able to complete several of our objectives, despite the issues associated with COVID-19. We hosted our first ever virtual ADCIRC Boot Camp from April 1st through April 3rd. Through this we recognized that we are able to reach a much greater, worldwide audience than the in-situ format we had been working with prior to COVID-19. We have continued to provide ongoing operation of ADCIRC Surge Guidance System and it is well within the realm of working 24/7 to produce guidance for current and historical events for the US Coast Guard, State and Regional stakeholders, and the private sector. For this, we have enlisted the aid of Brett Estrade of Coastal Computing Services, LLC. Jason and Brett continue to work together to formalize the developer/operator tasks.

3. <u>End users:</u> We have had several end users with the year 5 research projects. *Gordon Wells*, Research Associate at the Center for Space Research at the University of Texas and Texas State Operations Center in Austin. We have been delivering results for Gordon to use since 2010 during the Deepwater Horizon spill, and our most recent interactions were during Cindy and Harvey in the 2017 hurricane season. Gordon and the Texas State Operations Center (SOC) used our ADCIRC wind and water level guidance to make decisions about moving high profile vehicles, pre-positioning rescue and recovery assets, and operating the TxDOT Ferry system, among other things. We already have a CRC project in place to develop an inland wind product to fulfill a request he made, and we are planning multiple site visits to Texas to develop a sustainable funding agreement.

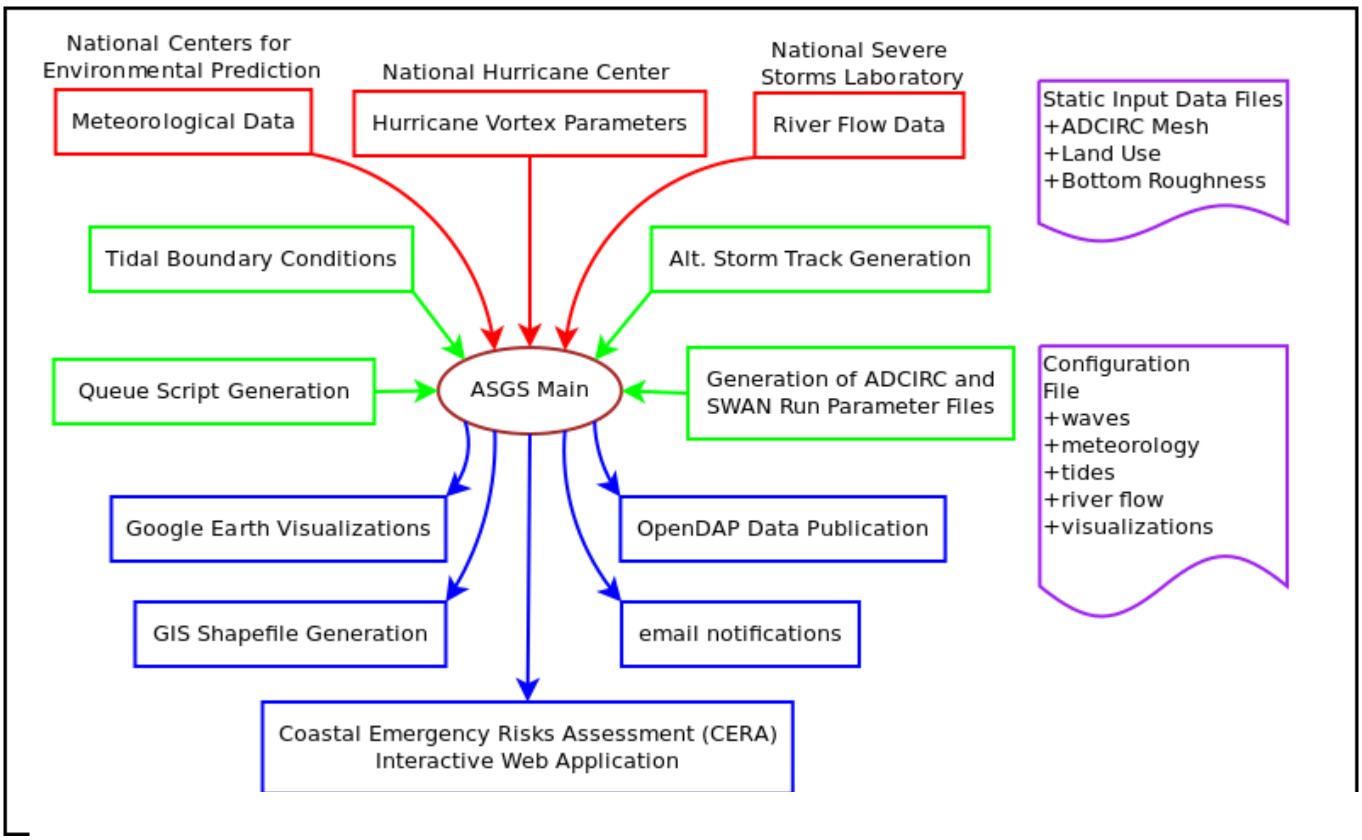


Figure 2 Research innovations require a clear technical structure for integration, delivery, and feedback collection. The ADCIRC Surge Guidance System (ASGS) provides this structure.

Lead Hydrologist for the West Gulf River Forecast Center of the National Weather Service during the Year 5 performance period. This person has specifically expressed an interest in developing model guidance for total water level, including both coastal storm surge and river discharge. Our research deliverables include improvements for modelling river discharge, and we are planning site visits to the WGRFC for outreach, training, and product feedback.

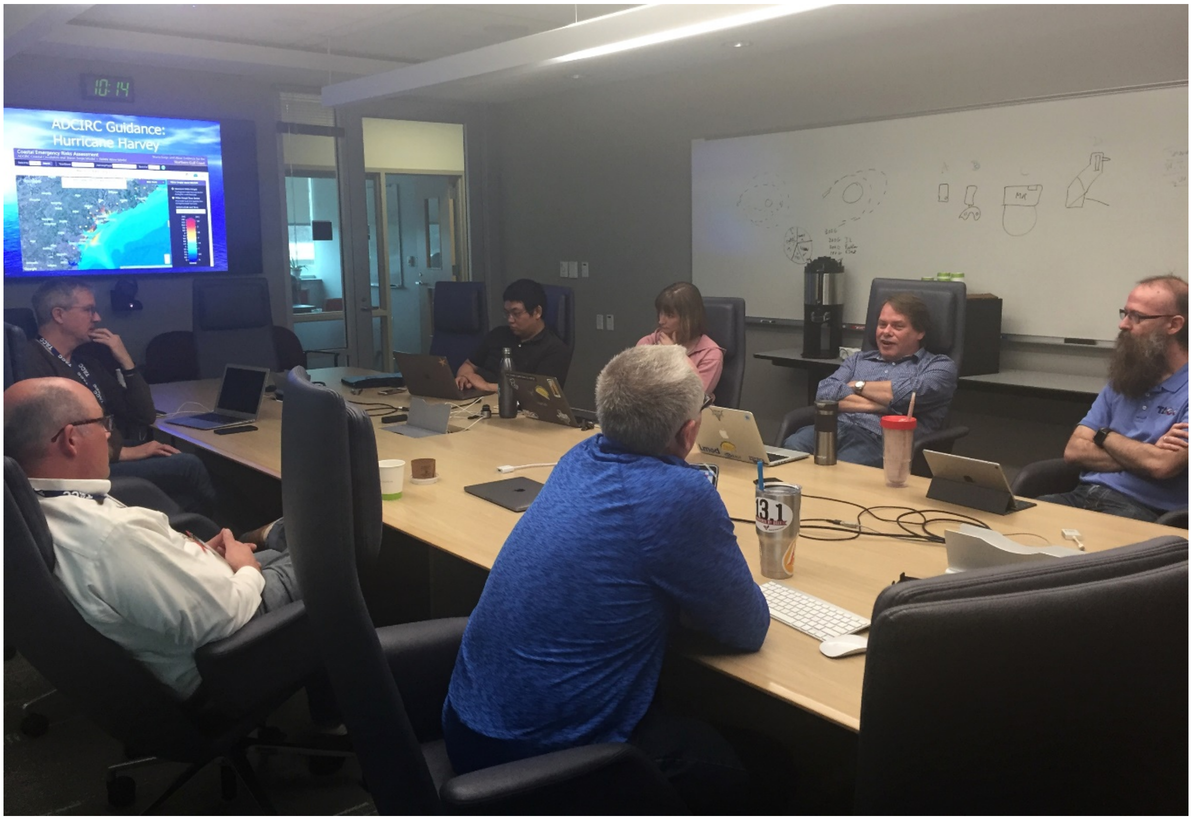


Figure 3 Success: Our new Summit meetings with our HPC partners brought key players together: science (Clint Dawson), end users (Gordon Wells), HPC (Bill Barth et al, from TACC), and Operations (Jason Fleming, Brett Estrade, and Carola Kaiser). The focus was on building relationships to facilitate the practical logistics of real time model guidance production.

Ignacio Harrouch, Director of Operations for Louisiana Coastal Protection and Restoration Authority (CPRA). The CPRA has responsibility to operate the flood protection structures (gates) and pumps throughout the hurricane protection system as well as the rest of the State of Louisiana. We have a sustainable funding contract already in place with CPRA (via LSU) to produce water level information products via ASGS. Ignacio and his team will be using our model guidance for water level (especially with timing information) to make operational decisions. He is providing detailed feedback on the effectiveness and appropriateness of our products and services; this feedback will be incorporated in future products for CPRA. We have multiple visits planned for Baton Rouge to provide outreach and training as well as receive feedback to strengthen this relationship and maintain its financial stability and growth.

Search and Rescue (SAR) Environmental Data Coordinator for the US Coast Guard during the Year 5 performance period. This person coordinates the acquisition and use of model guidance data for winds and currents for Search and Rescue Operations for the US Coast Guard. USCG SAROPS has been using our ADCIRC guidance from ASGS for water currents in the Albemarle-Pamlico Sound of North Carolina operationally since 2016. They have also recently expressed an interest in additional model products as well as expansion of

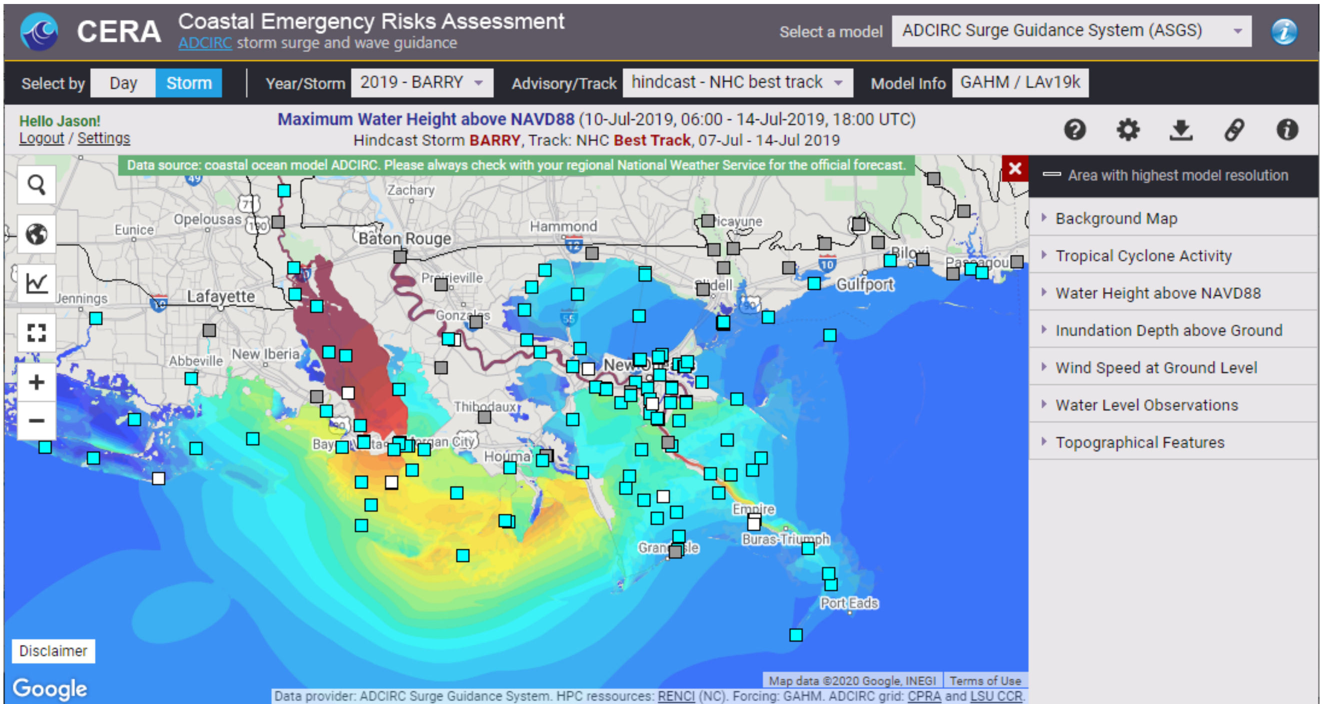


Figure 4 Hurricane Barry of 2019 successfully showcased the strength and uniqueness of our services and data products to high level stakeholders, particularly Ignacio Harrouch, Director of Operations at the Louisiana Coastal Protection and Restoration Authority (LA CPRA).

the use of our model guidance in other regions, starting with Lake Pontchartrain in Louisiana. We have begun developing plans for sustainable SAR funding going forward with Eoin Howlett at RPS ASA (their prime contractor for environmental data services) with new products in new geographical areas, both in the US and internationally.

Tom Langan, Engineering Supervisor, North Carolina Floodplain Mapping Program (NCFMP). Tom has expressed an interest in the resolution enhancement work that CRC PI Casey Dietrich has developed with leveraged research funding. The workflow that Casey has developed is fully functional and is used to enhance the resolution of storm surge results from the level of the ADCIRC mesh up to the spatial scale of the DEM, which is typically much finer. We have been working with Casey, in particular at our successful RENCI Hurricane Model Guidance Summit in January 2020, to operationalize his existing workflow and coordinate with Tom regarding the suitability and effectiveness of the resolution enhanced water level results for decision support in North Carolina.

4. <u>Transition:</u> During this Year 5, we were able to complete several of our objectives, despite the issues associated with COVID-19. We hosted our first virtual ADCIRC Boot Camp from April 1st through April 3rd. Through this we recognized that can reach a much greater, worldwide audience than the in-situ format we had been working with prior to COVID-19. We have continued to provide ongoing operation of ADCIRC Surge Guidance System and it is well within the realm of working 24/7/365 to produce guidance for current and historical events for the US

Coast Guard, State and Regional stakeholder, and the private sector. For this, we have enlisted Brett Estrade of Coastal Computing Services, LLC. Jason and Brett continue to work

together to formalize the developer/operator tasks. Finally, we had over 30 participants in our virtual Boot Camp from all over the United States and the world.

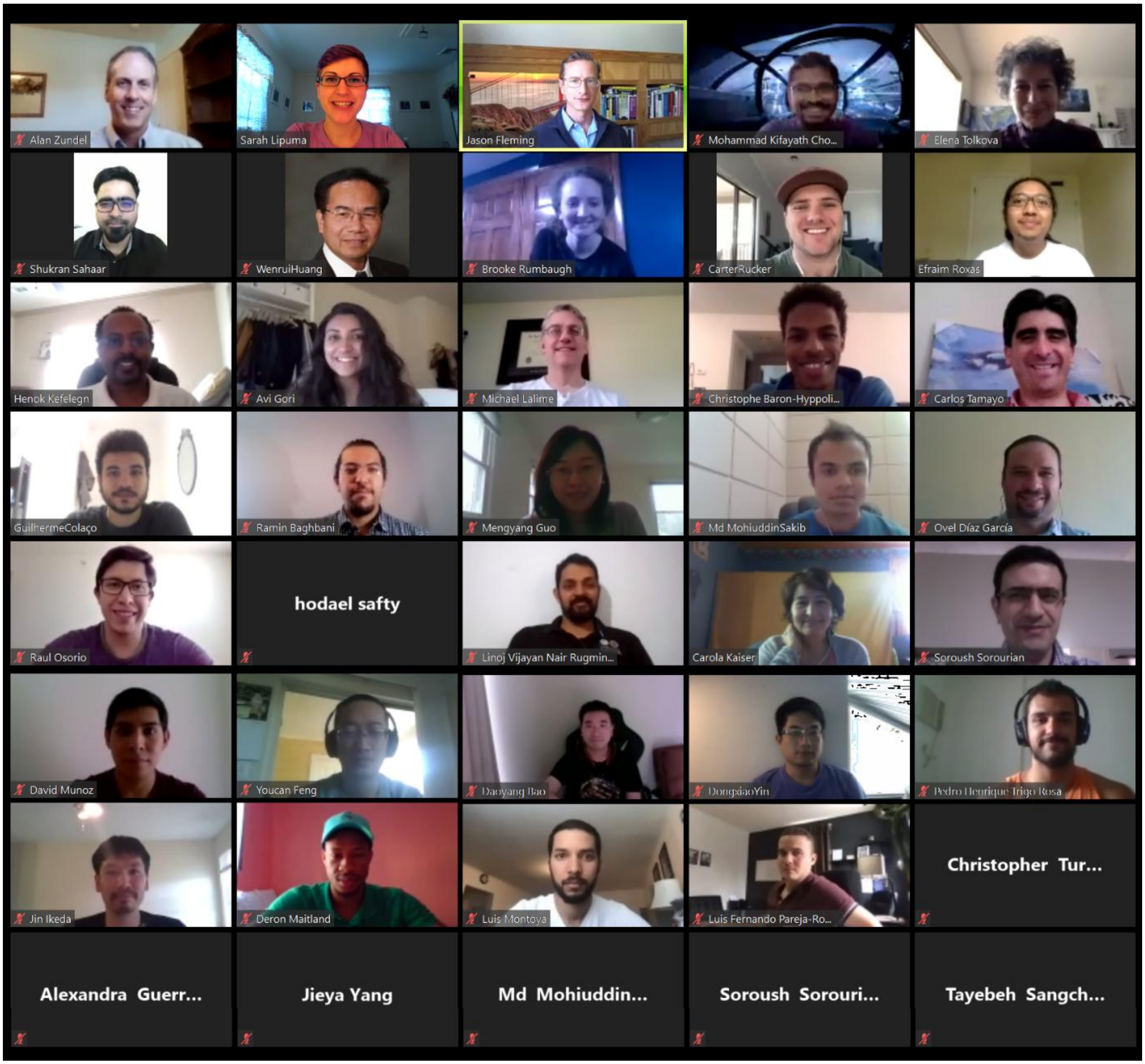


Figure 5 Our first ever **Virtual ADCIRC Boot Camp** in 2020 was a great success, with many new participants registering to participate after the change to a fully virtual format was announced. This increased the reach of the event considerably, as well as reducing the cost for all involved. We are taking this as a very positive lesson learned for all future training events.

5. <u>Project Impact:</u> Describe the real-world impact of your project that you accomplished or worked toward during Year 5. Include information about how your project's outcomes advanced current technologies or capabilities, especially with regard to DHS component agencies (e.g., saves lives, saves money and/or property, increases operational efficiency)

We made significant advances in coordination of real time model guidance, including training (Virtual ADCIRC Boot Camp in Spring 2020), team coordination for operational efficiency (leading virtual weekly meetings throughout calendar 2020 and leading daily virtual meetings during an active tropical cyclone event), actual storm impacts during this record breaking hurricane season (Tropical Storm Cristobal being the most significant event in the performance period ending 30 June 2020), and commercial transition for value proposition design including business model generation and testing based on stakeholder feedback gathered in Years 1-4. End user impact of this real time model guidance included the public sector at all levels as well as the private sector, academic researchers, and NGOs.

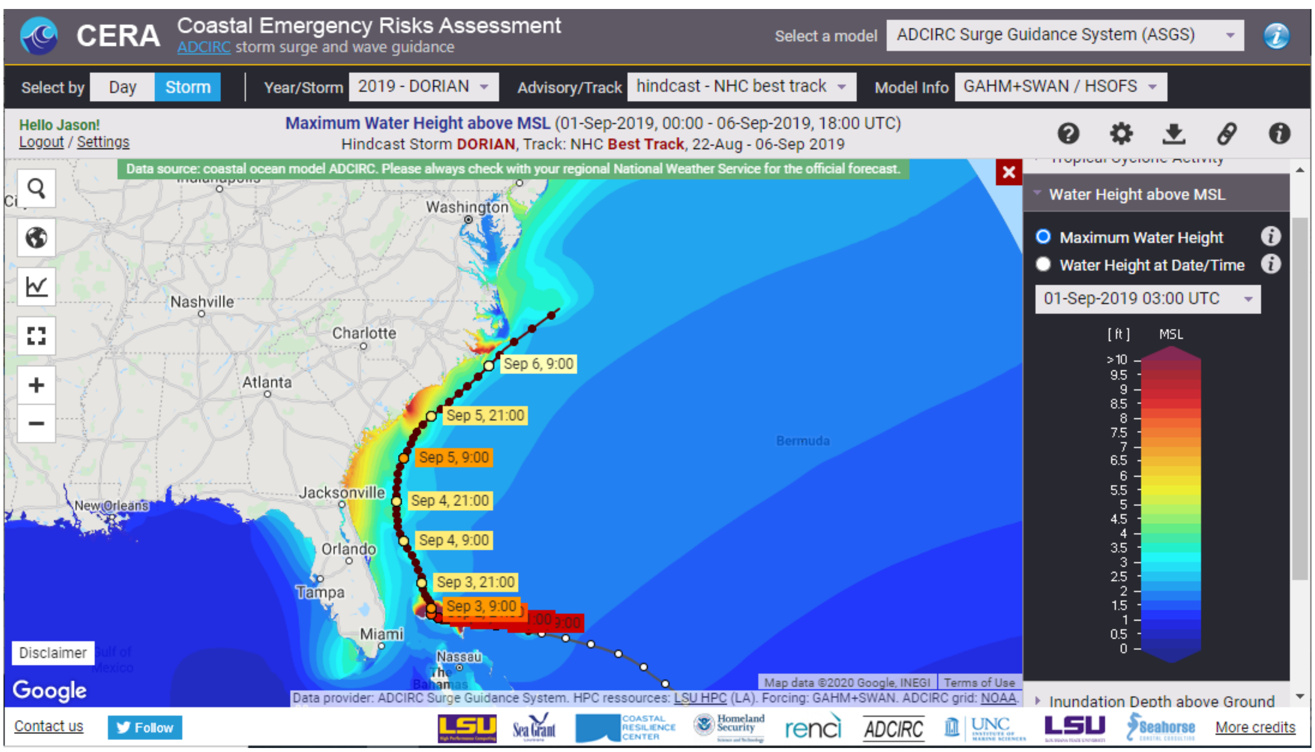


Figure 6 Hurricane Dorian of 2019 decimated the Bahamas and was forecast to do the same to Miami. We successfully deployed three FEMA meshes to provide guidance, leveraging the existing investments made by DHS for the HSE for Flood Insurance Studies (FIS) to also protect life and property in real time.

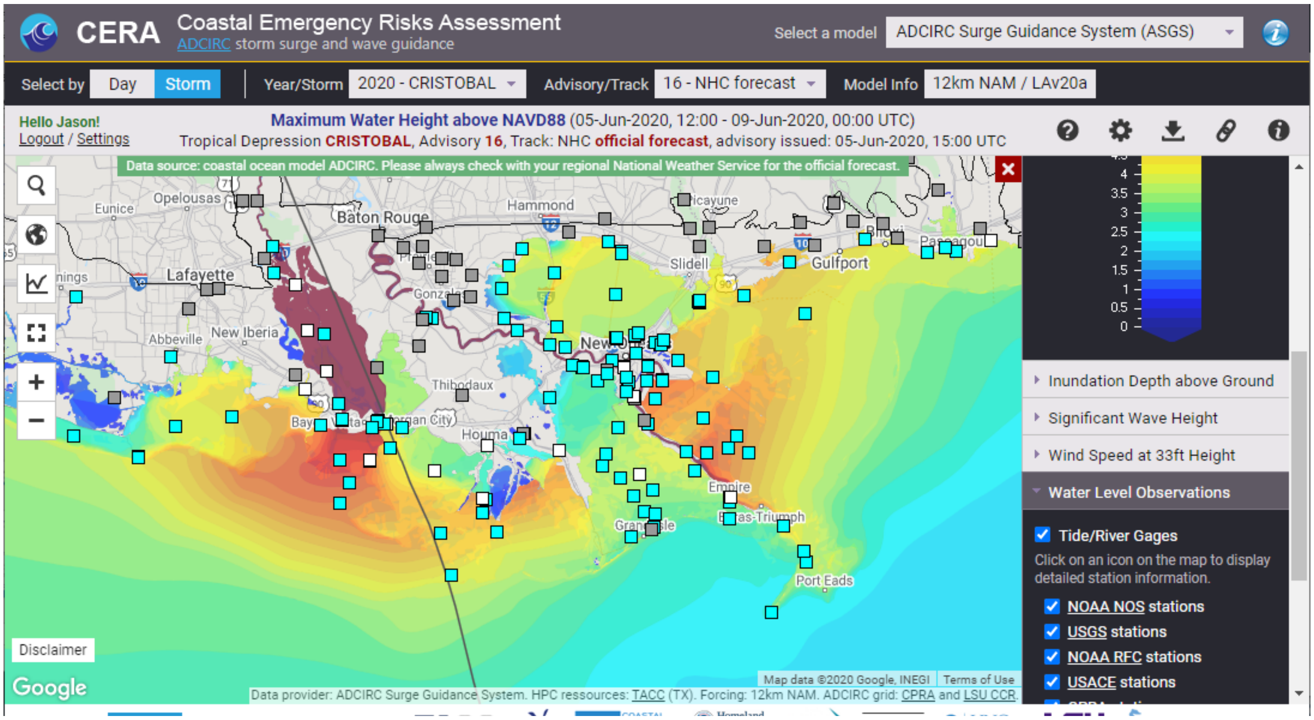


Figure 7 Tropical Storm Cristobal was our third named storm of the already active 2020 hurricane season. Our data products are now so important to LA CPRA that they timed the initiation of their battle rhythm to coincide with the first arrival of our model guidance products. Our model guidance team also held daily briefing calls with them each morning to discuss our latest results.

6. Unanticipated Problems: COVID-19 has impacted several of our outreach opportunities. In addition, a side-effect was that several of the super-computer locations were under-staffed during the pandemic. This led to unexpected computer outages that weren't solved within a timely manner due to diminished staffing.

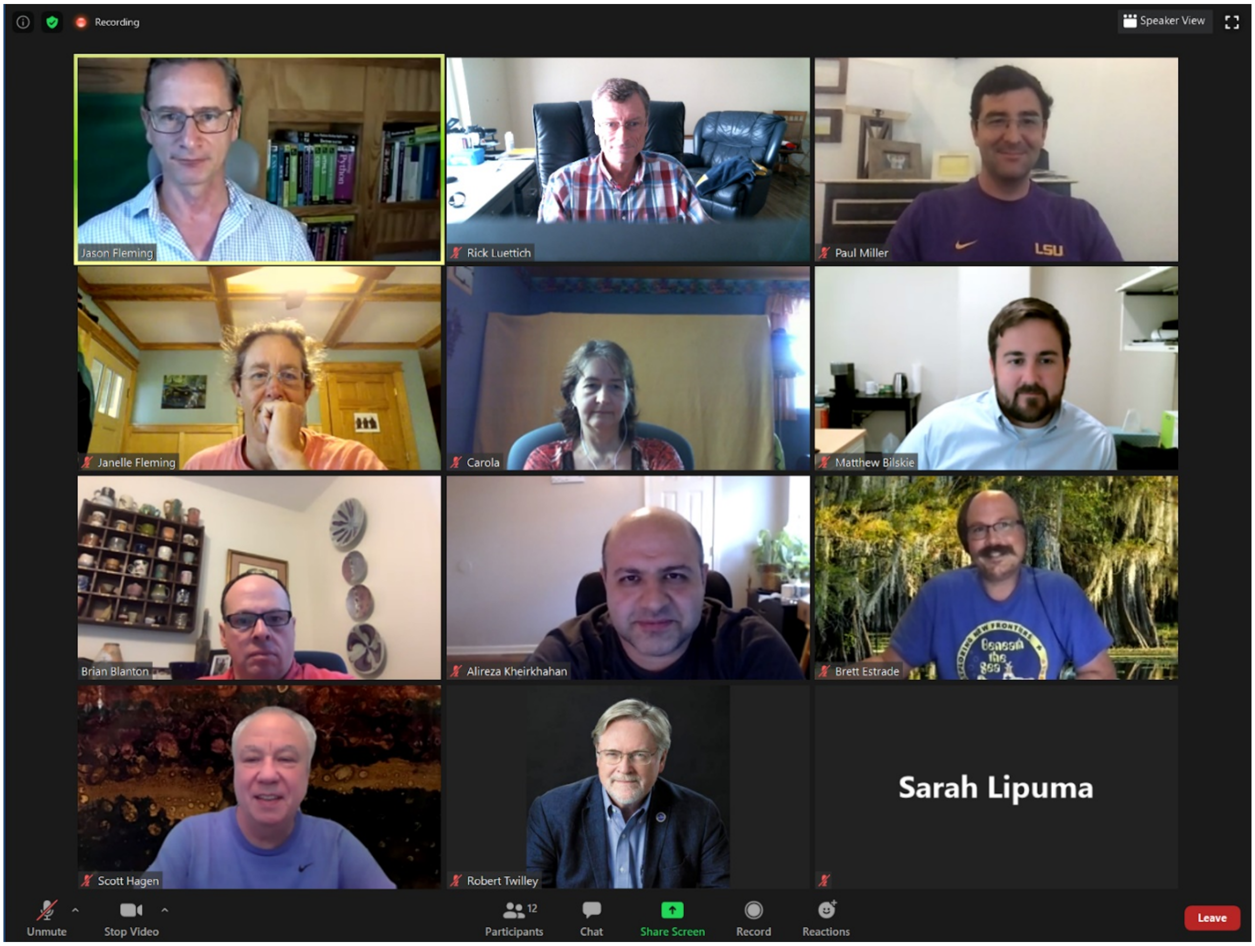


Figure 8 This is a screenshot of one of our real time model guidance coordination calls meant to illustrate our process for achieving operational efficiency for the HSE through coordination and execution during active tropical cyclone events.

7. <u>Student Involvement and Awards</u>:

a) We have been working with Sarah Lipuma, a graduate student studying coastal policy and land use planning at Duke University that is interested in storm surge impacts on communities. She also co-organized the first all-virtual ADCIRC Users Group and ASGS Boot Camp meetings this year.

b) Sarah Lipuma is a graduate student. Beyond this, several participants in the Boot Camp were graduate students and post-doctoral researchers from different Universities.

a) List any degrees attained by CRC-supported students during Year 5. Include student name and degree (BS, MS, Ph.D.) and major or field of study.

N/A

b) List any awards/recognition students achieved during Year 5.

N/A

8. Interactions with CRC education projects: None

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Experimenting with boundary conditions in ADCIRC from National Water Model	12/31/2021	40%	Insufficient calendar time : no cost extension needed
Complete testing of the resolution enhancement algorithm	06/30/2021	40%	Insufficient calendar time : no cost extension needed
Complete evaluation of results from multiresolution modeling	06/30/2021	40%	Insufficient calendar time : no cost extension needed
Research Milestone			
Integration of National Water Model boundary conditions in ASGS	12/31/2021	40%	Insufficient calendar time : no cost extension needed
Merge resolution enhancements workflow into ASGS post processing	06/30/2021	40%	Insufficient calendar time : no cost extension needed
Add workflow option to ASGS to implement multiresolution modeling	12/31/2021	40%	Insufficient calendar time : no cost extension needed

2. **Year 5 Transition Activities and Milestone Achievements**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Coordination a meeting between the developer, stakeholder, and institution for all transition activities	6/30/2020	100%	
Ongoing handling and managing support requests related to decision support services.	6/30/2020	100%	
Travel to client sites to gather technical requirements and feedback and establish business relationships.	6/30/2020	100%	
Planning and Organizing 2020 ADCIRC Boot Camp for graduate students, postdocs, faculty members, and practicing professionals to learn the details of running the ADCIRC model.	4/30/2020	100%	
Provide operational support for existing ADCIRC Surge Guidance System for all clients and stakeholders.	6/30/2020	100%	
Complete onboarding for the new backup ASGS Developer/Operator.	6/30/2020	100%	
Complete monthly readiness exercises to evaluate and demonstrate readiness.	6/30/2020	100%	
Prototype e-commerce portal implementation	6/30/2021	40%	Covid – 19 and prep for a unique hurricane season has delayed this
Travel to technical, business, and scientific meetings as described in the planned travel schedule below.	12/31/2021	50%	Covid -19 (travel replaced with virtual meetings)
Transition Milestone			
Successful delivery of Year 5 deliverables assigned to transition project participants	6/30/2021	50%	
Complete a report detailing support ticketing system and related metrics for use in improving client and stakeholder experiences as well as sales conversion.	6/30/2021	50%	Survey sent out to CERA users, Surveys sent out to Boot Camp participants
Highly available ASGS results produced and delivered redundantly and robustly 24/7/365.	6/30/2020	100%	

Delivering 2020 ADCIRC Boot Camp for graduate students, postdocs, faculty members, and practicing professionals to learn the details of running the ADCIRC model.	4/30/2020	100%	Completed virtually due to covid-19
Ongoing operation of existing ADCIRC Surge Guidance System for all clients and stakeholders.	6/30/2020	100%	We continue to produce quality guidance
Complete onboarding for the new backup ASGS Developer/Operator.	6/30/2020	100%	Brett Estrade
Complete monthly readiness exercises to evaluate and demonstrate readiness	6/30/2020	100%	With Covid-19, we were a little delay, but 3 named storms within 2 weeks has remedied this.
Prototype e-commerce portal implementation ready for business in 2020 hurricane season	6/30/2021	50%	Covid-19

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function	Brief Product Description, including type (e.g., software, algorithm, guidance document, knowledge product)	Date Delivered (or projected date of delivery)	Recipient or End User(s)

IV. PUBLICATIONS AND METRICS

1. Publications:

- "Dynamic Water Level Correction in Storm Surge Models Using Data Assimilation." Authors: Taylor G. Asher, Richard A. Luettich Jr. and Jason G. Fleming. Submitted to Ocean Modelling. In revision.
- "Influence of storm timing and forward speed on tides and storm surge during Hurricane Matthew." Authors: Ajimon Thomas, JC Dietrich, TG Asher, M Bell, BO Blanton, JH Copeland, AT Cox, CN Dawson, JG Fleming, RA Luettich. Ocean Modelling. Published. https://doi.org/10.1016/j.ocemod.2019.03.004
- "Forecasting Model, Forecast Advisories and Best Track in a Wind Model, and Observed Data – Case Study Hurricane Rita." Authors: Abram Musinguzi, Muhammad Akbar, Jason

G. Fleming, Samuel K. Hargrove. Journal of Marine Science and Engineering. Published. J. Mar. Sci. Eng. 2019, 7(3), 77; https://doi.org/10.3390/jmse7030077

- Media coverage of the 2019 Texas ADCIRC Week training event that PI Jason Fleming organized: "DesignSafe ADCIRC Provides Storm Surge Simulators for Natural Hazards Community" (picked up and republished by HPCWire): https://www.hpcwire.com/off-the-wire/designsafe-adcirc-provide-storm-surge-simulators-for-natural-hazards-community/
- CRC Coverage of 2019 ADCIRC Users Group Meeting event that PI Jason Fleming organized: https://www.flickr.com/photos/133219410@N05/albums/72157709249042136

2. Performance Metrics

N/A

RICHARDSON, JSU
DHS COASTAL RESILIENCE CENTER
APS™ Business Plan
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020

I. INTRODUCTION

Project Title: ADCIRC Prediction System™ Business Plan Development

Principal Investigator Name/Institution: Tom Richardson, Jackson State University

Additional Research Participants/Partners: Nancy Maron and Kimberly Schmelzinger, Blue Sky to Blue Print, LLC; Jason Fleming, Seahorse Coastal Consulting; Brian Blanton, University of North Carolina at Chapel Hill; Robert Twilley, Louisiana State University; Rick Luettich, University of North Carolina at Chapel Hill

Short Project Description:

We intend to transition products and services associated with the real-time 24/7 ADCIRC Prediction System™ (APS™), comprised of the ADCIRC Surge Guidance System (ASGS), the Coastal Emergency Risks Assessment decision support web portal (CERA) and the ADCIRC storm surge model. Based on several years of development and pilot testing supported by the Coastal Resilience Center of Excellence (CRC), we believe a base of stakeholders exists who place high value on the products and services the APS™ can provide. The challenge is to develop a viable business model for the APS™ that will allow us to transition innovations from CRC projects into stakeholder desired products and services and to ensure their continued operation and expansion past the end of the CRC funding cycle in 2020. Setting up the APS™ business model involves three primary activities: (i) the development of a business plan to support the APS™ ; (ii) the continued build out of the APS™ by transitioning recent CRC innovations into its product offerings; and (iii) stakeholder identification and the expansion of the stakeholder community via enhanced outreach and training activities. This scope of work describes the first of these activities, the development of an APS™ business plan. The continued buildout of the APS™ and the identification / expansion of stakeholders are described in scopes of work to Seahorse Coastal Consulting (Jason Fleming, PI) and Louisiana State University, (Robert Twilley, PI).

II. PROJECT NARRATIVE

1. Project overview: APS™ has been developed and operated primarily with funds provided under a Cooperative Agreement between the Department of Homeland Security and the University of North Carolina at Chapel Hill. Supplemental funding has come from the Louisiana Sea Grant program. The Cooperative Agreement will terminate 30 days after the start of the 2022 hurricane season, and will receive reduced funding for most of the 2021 season. If APS™ is to continue providing high-resolution, near-real-time surge forecasts,

there is an urgent need to establish a business plan for continued support and to begin implementing that plan during or shortly after the 2020 hurricane season.

2. Results: In September, 2019, a contract was established with BlueSky to BluePrint, LLC, to lead development of the APS™ business plan. Activities during Year 5 have centered largely around providing the information and data needed to support that contract and its efforts. Results during Year 5 included market assessments via surveys and individual interviews and development of a detailed cost and revenue model. A project support team was formed that consists of the PI plus the additional research partners listed above. During Year 5, this support team met in person 3 times and virtually approximately 25 times. Other related activities during Year 5 included exploring data visualization options with several companies and platforms already active in the field of natural hazard risk assessment. Several of these options appear promising and will be explored in more detail in Year 6.

3. End users: End users who participated in the project during Year 5 included the 668 registered CERA users plus over 35 individuals representing key market segments in the Federal government, state and local agencies, academia, and the private sector.

4. Transition: In early April, 2020, a survey was sent (http://tiny.cc/5z0kmz) to the 668 registered CERA users to assess their patterns of interacting with CERA, how they were using APS™ products, and what additional capabilities they would like to see. Soon thereafter, individual interviews were conducted with many of the 35 individuals mentioned in item 3 above. These interviews explored product use and potential market needs in much greater detail.

5. Project Impact: The impact thus far of this project on APS™ has been to help identify structural, governance, and financial issues that will be key to its success in the post-Cooperative-Agreement environment. Since APS™ originated in academia and grew somewhat organically in its early years, it lacked many of the features and characteristics common to small businesses. The process of developing a business plan has highlighted the need for a more focused approach to the overall enterprise.

6. Unanticipated Problems: Although BlueSky to BluePrint, LLC, had broad experience in helping transition products and systems from academia to “the real world”, they were completely unfamiliar with the highly specialized field of numerical modeling and storm surge prediction. They were selected in part because this unfamiliarity would help ensure a fresh perspective, which it has. However, we underestimated its effect on the learning curve necessary to be able to give sound business advice. Therefore, project spin-up was slower than originally planned.

7. Student Involvement and Awards: NA

8. Interactions with CRC education projects: NA

III. STATUS OF CONTRACT TASKS A/O JUNE 30, 2020

Phase	Description	# Days	Timings
Project Initiation	Kick-off meeting & project set-up	2	Month 1
	Interview members of project team (5-8)	2	
	Attend PI Meeting Chapel Hill	2	
Phase I: Defining the Product/Service and its Competitive Positioning			
Landscape Review	Scan of environment	3	Month 2
	Develop interview guide and interview up to 10 experts	5	
	Draft findings, including recommendations for positioning vis à vis partners, competitors	2	
Audience Assessment	Develop segmentation and identify interviewees	3	Months 3-5
	Draft interview guide & develop product/service concepts	3	
	Up to 20 Interviews with members of these segments	7	
	Draft findings	2	
Product Definition	Facilitated meeting - review findings, define product	3	Month 5
Phase II: Strategic Assessment of Operations and Finance			
Financial Analysis	Develop projections based on possible revenue streams	5	Months 5-6
	Develop pricing model for leading option	5	
	Develop forward operational budget, P+L format	5	
Marketing/Sales Strategy	Based on revenue projections, develop 6- & 12-month strategy for client acquisition, including guidance on marketing and outreach	5	Month 7
Governance	Gather data from partners/stakeholders	3	Months 8-9
	Develop documentation - terms of reference; staffing role descriptions; participation guidelines, governance model -showing decision-	4	
	Meet with leadership team to review & revise plan	2	
Final Report	Production of final recommendation report	2	Month 10

< All Complete

< Complete
< Complete
< Underway

< Complete
< Complete

< Complete
< Initiated

< Shift to Year 6

< Partial Complete
< Shift to Year 6
< Shift to Year 6

Theme 4

Education and Workforce Development

WHALIN, JSU
DHS COASTAL RESILIENCE CENTER
EDUCATION PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: PhD in Engineering (Coastal Engineering and Computational Engineering) at an HBCU.

Principal Investigator Name/Institution: Robert W. Whalin, Ph.D., P.E., D.CE; Professor of Civil Engineering and Education Director, Coastal Resilience Center of Excellence, Jackson State University (JSU).

Other Partners/Institutions: US Army Engineer Research and Development Center, Vicksburg, MS and Texas A&M University at Galveston.

Short Project Description ("elevator speech"):

This project focuses on strengthening the establishment and institutionalization of the PhD in Engineering (Coastal Engineering and Computational Engineering concentrations) accomplished during years 1 to 3 of this CRC education project. A steady output of MS and PhD Engineering degree graduates with Coastal Engineering or Computational Engineering concentrations focused on coastal natural disasters is projected to be established by the end of year six, This output of graduates will help increase workforce diversity in the greater Homeland Security enterprise.

II. PROJECT NARRATIVE:

1. **Project overview:** This project directly addresses the education need for graduate engineering programs focused on coastal natural disasters to provide engineers that can help mitigate the ever-increasing cost of damages, especially those from tropical storms and hurricanes, that DHS is confronted with through FEMA missions. Almost no graduate coastal engineering programs are focused on coastal natural disasters and none are located at an HBCU where a large percentage of African American engineers matriculate. Jackson State University has an African American student body exceeding 80% which will directly support the DHS Strategic Plan Goal to Enhance the DHS Workforce, especially the Objective to increase Workforce Diversity and Priority Goal 3 to Enhance Resilience to Disasters. Leverage of federal assets is assured by the Education Partnership Agreement (authorized by Public Law) between the Engineer Research and Development Center and Jackson State University. The Agreement facilitates ERDC providing Adjunct Faculty, student internships and potential use of ERDC experimental and computational facilities for graduate research. An excellent record of DHS End User involvement and transition of graduates to end users continued throughout year five of the Coastal Resilience Center of Excellence. Research staff and graduate students had direct participation in a research project; and in highly relevant hurricane barrier projects nationwide (funded by others)

including the Ike Dike concept for protecting Galveston Island and the greater Houston metropolitan area from devastating, albeit low probability, hurricane surges. Coastal Engineering education programs nationwide have been on a decline for the past two decades and United States leadership in the coastal engineering profession has declined relative to other nations. This project will help ameliorate the trend while increasing the supply of minority coastal and computational graduate level engineers focused on the field of coastal natural disasters.

2. **End users:** A list of end-users that participated in this project during Year 5 follows. Their project role is included focusing on facilitating transitions to these end users as appropriate. Discussions were held with each at either the CRC Annual Meeting, at ERDC, at MS Engineering Society Meetings, during classes or on other professional occasions.

Table 1: End-User Involvement

End-User	Agency/Employer	Project Role (Year 5)
Subject Matter Expert, DHS	FEMA Region IV	Transition, potential employer
Chairman, Free Flow Power Development, LLC	Free Flow Power	Collaborator (guest lecturer), Transition (assists with student internships/employment).
GIS Specialist	MEMA	Collaborator, Transition (potential employer of graduates)
Division Chief, MVX	USACE Vicksburg District	Transition (potential employer): Sponsored student Society of American Military Engineers. Discussed engineer government careers, employer of graduates.
Vice President, PE	SDW	Transition (potential employer)
Research Engineer	USACE, ERDC, CHL	Collaborator, research advisor for a PhD student: discussed dissertation research several times during Year 5.
Research Mathematician	USACE ERDC	Collaborator, Leveraged Project from TAMUG
Director, ERDC	USACE, ERDC	Transition, signatory for Education

		Partnership Agreements; had several discussions during Year 5.
Director, Geotechnical and Structures Lab	USACE, ERDC	Transition; GSL employs graduates. Held discussions.
Research Engineer, CHL	USACE, ERDC, CHL	Adjunct Professor, graduate courses; served on two graduate committees and one Qualifying Exam.
Research Engineer, CHL	USACE, ERDC, CHL	Adjunct Prof., graduate courses; served on one graduate committee and one Qualifying Exam.
Director, Coastal and Hydraulics Lab	USACE, ERDC	Approved joint research project and use of ERDC facility for project of mutual interest.

There is a very small number of end-users in FEMA, Corps of Engineers Districts, Emergency Management Agencies and private industry contractors who have engineers with graduate Coastal Engineering education (most especially African American and Hispanic American engineers). This project will help ameliorate this critical deficiency in widespread expertise (over 80% of JSU students are minorities, mostly African American). The immense cost to the taxpayers of rescue and recovery from Hurricane inundation, coastal and estuarine flooding from intensified precipitation events and tsunami inundation drives the need for additional engineers with graduate education focused on coastal natural disasters

3. **Unanticipated Problems**: None. A good year. But, I would point out three Year 5 unexpected circumstances. First, two international graduate students were denied student visas to study in the MS Coastal Engineering concentration a week before their departure for JSU in August 2019. Second, the pandemic induced shift to online classes in March 2020 was inconvenient and resulted in cancellation of The Netherlands research trip in May 2020. The third unexpected loss of a projected Year 5 PhD graduate which was an unavoidable occurrence. See Education Milestones.

4. **Students and recent graduates**:
   This project is a graduate program only. There are no undergraduate students. The number of students who want to enroll in graduate- level programs is not applicable. The data requested for students enrolled in CRC-supported courses during year 5 is restricted to the Core Coastal Engineering concentration graduate course. Elective courses are not CRC-supported.

   The number of student’s enrolled in CRC-supported courses during Year 5 was 24. There were zero undergraduates, 9 full time graduate students and 15 working professionals. 54% were minority students. One minority student graduated with a MS Engineering (Coastal Engineering concentration) degree and another minority student graduated with a PhD Engineering (Environmental Engineering concentration) degree. Two other students graduated with a MS Engineering (Civil Engineering concentration) degree. The total number of MS Engineering (Coastal Engineering concentration) degrees awarded through Year 5 is 11 of which 10 are minorities (6 female and 4 male). Seven of the eleven graduates are employed in the Greater Homeland Security Enterprise. Two of the seven are employed by the Corps of Engineers, one by Texas Department of Transportation and four by private industry engineering and construction firms. Of the four other graduates, one is a post doc in China, one at Nissan, one at Blue Origin and the other is self-employed.

5. **Project Impact**: This project impacted workforce capabilities during year five by graduating an additional MS (coastal engineering concentration student), as scheduled, that was a working professional in private industry. He was African American. One additional MS graduate is scheduled for July 2020. Two additional MS Engineering graduate students completed a year of graduate studies and are scheduled to graduate in May 2021 (one African American and one Caucasian). An additional, two graduate students were recruited to begin Coastal Engineering concentration studies in Fall 2020. Courses are revised every time taught by adding relevant new literature content. Most commonly from publications in the International Conferences on Coastal Engineering (ICCE), Journal of Coastal Engineering and the ASCE Coastal, Oceans, Ports and Rivers Institute journal. It is a responsibility of all faculty professors to update course content each time taught.

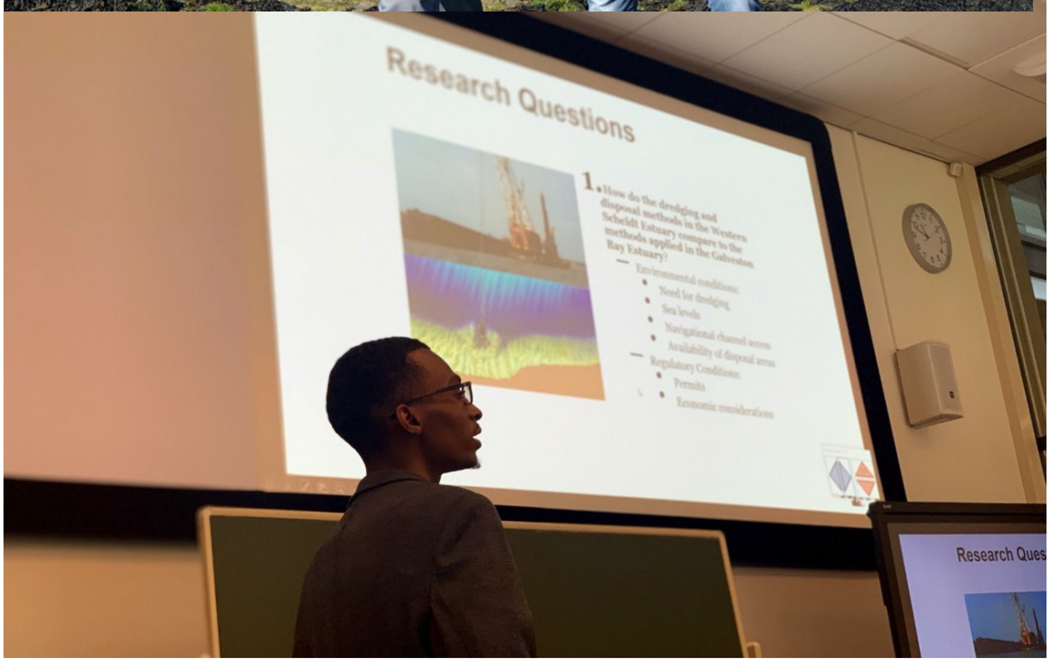
6. **Institutionalization**: The location where the project deliverables are maintained was confirmed upon submittal of the proposal. It is in the former Coastal Hazards Center, renamed the Coastal Resilience Center office complex (with conference room) in the JSU Mississippi e-Center (a 250ft^2 building on 30 acres). The Education program resides in the Department of Civil and Environmental Engineering and classes taught are part of the Civil and Environmental Engineering Department graduate academic offerings.

   The PI prepared all documentation required to gain approval for the PhD Engineering (Coastal Engineering concentration) Degree Program. The PhD Engineering degree was previously approved by the Mississippi Institutions of Higher Learning (IHL) along with concentrations in Civil Engineering, Environmental Engineering, Geological Engineering, Computer Engineering, Computational Engineering and Electrical Engineering. Degrees are approved at the IHL level. Concentrations within degree programs are approved at the University level. Formal institutionalization of a program occurs upon approval of the concentration, in this case, by the university and upon listing the degree program and concentration in the official University Catalog along with the degree requirements, admission requirements, curriculum, class numbers and class descriptions. The Coastal Engineering concentration of the PhD Engineering degree was evaluated, approved and formally signed by (in order):

   1. Department of Civil and Environmental Engineering Curriculum Committee
   2. Chair, Department of Civil and Environmental Engineering
   3. College of Science Engineering and Technology Curriculum Committee
   4. Dean, College of Science, Engineering and Technology
   5. Jackson State University Curriculum Committee
   6. Dean, Graduate Division, Jackson State University
   7. Provost and Vice President for Academic Affairs (Approved May 2018)

Post-CRC support will be on an equal footing with all other academic programs at JSU (similar to any university). Requests can and will be made for funds for graduate assistantships, teaching assistantships. Proactive efforts to obtain grants for graduate research assistantships have been and are being made. At the current time, external funding of about $400,000 annually seems to be relatively stable from the National Science Foundation and Department of Transportation. All are subcontracts from prime grant (Cooperative Agreement) recipients. Excellent partnerships and working relationships with several universities have been developed and nurtured (specifically University of North Carolina, University of Arkansas, Texas A&M University at Galveston, University of Florida and University of Puerto Rico at Mayaguez). Perhaps the most important source of Post CRC support is the Education Partnership Agreement (EPA) with the US Army Corps of Engineers Engineer Research and Development Center in Vicksburg, MS that is fully expected to continue. The EPA facilitates (a) joint research projects with ERDC, (b) ERDC researchers to teach mutually agreeable graduate courses, and serve on graduate committees and (c) use and/or loan of ERDC research equipment (including high performance computing assets).

7. **Interactions with research projects**: Year five interactions with research projects were mostly focused on interactions with the JSU CRC group. After the unexpected departure of one PhD Candidate at the beginning of Year 5, our other PhD Candidate was intensely immersed in his dissertation research and published one journal paper (as a co-author) and submitted another journal paper, as first author, based on his dissertation research. He has a third journal article near completion. One other PhD student was administered the PhD Qualifying Exam during Year 5 and should initiate her research during year six. Both the PhD students have full time engineering jobs in the Greater Homeland Security Enterprise as do four of the five MS students. SUMREX is not an option for students with full time positions. The most unusual and rewarding research experience for our graduate students is to compete to participate in the Independent place-based research in The Netherlands with a group of 15 students competitively selected by a NSF sponsored Partnership for International Research and Education (PIRE) entitled Coastal Flood Reduction. The 15 selected students are from Texas A&M University at Galveston (Prime), Rice University, Texas A&M at College Station, Jackson State University and University of Puerto Rico at Mayaguez. A two week place based research trip to The Netherlands is made during May each year to gain information needed for each student's report. The report is due in August at the end of the summer term. The pandemic cancelled the May 2020 trip where we had one student selected. Through Year 5, six of our students had been selected and produced research reports. The first four research reports (2016 and 2017 trips) are in the fifth listed publication by Kothius, Lee and Brody, Mr. Akil Mohammed who was selected to make the May 2019 trip, completed his research report in August 2019 during Year 5 and earned an A for his Independent Research investigation. Mr. Mohammad received his MS Engineering degree in May 2020. ERDC research engineers gave a lecture in each of my Year 5 academic year courses and I participated in the Tougaloo College research awards day ceremony.



Mr. Akil Mohammad: Making Research Presentation in Netherlands

III. EDUCATION ACTIVITIES AND TRANSITION MILESTONES

1. **<u>Year 5 Education Activities and Milestone Achievements:</u>** All four Year 5 education activities were completed. There were five education milestones of which four were met and one was partially met. The milestone Award at least one MS Engineering degree and one PhD Engineering degree to Coastal Engineering concentration students was partially met with Award of one MS Engineering degree in May 2020. The totally unexpected withdrawal from the university (to accept an engineering job) of a PhD Candidate (projected to graduate in Year 5) at the beginning of Year 5 caused us to miss the award at least one PhD Engineering degree part of this milestone. The young lady was an international student and her work VISA did not allow her to enroll in a university course to complete her dissertation research. She was scheduled to graduate in May 2020 and was well along with her dissertation research. She is working in the Greater Homeland Security Enterprise with a company that performs design and construction for the U.S. Army Corps of Engineers, State agencies and commercial firms. One PhD Qualifying Exam was scheduled and administered and one student completed the minimum required coursework for the PhD degree. One other student has completed all MS Engineering degree requirements except for one course which he is enrolled in for the Summer 2020 semester. He will graduate in July 2020 and has been accepted to the PhD Engineering degree program. The remaining PhD Candidate will either graduate in December 2020 or May 2021. He has one published paper relating to his dissertation research and has another paper being reviewed for publication. His PhD Preliminary Examination is scheduled for September 2020. This PhD graduate will 100% work for the greater Homeland Security Enterprise since he is an employee of the Coastal and Hydraulics Laboratory of the Engineer Research and Development Center. His dissertation research involves evaluating innovative concepts to mitigate hurricane flooding in back bays along the New Jersey coast.

Education Activities and Milestones: Status as of 6/30/2020			
Education Activities	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Enroll students in Coastal Engineering concentration of MS/PhD Engineering Degree Program.	Continuous	100%	
Advise MS/PhD Coastal Engineering concentration students.	Continuous	100%	
Schedule PhD Qualifying Exam.	Continuous	100%	
Administer PhD Qualifying Exam.	Continuous	100%	
Education Milestones		100%	

Enroll at least two students in Coastal Engineering concentration of PhD Engineering degree program.	6/30/2020	100%	
Schedule one or two PhD Qualifying Exams (Coastal Engineering concentration).	1/30/2020	100%	
Administer one or two PhD Qualifying Exams (Coastal Engineering concentration)	6/30/2020	100%	
At least one student complete minimum required PhD courses (non-research) in the Coastal Engineering concentration.	6/30/2020	100%	
Award at least one MS Engineering Degree and one PhD Engineering degree to Coastal Engineering concentration students.	5/30/2020	50%	The projected PhD graduate accepted a job offer at the start of Year 5. She was an international student and her VISA would not allow her to enroll in dissertation research.

2. **Year 5 Transition Activities and Milestone Achievements:** Achievements of Activities and Milestones were accomplished as scheduled with the exception of the totally unexpected loss of a PhD Candidate at the beginning of Year 5 as explained above for education milestone. By oversight, one transition milestone was identical to the education milestone. Otherwise, all transition milestones were met.

Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activities	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Recruit/sustain both MS and PhD students for Coastal Engineering concentration. Sustainment target is two students for both the MS and PhD program.	Continuous	Continuous 100%	
Advise MS and PhD Coastal Engineering concentration students. PI is the primary advisor, records of students advised are kept by PI.	Continuous	Continuous 100%	
Transition Milestones			
Award at least one MS Engineering degree and one PhD Engineering degree to Coastal Engineering concentration students.	06/2020	50%	Identical explanation to Education Milestone 5

Student employment/matriculation will be tracked post-graduation.	06/2020	100%	

3 Annual Courses and Enrollments

The following Tables enumerate the core courses and elective courses taught through Year 5 and their enrollment.

Table 1: Core Courses (Coastal Engineering Concentration)	
CIV 520	Advanced Engineering Analysis
CIV 538	Coastal Structures
CIV 539	Advanced Coastal Engineering Design
CIV 631	Linear Theory of Ocean Waves
CIV 632	Tides and Long Waves
CIV 636	Spectral Wave Analysis
CIV 637	Advanced Design for Breakwater Rehabilitation
CIV 698	Independent Study (4 Separate Courses of 1-4 hours)
CIV 899	Dissertation Research

Table 2: Elective Courses	
CIV 521	Advanced Engineering Analysis II
CIV 535	Pavement Design
CIV 542	Advanced Design of Concrete Structures
CIV 544	Advanced Design of Steel Structures
CIV 544	Advanced Design of Hydraulic Structures
CIV 550	Engineering Hydrology
CIV 561	Chemistry for Environmental Engineering
CIV 562	Hazardous Waste Engineering
CIV 566	Air Pollution
CIV 567	Environmental Remediation
CIV 568	Land Disposal of Waste
CIV 574	Engineering Hydrogeology
CIV 640	Finite Element Method
CIV 642	Pre-Stressed Concrete Design
CIV 661	Biological Processes in Wastewater Engineering
CIV 675	Earth Dams and Slopes

Table 3: Core and Elective Courses Core and Elective Courses Taught with Enrollments (Years 1-5)						
#CIV631	Course Title: Linear Theory of Ocean Waves	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	--	--	T/C
	Offering: Elective (E), Concentration (C), Minor (M)	C	C	--	--	C
	Number of Students Enrolled	6	5	--	--	5
#CIV637	Course Title: Advanced Design for Breakwater Rehabilitation	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	--	T	--	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	C	--	C	--	C
	Number of Students Enrolled	3	--	7	--	8
#CIV642	Course Title: Pre-Stressed Concrete Design	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	--	--	T/R	--
	Offering: Elective (E), Concentration (C), Minor (M)	E	--	--	E	--
	Number of Students Enrolled	4	--	--	5	--
#CIV698	Course Title: Independent Study (4 separate courses)	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T) (1 one hour course) (2 three hour courses)	T/R (4 courses)	T/R (4 courses)	T/R (3 courses)	T/R (1 course)	T/R (3 courses)
	Offering: Elective (E), Concentration (C), Minor (M)	C	C	C	C	C
	Number of Students Enrolled	1 each	1 each	1 each	1 each	1 each (3)
#CIV538	Course title: Coastal Structures	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	--	T	--	T/R	--
	Offering: Elective (E), Concentration (C), Minor (M)	--	C	--	C	--
	Number of Students Enrolled	--	6	--	8	--
#CIV636	Course title: Spectral Wave Analysis	**YR 1**	**YR 2**	**YR 3**	**YR 4**	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	--	T	T/R	--	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	--	C	C	--	C
	Number of Students Enrolled	--	5	5	--	5
#CIV539	Course title: Advanced Coastal Engineering Design	**YR 1**	**YR 2**	**YR 3**	**YR 4**	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	--	T	--	T/R	--
	Offering: Elective (E), Concentration (C), Minor (M)	--	C	--	C	--
	Number of Students Enrolled	--	6	--	7	--
#CIV520	Course title: Advanced Engineering Analysis I	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	--	T	T/R	T/R	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	--	C	C	C	C
	Number of Students Enrolled	--	9	4	7	8
#CIV535	Course Title: Pavement Design	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	T	-	T/R	T/R

	Offering: Elective (E), Concentration (C), Minor (M)	-	E	-	E	E
	Number of Students Enrolled	-	8	-	8	9
#CIV542	Course Title: Advanced Design of Concrete Structures	YR 1	YR 2	YR3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	T	--	--	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	E	-	--	--
	Number of Students Enrolled	-	9	-	--	--
CIV544	Course Title: Advanced Design of Steel Structures	YR 1	YR 2	YR 3	YR4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)		T	--	T	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	E	--	E	--
	Number of Students Enrolled	-	8	--	6	--
CIV544	Course Title: Advanced Design of Hydraulic Structures	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	T	-	T	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	E	-	E	--
	Number of Students Enrolled	-	9	-	5	--
CIV632	Course Title: Tides and Long Waves	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	T/R	-	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	C	-	--
	Number of Students Enrolled	-	-	10	-	--
CIV550	Course Title: Engineering Hydrology	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	T	-	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	E	-	--
	Number of Students Enrolled	-	-	10	-	--
CIV661	Course Title: Biological Processes in Wastewater Engineering	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	T	T	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	E	E	E
	Number of Students Enrolled	-	-	9	6	7
CIV561	Course Title: Chemistry for Environmental Engineering	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	T	-	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	E	-	E
	Number of Students Enrolled	-	-	6	-	7
CIV567	Course Title: Environmental Remediation	YR 1	YR 2	YR 3	YR 4	Yr 5

	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	T	-	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	E	-	--
	Number of Students Enrolled	-	-	7	-	--
CIV675	Course Title: Earth Dams and Slopes	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	T	-	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	E	-	E
	Number of Students Enrolled	-	-	9	-	8
CIV568	Course Title: Land Disposal of Waste	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	-	T/R	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	-	E	--
	Number of Students Enrolled	-	-	-	7	--
CIV574	Course Title: Engineering Hydrogeology	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	-	T/R	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	-	E	--
	Number of Students Enrolled	-	-	-	8	--
CIV640	Course Title: Finite Element Method	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	T	-	T/R	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	E	-	E	--
	Number of Students Enrolled	-	6	-	7	--
CIV681	Course Title: Excavation Support Systems and Retaining Structures	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	-	T	--
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	-	E	--
	Number of Students Enrolled	-	-	-	6	--
CIV899	Course Title: Dissertation Research	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	-	T/R	T/R
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	-	C	C (10 hours)
	Number of Students Enrolled	-	-	-	1	1
CIV521	Course Title: Advanced Engineering Analysis II	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	T	T	T
	Offering: Elective (E), Concentration (C), Minor (M)	E	E	E	E	E
	Number of Students Enrolled	6	7	6	5	6
CIV562	Course Title: Hazardous Waste Engineering	YR 1	YR 2	YR 3	YR 4	Yr 5

	Status: Developed (D), Revised (R), and/or Taught (T)	-			-	T
	Offering: Elective (E), Concentration (C), Minor (M)	-			-	E
	Number of Students Enrolled	-			-	8
CIV566	Course Title: Air Pollution	YR 1	YR 2	YR 3	YR 4	Yr 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	-	-	T
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	-	-	E
	Number of Students Enrolled	-	-	-	-	9
	TOTALS	**23**	**76**	**76**	**87**	**84**

IV. PUBLICATIONS AND METRICS

1. Publications:

- **Ebersole, Bruce; Richardson, Thomas** and **Whalin, Robert**, "Minimize Hurricane Surge Penetration into West/Galveston Bays: It's Crucial!" Proceedings, 11th Texas Hurricane Conference, University of Houston, Houston, TX, Aug. 2, 2019.
- Hu, Guojing, Lu, Weike; Wang, Feng; and **Whalin, Robert**, "Macroscopic Fundamental Diagram Based Discrete Transportation Network Design," Journal of Advanced Transportation, February 2020
- **Whalin, Robert W**., "A PhD in Engineering Degree: Coastal Engineering Emphasis Area," Proceedings, 126th ASEE Conference, Tampa Bay, FL, June 2019.
- **Ebersole, Bruce; Richardson, Thomas W.; Whalin, Robert W.,** "Suppression of Hurricane Surge Forerunner and Peak Surge in Galveston and West Bays Achieved with a Western Segment of the Coastal Spine," 10th Annual Texas Hurricane Conference, University of Houston, Houston, TX; Aug. 3, 2018.
- "NSF-PIRE, Coastal Flood Risk Reduction Program, Authentic Learning and Transformative Education", Volume 1-2015-2017; Edited by Baukje "Bee" Kothius, Yoonjeong Lee and Samuel Brody, March 2018.
- **Ebersole, Bruce; Richardson, Thomas**; and **Whalin, Robert, W.**, "Surge Suppression Achieved by Different Coastal Spine (Ike Dike) Alignments", 9th Annual Texas Hurricane Conference, University of Houston, August 4, 2017, Houston, TX.
- **Whalin RW**, Pang Q, Latham J, **Lowe LN**. Assessment of a Summer Bridge Program: Seven Years and Counting, 2017 ASEE National Conference Proceedings, Columbus, OH, June 24-28, 2017.
- **Whalin RW**. HBCU Engineering Faculty and Graduates: Implications for Race, Retention and Graduation Linkages, NAAAS & Affiliates 2016 National Conference Proceedings, Baton Rouge, LA, published Oct. 2016.
- **Whalin RW**, Brody SD, and Merrell WJ. The Galveston Bay Region as an International Test Bed for Flood Risk Reduction, 8th Annual Texas Hurricane Conference, University of Houston, Houston, TX, August 5, 2016.
- **Ebersole B, Richardson TW**, and **Whalin RW**. Modeling Coastal Storms: Past, Present and Future, 8th Annual Texas Hurricane Conference, University of Houston, Houston, TX, August 5, 2016
- **Whalin, Robert, W.; Pagan-Trinidad, Ismael**; Villanueva, Evelyn; and Pittman, David, W., "A Quarter Century of Resounding Success for a University/Federal Laboratory

Partnership", Proceedings, 123rd ASEE Annual Conference and Exposition, New Orleans, LA, June 26, 2016.

*All names are bold that were funded by CRC; Whalin, Richardson, Ebersole and Lowe

2. Performance Metrics

Whalin: Performance Metrics

Metric	**Year 1** (1/1/16 – 6/30/16)	**Year 2** (7/1/16 – 6/30/17)	**Year 3** (7/1/17- 6/30/18)	**Year 4** (7/1/18- 6/30/19)	**Year 5** (7/1/19- 6/30/20)
HS-related internships (number)	5	4	3	3	1
Undergraduates provided tuition/fee support (number)	1	0	0	0	0
Undergraduate students provided stipends (number)	0	0	0	0	0
Graduate students provided tuition/fee support (number)	4	7	10	4	6
Graduate students provided stipends (number)	2	6	6	3	3
Undergraduates who received HS-related degrees (number)	2	3	3	3	3
Graduate students who received HS-related degrees (number)	0	4	4	5	4
Certificates awarded (number)	0	0	0	0	0
Graduates who obtained HS-related employment (number)	1	2	3	4	3
Lectures/presentations/seminars at Center partners (number)	1	1	1	1	1
DHS MSI Summer Research Teams hosted (number)	0	0	0	0	1
Journal articles submitted (number) (includes peer reviewed conference proceeding)	2	0	0	0	1
Journal articles published (number) (includes peer reviewed conference proceeding)	2	4	0	0	1
Conference presentations made (number)	2	4	3	2	2
Other presentations, interviews, etc. (number)	5	3	5	3	4
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	0	4	2	2	2
Requests for assistance/advice from other agencies or governments (number)	0	3	2	2	2
Dollar amount of external funding			$941,825 (YRs 1-3)	$424,854 Year 4	$404,791
Total milestones for reporting period (number)	3	4	3	7	7
Accomplished fully (number)	2	3	3	7	5
Accomplished partially (number)	1	0	0	0	2
Not accomplished (number)	0	1	0	0	0

FAIK, JCSU
DHS COASTAL RESILIENCE CENTER
EDUCATION PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Preparing Tomorrow's Minority Task Force in Coastal Resilience through Interdisciplinary Education, Research, and Curriculum Development.

Principal Investigator Name/Institution:
PI, Dr. Ahmed Faik, Chair and Assistant Professor of the Department of Computer Science and Engineering Johnson C. Smith University
Other Partners/Institutions: UNC-Chapel Hill, UNC-Charlotte, and Jackson State University (major partners)
Short Project Description ("elevator speech"):

In this DHS-funded program we aim to emulate the integrative and interdisciplinary nature of real-world problems with our project based courses and summer camps. This program aims at preparing tomorrow's minority task force in coastal resilience (almost all of JCSU students are minorities) by presenting tailored courses in coastal resilience, applied research experience, knowledge transfer activities, scientific seminars, and summer camps. Project-supported courses are designed to introduce engineering and data analytics to better understand coastal resilience. Summer camps, seminars and undergraduate research projects are powerful tools used to engage all students and all disciplines in addressing coastal resilience issues.

II. PROJECT NARRATIVE:

1. Project overview:

Given the national need to prepare future coastal resilience professionals with educational and research experience, this proposed program supported a critical mission. Most existing coastal resilience related curriculum currently either target graduate programs or vocational education. We developed an undergraduate education framework that meets the needs and standards for excellence in undergraduate education. In addition, we conducted several research projects during the regular semesters as well as during the summer that aimed at engaging the students in coastal resilience-related subjects. The students were introduced to and learnt how to use specialized software (e.g. Tableau and Arc-GIS) and apply them on real-life events.

The project was designed around the following aims:

1) **Goal 1:** Develop a curriculum to prepare undergraduate students for careers in coastal resilience;
2) **Goal 2**: Create partnerships to conduct applied research in the area of coastal resilience;
3) **Goal 3:** Create ongoing opportunities for the transfer of skills, knowledge, people and ideas between JCSU and the community at large.

To help reach the above-mentioned goals, we defined the following processes:

1) Process 1: Develop four new courses to educate students with demonstrated interests and aptitudes in coastal resilience study;
2) Process 2: Design and deploy interdisciplinary coastal resilience seminar series;
3) Process 3: Establish and develop Faculty/Student research collaborations in coastal resilience;
4) Process 4: Design and offer a 1-week summer research camp to expose and increase the awareness of undergraduate students in coastal resilience study.
5) Process 5: Design and offer a 4-week summer research project to expose and increase the awareness of undergraduate students in coastal resilience study.

2. End users:

   - In the Fall of 2019 two faculty members with 4 students each conducted two separate DHS CRC related research projects.
   - In the Spring of 2020 four faculty members with a total of 12 students conducted four separate DHS CRC related research projects.
   - In the Summer of 2020 two faculty members guided 25 students through a 1-week intensive DHS CRC related research projects.
   - In addition, during the Summer of 2020 three faculty members with a total of 12 students conducted four separate DHS CRC related research projects.

3. Unanticipated Problems:

   We did not manage to get any faculty from the End user's list in our work-plan to give their talks during the Fall 2019 semester. We planned on getting at least a couple during the Spring 2020 semester, but our plans were cut short by the unforeseen circumstance brought by the COVID-19 pandemic.

4. Students and recent graduates:

   Given the current circumstances due to the pandemic and the fact that the students have just graduated 2 weeks ago, we do not know yet where our graduates may end up applying for.

Information was collected last semester, Spring 2020, from graduating students and more information will be collected from more graduating students this semester. This information will be reported later in the year.

5. Project Impact:

   The courses incorporated cybersecurity, data mining, machine learning, ArcGIS and bioinformatics.

a) Institutionalization:

Funding Agency	Project Title	Project Director or PI	Project Period	Amount Awarded
UNCC/Defense Intelligent Agency	UNC Charlotte Intelligence Community Center of Academic Excellence	Awatif Amin, Anita Bledsoe-Gardner	09/09/2019 09/08/2024	$195,651
DOL/University of Cincinnati subaward	The "NEXT" Apprenticeship Program	Terik Tidwell, Ahmed Faik	01/01/2020 07/14/2023	$261,580
Exxon Mobile/Oxford University's subaward	Worldwide Antimalarial Drug Resistance Network Project	Sabina Otienoburu	01/01/2020 12/31/2020	$19,809
Department of Education, Office of Post-secondary Education	Minority Science and Engineering Improvement Program (MSIEP): Embedding Active and Experiential Learning and Entrepreneurial Thinking into Computer Science and Engineering Education	Suryadip Chakraborty	10/01/2017 09/30/2020	$736,286
Department of Education, Office of Postsecondary Education, MSEIP Supplemental Grant	Minority Science and Engineering Improvement Program Capacity Competitiveness Enhancement Model (MSEIP CCEM)	M. Todd Coolbaugh, Sabina Otienoburu, Rosalyn Lang Reid	10/01/2018 09/30/2020	$197,282

b) Where will project deliverables be maintained?

The project will be maintained in our STEM College

c) Who was involved in planning for institutionalization?

Some of the faculty members of our Computer Science and Engineering department as well as one or two faculty members of the Natural Sciences and Mathematics (NSM) department will be involved in sustaining the project. Mostly the same faculty members who were involved in the project in the past year, plus one or two others.

6. Interactions with research projects:

Location: US Department of Homeland Security Centers of Excellence Summit - George Mason University in Arlington, Virginia.
Time: July 21 – August 1, 2019
Presentation: Building Tornado Resilient Communities.
Presentation: Drone-based MIR Laser Induced Thermal Imaging for Identification of Chemical Substances (presentation at Summit)

Location: American Society of Engineering Educators - Auburn University - Auburn, Alabama.
Time: March 8-10, 2020.
Presentation: National Coastal Hazards Preparedness Evaluation

Location: DHS Coastal Resilience Center of Excellence 5th Annual Meeting. 2019 DHS COE Summit - Chapel Hill, North Carolina.
Time: March 11-13, 2020.
Presentation: An experience in group development

Smith Institute Student Poster Competition - Johnson C. Smith University - Charlotte, North Carolina
Time: May 15, 2020
Presentation: Building Tornado Resilient Communities.

III. EDUCATION ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Education Activities and Milestone Achievements:

Education Activities and Milestones: Status as of 6/30/2020			
Education Activities	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Host three seminars each semester.	6/1/2020	100	
Select eight students to conduct research projects.	6/1/2020	100	
Select 20 students to participate in the one-week summer camp focused on Coastal Resilience.	6/30/2020	100	
Select nine students and three faculty to form the summer research teams.	6/30/2020	100	
Dissemination of undergraduate coastal resilience education and research, by attending conferences and publishing. The	6/30/2020	100	

target audience are faculty and students of other education institutions. Faculty and students of other education institutions will benefit from the research, as well as our students who will benefit from the networking during the conferences.			
Create ongoing opportunities for the transfer of skills, knowledge, people and ideas between JCSU and the community at large. By collaborating with other education institutions, local county and companies.	Continuous	100	Looking back at our records, we did have collaboration with the graduate program coordinator at UNC Charlotte. We also had representatives from Wells Fargo, Bank of America and Slalom Consulting (Business management consultant in Charlotte, North Carolina), who gave seminars to our students.
Education Milestones			
Students are registered in the four developed courses. The desired number of students enrollment in each course is 20.	6/1/2020	100	
Eight students complete the spring research course and research project	6/1/2020	100	
20 students complete the one-week summer camp	6/30/2020	100	
Nine students and three faculty members complete four-week summer research projects. The end results are power point presentations and posters that can be presented in conferences.	6/30/2020	100	
Student participants receive external scholarships, fellowships, internships, and training opportunities from DHS enterprise. Estimated one or two in each category.	6/30/2020	0	Did not manage to find external scholarships, fellowships, internships, and training opportunities from DHS enterprise Status remains the same. We will try to collaborate with other Coastal Resilience centers.
We are planning on embedding research projects, which were carried out during the grant period, into the four courses that were developed specifically for this DHS program. By doing so we would have established a process	6/30/2020	100	

that will sustain our achievements during the DHS grant period.			

2. Year 5 **Transition** Activities and Milestone Achievements:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Continued enrollment of students in developed courses and research projects. We will be applying to the university and outside agencies to fund the research projects of approximately $200,000-$500,000, as described ahead of this table.	6/30/2020	100	
Dissemination of the undergraduate education and research education framework and results. The results will be presented to practitioners in the field through conferences and publications. Other universities will benefit from the information.	6/30/2020	100	
Develop the collaboration with research partners at other academic research institutions by exchanging personnel, as well as collaborating with local companies and the county by exchanging data.	6/30/2020	0	Did not have the opportunity and the time to find the companies to collaborate with. Status remains the same, but we will keep trying.
Transition Milestone			
Graduation of BS students and employment in greater HS enterprise or continued graduate school enrollment. Our total number of department graduates is 10-20 per year, of which we estimate 1-5 students will go into HS employment or graduate school.	6/30/2020	0	Some graduates we were unable to track. Students who we were able to track we were unable to find HS employment for. Status remains the same, but we will try to track students who graduated in May 2020, as well as students who will be graduating in May 2021.
conference presentation and publications of the project results. Estimate 3-5 presentations/publications.	6/30/2020	100	
Students present research finding at one or two regional and national conferences.	6/30/2020	100	

We are in the process of getting connected with potential employers who are in the field of HSE-STEM domain. We also plan to invite more experts and recruiters in this field to give their presentations in our seminar courses. The experts and recruiters are expected to introduce our students to potential research and job opportunities.	6/30/2020	0	Did not manage to get connected with potential employers due to time conflicts and limited time. In year 6 we plan to collaborate with UNC Chapel Hill faculty experts in HSE-STEM domain to interact and share their experience with our students for potential research and job opportunities.
We are planning on contacting our graduates who participated in this DHS program to keep track of their career pathways.	6/30/2020	0	Have not managed to contact 2019 graduates. Status remain the same and efforts will continue to be made.

3. Annual Courses and Enrollments

Annual Courses and Enrollments

Courses Developed and Taught by Johnson C Smith University under Project DHS CRC						
Course		YEAR				
Number	Title	YR 1	YR 2	YR 3	YR 4	YR 5
CSC432	Course Title: Data Mining					
	Status: Developed (D); Revised (R); and/or Taught (T)	D, T	T	R, T	R, T	T
	Offering: Elective (E), Concentration (C), Minor (M)	E	E	E	E	E
	Number of students enrolled	12	8	10	10	7
CSE439 A	Course Title: Introduction to Geographic Information System (GIS)	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D); Revised (R); and/or Taught (T)	-	-	D, T	R, T	T
	Offering: Elective (E), Concentration (C), Minor (M)	-	-	E	E	E
	Number of students enrolled	-	-	10	10	18
CSE439 B	Course Title: Risk Analysis and Management	YR 1	YR 2	YR 3	YR4	YR 5
	Status: Developed (D); Revised (R); and/or Taught (T)		D, T			
	Offering: Elective (E), Concentration (C), Minor (M)	E	E	E	E	E
	Number of students enrolled		10			
CSC210	Course Title: Career Prep I	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D); Revised (R); and/or Taught (T)		D	T	R, T	T

	Offering: Elective (E), Concentration (C), Minor (M)			C	C	C
	Number of students enrolled			16	30	32
CSC211	Course Title: Career Prep II	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D); Revised (R); and/or Taught (T)		D	T	R, T	T
	Offering: Elective (E), Concentration (C), Minor (M)			C	C	C
	Number of students enrolled			19	30	20
#	Course Title: Introduction to Network Science	YR 1	YR 2	YR3	YR 4	YR 5
	Status: Developed (D); Revised (R); and/or Taught (T)				D	T
	Offering: Elective (E), Concentration (C), Minor (M)				E	E
	Number of students enrolled					13

IV. PUBLICATIONS AND METRICS

1. Publications:

a) Publications

- Ying Bai & **Hang Chen**, "Build an Optimal Evacuation Contraflow Model for Natural Disasters by Using Fuzzy Inference System", to be appeared on Proceedings of the 2018 IEEE International Conference on Fuzzy System, July 8-13, Rio de Janeiro, Brazil, 2018.
- Cody Byrd, Jean-Marie Nshimiyimana, Ehije Idehenre, **Hang Chen** (Faculty Advisor), "Data Analysis of Haiti's Resiliency Post-2010 Earthquake". Presented at the 2017 Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM).
- NyJae Dickerson, Adonis Tillman, Desmond Taylor, Awatif Amin (Faculty Advisor) "Using Data Mining to analyze Natural Disasters at 10 countries". Presented at the 2017 Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM).

2. Performance Metrics

Faik: Performance Metrics:

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17 – 6/30/18)	Year 4 (7/1/18 – 6/30/19)	Year 5 (7/1/19 – 6/30/20)
HS-related internships (number)	1	1	0	0	0
Undergraduates provided tuition/fee support (number)	0	0	0	0	0
Undergraduate students provided stipends (number)	37	47	40	51	57
Graduate students provided tuition/fee support (number)	0	0	0	0	0
Graduate students provided stipends (number)	0	0	0	0	0
Undergraduates who received HS-related degrees (number)	9	20	7	12	18
Graduate students who received HS-related degrees (number)	0	0	0	0	0
Certificates awarded (number)	0	0	0	0	0
Graduates who obtained HS-related employment (number)	3	0	0	0	0
Lectures/presentations/seminars at Center partners (number)	0	0	0	0	4
DHS MSI Summer Research Teams hosted (number)	0	0	0	0	0
Journal articles submitted (number)	1	1	1	0	0
Journal articles published (number)	0	0	1	11	0
Conference presentations made (number)	0	2	0	2	4
Other presentations, interviews, etc. (number)	0	0	0	0	0
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	0	0	0	0	0
Requests for assistance/advice from other agencies or governments (number)	0	0	0	0	0
Dollar amount of external funding	$267,417	$887,917	$2,031,917	$987,736	
Total milestones for reporting period (number)	7	6	0	7	6
Accomplished fully (number)	4	6	0	5	5
Accomplished partially (number)	3	0	0	0	0
Not accomplished (number)	0	0	0	2	1

LAIJU, TC
DHS COASTAL RESILIENCE CENTER
EDUCATION PROJECT
YEAR 5PROGRESS REPORT
July 1, 2019 – June 30, 2020

I. INTRODUCTION

Project Title: Multidisciplinary Certificate: Disaster and Coastal Studies (DCS)

Principal Investigator Name/Institution: MeherunLaiju, Ph.D.; Tougaloo College

Other Partners/Institutions: Internal collaboration with Political Science, Psychology, Mass-Communications, Sociology Department, and Natural Science Division

Short Project Description ("elevator speech"):

Multidisciplinary Certificate: Disaster and Coastal Studies (DCS) is housed in the Sociology and Social Work Department in the Social Sciences Division at Tougaloo College, a Historically Black College (HBCU). Certificate program's main objective is to diversify the Department of Homeland Security's (DHS) workforce. To achieve the intended objective DCS certificate curriculum includes: a) training interested students in the field of disaster management for local emergency management agencies and graduate studies; and b) creating neighborhood outreach training programs in collaboration with Mississippi Emergency Management Agency (MEMA) to facilitate DHS resilient community building initiative.

II. PROJECT NARRATIVE:

1. Project overview: The education project, Multidisciplinary Certificate: Disaster Coastal Studies (DCS), addresses the acute underrepresentation of minorities in the Science, Technology, Engineering, and Mathematics areas (STEM). The project's goal is to diversify the future DHS and S&T related workforce by training underrepresented minorities, mirroring some of the more vulnerable populations impacted by disaster scenarios. The DCS curriculum allows students to develop skills and knowledge and provides an opportunity to be trained in multidisciplinary fields across academic divisions (Humanities, Natural Sciences, & Social Sciences). The curriculum helps create a pipeline of underrepresented minority students with multidisciplinary skills, incorporating a Social Science focus that is marketable in the field of disaster and emergency planning, management, response, and recovery. In addition to coursework that addresses the legal, social, and public health aspects of natural disasters, practical skills—such as student internship with emergency management agencies, Geographical Information System (GIS) training, and FEMA's Independent Study (IS) training—are incorporated into the coursework. The Project also provides students the opportunity to participate in faculty lead research in the field of community preparedness to enhance community resilience. Students present their research findings in the field of disaster preparedness and recovery at the annual, year-end symposium—attended by various stakeholders including students, faculty, staff, administration, project partners, homeland

security related organizations, and community members. Additionally, the project incorporated a program *Neighborhood Outreach Initiative*, in collaboration with MEMA, and offered opportunities for community leaders and interested citizens to be trained as first responders. The neighborhood training initiative addresses Homeland Security's Post–Katrina Emergency Reform Act of 2006—building resilient communities as a part of national preparedness.

2. <u>End users:</u> In Year 5, project collaborated with Mississippi Emergency Management Agency (MEMA), American Red Cross, Salvation Army, Mississippi Department of Child Protection Services (MDCPS), and Mississippi State Department of Health (MSDH), Office of Emergency Planning and Response (OEPR). Dr. George Humphrey, Grant Director of MEMA taught the DCS 320 Emergency Management course in Fall 2019.Six students who were in DCS 400 Internship course were placed in MEMA, Red Cross, and Salvation Army. In Year 5, project launched a new collaboration with MSDH. Project hosted a Community Disaster Preparedness Forum on November 14, 2019 and Mr. Wes Holsapple, II, the OEPR Health Care Coalition and Training Coordinator of MSDH, facilitated the forum.

Interns and MEMA Personnel

Instructor Dr. Humphrey

OEPR Personnel Conducting community outreach forum

3. <u>Unanticipated Problems:</u> Year 5 was one of the most challenging years faced by the project due to COVID -19. During Spring Break, the Mississippi Governor issued a Stay Home order. So college resumed and adopted remote learning by using alternative modes of teaching. The faculty teaching the DCS courses had to go through Moodle software training

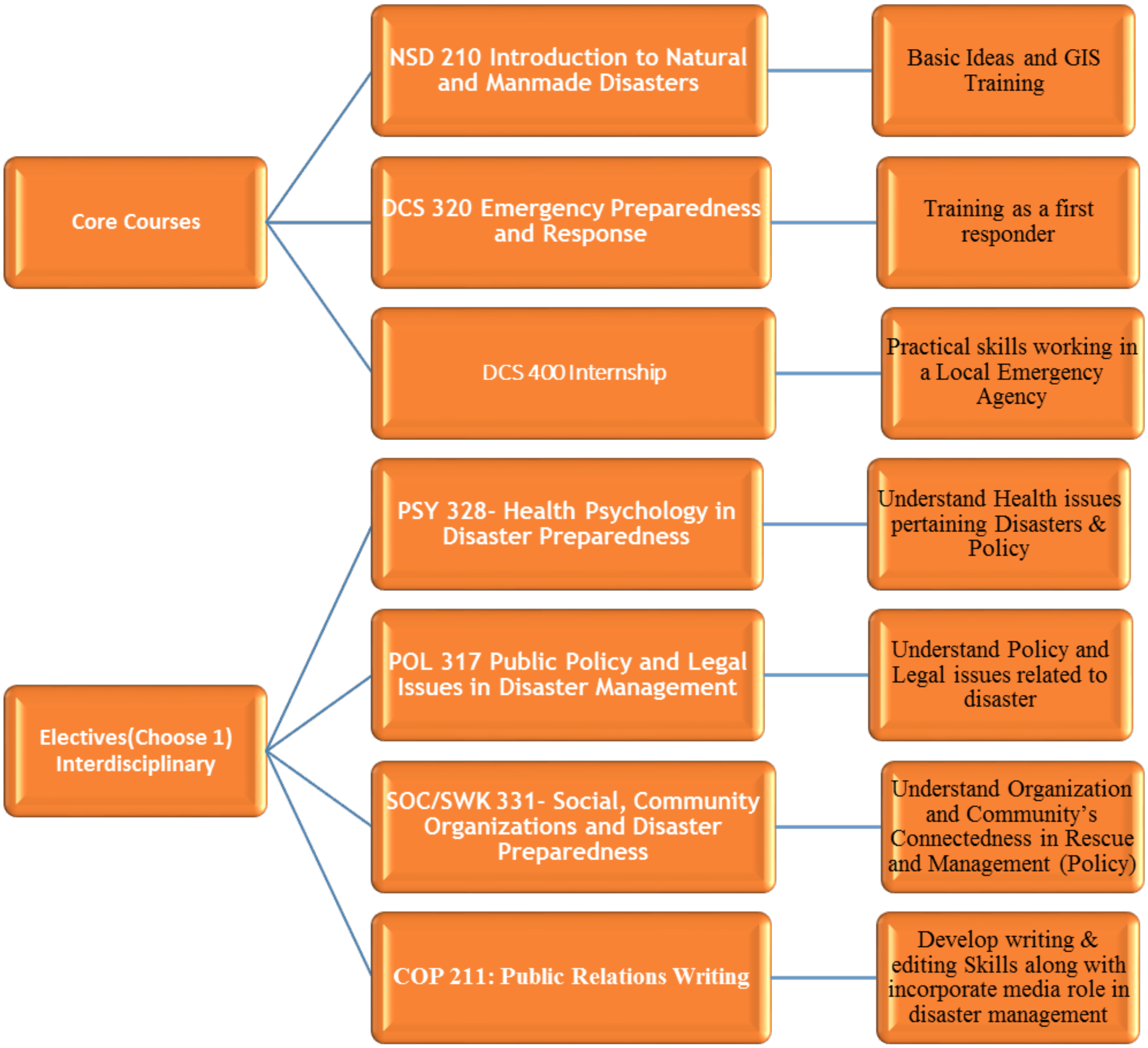
and arranged their course materials (lectures, exams assignments and quizzes) to upload on Moodle to teach the course remotely using Microsoft Team. The DCS symposium, students' participation in conferences, and second community outreach forum all had to be cancelled. Depending on the situation, the project is planned to resume some of the missed activities in Fall 2020. The intern students were not able to complete their field practicum in person, using Microsoft Team the instructor incorporated case studies (scenarios) with the students and did a virtual class.

4. Students and recent graduates: Tougaloo College is a Historically Black undergraduate institution, 99% of the student body is African-American and full-time students. The Certificate program was launched during Year 4. In Year 5, a total of 7 courses were offered:3 core requirements and 4 electives. There were 82 students who took courses offered by the certificate Program—12 were DCS students and 70 used these courses as an elective count towards degree requirements. This academic year, 5 students graduated with DCS certificate: 2 females and 3males.Out of the 5 students 2 female and 1 male were accepted in graduate programs (Health Science, Psychology, and Social Work).Between the other two, 1 applied for a local emergency management agency in LA and 1 is undecided.

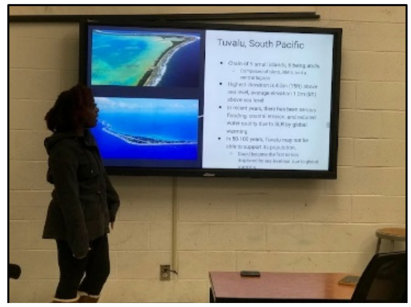
5. Project Impact: Interdisciplinary Minor Disaster Coastal Studies (DCS) was modified and changed into a multidisciplinary certificate program. In Fall 2018, the project commenced the multidisciplinary certificate Disaster Coastal Studies (DCS)program. The curriculum of the professional certificate incorporated the Interdisciplinary Minor (DCS) courses and courses from Humanities, Natural Sciences, and Social Sciences. The focus of this certificate program is to strengthen student careers in public safety, emergency management, community and research planning, and public-policy making. The goal of the certificate program is to create well-informed and socially-committed professionals able to use holistic, humane, and integrated strategies to mitigate the impact of disasters and support DHS efforts to build more resilient communities. The 12 credit hour multidisciplinary certificate in Disaster and Costal Studies (DCS) is open to degree seeking students across the institution's majors. The DCS certificate conforms to the mission and vision of Tougaloo College by emphasizing a multidisciplinary and policy-relevant approach to a major 21st century challenge that will also confer competitive career advantages to students. The certificate consists of four courses (12 credit hours) including 40 hours of practical internship experiences with local, state, federal agencies, or NGOs.

   The multidisciplinary certificate curriculum included three DCS minor courses as core requirements and one elective course. The elective courses were adopted from participating departments. These departments modified one of their required electives to be part of the certificate program. The modified elective courses include content, assignments as well as field experts as guest lecturers to address natural disasters and building/strengthening community resilience. This curriculum also exposed students not pursuing the certificate to become familiar with the field of natural disaster, resilience, and skills in GIS. Students who are pursuing the DCS certificate are guided by the instructor to conduct research in the field of disaster resilience, publish, and attend national conferences to present the findings. Also, students who are pursuing the certificate shared their course related project at the DCS Research Symposium (Cancelled due to COVID -19).The following are some examples of DCS certificate course content which highlights the incorporation of current literature, advances in the field, and technology:

The certificate program curriculum:

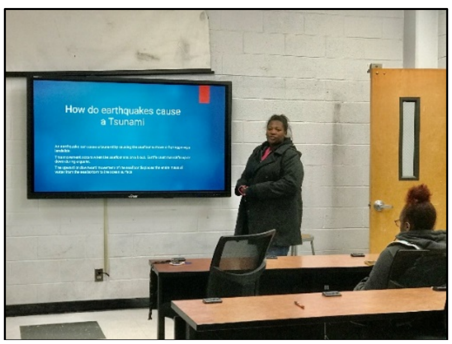


DCS/ NSD 201 Introduction to Natural and Man Made Disaster: Core requirements STEM oriented course offered in Fall by NSD. Course is designed to give a broad overview of natural and man-made disaster and applications of modern tools like GIS to study natural disasters. Interested students gained fundamental knowledge of Natural Disasters and learn about future prospects in this field. Instructor: Dr. Santanu Banerjee; Professor of Physics



DCS 201: Dr. Banerjee and student's presentation

DCS 320 Emergency Preparedness Planning and Response: The course introduces students to the field of Disaster Preparedness. Students are exposed to the terminology, policy, planning, and management issues that arise in preparing for and responding to disasters. Help students understand the role of human organizations in providing assistance to people and communities affected by disasters in the immediate aftermath and for long term recovery. The course examined particular events that occur recently as well as past incidents. Core requirements, taught by Emergency Management Professional.



DCS 320: Class and student presentation

DCS 400 Internship: An educationally-directed practice experience in disaster management agencies with trained site supervisor. Focus placed upon the application of the theoretical knowledge in real-life situation. Prerequisite: must complete the core requirements. Dr. Shaila Khan Psychology Professor is overseeing the student placement.

DCS 400 Interns and Instructor

PSY 328-01: Health Psychology and Disaster Preparedness: This is a three-hour, credit course that focuses on psychological factors (e.g., stress, anxiety, depression, individual differences, or personality characteristics) and environmental events (e.g., natural or man-made disasters) that can negatively affect survivors' mental and physical well-being as well as the relationship between patients and practitioners. Students in the course learned about the role of psychologists in the assessment and treatment of disaster related mental and emotional problems, and the promotion of changes to lifestyle, health habits, and coping practices to optimize recovery from disaster (i.e., dealing with psychosocial aspects of disasters). This is a required elective for Psychology majors and serves as one of choices for DCS electives, Dr. Carmen Lewis Psychology Professor is teaching this course.

POL 317 Public Policy and Legal Issues in Disaster Management: Offer in Spring by Political Science Department. Attorney specialized in the field teaches this course. The course presents concepts and basic descriptive information about the public policy process in the executive and legislative branches of government and actions of the judicial branch in court cases that relate to disaster preparedness. Examine the Federal Emergency Management Agency's legal requirements, responsibilities, laws pertaining to emergency management, and actions based on these laws. Also includes analysis of public policies and understanding the procedures and requirements in emergency management. The course is a required elective requirement for Political Science majors and serves as one of choices for DCS electives. Atty. Dennis Sweet specializes in the field teaches this course

Atty. Sweet

POL 317 Guest Lecturers

SOC/SWK 331 Social, Community Organizations and Disaster Preparedness: The course investigates the nature of complex social and community organizations such as business, industry, and government. Students learned certain basic social concepts and theories and their functions as a framework for bringing about effective community based social action **(or community organization as a tool for addressing issues affecting the local community to advocate for social justice)**. Special attention (topic) is given to community-based disaster preparedness, recovery efforts, and management strategies. Students became familiar with the strategies to build resilient community, community-mindedness and cooperative relationships between disaster victims and recovery organizations. How disasters lead to rapid social change is also be explored. The course is a required elective requirement of Sociology and Social Work majors and serves as one of the choices for DCS electives. Social Worker, Mr. Mario Johnson of MDCPS, specialized in the field teaches this course.

SWK 331 Instructor and Class

6. Institutionalization: The certificate program replaced the DCS minor and was executed in Fall 2018 as part of Tougaloo College Curriculum *Career Pathways*. The Multidisciplinary Certificate is housed in the Division of Social Sciences (SSD) and will operate under the umbrella of Career Pathways/ Career Services. The Division Dean in collaboration with the Career Pathways/Career Services Director will be in charge of monitoring the certificate program. The institutionalization process involved collaborating with different disciplines, modifying courses, incorporating elective courses from other disciplines, and designing a self-sustaining Multidisciplinary Certificate Program. To be a self-sustaining program, the twelve credit-hour certification curriculum incorporates the existing elective courses from different disciplines (see Curriculum table). One of core required course, *DCS 201: Intro to Natural Disaster,* was adopted by the Natural Science and co-listed (NSD 201) and offered by the NSD division as an elective requirement. Mississippi Emergency Management Agency (MEMA) personnel currently teach another core requirement DCS *320: Emergency Preparedness and Response* as adjunct faculty. Academic Affairs agreed to pay the adjunct salary if the enrollment in the course is 8-10students after 2020. The same holds true for the Internship course (*DCS* 400). College rolled out Bachelor of Social Work (BSW) as a degree granting program in Fall 2018 and the DCS certification is included within the BSW degree program as an option of specialization. The DCS certificate is also a part of Tougaloo College's *Career Pathways/Career Services* program. During Year 5, the project took initiatives, such as continuing with the existing end-users, as well as establishing collaboration with FEMA, Mississippi State Department of Health (MSDH), Office of Emergency Planning and Response (OEPR), Mississippi Department of Child Protection Services (MDCPS), and other private agencies which deal with emergency management. The project placed interns; invited personnel to teach classes, as field experts' personnel brought in class as a guest speaker, and invited these agencies to participate in the Tougaloo College job fair to help DCS graduates' recruitment. I am expecting these initiatives will help strengthen to sustain the certificate program beyond 2020.

7. Interactions with research projects: Gregory Slusarczyk, Research Mathematician (ERDC), a PhD student in Coastal Engineering (JSU), and Von Anderson, Jackson Emergency City Planner were scheduled to speak at DCS Symposium. Due to COVID -19 the Symposium was cancelled and SUMREX did not matriculate either

III. EDUCATION ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Education Activities and Milestone Achievements:

Education Activities and Milestones: Status as of 6/30/2020			
Education Activities	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Promote DCS certificate program & recruit students	ongoing	100%	
Offer three courses in Fall Semester (NSD 201, DCS 320, & SOC/SWK 331)	08/2019	100%	
Offer four courses in spring semester (PSY 328, COP 211, POL 317, & DCS 400)	01/2020	100%	
Select 6-8 students for course project twice a year	08/2019; 01/2020	100%	
Place 5-6 Interns with end-users	01/2020	100%	
RETALK- invite one guest for symposium	02/2020	0%	COVID-19
Education Milestones			
4-6 DCS Students participation in nationally recognized conferences (Mississippi Academy of Sciences (MAS); Southern Sociological Conference (SSC); Public Relations Association of Mississippi (PRAM); etc.	Feb., Mar., April, 2020	50%	Due to COVID - 19
SUMREX –selection and placement of two students	04/2020	0%	COVID – 19
Execute DCS Symposium each academic year to showcase student activities	04/2020	0%	COVID – 19
Interview conducted by student advisor and/or PI regarding future plans of graduates with DCS certificate	05/2020	100%	

2. Year 5 **Transition** Activities and Milestone Achievements:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Recruitment for Certificate Program: 10 students	08/2019; 01/2020	100%	
Advise and track the students pursuing the Certificate: 10 to 12 students	05/2019	100%	
Transition Milestone			
SUMREX – Summer Internship and bringing guest Lecturer (DCS Symposium): Two students and one guest speaker	02/2020	0%	COVID -19
DCS certificate graduates placement: 2 to 3 students in graduate program in the field or job related to the field	06/2020	100%	Out of 5, three already are accepted in graduate program. Other 2 interested to join workforce

3. Annual Courses and Enrollments (next page)

Courses Developed and Taught by Tougaloo College through project titled "Multidisciplinary Certificate: Disaster and Coastal Studies(DCS)"						
Course Number	**Course Title**					
NSD/DCS 201	**Course Title: Introduction to Natural & Manmade Disaster**	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	--	R,T	T	R/T	T
	Offering: Elective (E), Concentration (C), Minor (M)		M	M	CERT** CORE	CERT C
	Number of Students Enrolled	*	10	10	10	10
*offer in fall semester						
DCS 211	**Course title:Public Health Issues in Disaster Preparedness**	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	T,R	R	
	Offering: Elective (E), Concentration (C), Minor (M)		M	M		****
	Number of Students Enrolled	1**	8	11		
**Schedule to offer in fall; 2016 spring offered as an independent study for a graduating Senior with DCS minor						
DCS 301	**Course title:Political & Legal Issues in Disaster Preparedness**	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	T,R	R	****
	Offering: Elective (E), Concentration (C), Minor (M)	M	M	M		
	Number of Students Enrolled	14	10	8		
DCS 320	**Course Title: Emergency Preparedness Response & Planning**	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	R,T	T	T	T
	Offering: Elective (E), Concentration (C), Minor (M)	M	M	M	CERT** CORE	CERT C
	Number of Students Enrolled	16	5	11	9	10
DCS 314	**Course title: Economic Aspects of Disaster**	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)		T	T,R	R	****
	Offering: Elective (E), Concentration (C), Minor (M)		E	E	-	
	Number of Students Enrolled		13	7	-	
DCS 311	**Course title:Psychological Dimension of Disaster**	YR 1	YR 2	YR 3	YR4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	-	-	R	R	****
	Offering: Elective (E), Concentration ©, Minor (M)		E	E	-	
	Number of Students Enrolled	***			-	
***offer one elective in fall for each academic year						
DCS 400	**Course title: Internship**	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised ©, and/or Taught (T)	T	T	****	T	T
	Offering: Elective (E), Concentration ©, Minor (M)	M	M		CERT** CORE	CERT C
	Number of Students Enrolled	7	8		5	6
CERT** (Certificate Program)						

Course title: COP Public Relations Writing**	YR 1	YR 2	YR 3	YR 4	YR 5
Status: Developed (D), Revised ©, and/or Taught (T)			R	-	T
Offering: Elective (E), Concentration ©, Minor (M				E	E
Number of Students Enrolled				-	6
Course title: SOC/SWK 331 Social, Community Organizations & Disaster Preparedness**	YR 1	YR 2	YR 3	YR 4	
Status: Developed (D), Revised ©, and/or Taught (T)			R	T	T
Offering: Elective (E), Concentration ©, Minor (M				E	E
Number of Students Enrolled				10	18
Course title: POL 317 Public Policy & Legal Issues in Disaster Management**	YR 1	YR 2	YR 3	YR 4	YR 5
Status: Developed (D), Revised ©, and/or Taught (T)				T	T
Offering: Elective (E), Concentration ©, Minor (M				E	E
Number of Students Enrolled				17	17
Course title: PSY 328 Health Psychology in Disaster Preparedness**	YR 1	YR 2	YR 3	YR 4	YR 5
Status: Developed (D), Revised ©, and/or Taught (T)				T	T
Offering: Elective (E), Concentration ©, Minor (M				E	E
Number of Students Enrolled				14	15

****: courses have been modified and integrated to regular elective courses with different departments. EX: DCS 301 integrated with POL 317; DCS 311& DCS 211 integrated with PSY 328; DCS 314 & Part of DCS 211, DCS 314 integrated with SWK/SOC 331.

IV. PUBLICATIONS AND METRICS

1. Publications:

Year 2 and 3 Publications and Presentation:

Laiju, M. (2016) *Natural Disaster and Child Trafficking,* Mellon Fellowship

Ball, I &**Laiju, M.** (2017) Socio- demographic Characteristics and Natural Disaster Preparedness among Mississippi Residence, abstract published in *The journal of Mississippi Academy of Sciences (*ISSN 0076-9436) April edition.

Laiju, M. (2017) *A Global Issue: Natural, Manmade Disaster, and Exploitation of Children,* Pardee RAND Faculty Leaders Fellowship, manuscript under review.

Laiju, M.& Banerjee, S. (2017) *Innovative Interdisciplinary Undergraduate Curriculum in Homeland Security at a HBCU*, Presented at the 10th Anniversary Homeland Defense & Security Education Summit on March 23, 2017

Mage, D. Reed, S. Hokins, A. Mangum, C. & Banerjee, S. (2018) Using Arc GIS to Map Disaster Effects on Mississippi, abstract published in *The journal of Mississippi Academy of Sciences (*ISSN 0076-9436) vol 63, 1 February edition

Bryant, J. Hill, C. Bibbs, M. Boler, D. & Khan, S. (2018) *Role of Effective Communication in Disaster Preparedness,* abstract published in *The journal of Mississippi Academy of Sciences (*ISSN 0076-9436) vol 63, 1 February edition

Year 4 Publications:

Long, J., Rose, S., Jwainat, A. & Hunter, F. (2019), Tougaloo Community Preparedness for Homeowners*,* abstract published in *Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1

Jones, T. Robinson, S. Boler, D.& Hunter, F. (2019) Disaster Preparedness: How Prepared Are They? An Assessment of Renters in Tougaloo Mississippi*,* abstract published in *Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1
Kinkaid, D.,Ze'ronte, B.Sneed, H., &Banerjee, S., (2019), *Using GIS to Study*

Disproportionate Disaster Impact on Vulnerable Mississippi Population, abstract published in *Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1, & Presented at 83rd Annual Meeting in Hattiesburg, MS on February 21, 2019

Laiju, M. (2019), *A Framework: Address Vulnerability of Children and Current Policy of Disaster,*
abstract published in *Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1, &presented at 83rd Annual Meeting in Hattiesburg, MS on February 21, 2019

Laiju, M. (2019) *Career Pathway: Multidisciplinary Undergraduate Curriculum in Homeland Security's Coastal Resilience at a HBCU.* Abstract published in *Southern Sociological Society* (SSS) Journal and presented at SSS Conference on April 11, 2019, at Atlanta, GA.

Presentation:

Laiju, M. & Hunter, F. (2018), *Transforming the Curriculum: Adding Disaster Management and Coastal Infrastructure Management to the Curriculum,* abstract accepted and presented at the Historical Black Colleges &Universities(HBCU) Faculty Development Network Conference
in Jackson, Mississippi, November 2,2018

Senior Paper:
Jwainat, A. (2019), senior paper Knowledge and Attitudes Regarding Disaster/ Emergency Preparedness

Porter, J. (2019), New Orleans Residents' Awareness of Disaster Preparedness

Year 5 Publications:

Presentation and Senior Paper:

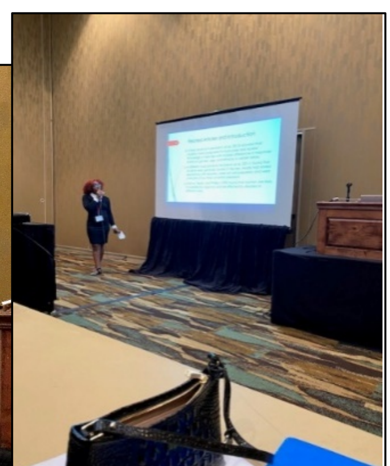
Thomas, C&Laiju, M (2020)*Natura Disaster Preparedness Among Undergraduate Students In Jackson, Mississippi,* abstract published in 84th MAS (ISSN 0076 – 9436, Vol 65 # 1) journal and presented the Paper at MAS conference on February 20, 2020. (Ms. Thomas's Senior Paper)

Hill, N., Randle, D.iMaya Randle, & Khan, S. (2020) *Assessment of Psychological Impact of Coastal Disaster,* abstract published in 84th MAS (ISSN 0076 – 9436, Vol 65 # 1) journal and presented the Paper at MAS conference on February 20, 2020

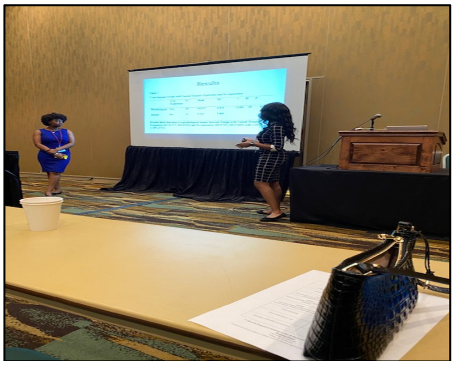
Tashana Irving, Desiree-Gift Mills, Jacory Clayton, Meherun Laiju, Santanu Banerjee, *Using GIS to Study Recent Past, Present and Potential Major Disaster Patterns' Impact on the Mississippi Demography*, supposed to be presented at the 8th International Conference on Flood Management in Iowa City, Iowa (postponed until August 2021 due to COVID-19)

Randle, D& Khan, S. (2020) *Time Management and Academic Adjustment among First Year African American Students,* abstract published in 84th MAS (ISSN 0076 – 9436, Vol 65 # 1) journal and presented the Paper at MAS conference on February 20, 2020 (Ms. Randle's Senior Paper)

DCS Students, Di'Maya Randle (Psychology) Presenting at MAS also selected for Millsaps Undergraduate Scholar Program



DCS Students, Sociology Major Courtney Thomas presenting Senior Paper at MAS



DCS Students Psychology Major Presenting at MAS

DCS Research Interns with Instructors

2. Performance Metrics

Laiju: Performance Metrics:

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17— 6/30/18)	Year4 (7/1/18— 6/30/19)	Year 5 (7/1/19- 6/30/20)
HS-related internships (number)	7	8	0	5	4
Undergraduates provided tuition/fee support (number)					
Undergraduate students provided stipends (number)	15	17	20	24	6
Graduate students provided tuition/fee support (number)	NA	NA	NA	NA	NA
Graduate students provided stipends (number)	NA	NA	NA	NA	NA
Undergraduates who received HS-related degrees (number)	3	5	4	5	5
Graduate students who received HS-related degrees (number)	NA	NA	NA	NA	NA
Certificates awarded (number)	NA	NA	NA	5	5
Graduates who obtained HS-related employment (number)			0	1	0
Lectures/presentations/seminars at Center partners (number)	1	1	1	1	0
DHS MSI Summer Research Teams hosted (number)	0	0	0	0	0
Journal articles submitted (number)	0	0	0	0	0
Journal articles published (number)ABSTRACT	0	0	3	5	2
Conference presentations made (number)	1	4	6	6	2
Other presentations, interviews, etc. (number)	10	12	14	15	4
Trademarks/copyrights filed (number)	0	0	0	0	0
Requests for assistance/advice from DHS agencies (number)	2	1	1	1	2
Requests for assistance/advice from other agencies or governments (number)	5	2	2	3	3
Dollar amount of external funding	$12,000	--	$8,000	-	-
Total milestones for reporting period (number)	7	7	7	7	6
Accomplished fully (number)	4	5	6	6	2
Accomplished partially (number)	3	1	1	-	1
Not accomplished (number)	-	1	-	1	3

PAGAN, UPRM
DHS COASTAL RESILIENCE CENTER
EDUCATION PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Education for Improving Resilience of Coastal Infrastructure

Principal Investigator Name/Institution: Ismael Pagán-Trinidad (PI), Ricardo R. López (July 2019-dic. 2019, Co-PI, Retired Dec. 2019); Carla López del Puerto (Co-PI); Raúl Zapata (Co-PI).

Other Partners/Institutions:

ERDC-US Army Corp of Engineers, PR Emergency Management Agency, FEMA, PR Department of Natural Resources, Association of Professional Engineers of PR, UPRM partners (Marine Science Department, Sea Grant Program, CariCOOS NOAA project, Transportation Technology Transfer Center, Civil Infrastructure Research Center); NOAA (National Weather Service), INESI (Instituto Nacional de Energía y Sostenibilidad Isleña = "National Institute on Energy and Island Sustainability"), CRB (Community Resilient Building). Senior Personnel: Dr. Carla Lopez del Puerto, Dept. Of civil Engineering and Surveying, UPRM.

ERDC-US Army Corp of Engineers; US Army Corp of Engineering PR District Office; PR Emergency Management Agency; FEMA; RAND Corporation – HSOAC Project; PR Department of Natural Resources; PR Climate Change Council (PRCCC) – Mr. Ernesto Díaz; Association of Professional Engineers of PR- Eng. Marilú de la Cruz; Aqueduct and Sewer Authority (AAA)- Eng. José Rivera, Eng. Joel Lugo and Eng. Glorimar Cortes; Integrated Añasco River Basin Management Group - Mr. Luis Villanueva; UPRM partners (Marine Science Department, PR Sea Grant Program Ruperto Chaparro; CariCOOS NOAA project-Dr. Miguel Canals; Transportation Technology Transfer Center- Dr. Benjamín Colucci; Civil Infrastructure Research Center); NOAA (National Weather Service); INESI- Dr.Cecilio Ortiz (Instituto Nacional de Energía y Sostenibilidad Isleña = "National Institute on Energy and Island Sustainability"); CRB (Community Resilient Building); Re-Imagina Puerto Rico; Senior Personnel: Dr. Carla López del Puerto, Dept. of Civil Engineering and Surveying, UPRM; Collaborating Faculty at UPRM: Dr. Luis Aponte, Professor, Wind Engineering; Dr. José Guevara, Professor, Rehabilitation of Coastal Infrastructure; Dra. Alesandra Morales, Geotechnical Engineering; Dr. Walter Silva and Jorge Rivera Santos - Hydraulics; Dr. Ali Saffar, Structural Reliability; Dr. Raúl Zapata, Water Resources; Dr. Francisco Maldonado, Construction and Cost Management; Dr. Alberto Figueroa, Resilient Transportation Systems; Dr. José Cedeño, Electrical and Power Systems; Beatriz Camacho, Geotechnical Engineering; Ameesha Mehta-Sampath, EPA, Healthy Buildings.

Short Project Description ("elevator speech"):

This project helps educate the community by transferring state of practice knowledge to stakeholders (students, faculty, professionals, first responders, and workforce) through formal (curriculum, internships, student projects, undergraduate research) and informal (workshops, seminars, lectures, short courses, webinars) learning experiences. It will serve as a vehicle to engage the community as a whole to understand and learn its members' roles and responsibilities in providing resilient coastal infrastructure systems. The project will help the community understand better various stages in coastal infrastructure hazard prevention, preparedness, response, recovery, and mitigation. The focus will be on understanding the natural phenomenology, the engineering methodologies to address the level of risk the infrastructure is exposed to, the engineering methodologies and technology to analyze and predict the level of resistance and vulnerability the infrastructure and community is exposed to, the sustainable and resilient alternative available at the state of practice or state of art to cope with risks and vulnerabilities. The project will help motivate students and faculty which will create pipelines of students and professionals into CRI careers and practice.

II. PROJECT NARRATIVE:

1. Project overview:

The main goal of this project is to develop and offer formal and informal education through courses, workshops, seminars, lectures, and other educational means leading to advance knowledge on the state of practice on the Resiliency of Coastal Infrastructure (RCI) of the built and natural environment. This initiative aims at creating a Certificate in Resiliency of Coastal Infrastructure. The focus of the project is to provide students and faculty, professionals and homeland security personnel, and affected citizens with capabilities to assess the effects of natural hazards on coastal infrastructure, the conditions of existing structures, and rehabilitation alternatives to mitigate future damage and potential risks. The educational content will focus on pre-incidents, incidents and post-incidents. New courses and revisions of existing course will be evaluated in Civil Engineering and related disciplines dealing with estimates of causes and effects of coastal flooding, storm surge, ocean waves, tsunami loads, earthquake effects, and strong winds. Courses will be alternatively offered in the form of conferences, workshops, and lectures. Lecturers and experts from CRC, ERDC, FEMA, and other partners will be invited to participate. State of practice technology will be a priority, e.g., FEMA P646 publication for tsunami load estimates. The National Infrastructure Protection Plan and state infrastructure protection programs and plans will be addressed. Results of recent research work by UPRM, ERDC, and other CRC partner investigators regarding flood, wave, earthquake and tsunami, and hurricane wind effects on structures will be incorporated. Being a small and fully developed island, Puerto Rico offers the ideal setting to assess lessons learned of the effect of natural hazards on built and natural infrastructure including housing, commercial, industrial, institutional, transportation, communication systems, and others. Most recent Hurricane Irma and María experiences on the devastation over Puerto Rico will continued to be evaluated and the lessons learned will be incorporated in presentations, curriculum contents, and guidelines. The principal investigators will continue participating in various working teams, forums and meetings addressing building a resilient community in Puerto Rico for the future. At present time the PI's are involved with various initiatives, for example, Resilient Puerto Rico, Imagine Puerto Rico, and others. All communities in Puerto Rico have been left overexposed to major damages and recovery challenges which requires strong capacity building from the engineering perspective. The Island continues to present more catastrophic settings from overdeveloped and exposed urban and rural communities, more vulnerable zones (flood prone, weak soils and landslides, hurricane wind exposure), highly concentrated and poorly planned urban communities, stressful tradeoff between urban development and natural ecosystems development and conservation, extreme economic development constraints and suboptimal first responders resources (e.g. funding, equipment, capabilities, training, and others) make the Island educational settings most challenging. All this setting will be available for first hand assessment and evaluation from the educational and research perspective.

Puerto Rico will be in a continuous development process focusing on providing a more resilient community, infrastructure, families, and individual. The project will collect, disseminate and expose new knowledge and lessons learned from our past and expected natural events causing damages to the community.

This program has also the goal to facilitate internships at CRC universities performing research in CRI and in government agencies and industry dealing with coastal hazards. Being a minority serving institution (MSI) with a high women's participation (near one-third in Civil Engineering) it is also our goal to create and capacitate minority Hispanic students, faculty, professionals, and affected citizens to warranty up to date level of competency in Coastal Resilient Infrastructure to this part of the community. Our MSI University has been providing well qualified Hispanic engineers to the mainland United States for many years and will benefit from the opportunity to collaborate with DHS and the community it serves.

2. End users:
    a. **Students** (Roles: trainees, undergraduate and graduate research): Students participated in formal and informal education. A variety of undergraduate and graduate research and projects addressing local projects associated with civil infrastructure exposed and vulnerable to natural hazards.
    b. **Faculty** (Roles - trainers, trainees, researchers) Course development and supervision, research work-proposals and projects: Faculty continued engaged in resilience of coastal infrastructure either by offering training and courses and engaging in research work (proposals and projects) but also as trainees in trainings and workshops. Various professors engaged course amendments and course development in resilience topics. Some turned into leadership roles in their research teams.
    c. **Professional Engineers and Planners** – Industry (Role – trainers and trainees, partners and sponsors): Participated as audience, certificate of participation and recipients of continuing education certifications. They also participate as trainers in expertise areas of interest.
    d. **PR Emergency Management Agency Staff - FEMA** (Roles - trainees, collaborators, partners): Provided training and tools through a partnership with administrators for coordinating trainings, workshops, meetings and collaboration activities (see list in Section 9. Educational Activities and Milestones) based on their needs and priorities. Provide instructors for trainings, provide facilities, videotaped of activities, and issued Certificates

of Participation to FEMA officials were invited and participated in all the activities sponsored by the CRC.

e. **Partnership with RAND Corporation - Contactor to FEMA** (Role- sponsor, trainers, and trainees): A research service partnership (Project DR4339PR -Expert Analysis of FEMA Cost Estimate Development Process and Validation for FEMA-4339-DR-PR was established in 2018 (2018-2019: $0.5M) and extended to 2020 (added $0.5M to support RAND officials in the reconstruction efforts of Puerto Rico focusing on providing expert advice and support on cost estimation and validation of permanent reconstruction projects to be sponsored by FEMA public assistance projects . The partnership was established through the initiative of the CRC. CRC PI's as a PI's of this project and Point of Contact, were instrumental in establishing the relationship and recruited a team of faculties and students to continuously work on various scope of works on reconstruction projects in public infrastructure, namely: buildings, water/waste water, dams, power and energy, transportation, communications, and cost estimates and validations, and others. This initiative operates through periodic meetings, communications and meetings between officials from both parties. Six professors and seven students have been involved in this research project which complements.

f. **Partnership with EPA** (Role: mentors, sponsors, trainers, and partners). "*As Chairman/Professor of the DHS Coastal Resilience Center of Excellence-UPRM Partner Department of Civil Engineering & Surveying at UPR-Mayagüez (Partnership developed in Year 4) ; Ismael is a key partner of the EPA-led PR Healthy Buildings Workshop (Homes/Public Housing/Schools/Public Buildings) Long-Term Recovery Initiative.*" - citation from the LEED-AP Indoor Air Quality Coordinator- Asthma, Mold, Radon & Radiation, Disaster Recovery HSS-RSF Co-Lead Technology, Transportation and Radiation Branch, Air and Radiation Division, US EPA Region II, 212-637-3719 This partnership was established through a reference from the CRC personnel at DHS in Year 4. In Year 5 the partnership evolved. Various initiatives have been developed in this direction, namely: 1) "New Test Method for Community Mapping of Radon in PR"; EPA Project Leaders; The specific objectives from UPRM with this project are to: (1) provide assistance to EPA in deploying and retrieving radon monitoring devices; (2) provide technical assistance in testing and monitoring air samples in the identified municipalities; and (3) train and empower community leaders. A total of 9 undergraduate students (both from Civil and Chemical Engineering Departments) have joined this effort under the lead of Dr. Pedro Tarafa, who will be the On-site Technical Leader. $25,000 (January 2020 – Projected end August 2020).

g. **Partnership The American Society of Agricultural and Biological Engineers (ASABE)**- (Roles: Participants, Invited Speakers, Students, Faculty, professionals) CRC collaborates with the organization of a one-day conference as part of the five-day International Symposium on Soil Erosion Research under a Changing Climate (A decadal ASABE Soil Erosion Research Symposium) at UPRM- Department of Civil Engineering and Surveying. (postponed January 2022)

h. **RISE-UP Program-A Collaborative Undergraduate STEM Program in Resilient and Sustainable Infrastructure sponsored by National Science Foundation** (Role: Collaboration, support, partnership in educational activities): RISE-UP is an interdisciplinary program that includes undergraduate students pursuing Civil Engineering, Surveying, Electrical Engineering and Environmental Design (Architecture) degrees at three University of Puerto Rico Campuses (Mayagüez, Rio Piedras and Ponce). RISE-UP student participants have participated as audience in workshops and field trips.

i. **Municipality and state government** - engineers, planners, technicians, administrators, others (Role: trainees, collaborators): Participated as audience and certificate recipients. Share their problems and priorities. Coordinated field trips and inspections.

j. **Community leaders and members** (Roles: trainees, certificate recipients): Community leaders and members of communities at risk participate in trainings, workshops and team building where they can share their experiences and needs.

k. **Partnership with the Añasco River Watershed Management Working Group:** (Roles: Collaboration, training , sponsorship) A basin wide stakeholder's team has been formed focusing of basin wide resilient attention to the Añasco River basin flooding and environmental problems. This imitative has been led by the Community Planning and Capacity Building Recovery Support Function (CPCB RSF) – Aguadilla Office with the participation of many government and community stakeholders.

l. **Collaboration Initiative with The Nuclear Alternative Project (NAP)-(**Roles**:** partners for seismic, geotechnical and water resources studies). The UPRM-CRC Team coordinated to participate in practical research work for evaluating the feasibility of alternative nuclear energy for the Island. A feasibility study is proposed (FEASIBILITY STUDY FOR MICRO AND SMALL MODULAR REACTORS (SMR) FOR PUERTO RICO $3.1M) by the NAP to the USA Department of Energy to evaluate the economic, safety and societal aspects of deploying micro-reactors and SMRs for Puerto Rico. Puerto Rico aspires to a clean, resilient, zero-carbon emission energy generation portfolio as the basis for a modernized, robust and dynamic economy. Based on the latest draft of the Integrated Resources Plan (IRP), for the near-term, Puerto Rico plans to replace all oil and coal plants with natural gas plants while at the same time reforming regulatory and financing tools to expedite solar and wind projects across the island.

m. **NIST Intergovernmental Personnel Act with NIST** (Roles: Dr. Aponte-Bermudez has brought significant expertise in wind and structural engineering to the NIST team studying Hurricane Maria's impacts on Puerto Rico. Dr. Aponte-Bermudez contributed with measurements and modeling of the wind environment in Puerto Rico, as well as documentation of the performance of buildings through post-hurricane damage assessments. Dr. Aponte has continued his collaboration with NIST for the ongoing evaluation of structural condition of the infrastructure of Puerto Rico.)

n. **Oregon State University** (Dr. Dan Cox): We planned to supply two UPRM students for 2020 SUMREX opportunities. Unfortunately, this could not be executed for the COVID-19 pandemic and the Puerto Rico lock down public policies.

3. Unanticipated Problems:

Year five has presented significant challenges that we faced, evaluated, managed and adapted to. They are described in the following:

(1) Seismic Sequences in Puerto Rico: From December 28 until present time Puerto Rico has experienced sequences of seismic activities including a major earthquake and several aftershocks with significant magnitudes and ground acceleration. The PI was appointed by the Chancellor to lead a team to perform Rapid Visual Inspections in order to certify the suitability of the building to be occupied and be able to return to classes and research

at the university. A team of 25 Faculties, professional Engineers and students were led to inspect over 100 buildings in campus. Although classes began with one week delay, the PI continued working almost exclusively on the assignment until February.

(2) COVID-19 Pandemic: By early March, less than a month after the first phase of the seismic assignment, the Governor of Puerto Rico, the President of the University and the UPRM Chancellor declared a lock down which closed the university for the rest of the semester. All in-person activities that were planned at the university were cancelled or switched to distance activities assisted by technologies. This included all CRC planned activities which some were reprogrammed for next semester or until allowed. Others were switched to webinars. Various activities initiated to focus on lessons learned and learning experiences, including a Special Project with 11 undergraduate and graduate students, had the be postponed to be finished by Summer for the inability to go back to develop detailed seismic building inspection of the most critical case studies that were assigned to evaluate UPRM buildings.

(3) An initiative that was negotiated to support the Governor's initiative to evaluate the suitability of returning to normal operation of schools and correctional facilities, has been postponed until the Lock Down is over.

(4) Two SUMREX opportunities that were announced for two UPRM candidates to participate with Dr. Dan Cox SUMREX Program, as we have done in the past, were canceled.

(5) The traditional UPRM- ERDC Educational and Research Internship Program that seeks opportunities in resilient infrastructure topics for undergraduate and graduate students was also cancelled, reducing significantly the opportunities and accessibility of excellent prequalified candidate to be assigned to exiting summer experiences in resilient topics with US ARMY Corp of Engineers (ERDC).

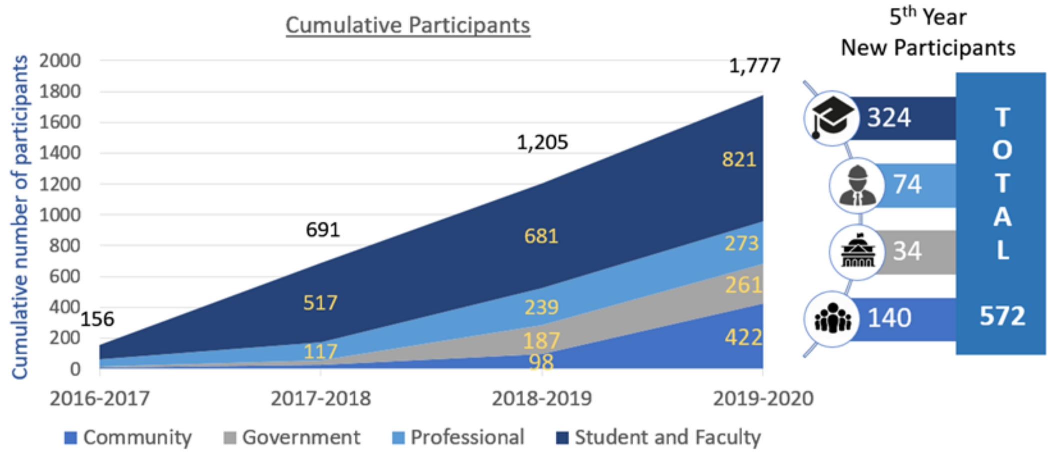
(6) The Co-PI who worked effectively for 4.5 years, retired in December. The CRC team was reorganized during this semester.

4. Students and recent graduates:

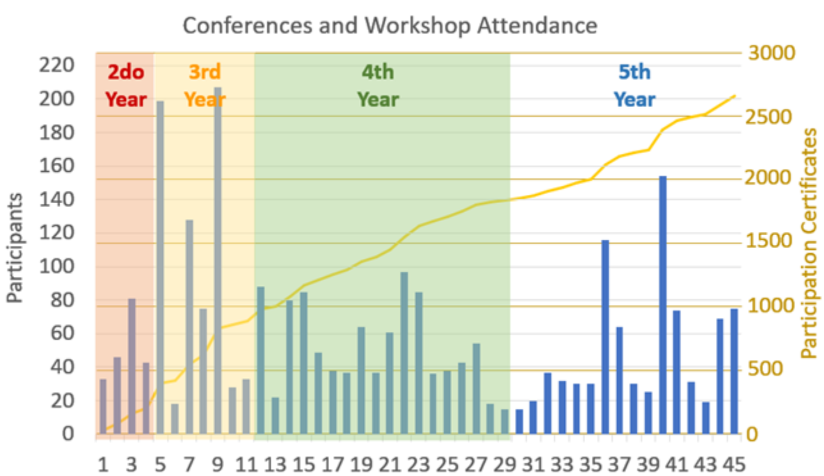
a) Number of undergraduates, graduates, working professionals: 572
b) Percentage minority students: over 95% of participants are Hispanics (Puerto Rico)
c) Number of students graduated: 51
d) Number of former students employed in resilience-related fields: 5
e) Number of former students who went on to enroll in graduate-level programs: 4

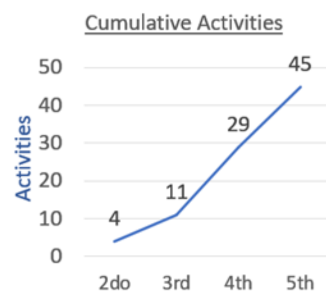
5. Project Impact:

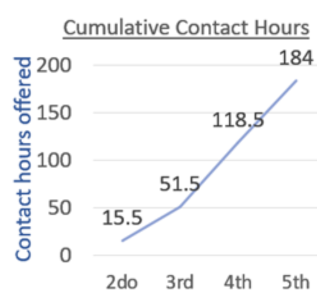
Number of participants: 1,777
Total contact hours of participation: 8,784



Conferences and Workshop: 45
Contact Hours Offered: 184
Participation Certificates: 2,659

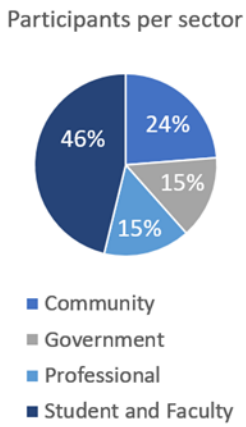


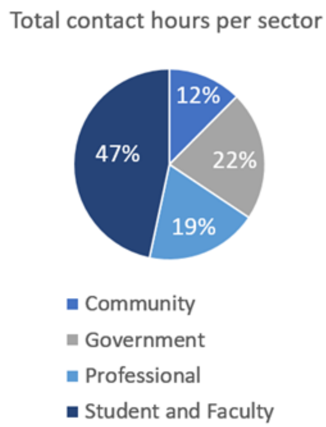


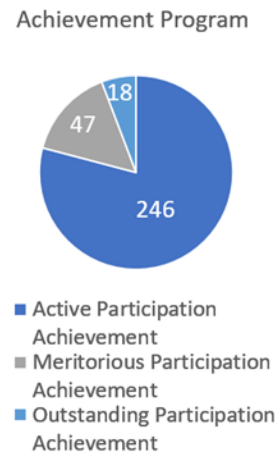


Community, private sector, government and academic participation.

311 Achievement Program Certificates and 105 Instructor Recognitions







UPRM - Coastal Resilience Center

Stats - May 31, 2020

UPRM - Coastal Resilience Center Participants

Number of participants:	1,777	Instructor Recognitions:	105
Total contact hours of participation:	8,784		

Segregation by sector:

	Community	Government	Professional	Student and Faculty
Number of participants:	422	261	273	821
Total contact hours of participation:	1092.5	1,927.5	1,665.0	4,099

UPRM - Coastal Resilience Center Activities

Number of activities:	45
Contact hours offered:	184

Segregation by year:

	2do	3rd	4th	5th
Number of activities:	4	11	29	45
Contact hours offered:	15.5	51.5	118.5	184

UPRM - Coastal Resilience Center Achievement Program:

Achievement	Participants
Active Participation Achievement	246
Meritorious Participation Achievement	47
Outstanding Participation Achievement	18

Segregation by sector:

	Community	Government	Professional	Student and Faculty
Active Participation Achievement	19	77	67	83
Meritorious Participation Achievement	1	18	4	24
Outstanding Participation Achievement	0	5	1	12

Segregation by year:

	2016-2017	2017-2018	2018-2019	2019-2020
Active Participation Achievement	66	28	100	52
Meritorious Participation Achievement	0	7	21	19
Outstanding Participation Achievement	0	1	11	6

UPRM - Coastal Resilience Center

Stats - May 31, 2020

UPRM - Coastal Resilience Center Participants

Number of participants:	1,777	Instructor Recognitions:	105
Total contact hours of participation:	8,784		

Segregation by sector:

	Community	Government	Professional	Student and Faculty
Number of participants:	422	261	273	821
Total contact hours of participation:	1092.5	1,927.5	1,665.0	4,099

UPRM - Coastal Resilience Center Activities

Number of activities:	45
Contact hours offered:	184

Segregation by year:

	2do	3rd	4th	5th
Number of activities:	4	11	29	45
Contact hours offered:	15.5	51.5	118.5	184

UPRM - Coastal Resilience Center Achievement Program:

Achievement	Participants
Active Participation Achievement	246
Meritorious Participation Achievement	47
Outstanding Participation Achievement	18

Segregation by sector:

	Community	Government	Professional	Student and Faculty
Active Participation Achievement	19	77	67	83
Meritorious Participation Achievement	1	18	4	24
Outstanding Participation Achievement	0	5	1	12

Segregation by year:

	2016-2017	2017-2018	2018-2019	2019-2020
Active Participation Achievement	66	28	100	52
Meritorious Participation Achievement	0	7	21	19
Outstanding Participation Achievement	0	1	11	6

6. **Institutionalization**:

i. Certificate on Resilient Infrastructure: Various modules have been developed for offering as part of the initiatives to institutionalize the Certificate:

(a) **"Introduction to the Structural Seismic Design of Reinforced Concrete Structures (in Spanish) & FEMA Rapid Visual Screening of Buildings for Seismic Resistance"** – Dr. Ricardo López, Retired Faculty;
(b) INCI 4138- Water Resources Engineering modules were incorporated in the CRC project and has updated - Dr. Raúl Zapata, adapted a required CE core course to incorporate resilience content.
(c) **"Soil Hazards, Landslides and Erosion"** – Alexander Molano- CRC Graduate Student,
(d) "***Orientación - Carreras de Ingeniería Civil y Agrimensura; Riesgos y Desastres Naturales; Terremotos*** y Huracanes"- Juan Rodríguez, CRC Ph.D. Student;
(e) **A First Course on Coastal Resilient Structures, The course is divided into four modules.** Dr. Alí Saffar) The first module reviews the fundamentals of probability theory as it relates to extreme low probability coastal events; x2) The second module discusses the principles of the reliability based design. Safety indices are augmented to account for the conditional nature of coastal hazards. x3) The sensitivity analysis is the focus of the third module. The necessary steps in defining uncertainties and the use of decision trees and fault trees are discussed. x4) The fourth module teaches the fundamentals of the fragility analysis. The risk assessment toolkits are developed as part of this module.
(f) **Multihazard Mitigation: Resilient Alternatives – Events, Risks, and Hazards**- Dr. Raúl Zapata is developing a module on the relationship of the four needed natural elements of life air, water, soil and energy (fire) to the hazards they present to us. Their interlocking effect they have can also can produce natural hazards which are not single event hazards, because they generate a combined effect that humans need to recognize and deal with them as a multihazards perspective.

ii. Grant : **RAND Corporation - Contactor to FEMA** (Role- sponsor, trainers, and trainees): A research service partnership (Project DR4339PR -Expert Analysis of FEMA Cost Estimate Development Process and Validation for FEMA-4339-DR-PR was established in 2018 (2018-2019: $0.5M) and extended to 2020 (added $0.5M to support RAND officials in the reconstruction efforts of Puerto Rico focusing on providing expert advice and support on cost estimation and validation of permanent reconstruction projects to be sponsored by FEMA public assistance projects .

iii. Grant: "New Test Method for Community Mapping of Radon in PR"; EPA Project Leaders; The specific objectives from UPRM with this project are to: (1) provide assistance to EPA in deploying and retrieving radon monitoring devices; (2) provide technical assistance in testing and monitoring air samples in the identified municipalities; and (3) train and empower community leaders. A total of 9 undergraduate students (both from Civil and Chemical Engineering Departments) have joined this effort under the lead of Dr. Pedro Tarafa, who will be the On-site Technical Leader. $25,000 (January 2020 –Projected end August 2020).

Faculty involvement:
- Instructors: Ricardo López, Ismael Pagán Trinidad, Carla Lopez del Puerto; José Guevara, Alberto Figueroa, Beatriz Camacho, Luis Suárez;
- Module Development: Ali Saffar, Resilient Coastal Structural Design, Reliability and Fragility Curves; Ricardo López: Seismic Rapid Visual Inspections; Carla López del Puerto: Five Dimensional Construction Management; Raúl Zapata- Multihards; Ismael Pagán Trindad-Water related multihazards.
- Participants – Over 20 UPRM faculties engaged in the CRC Activities.

f) **Maintenance of project products**:
   i. The Department of Civil Engineering and Surveying through the Civil Infrastructure Research Center (CIRC) has been and will continue to be the host for Resilient Civil Infrastructure Capacity Building (RCICB)

g) **Planning for institutionalization**
   i. The CRC Co-PI's, the Civil Engineering Directors, the Director of the CIRC the Academic Affairs Committee, the faculty, the Deanship.

7. Interactions with research projects:

- Two students participated in at Oregon State University with Dr. Dan Cox (July 2019 SUMREX). The initiative for another SUMREX at Oregon State University for two students had to be canceled due to the national lock down.
- The interaction with Dr. Gavin Smith and the RETALK initiative was interrupted for the Seismic and the COVID-19 lock down for which it was necessary to postpone as some other activities. These initiatives are focused on expanding the collaboration between both institutional and CRC projects.

III. EDUCATION ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Education Activities and Milestone Achievements:

Education Activities and Milestones: Status as of 6/30/2020			
Education Activities	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Continue with Second Round of the series of seminars/lectures/short courses (SLSc) in **"Advances in Analyses/Design/Operation/Maintenance/Retrofitting of Resilient Coastal Infrastructure."** to be selected from the following list of topics. Possible resources will be identified by the end of first year.	One per month (at least	100	

1. Keep Safe: A Guide for Resilient Housing Design in Island Communities (Spanish/English) – Book (Enterprise, 2019) (Participants = 60) 2. Regional PRASA Response to Hurricane Maria & Post-Event Resilient Water Infrastructure Recovery Activities; UPRM-CRC, PRASA Western Region, UPRM-CIRC October 15, 2019 (Participants=116) 3. Basin Wide Initiatives for Improved Coastal Resilience: UPRM-CRC, FEMA, USACE-ERDC, DRNA, November 13-15, 2019. a. **Uniqueness of Puerto Rico Hydrology:** Topography, Rainfall-Runoff, Riverine Flash Floods, Urban Development, Coastal Risks, Sediment Loads - Ismael Pagán Trinidad and Ricardo López-Rodríguez, UPRM CRC b. **Consideration for Coastal Communities Key Vulnerabilities:** Sea Level Rise, Coastal Flooding, Inland Flooding, Erosion/Sedimentation, and Debris. - Ernesto Díaz, PR Climate Change Council/DNER-Coastal Management Zone c. **Integration of Nature Based Solutions:** Wetlands, Farm ponds, Stormwater Detention Basins, Terraces, Sediment Detention Basins, Floodplain Restoration, Channel Bank Stabilization, Buffer Strips, Saturated Buffers, Bioreactors and Scalable Low Impact Development – Environmental Lab, ERDC-USACE d. **Green infrastructure myth busting:** Dealing with site constraints, Cost, Utilities and Performance – Environmental Lab. ERDC-USACE e. **Engineering with Nature – NNBF** – Environmental Lab, ERDC-USACE f. **USACE Jacksonville District Perspectives; Projects**: Río Guayanilla, Río Guanajibo, Río Portugués, Río Bucaná, and Río Puerto Nuevo, PR District Offcie-USACE g. **Small-Scale Rainfall Variability in Western Puerto Rico and its Implications on Agricultural Water Management** - Eric Harmsen, UPRM 4. Transforming University Engagement In Pre- and Post-Disaster Environments: Lessons from Puerto Rico; PANEL; University Partnership R&D, Education & Engagement: Tapping the Potential of Universities to Develop the Next Generation of Disaster Professionals, Knowledge Creation, Campus Resilience Building and Community Service, presented at the University of Albany, N.Y.; RISE CONFERENCE 2019, Ismael Pagán			

Trinidad and Ricardo R. López Rodríguez, November 18-20, 2019. 5. Observations on the Impact of Hurricane María in PR presented at the University of Albany, N.Y. ; RISE 2019 National Conference; Panel: Infrastructure Challenges Facing our Islanded Communities; Ricardo R. López Rodríguez and Ismael Pagán Trinidad, November 18-20,2020 6. UPRM -CRC Response to Seismic Sequence in PR Major shot down: Earthquake (6.4M) and aftershocks (5.9M, 5.8M); Chancellor commissioned PI's/CE Department to support recovery process ; In-charge: Inspecting/Certifying/Orienting/Assessing University infrastructure; Team: 13 faculties; 12 students; 10-16 hr/day; Jan 8-Jan 20; About 100 university facilities; many community facilities (Good Samaritan work); Buildings were gradually reoccupied – only one week delay in classes; 7. Five faculties were appointed to study the earthquake impact on university buildings and to develop Best Seismic Resistant Practice for Buildings 8. IIC Student Chapter & CRC: Engineering Students Field Visit to Perform Rapid Visual Inspections to Earthquake Zone, 2020 Southwest Puerto Rico Earthquake Sequence Damage, Sat, march 7, 2020 (31 students, 9 professionals). 9. **Introduction to Seismic Analysis of Structures with SAP2000 -** Luis E. Suárez, UPRM, March 10, 2020. 10. **Introduction to Seismic Analysis of Structures with SAP2000 -** Luis E. Suárez, UPRM, March 12, 2020 11. **Coastal Flood Exposure Mapper Webinar -** NOAA Office for Coastal Management, May 21, 2020. 12. **Introducción al Diseño Sísmico de Estructuras de Concreto Reforzado & FEMA Rapid Visual Screening of Buildings for Seismic Resistances, Webinar, Ricardo Lopez, June 11, 2020 (in Schedule)** 13. **Coastal Resiliency Building, Mainstreaming Adaptation (Capstone Course) -** Ernesto Díaz, PR Climate Change Council/DNER-Coastal Management Zone, 8/22/2019. 14. **Planning and Scheduling a Design and Construction Project -** Ismael Pagán Trinidad and Carla López del Puerto, UPRM CRC. Sept 24, 2019.			
Internships: 1. SUMREX (July 2019) Two students participated at Oregon State University, sponsored by Dr, Dan Cox (carried over from June 2019) Ihan Jarek Acevedo "**Measuring Run-up on a Laboratory-Scale Beach Dune using LiDAR**; Ihan-Jarek T. Acevedo González University of Puerto Rico at	May, 2020	100	

Mayagüez Dr. Meagan Wengrove, O.H. Hinsdale Wave Research Laboratory; Oregon State University, REU • **NSF PIRE Program Follow Up: "Effects of Storm Surge Barriers on Estuary Ecosystems: A Comparison between Eastern Scheldt and Galveston Bay", Poster presented in September as a result of her continued research work during Summer 2019 (July) Sofia Rivera, with JSU and TAMUG, Continued.** • Cancelled due COVID-19, 2 Candidates were pending to be sent to OSU-Dr. Dan Cox • ERIP - Coastal and Hydraulic Laboratory - Engineer Research and Development Center, Vicksburg. MS • Seek and make available to students and faculty new internship opportunities at other federal agencies and universities.			
Repeat workshops to new audience (tentative dates) a. Basin Wide Initiatives for Improved Coastal Resilience: UPRM-CRC, FEMA, USACE-ERDC, DRNA, November 13-15, 2019: **Basin Wide Coastal Resilience Workshop Group think:** Each watershed will identify eligible subwatersheds to construct and implement built projects, both conventional hard engineered and soft engineered solutions. – X,Y,Z, ERDC-USACE b. **Basin Wide Initiatives for Improved Coastal Resilience Site Visit to Watershed; Río Guayanilla** - Ismael Pagán Trinidad, UPRM CRC c. Workshop: GIS Training for Coastal Resource Professionals UPRM-CRC, NOAA, UPRM-CIRC, Sea Grant, December 10-11, 2019 (Participants=30) d. NOAA Digital Coast Tools for Coastal Resource Professionals; UPRM-CIRC, NOAA, Sea Grant, UPRM-CRC, December 12, 2019 (Participants=25) e. Riverine and Coastal Flood Hazards with USGS– Planned for April – Postponed for Fall Semester October 2019. f. PR Chamber of Commerce's Healthy Buildings' Task Force: Developing Workforce Projections; (Short, Mid and Long-term) for Environmental Skilled Trades: Asbestos, Lead, and Mold; Friday, Dec. 13, 2019; Interamerican University Law School, San Juan, PR (By Invitation Only). 3. **Five-Dimensional Project Management (5DPM) for Coastal Communities Workshop** - Carla López del Puerto, UPRM CRC, 7/5/2019. 4. **Tsunami AwarenessAWR-217** - Victor Huérfano, Puerto Rico Seismic Network and Christa von Hillebrandt, Caribbean Tsunami Warning Program. July 31, 2019.	May, 2020	100	

Formal Courses: 1) INCI 5996 - (Earthquake Assessment and Evaluation) Experiential Learning course offered - 11 students; Dr. José Guevara, Dr. Felipe Acosta, Dr. Arsenio Cáceres, Dr.Ali Saffar, January –May 2020. 2) INCI 4998 – Undergraduate Research: Sofia Rivera Soto, **NSF PIRE Program Follow Up: "Effects of Storm Surge Barriers on Estuary Ecosystems: A Comparison between Eastern Scheldt and Galveston Bay", Paper and Poster presented in September as a result of her continued research work during Summer 2019 (May-September) with JSU and TAMUG, continued. Prof. Ismael Pagán Trinidad.** 3) INCI 8999- Dissertation: "Variation of the nonlinear dynamic response of three-dimensional buildings of reinforced concrete considering the directionality of seismic accelerations" by Juan Rodríguez 4) INCI 6066-MS Thesis: • "Structural Effects of Tsunami Loads on Coastal Infrastructure," by Kevin Cueto (Ricardo Lopez). • "Stochastic Simulation of Tropical Cyclones for Quantification of Uncertainty Associated with Storm Recurrence and Intensity" by Efrain Ramos (Ismael Pagán-Trinidad and Norberto Nadal) • "Transportation Resilience in Western Puerto Rico: Hurricane Maria Case Study" By Alexander Molano Santiago (Benjamín Colucci, Ismael Pagán Trinidad, Ricardo López Rodríguez and Luis Aponte Bermúdez) 5) INCI 6065 (Master Engineering Project): • Structural Analysis of Common Coastal Structures found on the West Coast of Puerto Rico using FEMA P-646 by Jorge Romeu (Ricardo López/Dr. José Guevara) • "Assessment of Hurricane Vortex Models for the Development of Wind and Pressure Profiles and Fields", By Nelson Y. Cordero (Ismael Pagan & Norberto Nadal) • "Decision support system for gate operation at Claren Cannon National Wildlife Refuge in Pikes County, Missouri" by Oscar Velez Ramos (Ismael Pagán Trinidad) 6) INCI 4950 – Capstone Course: Integrated Civil Engineering Design Project: The WIRE CENTER; 45 students work in the design of resilient and sustainable mix use urban development project which were subjected to multihazards (earthquakes, flooding, and hurricane winds. And soil instabilities. Appropriate courses (including new ones) in the curriculum sequence will be offered based on demand. One to two courses will be offered per semester based on needs and demands.	Dec. 2019 & May 2020	100	

Curriculum Sequence – Certificate • We are developing capacity building trainings and educational modules which will Impact on the formal Civil Engineering curriculum. • This includes incorporating new content into existing courses and providing professional complementary trainings. • Students are issued certificates of participation to recognize their involvement in the program.	January 2021	95%	Almost completed. The plan was followed. • Courses to be impacted were identified. • Educational modules were developed. • Collaboration with other parallel initiatives in these topics were completed • Certificates have been awarded to students • The only thing pending is to issue certificates to participating students. Pending to finish in January
Website: The website will be updated and documentation form the project and CRC will be incorporated.	Dec. 2019	100	
Publications/Documentation/Divulgation: Continue efforts to facilitate access to public domain literature on state practice and advances in resilience of coastal infrastructure. Efforts will be targeting peer-reviewed forums, preferable at the national level, e.g., ASEE, ASCE Annual conferences.	June, 2019	100	Web Site
<u>Education Milestones</u>			
Advance the state of knowledge of various constituencies through technology transfer, training, and teaching <u>Metric:</u> Number of participants and number of certificate issued	Aug. 2019 – June 2020	100	
Provide alternative learning, motivation and incentives to students through research and experiential work in internships. Introduce students into a pipeline toward HSE advanced graduate education and research careers and jobs <u>Metric:</u> Number of students and nature of experiences participating in alternative learning initiatives	Summers 2019 & 2020	100	
Provide state of practice through practical workshops	Dec-19, Jun-20	100	

Incorporate HSE into the continuing education and formal education curriculum	Dec-19, Jun-20	100	
Advance state of knowledge by divulgation and providing access to state-of -practice technology on resilient infrastructure. Metric: Number and nature of initiatives for divulgation	June, 2019	100	
Institutionalize the Curricular Sequence (Certificate) on Infrastructure Resilience Metric: Number and nature of activities support by the Center- See Statistics and list of activities presented previously.	May, 2020	100	

2. Year 5 **Transition** Activities and Milestone Achievements:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
A target of 10 students is expected to begin the first round of certificates. (35 students enrolled in Capstone Course were issued the Certificate)	May 2020	100	
Establish the Civil Infrastructure Research Center (CIRC) at the CE Department as a Technology Transfer and Training Unit for RCI	May 2020	100	
Institutionalize a Local Annual Meeting addressing the advances of "Advances in Analyses / Design / Operation/Maintenance / Retrofitting of Resilient Coastal Infrastructure." Invitees will include academics, university partners, and local emergency planners.	April 2020	100	
Identify and diversify possible resources to offer SLSc activities (Advances in Resilient Coastal Infrastructure) by the end of first year :Water/Wastewater; Transportation (bridges, roads, etc.); Flood/Drainage; Buildings (Housing / Commercial / Industrial / Hospitals / Schools, etc.); Airports / Seaports Pending); Communication / Power; Geotechnical Structures / Landslides / Liquefaction; Coastal Protection Infrastructure (Partners from ERDC, CRC, others to be invited); Green Protective Infrastructure (Partners from ERDC, CRC, others); Extreme Climate Adaptation.	Dec. 2019	100	
Internships: Internships are dependent on availability of positions, qualification requirements, and acceptance by particular internship hosts. Our target will be at least three different sites, receive at least 10 applications, and place at least five students. For the uncertainty of not	Summer 2019	100	

depending on ourselves to allocate students for internships and professional practical experiences, we will also consider hosting summer students at UPRM through undergraduate research and special problems in the topics. • SUMREX: Coordination with CRC Research PIs to identify and diversity positions to allocate students with available partner PIs • Seek new opportunities at the Coastal and Hydraulic Laboratory-ERDC, Vicksburg, MS • Seek new opportunities at other federal agencies and universities • Pursue student exchange programs with NCSU, UNC, OSU, and others			
Repeat workshops to new audience (tentative dates) • Basin Wide Initiatives for Improved Coastal Resilience: UPRM-CRC, FEMA, USACE-ERDC, DRNA ,November 13-15, 2019 : Basin Wide Coastal Resilience Workshop Group think: Each watershed will identify eligible subwatersheds to construct and implement built projects, both conventional hard engineered and soft engineered solutions. X,Y,Z ERDC- USACE • Basin Wide Initiatives for Improved Coastal Resilience Site Visit to Watershed; Río Guayanilla - Ismael Pagán Trinidad, UPRM CRC • Workshop: GIS Training for Coastal Resource Professionals UPRM-CRC, NOAA,, UPRM-CIRC, Sea Grant, December 10-11, 2019 (Participants=30) • NOAA Digital Coast Tools for Coastal Resource Professionals; UPRM-CIRC, NOAA, Sea Grant, UPRM-CRC, December 12, 2019 (Participants=25) • Riverine and Coastal Flood Hazards with USGS (Walter Silva)– Planned for April – Postponed for Fall Semester October 2019. • PR Chamber of Commerce's Healthy Buildings' Task Force: Developing Workforce Projections; (Short, Mid and Long-term) for Environmental Skilled Trades: Asbestos, Lead, and Mold; Friday, Dec. 13, 2019; Interamerican University Law School, San Juan, PR (By Invitation Only). • Five-Dimensional Project Management (5DPM) for Coastal Communities Workshop - Carla López del Puerto, UPRM CRC, 7/5/2019. • Tsunami AwarenessAWR-217 - Victor Huérfano, Puerto Rico Seismic Network and Christa von Hillebrandt, Caribbean Tsunami Warning Program. July 31, 2019. •	May 2020	100	
Curriculum Sequence - Certificate and Formal Courses Offering • Increase students in the curriculum sequence • Certificate program will continue to be promoted and announced	• Jan 2021	• 95%	• Almost finished. The plan was being followed. • 1. Certificates: Issuing certificates to participating students will be

• Completion of first round of certificates. • Theses, undergraduate research, special problems and other appropriate course will offered based on demand to be included in the curricular sequence.			finished be the end of January. • • Module development: • a. Water Resources Engineering (INCI4138) course: "This module was incorporated and presented to the 26 students in the course. The natural hazards directly related to water such as hurricanes, storm surge, floods, heavy rainfall as well as droughts periods are frequently associated to the class material. The risk assessment to have more resilient infrastructure during the construction process as well as during the service life of the water infrastructure is also presented. propose alternative for future study. • b. "Planning and Accounting for Adverse Weather" (3 contact hours) • A module titled "Planning and Accounting for Adverse Weather" was developed based on AACE® International Recommended Practice No. 84R-13. Construction

			projects, particularly those in coastal communities, are exposed to adverse weather events which impact the project schedule. The module developed discusses weather-related terms and definitions, identifies methodologies for adverse weather planning, and provides recommendations for managing actual weather documentation. • During Fall 2020, 4 graduate students and 1 undergraduate student enrolled in INCI 6070 completed the module. • c. Other modules will continue to be developed based on the structure already developed.
Publications/Documentation/Divulgation: Continue efforts to divulge public domain literature on state practice and advances in resilience of coastal infrastructure. The website will be updated and documentation form the Project and CRC will be incorporated. These publications could be peer reviewed or from other reputable accessible sources.	June 2020	100	
<u>Transition Milestone</u>			
Curricular Alternatives in Civil Engineering/Surveying: Expand and diversify the students' participation in the certificate curricular sequence to the RCI specialty by offering a variety of learning alternatives. Seek more courses and alternative learning opportunities for students. <u>Metric:</u> Number and nature of impacts on the curriculum	June 2020	100	

Technology Transfer and Capacity Building: Maintain the technology transfer mechanisms on RCI to professionals and civil engineering/surveying students through training or access to the state of practice literature and educational resources. Metric: Number and nature of initiatives	June 2020	100	
Enhance Students Options and Opportunities to Access Jobs in HSE: Provide civil and surveying students the opportunity to expand their opportunities to study and work in the HSE business and be a part of a pipeline for its national labor force team by means of alternative. Seek and follow up on job opportunities from federal, state and local government. Post and distribute job opportunities among participating students and the student's community either in Civil Engineering or other disciplines in Campus. Metric: Number of job opportunities, job fairs, HLS companies visiting campus	June 2020	100	
Engage Faculty Leaders: Engage civil engineering and surveying faculty as leaders in the RCI field which help seek new opportunities in resilience of coastal infrastructure education, research and practice. Attract and collaborate with faculty from other disciplines like Social Sciences, Marine Science, and other engineering disciplines to motivate and support their engagement in RCI initiatives. Metric: Number faculty has engaged in RCI leadership and type of initiative	May 2020	100	

3. Annual Courses and Enrollments

Annual Courses and Enrollments

Courses Developed and Taught by University of Puerto Rico Mayaguez under Project Education for Improving Resiliency of Coastal Infrastructure						
Course Number	**Course Title**	**Project Year**				
INCI6997	**Course Title: *"Rehabilitation of Coastal Structures (under development)"*- Guevara**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
INCI5995	[Dual codes for graduate and undergraduate]					
Status: Developed (D), Revised (R), and or Taught (T)		-	**D**	**T**	-	-
Offering: Elective (E), Concentration (C), Minor (M)		**0**	**E**	**E**	-	-
Enrollment		**0**	**0**	**7**	-	-
INCI6XXX	**Course Title: *"Resilience and Reliability of Coastal Infrastructures (under development)"*- Saffar**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
INCI5XXX						
Status: Developed (D), Revised (R), and or Taught (T)		-	**D**	**R**	**R**	**R**
Offering: Elective (E), Concentration (C), Minor (M)		-	**E**	**E**	-	-

Enrollment		-	**0**	**0**	**0**	**0**
INCI6995	**Course Title: *"CE Special Problems"* (Graduate)**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
	Status: Developed (D), Revised (R), and or Taught (T)					
	"A Novel Boussinesq -Type Numerical Wave Model Development" – IPT	**T**	**T**	-	-	-
	"Stochastic Simulation of Tropical Cyclones for the Quantification of Uncertainty Associated with Storm Recurrence and Intensity: Phase II" – IPT	**T**	**T**	-	-	-
	"Analysis of a Ring Levee Breach Using Adaptive Hydraulic" – IPT	**T**	**T**	-	-	-
	"US Army Improved Ribbon Bridge" – IPT	-	**T**	-	-	-
	Feasibility of Using the Weather Research and Forecasting Model (WRF) as forcing to the Advanced Circulation Model (ADCIRC) – IPT	-	**T**	-	-	-
	"Assessment of Existing Tropical Cyclone Vortex Models for the Development of Wind and Pressure Profiles and Fields"	-	-	**T**	-	-
	"Vulnerability of Rubble Mound Structures"	-	-	-	**T**	-
Offering: Elective (E), Concentration (C), Minor (M)		**E/C**	**E/C**	**C**	**C**	-
Enrollment		**3**	**5**	**1**	**1**	-
INCI5996	**Course Title: *"Special Problems (Undergraduate Project)"***	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
	Status: Developed (D), Revised (R), and or Taught (T)					
	"Impact of Projected Sea Water Rise on Coastal Infrastructures" - IPT	**T**	-	-	-	-
	"Ship Simulation Study"- IPT	-	**T**	-	-	-
	"Utilities and Building Inventory For Resiliency Analyses at the Mayagüez Municipality Coastal Zone" - Dr. Ricardo Ramos	-	**T**	-	-	-
	"Design and Analysis of Pavements in Coastal Environments"-BCR	-	-	**T**	-	-
	Assessment of Hurricane Vortex Models and Boundary Layer Models for the Development of Wind and Pressure Profiles and Fields - IPT	-	-	-	**T**	-
	"Inspection and Rehabilitation of Earthquake-Affected Structures" - Dr. José Guevara	-	-	-	-	**T**
Offering: Elective (E), Concentration (C), Minor (M)		**E**	**E**	**E**	**E**	**E**
Enrollment		**1**	**4**	**1**	**1**	**11**
INCI6066	**Course Title: *Master of Science Thesis***	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
	Status: Developed (D), Revised (R), and or Taught (T)					
	"Structural Effects of Tsunami Loads on Coastal Infrastructure," by Kevin Cueto (Ricardo Lopez)	-	**D**	**T**	**T**	**T**

	"Computation of Gradually Varied Flow in Channel Networks with Hydraulic Structures" by Felix Santiago (Walter Silva)	-	**D**	**T**	-	-
	"Cost analysis of the alternatives to mitigate damage to the infrastructure in Rincon" by Francisco Villafañe (Luis Aponte)	-	**T**	**T**	-	-
	"Stochastic Simulation of Tropical Cyclones for Quantification of Uncertainty Associated with Storm Recurrence and Intensity" by Efrain Ramos (Ismael Pagán-Trinidad and Norberto Nadal)	**D**	**T**	**T**	**T**	**T**
	"Transportation Resilience in Western Puerto Rico: Hurricane Maria Case Study" By Alexander Molano Santiago (Benjamín Colucci, Ismael Pagán Trinidad, Ricardo López Rodríguez and Luis Aponte Bermúdez)	-	-	-	**D**	**T**
Offering: Elective (E), Concentration (C), Minor (M)		-	**C**	**C**	**C**	**C**
Enrollment		**1**	**4**	**4**	**3**	**3**
INCI6065	**Course Title: *Master of Engineering Project***	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
	Status: Developed (D), Revised (R), and or Taught (T)					
	Structural Analysis of Common Coastal Structures found on the West Coast of Puerto Rico using FEMA P-646 by Jorge Romeu (Ricardo López)	-	**D**	**T**	**T**	**T**
	"Assessment of Hurricane Vortex Models for the Development of Wind and Pressure Profiles and Fields", By Nelson Y. Cordero (IPT & Norberto Nadal)	-	-	-	**D**	**T**
	"Decision support system for gate operation at Claren cannon national wildlife refuge in Pikes County, Missouri" by Oscar Velez Ramos (IPT)	-	-	-	**T**	**T**
Offering: Elective (E), Concentration (C), Minor (M)		-	**C**	**C**	**C**	**C**
Enrollment		-	**1**	**1**	**3**	**3**
INCI8999	**Course Title: *PhD Dissertation***	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**
	Status: Developed (D), Revised (R), and or Taught (T)					
	"Resistencia a Cargas de Tsunami de Estructuras Críticas en el Norte de Puerto Rico" (Resistance to Tsunami Loads of Critical Structures in the North of PR) by Johnny Rosario	-	**T**	**T**	**T**	-
	"Variation of the nonlinear dynamic response of three-dimensional buildings of reinforced concrete considering the directionality of seismic accelerations" by Juan Rodríguez	-	**D**	**T**	**T**	**T**
	"Dynamic Identification and Nonlinear Modeling for the Structural Health Assessment of Aged Coastal Infrastructure in Puerto Rico" by Angel Alicea	**D**	**T**	**T**	**T**	-
Offering: Elective (E), Concentration (C), Minor (M)		-	**C**	**C**	**C**	**C**
Enrollment		**1**	**3**	**3**	**3**	**1**
INCI4950		**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 5**

	Course Title: *Civil Engineering Integrated Design Project - Capstone Course*						
Status: Developed (D), Revised (R), and or Taught (T)			-	T	T	T	T
Offering: Elective (E), Concentration (C), Minor (M)			-	C	C	C	C
Enrollment			-	45	43	65	45
CIMA8999	Course Title: *Marine Science PhD Dissertation*		YR 1	YR 2	YR 3	YR 4	YR 5
Status: Developed (D), Revised (R), and or Taught (T)			-	D	D	D	-
Offering: Elective (E), Concentration (C), Minor (M)			-	C	C	C	-
Enrollment			-	1	1	1	-
CIMA6999	Course Title: *Marine Science Master Thesis*		YR 1	YR 2	YR 3	YR 4	YR 5
Status: Developed (D), Revised (R), and or Taught (T)			-	D	D	-	-
Offering: Elective (E), Concentration (C), Minor (M)			-	C	C	-	-
Enrollment			-	1	1	-	-
INCI4998	Course Title: *Civil Engineering Undergraduate Research*		YR 1	YR 2	YR 3	YR 4	YR 1
Status: Developed (D), Revised (R), and or Taught (T)			-	T	T	T	T
Offering: Elective (E), Concentration (C), Minor (M)			-	C	C	E	E
Enrollment			-	1	1	17	6
-		Course Title:	YR 1	YR 2	YR 3	YR 4	YR 5
Status: Developed (D), Revised (R), and or Taught (T)			-	-	-	-	-
Offering: Elective (E), Concentration (C), Minor (M)			-	-	-	-	-
Enrollment			0	0	0	-	-
-	-	-	-	-	-	-	-
-	-	Annual Enrollment:	6	65	63	94	67

IV. PUBLICATIONS AND METRICS

1. Publications:

a) Publications

- "Complexity Mapping for Resilient and Sustainable Infrastructure"; Manuscript Published as: López del Puerto, C., Suárez, L. Gransberg, D.D., and Montañez, J., "Complexity Mapping for Resilient and Sustainable Infrastructure, Proceedings, VII Conferencia Internacional de Ciencia y Tecnología de la Ingeniería, IESTEC-2019, Panama City, Panama, October, 2019. Peer reviewed.
- KEEP SAFE A GUIDE FOR RESILIENT HOUSING DESIGN IN ISLAND COMMUNITIES, All rights reserved. © Publiched by 2019 Enterprise Community Partners, Inc. Disclaimer: The PI's participated in the book

development as Advisors, Workshop leaders, Reporters and Invited participants of the book presentation.

- Effects of Storm Surge Barriers on Estuary Ecosystems: A Comparison between Eastern Scheldt and Galveston Bay, Sofía N. Rivera Soto; University of Puerto Rico at Mayagüez, Mayagüez, P.R., sofia.rivera6@upr.edu; Dr. Samuel Brody; Texas A&M at Galveston, Galveston, Texas, brodys@tamug.edu; Dr. Yoonjeong Lee; Texas A&M at Galveston, Galveston, Texas, yoonlee@tamu.edu; Prof. Ismael Pagán Trinidad; University of Puerto Rico at Mayagüez, Mayagüez, P.R., ismael.pagan@upr.edu. A Final Technical Paper submitted as part of the requirement of her participation in the NSF PIRE Program. 2019 Summer Research Internship Program Partnership for International Research and Education – The Netherlands Texas A&M at Galveston, Jackson State University and University of Puerto Rico at Mayagüez. September 2019.
- Measuring Run-up on a Laboratory-Scale Beach Dune using LiDAR, Ihan-Jarek T. Acevedo González University of Puerto Rico at Mayagüez Dr. Meagan Wengrove, O.H. Hinsdale Wave Research Laboratory, Oregon State University, REU, Summer 2019. (Report presented as part of his Summer Internship at OSU)
- Erosion Analysis of Dune Types for a Typical East Coast Beach under Hurricane Conditions using Bathymetric and LiDAR Measurements. Authors: Robert Lewis1,2, Jeremy Smith3, Meagan Wengrove1; 1O.H. Hinsdale Wave Laboratory, Oregon State University, Corvallis, OR 97331; 2Department of Civil Engineering, University of Puerto Rico-Mayagüez, Mayagüez, PR. 00682; *3Department of Civil and Environmental Engineering, Stanford University, Stanford, CA94305, December 2019. (Report presented as part of his Summer Internship at OSU)*

b) Theses/Dissertations

- A Decision Support System for Gate Operations at Clarence Cannon National Wildlife Refuge (CCNWR) in Pike County, MO., Oscar A. Vélez Ramos, A project report submitted in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING in CIVIL ENGINEERING UNIVERSITY OF PUERTO RICO, MAYAGUEZ CAMPUS. May 2020. Advisors: Ismael Pagán Trinidad, UPRM and Norberto Nadal, ERDC. Co-Advisors. UPRM-CHL ERDC Collaboration.
- STOCHASTIC SIMULATION OF TROPICAL CYCLONES FOR QUANTIFICATION OF UNCERTAINTY ASSOCIATED WITH STORM RECURRENCE AND INTENSITY; Efraín Ramos-Santiago; A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in CIVIL ENGINEERING, UNIVERSITY OF PUERTO RICO, MAYAGÜEZ CAMPUS, July 2019. Advisors: Ismael Pagán Trinidad, UPRM and Norberto Nadal, ERDC. Co-Advisors. UPRM-CHL ERDC Collaboration.
- ASSESSMENT OF HURRICANE VORTEX MODELS FOR THE DEVELOPMENT OF WIND AND PRESSURE PROFILES AND FIELDS, Nelson Y. Cordero-Mercado; Master's Progress Project Report Draft expected to be presented in Summer 2020 pending final submittal in partial fulfillment of the

requirements for the degree of MASTER OF ENGINEERING in CIVIL ENGINEERING UNIVERSITY OF PUERTO RICO, MAYAGÜEZ CAMPUS, May 2020.

2. Performance Metrics

Pagan: Performance Metrics:

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17— 6/30/18)	Year 4 (7/1/18— 6/30/19)	Year 5 (7/1/19— 6/30/20)
HS-related internships (number)	10	16	9	9	11
Undergraduates provided tuition/fee support (number)		1	2 - ERDC	5	5
Undergraduate students provided stipends (number)		2	1	9	10
Graduate students provided tuition/fee support (number)	5	9	5	7	3
Graduate students provided stipends (number)	6	9	4	7	4
Undergraduates who received HS-related degrees (number)		N/A	2	3	5
Graduate students who received HS-related degrees (number)		N/A	2	1	2
Certificates awarded (number)		245	800	893	821
Graduates who obtained HS-related employment (number)		2	1	1	6
Lectures/presentations/seminars at Center partners (number)		1	2	2	0
DHS MSI Summer Research Teams hosted (number)		N/A	N/A	N/A	N/A
Journal articles submitted (number) *- ASEE, ASCE, ITE	1	0	4	3*	1
Journal articles published (number) *- ASEE, ASCE, ITE	1	0	4	3*	1
Conference presentations made (number) **-All kind of conferences, Seminars, and panels	2	31	23	62	41
Other presentations, interviews, etc. (number)	2	8	5	6	5
Trademarks/copyrights filed (number)		0	0	0	0
Requests for assistance/advice from DHS agencies (number)				10	2
Requests for assistance/advice from other Federal agencies or state/local governments (number)	5		4	9	10
Dollar amount of external funding	$95,760	$58,000	$110,534	$550K	$796k *** RAND, ERDC, Southern Command, EPA
Total milestones for reporting period (number)		2	7	9	12
Accomplished fully (number)	2	2	7	9	11
Accomplished partially (number)		N/A	N/A	N/A	1
Not accomplished (number)		N/A	N/A	N/A	0

SMITH, NCSU
DHS COASTAL RESILIENCE CENTER
EDUCATION PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020 (Updated 12/15/2020)

I. INTRODUCTION

Project Title: Expanding and Institutionalizing Disaster Resilient Policy and Design Education through National Hazard Mitigation Policy Counsel and Course Development

Principal Investigator Name/Institution: Gavin Smith, Professor, Department of Landscape Architecture, North Carolina State University

Other Partners/Institutions:

- Andy Fox, Professor, Department of Landscape Architecture, North Carolina State University.
- Travis Klondike, Research Associate with the Coastal Dynamics Design Lab and Assistant Professor of Practice, Department of Landscape Architecture, North Carolina State University.
- NCSU faculty and students as identified through an emerging university-wide focus on coastal resilience and the new Graduate Certificate in Disaster Resilient Policy, Engineering and Design.
- FEMA Mitigation Directorate, Federal Insurance & Mitigation Administration.
- State Hazard Mitigation Officers, territory, and tribal representatives (charged with leading state hazard mitigation activities across the US).
- Local government officials tasked with developing and implementing hazard mitigation plans and projects in the U.S., New Zealand and Australia.
- Dr. Wendy Saunders, GNS Science, New Zealand.
- Stephen Dredge, Meridian Urban Consulting, Australia.
- Dr. Jae Park, AECOM, Coastal Resilience Center Advisory Board member.

Short Project Description:

This project is undertaking five activities: 1) Develop a new 3-hour courses titled Disaster Resilient Policy, Engineering, and Design that will serve as one of three core courses in a new 13-credit Graduate Certificate Program of the same name titled: Disaster Resilient Policy, Engineering and Design at North Carolina State University. 2) Host a number of nationally-recognized speakers as part of the Disaster Resilient Policy, Engineering and Design Course and Speaker Series Course at North Carolina State University. Faculty from the Departments of Landscape Architecture, Architecture, Public Administration and Civil and Environmental Engineering (sponsors of the policy, engineering and design tracks in the emerging NCSU Graduate Certificate respectively) as well as some of the more than 250 faculty identified on the

NC State University campus doing work in the field of disaster resilience will provide lectures subject to their availability. The NC State faculty referenced were identified by the PI and others on campus as part of a new university-wide effort focused on coastal sustainability and resilience that has been initiated by the Provost (enhancing community resilience is one of four university-wide goals put in place by the Chancellor). 3) Work with FEMA and AECOM (FEMA contractor) to develop policy recommendations (policy briefs) tied to the development and implementation of the new Disaster Recovery Reform Act (DRRA) and associated hazard mitigation program, Building Resilient Infrastructure and Communities (BRIC) program, drawing from personal experience, research findings in the academic and practice-based literature, and the preliminary findings of a survey; 4) Conduct survey research on the role of state government in the development of local government's capacity and commitment to achieve the goals of the DRRA; 5) Conduct preliminary research on the comparative analysis of the process by which housing acquisition programs in the US, Australia and New Zealand are developed and implemented (more detailed research will be conducted in year 6 should funds be available). The findings of the survey and comparative study are being incorporated into courses associated with the new graduate certificate program, a potential textbook focused on housing acquisition and relocation programs and the preliminary identification of a consortium of researchers and practitioners who would be interested in conducting future research on this topic, drawing from the expertise identified at NCSU and others. Much of the research conducted in Year 5 has been done by 6 NCSU students pursuing the graduate certificate, which was approved by the NC State University in May, 2020.

II. PROJECT NARRATIVE

1. **<u>Project overview:</u>**
   The creation of supporting courses and a larger graduate certificate in Disaster Resilient Policy, Engineering and Design helps to further interdisciplinary education focused on achieving disaster resilience. This effort has been informed, in part, by an Obama White House and DHS S&T-supported study (Year 4 project) addressing the gaps in the delivery of this type of education. Students are exposed to information through class lectures, guest speakers, case studies, classroom exercises and projects. The methods used are part of a larger focus on teaching and training students in a way that will help them become both scholars and practitioners, thereby providing them with the tools needed to pursue either career path.

   The research component of this project, including a comparative study of buyouts in the US, Australia and New Zealand helps to further cross-cultural lesson-drawing which is a major shortcoming in U.S. natural hazards policy. A national survey of state, territory and tribal governments ability to build local capacity to implement hazard mitigation grants fills a void in the study of state-level actors. In both cases, the results are being conveyed to FEMA, states, territories, and tribes and included in classroom teaching and used to inform interdisciplinary class projects, including those focused on the resettlement of hazard prone cities.

2. End users:

- Deputy Associate Administrator, Mitigation Directorate, Federal Insurance & Mitigation Administration FEMA. The Deputy Associate Administrator asked research team to conduct a national survey and do an international comparative buyout study. He and his staff provided feedback during the development of survey and had planned to introduce the survey at the EMI Hazards Workshop prior to its cancellation. The Deputy Associate Administrator serves as primary conduit for the delivery of research findings once completed. Techniques used to share information with he and his staff include regular briefings, reports, journal articles, book chapters and presentations. Once the survey is completed and the results compiled in the report, it will be presented to the Deputy Associate Administrator and his team, followed by a discussion with FEMA as to how the results may be incorporated into BRIC policy updates and how the results may inform state, territory and tribal government capacity building efforts. At the request of the Natural Hazards Center Director, the PI of this project has agreed to give a keynote presentation at the Natural Hazards Workshop in July (2020) to discuss the preliminary findings of the survey as part of a panel of FEMA, State and local officials focused on the Building Resilient Infrastructure and Communities program. If Year 6 funding is available, the research team will continue to meet with the Deputy Associate Administrator and his staff to explore further incorporating the survey findings into BRIC policy amendments that are likely to occur following the rollout and administration of the first BRIC funding tranche in 2021.
- State Hazard Mitigation Officers, territory, and tribal representatives (charged with leading state hazard mitigation activities across the US). Representatives will fill out the national on-line survey and the findings will be shared with them in the form of reports, policy recommendations and applied journal articles. Presentations will be given at national conferences and future SHMO Workshops in order to further disseminate the findings.
- Local government officials tasked with developing and implementing hazard mitigation plans and projects in the U.S., New Zealand and Australia. Local officials in the US and New Zealand were interviewed in person and via Zoom and the results inform the comparative buyout study, including its recommendations. Comparative buyout study findings and the national survey of state officials are being presented to local officials though national conference presentations, reports and connections with relevant professional associations.
- Dr. Jae Park, AECOM. Dr Park provided feedback on the development of survey questions and kept the research team up to date on evolving BRIC policy. The PI of this study has agreed to work with AECOM as part of a national team of consultants to advise FEMA over the next several years should the contract be approved.
- Ashton Rohmer, AECOM and former student/recipient of Natural Hazards Resilience Certificate from UNC-CH. Assisted research team with survey logistics and feedback on survey questions.
- Olivia Vila, AECOM summer intern and current PhD student at NC State University pursuing the emerging certificate in Disaster Resilient Policy, Engineering and Design. Worked with the research team in the Spring and summer to help develop, administer,

and analyze the findings. She included some questions in the survey that will be used in her dissertation research. She is assisting the research team write journal articles and reports, to include leading one paper focused on her dissertation research. Continues to lead the HazNerds student group that serves as a vehicle to inform current and prospective certificate participants.

- Margaret Keener, AECOM and former student/recipient of Natural Hazards Resilience Certificate from UNC-CH. Assisted with the review of the national survey.
- Practitioners and academics whose work emphasizes disaster resilient design that are invited to speak in the certificate classes.
- Members of the NCSU student group, the Haznerds continues to share information about existing literature, job and public service opportunities, campus lectures and other information that may be of interest to the group, including those pursuing the Graduate Certificate in Disaster Resilient Policy, Engineering and Design.

- Dr. Wendy Saunders, GNS Science, New Zealand is working with the PI to conduct a comparative study of buyouts in the US and New Zealand and to write up the findings in reports and journal articles. She is currently advising the New Zealand government on evolving national buyback policy, to include drawing on our work to inform the emerging policy dialogue. The PI of this study gave a presentation at GNS Science in December discussing our research and exploring continued research and engagement opportunities in the U.S. and New Zealand, including continued cross-cultural work focused on natural hazards policy learning.

- Stephen Dredge, Meridian Urban Consulting, Australia worked with the PI to assist the research team identify key local government informants to interview that have engaged in buyouts in Australia, to include communities that he has worked with following a number of disasters in the State of Queensland (Mr. Dredge was a former employee of the Queensland Reconstruction Authority and now advises them and other governmental agencies on disaster resilience-related topics). Results of the U.S., New Zealand and Australia study will be shared with the Queensland Reconstruction Authority and potentially incorporated into national, state and local policy documents as part of joint efforts we are engaged in together, including the rollout of several emerging Queensland Reconstruction Authority's resilience efforts (funded through a non-DHS/CRC grant).

3. **<u>Unanticipated Problems</u>**:

Primary problems encountered stem from Covid-19, to include the later release of the national survey, which affects the timing of a report to FEMA and journal article delivery. The outbreak resulted in the cancellation of the National SHMO Workshop that was to be held at the Emergency Management Institute, a venue where we had worked with FEMA to deliver the survey to all SHMO's, territory and tribal representatives at one time. The Deputy Associate Administrator and his staff were to work with us at the event to discuss the survey and its merits and with all respondents located at one venue, this was likely to result in a high response rate. The survey will be delivered on-line, starting June 3rd.

Covid-19 also disrupted the personal interview schedule of US and Australian respondents tied to the international comparative study of buyouts. The interviews with remaining communities will be conducted via Zoom. Interviews with US/NC participants (Charlotte, Lumberton, and Seven Springs, NC) were originally scheduled during the Fall (when Dr. Saunders was scheduled to be in the US). Instead, a Zoom interview was conducted with Charlotte/Mecklenburg County officials in May. Interviews are being scheduled with Lumberton and Seven Springs officials in the June/July timeframe.

The research team is working hard to make up for lost time by completing the elements of journal articles and reports that do not require the results of the survey of interviews with respondents, including the writing of introductions, methods, literature reviews, etc.

Covid-19 affected the delivery of certificate classes and the physical attendance of guest speakers. As required by NC State all faculty were required to develop an on-line teaching strategy. The PI of this study did so, to include shifting the Speaker Series and Disaster Resilient Policy, Engineering and Design courses on-line during Spring Break. Both classes were delivered using Zoom. This included inviting guest speakers (including Dr. Wendy Saunders from New Zealand, who was originally scheduled to be in NC to deliver lectures, conduct field interviews, provide in-person crits of student team projects) to present remotely and to conduct my 3-credit hour course lectures, student team reviews on-line. Final student projects were reviewed via Zoom by a team consisting of Dr. Jessica Whitehead (Chief Resilience Officer-NC); Jeff Carney, Architecture Professor, University of Florida; Adam Stein, Resilience Coordinator NOAA; and Holly White, Principal Planner, Nags Head, North Carolina.

An additional problem involved the late release of the funding, which arrived after FEMA had completed much of the Building Resilient Infrastructure and Communities (BRIC) policies, thereby limiting the direct involvement in policy counsel and the writing of associated policy briefs. It is believed that the findings of the comparative study of buyouts and the national survey can still be incorporated into BRIC policy updates in the future.

4. **Students and recent graduates**

a. Number of undergraduates, graduates, working professionals
LAR 554 Disaster Resilient Policy, Engineering and Design - 14 Graduate Students.
LAR 553 Natural Hazards, Disasters and Climate Change
Adaptation Lecture Series - 19 Graduate Students, 1 Undergraduate Student.
LAR 552 Survey of Natural Hazards and Disasters - 13 Graduate Students, 2 Undergraduate Students.

b. Percentage minority students
Estimate – 5 %

c. Number of students graduated
NA-certificate was approved in May, 2020.

d. Number of former students employed in resilience-related fields
   In Year 5 – 0; Total Year 1-5: estimate – 20

e. Number of former students who went on to enroll in graduate-level programs
   Year 5: Most students enrolled in courses are graduate students.

5. **Project Impact:**

The graduate certificate courses and larger certificate rely on a range of techniques to convey information, including presentations by nationally and internationally-recognized scholars and practitioners, emphasizing speaker / student interactions inside and outside the classroom through the Speaker Series course, staying abreast of the latest literature, research and engagement techniques by attending and participating in national conferences, deep community engagement efforts, and conducting research that is incorporated into classroom lectures, class assignments and interdisciplinary projects. For instance, the current research focus on buyouts in New Zealand was presented to students in my Disaster Resilient Policy, Engineering and Design class to help inform possible policy options they might consider in a class project involving the resettlement of parts of Boston, Charleston and the Outer Banks. A scheduled field trip to Charlotte was intended to show students how readings and class lectures are applied on the ground and could inform the final class project. Unfortunately, the field trip had to be cancelled due to Covid-19.

6. **Institutionalization:**

a. Sources of post-CRC support

Post-CRC support included obtaining a position as a Professor in the Department of Landscape Architecture which allows me to teach all classes and lead the certificate as part of my expected roles in the university. The Graduate Certificate in Disaster Resilient Policy, Engineering and Design was approved by the NCSU Curriculum Committee and the Graduate School in May 2020.

b. Maintenance of project products:

The administration of the certificate is housed in the Department of Landscape Architecture with tracks in policy, engineering and design led by the Departments of Public Administration, Civil, Construction and Environmental Engineering, and the Department of Landscape Architecture, respectively.

c. Planning for institutionalization:

Dr. Gavin Smith led the overall effort. Other faculty involved in the institutionalization effort included Dr. Christopher Galik, Department of Public Administration and Dr Sankar Arumugam, Department of Civil, Construction and Environmental Engineering. Courses were refined and approved as permanent courses in partnership with the College of Design Curriculum Committee (of which I am a member). Courses that fulfill the 6 elective credits are drawn from courses from across the university and the varied faculty that teach the courses are aware of the program. The Graduate School provided guidance on the steps required for approval, and the College of Design Curriculum Committee assisted in the creation of course syllabi and certificate prior to submittal to the Graduate School for approval.

7. Interactions with research projects:

The Year five project blended research and education as the emerging findings of the comparative study of buyouts in New Zealand were presented in my new class Disaster Resilient Policy, Engineering and Design and used to inform the final class project, which focused on the potential resettlement of Boston, Charleston and the Outer Banks of North Carolina. My colleague, Dr. Wendy Saunders provided a guest lecture in the Speaker Series course and provided expert feedback to student teams in the Disaster Resilient Policy, Engineering and Design course who were tasked large-scale resettlement challenges as part of their final class project. In addition, CRC research partner Dr. Casey Dietrich, a CRC Researcher provided a lecture in my Speaker Series class. I provided a lecture at the University of Puerto Rico at Mayaguez as part of the SUMREX program. A student team (with oversight provided by me) has submitted an abstract to the Journal of Environmental Studies and Sciences (JESS). The Special Issue is titled Perspectives on managed retreat: Environmental justice and beyond. The proposed journal article focuses on a description of the Spring course Disaster Resilient Policy, Engineering and Design and its final class project which involved interdisciplinary teams of students developing a proposed strategy to relocate parts of Boston, Charleston and the Outer Banks of North Carolina.

III. EDUCATION ACTIVITIES AND TRANSITION MILESTONES

4. Year 5 Education Activities and Milestone Achievements:

Education Activities and Milestones: Status as of 6/30/2020			
Education Activities	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Collect best practice case studies in disaster resilient design and incorporate into new course curriculum.	08/2019	100%	
Incorporate findings of DRRA/BRIC study and initial findings of comparative buyout study into new graduate certificate course curriculum and interdisciplinary class exercises and projects.	06/2020	100%	
Education Milestones			
Develop disaster resilient policy, engineering, and design course.	12/2019	100%	

Teach disaster resilient policy, engineering, and design course in the Spring of 2020.	04/2020	100%	
Approve Graduate Certificate in Disaster Resilient Policy, Engineering and Design.	05/2020	100%	

5. Year 5 **Transition** Activities and Milestone Achievements:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Develop disaster resilient policy, engineering and design course (deliverables: syllabus, best practices and interdisciplinary class project guidance).	12/2019	100%	
Identify and host speakers for Graduate Certificate Program.	04/2020	100%	
Create policy recommendations based on the findings of the survey and comparative assessment of housing acquisition programs. Policy briefs 2-3 pages in length.	03/2020	100%	Delivery of completed survey delayed at the request of FEMA. Initial plan to deliver survey at the Emergency Management Institute SHMO Workshop was discontinued after workshop was cancelled due to Covid-19. FEMA asked our team to wait to release the survey until June. Survey will be delivered on-line, beginning June 4, 2020 with final return date of the surveys June 30th.A detailed report describing the survey findings has been completed and will be shared with FEMA officials along with a journal article in January 2021.
Develop survey instrument assessing state hazard mitigation capacity and commitment.	12/2019	100%	
Collect preliminary information on New Zealand and Australia Cases	05/2020	50%	Information collected for 3 New Zealand cities as part of a trip in December (2019). Trip to Australia cancelled due to Covid-19.

			Plans are underway to collect information on Australian communities remotely via Zoom in the summer of 2020. Australian data collection was delayed due to COVID-19. Data will be collected in the Spring of 2021 as officials have stated that they are willing to work with us at this time.
Conduct survey; compile and analyze data.	04-05/ 2020	100%	Survey developed; to be administered in June; analysis completed in July. Survey conducted, data compiled and analyzed. Journal article and FEMA report completed. In addition, survey published for use by other researchers as part of NSF CONVERGE project. Citation - Smith, G., Vila, O., Caverly, G. 2020. “A National Evaluation of State Roles in Hazard Mitigation: Building Local Capacity to Implement FEMA Hazard Mitigation Assistance Grants.” DesignSafe-CI. https://doi.org/10.17603/ds2-sjbv-eg87.
Write role of the state in building local capacity policy report (2 – 3 pages).	06/2020	100%	Report pending survey results in July. Report should be finalized in the summer of 2020. Report complete, submitted to FEMA in January 2021.
Write role of the state in building local hazard mitigation capacity journal article (submitted to journal for review) / incorporate findings into certificate courses and interdisciplinary class exercises.	06/2020	100%	Journal article and incorporation of findings into courses pending completion of survey, analysis of data and writing paper. Survey should be completed in July, findings analyzed and article written by August. Journal article complete and published by journal *Sustainability* in December 2020. Findings

			incorporated into courses taught in the Fall 2020 and Spring 2021 courses. Citation - Smith, Gavin, Olivia Vila. 2020. A National Evaluation of State and Territory Roles in Hazard Mitigation: Building Local Capacity to Implement FEMA Hazard Mitigation Assistance Grants. Sustainability 12(10013): 1-18. doi:10.3390/su122310013.
Transition Milestone			
Complete class syllabus.	12/2019	100%	
Include disaster resilient policy, engineering and design class in regular teaching schedule as part of Certificate Program (permanent course number assigned in Fall 2020).	06/2020	100%	
Write journal article on role of the state / incorporate findings into certificate courses.	06/2020	100%	Journal article and incorporation of findings into courses pending completion of survey, analyzing data, and writing paper. Survey should be completed July 1, findings will be analyzed and article written by end of August. Students have begun conducting literature review this summer prior to distribution of survey and analysis of results. Introduction and methods section of article will be completed in June. Draft article should be completed by August and submitted for publication to a journal. Journal article published in December 2020 and incorporated into Fall 2020 and Spring 2021 courses.
Write role of the state in building local capacity policy report / provide to FEMA.	06/2020	100%	Role of the state in building local capacity policy report is delayed pending the completion of survey and writing up findings. Survey

			should be completed in July, findings analyzed and report written and submitted to FEMA by August. Report complete. Submitted to FEMA in January 2021.
Write preliminary report on the comparative analysis of US, Australian and New Zealand housing acquisition programs, to include lessons derived from this study.	06/2020	75%	Two documents have been completed: 1) A Book Chapter, titled *A Comparative Review of Hazard-Prone Housing Acquisition Laws, Policies and Programs in the United States and Aotearoa New Zealand: Implications for Improved Practice* (Smith and Saunders). The draft chapter (which includes lessons and associated policy recommendations) was submitted to the publishers (Cambridge Press) on June 1, 2020 for initial review and comment. The title of the text is Cambridge Handbook of Disaster Law: Risk, Recovery and Redevelopment. Book chapter in press. 2) A report co-authored with my Colleague Dr. Wendy Saunders, focuses on the results of the New Zealand-based case studies. Report completed and published. Citation - Saunders, W.S.A, and G. Smith. 2020. Spend to Save: Investigating the property acquisition process for risk reduction in Aotearoa New Zealand. Lower Hutt (NZ): GNS Science. 65 p. (GNS Science report; 2020/23). doi:10.21420/6GR9-EE44. An additional journal article has been initiated by Saunders and Smith that is focused on the development of a set of global guiding

			principles for the acquisition of hazard-prone housing. Draft expected to be completed in July. Article under development. The collection of the Australian case study information has been delayed due to Covid-19, which required the cancellation of a June trip (June 1-12) to Australia. Tasks to be completed in Australia included: a presentation at the Australasian Hazards Conference in Brisbane, Australia on June 1st and interviews with Grantham, Australia officials. Interviews with Australian officials will be conducted via Zoom this summer. Australian data collection was delayed due to COVID-19. Data will be collected in the Spring of 2021 as officials have stated that they are willing to work with us at this time. Abstract submitted (June 1) to the Journal of Environmental Studies and Sciences (JESS). The Special Issue is titled Perspectives on managed retreat: Environmental justice and beyond. The proposed article is titled *A Comparative Analysis of Hazard-Prone Housing Acquisition Programs in the United States and New Zealand.* To date we have conducted key informant interviews with 4 of 6 communities (3 in NZ, 1 in US-Charlotte, NC), written introduction, methods and literature review sections of article. Article complete; in press. Graduate students involved in writing and cited below.

			Smith, Gavin, Wendy Saunders, Olivia Vila, Samata Gyawali, Samiksha Bhattarai, and Eliza Lawdley. 2020. A Comparative Analysis of Hazard-Prone Housing Acquisition Programs in United States and New Zealand Communities. Special Issue on Managed Retreat and Environmental Justice. Journal of Environmental Studies and Sciences. Perspectives on Managed Retreat: Environmental Justice and Beyond. A.R. Siders and Jola Ajibade, Editors. (to be published). Reached tentative agreement with Springer Press to publish textbook focused on an international assessment of buyouts, to include authors drawn from around the world. Start date likely to be the Fall of 2020. Delayed due to COVID and focus on catching up with FEMA reports and journal articles.
Include speaker series class in regularly teaching schedule as part of Certificate Program. Permanent course number assigned in Spring 2020 (speaker series class taught as a "special topics class" at NCSU for the first time in the Spring of 2019).	06/2020	100%	

6. Annual Courses and Enrollments

Annual Courses and Enrollments

Courses Developed and Taught at University of North Carolina under Project Expanding Coastal Resilience Education at UNC (Years 1-4)						
PLAN 755	Course Title: Planning for Natural Hazards and Climate Change Adaptation	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	T	T	NA
	Offering: Elective (E), Concentration (C), Minor (M)	C	C	C	C	NA
	Enrollment	8	20	40	26	NA
PLAN 754	Course Title: Speaker Series	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	T	T	NA
	Offering: Elective (E), Concentration (C), Minor (M)	C	C	C	C	NA
	Enrollment	14	31	28	32 (UNC CH); 22 (NCSU)	NA
PLAN 756	Course Title: Survey of Natural Hazards and Disasters	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	T	T	T	NA	NA
	Offering: Elective (E), Concentration (C), Minor (M)	C	C	C	NA	NA
	Enrollment	9	15	26	NA	NA

Courses Developed and Taught by University of North Carolina State University under Project Expanding and Institutionalizing Disaster Resilient Policy and Design Education through National Hazard Mitigation Policy Counsel and Course Development at NCSU (Year 5)						
LAR 554	Course Title: Disaster Resilient Policy, Engineering and Design	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	NA	NA	NA	NA	T
	Offering: Elective (E), Concentration (C), Minor (M)	NA	NA	NA	NA	C
	Enrollment	NA	NA	NA	NA	14
LAR 553	Course Title: Natural Hazards, Disasters and Climate Change Adaptation Lecture Series	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	NA	NA	NA	NA	T
	Offering: Elective (E), Concentration (C), Minor (M)	NA	NA	NA	NA	C
	Enrollment	NA	NA	NA	NA	20
LAR 552	Course Title: Survey of Natural Hazards and Disasters	YR 1	YR 2	YR 3	YR 4	YR 5
	Status: Developed (D), Revised (R), and/or Taught (T)	NA	NA	NA	NA	T
	Offering: Elective (E), Concentration (C), Minor (M)	NA	NA	NA	NA	C
	Enrollment	NA	NA	NA	NA	15

IV. PUBLICATIONS AND METRICS

1. Publications:

a) Publications

- **Smith, Gavin** and Wendy Saunders. 2020. A Comparative Study of Hazard-Prone Housing Acquisition Programs in the United States and New Zealand. Special Issue on Managed Retreat and Environmental Justice. Journal of Environmental Studies and Sciences. Perspectives on Managed Retreat: Environmental Justice and Beyond. A.R. Siders and Jola Ajibade, Editors. (in presst).
- McGovern, Shannon, Ryan Scott, Gretchen Caverly, **Gavin Smith**. 2020. Disaster Resilient Policy, Engineering and Design Class Project: The Resettlement of three Hazard-Prone Communities. Special Issue on Managed Retreat and Environmental Justice. Journal of Environmental Studies and Sciences. Perspectives on Managed Retreat: Environmental Justice and Beyond (under development-not accepted for publication).
- **Smith, Gavin**. April, 2020. Best Practices and Lessons (Learned and Not Learned) in the United States Regarding the Role of States in Fostering Disaster Resilience at the Local Level through Program Design and Implementation. Report for the Queensland Reconstruction Authority and the Regional Resilience Strategies (Statewide Rollout) Project. Brisbane, Australia: Queensland Reconstruction Authority.
- **Smith, Gavin**, Allison Anderson and David Perkes. New Urbanism and the H-Transect: Improving the Integration of Disaster Resilience and Design (final revisions accepted-scheduled for publication in Spring).
- Saunders, Wendy and **Gavin Smith**. Global Principles Guiding the Acquisition of Hazard-Prone Housing. (under development).
- Nguyen, Mai and **Gavin Smith**. Resilient Design Education in the United States (submitted for review).
- **Smith, Gavin**, Hurricane Matthew Disaster Recovery and Resilience Initiative: Achieving Rural Resilience through Research, Teaching and Engagement? (submitted for review).
- **Smith, Gavin** and Wendy Saunders. A Comparative Review of Hazard-Prone Housing Acquisition Laws, Policies and Programs in the United States and Aotearoa New Zealand: Implications for Improved Practice. In the Cambridge Handbook of Disaster Law: Risk, Recovery and Redevelopment. Susan Kuo, John Travis Marshall, and Ryan M. Rowberry eds. (forthcoming Cambridge, 2021).
- Saunders, W.S.A, and **G. Smith**. 2020. Spend to Save: reducing natural hazard risks through property acquisition in Aotearoa New Zealand. Lower Hutt (NZ): GNS Science.
- **Horney, Jennifer**, Carolina Dwyer, Bhagath Chirra, Kerry McCarthy, Jennifer Shafer and **Gavin Smith**. 2018. Measuring Successful Disaster Recovery. International Journal of Mass Emergencies and Disasters 36(1): 1-22.
- **Gavin Smith**, Lea Sabbag and Ashton Rohmer. A Comparative Analysis of the Roles Governors Play in Disaster Recovery. Risk, Hazards & Crisis in Public Policy. 9(2): 205-243. DOI: 10.1002/rhc3.12133.
- **Horney, J.**, Dwyer, C., Aminto, M., **Berke, P.,** & **Smith, G.** (2017). Developing indicators to measure post-disaster community recovery in the United States. Disasters, 41, 124-149. DOI: 1111/disa.12190

- **Smith, Gavin**. The Role of States in Disaster Recovery: An Analysis of Engagement, Collaboration, and Capacity Building. 2019. In Building Community Resilience to Disasters: The Handbook of Planning for Disaster Resilience, Routledge Press.
- **Smith, Gavin**, Amanda Martin and Dennis Wenger. Disaster Recovery in an Era of Climate Change: The Unrealized Promise of Institutional Resilience. 2017. In Handbook of Disaster Research, Second Edition, Eds. Havidan Rodriguez, Joseph Trainor and William Donner. New York: Springer.
- **Smith, Gavin**. Pre- and Post-Disaster Conditions, their Implications, and the Role of Planning for Housing Recovery. 2017. Chapter 18, pp. 277-292. In Coming Home After Disaster: Multiple Dimensions of Housing Recovery, Eds. Ann-Margaret Esnard and Alka Sapat. Boca Raton, Florida" CRC Press.
- **Smith, Gavin**, Mai Thi Nguyen, Colleen Durfee, Darien Williams, Ashton Rohmer. September, 2018. **Resilient Design Education in the United States.** Chapel Hill, North Carolina: Department of Homeland Security Coastal Resilience Center of Excellence.
- **Smith, Gavin**, Barry Hokanson, Link Walther, **Jessica Southwell**. 2017. Hurricane Matthew Disaster Recovery and Resilience Initiative. A Project of the North Carolina Policy Collaboratory. Chapel Hill, North Carolina: Hurricane Matthew Recovery and Resilience Initiative.
- **Smith, Gavin**, Lea Sabbag, Ashton Rohmer. Role of States in Recovery Video Training Guide. March, 2016. Chapel Hill, North Carolina: Department of Homeland Security, Coastal Resilience Center of Excellence.
- **Smith, Gavin**, Sabbag, Lea, and Rohmer, Ashton. A Comparative Analysis of the Roles Governors Play in Disaster Recovery. 2018. Risk, Hazards & Crisis in Public Policy.
- **Smith, Gavin**. The Role of States in Disaster Recovery: An Analysis of Engagement, Collaboration, Leadership, and Capacity Building. 2017. In Building Community Resilience to Disasters: The Handbook of Planning for Disaster Resilience, Routledge Press.
- **Smith, Gavin**. Pre- and Post-Disaster Conditions, their Implications, and the Role of Planning for Housing Recovery. 2017. In Coming Home After Disaster: Multiple Dimensions of Housing Recovery, Eds. Ann-Margaret Esnard and Alka Sapat. Boca Raton, Florida" CRC Press.
- **Smith, Gavin**, Amanda Martin and Dennis Wenger. Disaster Recovery in an Era of Climate Change: The Unrealized Promise of Institutional Resilience. 2017. In Handbook of Disaster Research, Second Edition, Eds. Havidan Rodriguez, Joseph Trainor and William Donner. New York: Springer. (accepted/submitted)
- **Smith, Gavin**. 2016. Remembrances of the Past, Concerns for the Future, and the Potential Resilience of a Small Coastal Town. Southern Cultures. Summer: 64-87. DOI: 10.1353/scu.2016.0022

Smith: Performance Metrics:

Metric	**Year 1** (1/1/16 – 6/30/16)	**Year 2** (7/1/16 – 6/30/17)	**Year 3** (7/1/17-6/30/18)	**Year 4** (7/1/18-6/30/19)	**Year 5** (7/1/19-6/30/20)
HS-related internships (number)	2	14		4	2
Undergraduates provided tuition/fee support (number)					
Undergraduate students provided stipends (number)		1			
Graduate students provided tuition/fee support (number)	2	2	2		3
Graduate students provided stipends (number)		13	23		6
Undergraduates who received HS-related degrees (number)					
Graduate students who received HS-related degrees (number)		3	5	4	
Certificates awarded (number)	1	3	5	4	
Graduates who obtained HS-related employment (number)	1	3	5	4	
Lectures/presentations/seminars at Center partners (number)	3	3	4	3	
DHS MSI Summer Research Teams hosted (number)				1	1
Journal articles submitted (number)	1	1	2	3	3
Journal articles published (number)		2	2		2
Conference presentations made (number)	6	12	29	22	15
Other presentations, interviews, etc. (number)		11	14	17	10
Trademarks/copyrights filed (number)					
Requests for assistance/advice from DHS agencies (number)		1	5	2	2
Requests for assistance/advice from other agencies or governments (number)		4	2	6	7
Dollar amount of external funding	--	$614,966	$1,204,382	$54,329	$67,298
Total milestones for reporting period (number)	10	11	11	3	9
Accomplished fully (number)	9	11	11	3	6
Accomplished partially (number)	1				2
Not accomplished (number)					1

Appendices

Appendix A: Select Projects: Additional Material

Applying a Plan Integration for Resilience Scorecard to Practice: Experiences of Nashua, NH, Norfolk, VA, Rockport, TX

Preliminary Report: 6/9/20

Philip Berke, Research Professor
Department of City & Regional Planning
University of North Carolina
New East Bldg., Campus Box 3140
223 East Cameron Ave.
Chapel Hill, NC 27599-3140

Jaimie Masterson, AICP, LEED GA
Associate Director, Texas Target Communities
Public Partnership and Outreach
Office of the Provost and Executive Vice President
3137 Texas A&M University
College Station, TX 77843-3137

Matthew Malecha, Post-Doctorate
Department of Landscape Architecture & Urban Planning
3137 Texas A&M University
College Station, TX 77843-3137

Siyu Yu, Assistant Professor
Department of Landscape Architecture & Urban Planning
3137 Texas A&M University
College Station, TX 77843-3137

Acknowledgements
The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: this article is based on work supported by the U.S. Department of Homeland Security Science and Technology Directorate (Grant #0031369). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

The authors are especially grateful to three local government staff who assumed leadership roles in their cities to apply the *Plan Integration for Resilience Scorecard*™. We commend Paula Shea, City of Norfolk, Virginia; Justin Kates, City of Nashua, New Hampshire; and Amanda Torres, City of Rockport, Texas for their efforts.

Table of Contents

Executive Summary

Planning for land use and development is key to mitigating hazard events and the effects of climate change. Communities adopt multiple plans that directly and indirectly address hazard mitigation; the integration of local plans can significantly affect future community vulnerability to hazards. In partnership with community-based users, we tested and co-developed a *Resilience Scorecard*™ that enables local officials to self-evaluate the degree to which the network of local plans targets areas most prone to hazards, and then assess the coordination of local plans.

We chronicle and evaluate the impacts of the *Resilience Scorecard*™ application process from the local prospective in three communities vulnerable to flooding and climate change. Project objectives are: 1) To determine changes in *local capacity* to proactively plan, including: skill to evaluate plans, level of inter-organizational communication and coordination, and ability to develop integrated policy solutions; and 2) To determine changes in *outcomes* including: level of integration of mitigation actions in local networks of plans; strength of land use and development regulations, public investments for mitigation, and physical and social vulnerability (e.g., housing units relocated from hazard area, number of low-income people exposed to floods, and acres of hazard area conserved as open space).

Pilot 1: Norfolk, VA

Capacity Building

- Norfolk created a team of six members that represent diverse city agencies. Members indicated that the scorecard project was the first time that all key agency staff worked together at the same time in over three decades.
- Elected officials, the planning commission and the general public were informed about scorecard findings and staff recommendations for amending several plans during a public hearing.
- Team members agreed that the scorecard project strengthened their skills to spatially evaluate action policies in plans at the neighborhood scale, and to be unbiased and impartial in the evaluation, and to identify weaknesses, gaps and conflicts among plans.
- Cross agency communication improved and produced benefits, notably increased awareness of the connection between different types of plans that directly or indirectly affect hazard vulnerability. Notably, improved communication occurred between emergency management and urban planning as staff in both agencies were unintentionally excluding each other's plans in their plan making efforts.

Outcomes

1. In response to scorecard findings, significant revisions of the comprehensive plan were made to address major gaps in coordination, including city council approval of 27 policy amendments. Most notably, the comprehensive plan was amended to incorporate key policies and implementation actions in the hazard mitigation plan, and to incorporate major elements of the citywide resilience strategy in Vision 2100.
2. Resilience metrics in the zoning ordinance were added to location criteria for community facilities in the hazard mitigation plan and comprehensive plan. Prior versions of the plans only included conventional criteria based on accessibility of populations to facilities, but standards to steer the location of facilities away from hazard areas were not included.

3. Information generated by the scorecard supported the development of a successful $112 million proposal to the HUD National Disaster Resilience Competition. Results revealed legacies of unjust mitigation policy attention in two historic African American neighborhoods. Funds are used to invest in resilience projects in these neighborhoods.
4. Official notes from a public hearing initiated by the City Planning Commission indicated the information generated by the scorecard will be used as a fact base for preparation of a new comprehensive plan in 2020.

Potential Obstacles and Limitations

Since Norfolk was the first pilot community to apply the scorecard, the city had more recommendations to improve the process than other cities:

- Plan evaluators from the city initially attempted to evaluate 16 plans that required too much staff time to evaluate. They felt that the most influential plans that affect flood vulnerability should be the focus of attention. To make the process more efficient, plans that were out of date or already integrated in the comprehensive plan were eliminated.
- The Norfolk approach to application of the scorecard required significant reliance on staff with GIS expertise. Staff recommended that future applications should be flexible to meet varying local capacities, such as manual mapping for low capacity communities.
- Plan evaluators felt that in some instances finding the geographic locations targeted by plan policies was too time consuming. Too streamline evaluations, plan evaluators recommend that neighborhood districts can be reduced by combining locations where hazard exposure, development patterns, and socioeconomic conditions are roughly equivalent.
- Not all changes identified by the scorecard results were made as of about one-year after completion of the project. This was partly due to competing demands on staff time as local issues and priorities change, and city staff become preoccupied with other responsibilities.

Pilot 2: Nashua, NH

Capacity Building

- A core team of seven plan evaluators from city government learned about the values and priorities of staff, and learned about the policies and plans of different agencies.
- Application of the scorecard generated an inclusive engagement effort beyond government, including active involvement and training of 40 local leaders representing diverse interest groups to serve as "ambassadors of resilience."
- A place-based narrative for the district hazard zones - the basic geographic unit for scoring plans - was created using crowdsourcing mapping technology. This information offered a venue for public input about needs and preferences for mitigation actions in the districts.
- Nashua strengthened its analytical and collaborative capacity for resilience planning by integrating the *Resilience Scorecard*™ with the National Institute for Science and Technology's *Community Resilience Planning Guide,* and the *FEMA Local Hazard Mitigation Planning Handbook*.
- The scorecard process fostered communication and learning. An example is greater involvement of Office of Emergency Management in development permit reviews. The lead agency charged with reviews gained a better understanding of OEM's expertise and requested that OEM take on a more direct role.

Outcomes

- Core team members consistently observed that the *Resilience Scorecard*^{TM} produced a more coordinated and spatially specific network of plans. Prior attempts at plan integration were considered "aimless and undisciplined."
- Information generated by the scorecard was used to amend the 2019 Hazard Mitigation Plan. Seven policies were revised to give greater priority to reducing vulnerability in districts that are highly physically vulnerable and/or highly socially vulnerable.
- Nashua intends to use scorecard results as integral part of the fact base for preparing a new master plan in the years 2020-21, and developing an application for LEED (Leadership in Energy and Environmental Design) certification.
- The Director of OEM estimates that about 10 to 12 additional permits annually would be given more attention and scrutiny by OEM as a result of the scorecard application process.

Potential Obstacles and Limitations

- At the start of the scorecard project, core team plan evaluation members were overly ambitious by selecting over 50 plans adopted by the city since the 1990s. A mid-course correction was made to evaluate only the most influential plans that support economic development, critical infrastructure, climate change, and specific poor neighborhoods.
- A city official expressed concern that support for using scorecard results in the preparation of the new comprehensive plan may begin to dissipate since there was a recent major turnover in city staff that participated on the core team of plan evaluators.

Pilot 3: Rockport, TX

Capacity Building

- The city's commitment to integrating resilience into the comprehensive plan to guide recovery efforts was recognized by receiving a *Silver Achievement Award in Resiliency Planning* from the Texas Chapter of the American Planning Association in November 2019.
- Over 200 residents and elected officials attended 4 public hearings, and 13 members of a comprehensive plan advisory committee were informed about scorecard results.
- Two city staff were trained and learned how to craft the comprehensive plan policies, implementation actions, and use scorecard results to improve coordination with local recovery and mitigation plans.
- Scorecard results enabled staff to identify best practice policies in the existing local network of plans that are to be part of the policy framework of the new comprehensive plan.

Outcomes

- The new comprehensive plan includes 73 policies drawn from best practice policies in the local network of plans that support integration of resilience across all chapters (development, environment, housing, transportation, economy, facilities).
- Icons and textbox graphics are used to visually communicate how the comprehensive plan policies are coordinated with best practice policies from other plans.
- Information generated by the scorecard fostered development of balanced solutions. Policies from the local network of plans were integrated into the comprehensive plan to simultaneously preserve the cultural heritage, promote equity and economic vitality, restore environmental systems, and enhance flood mitigation.
- The implementation chapter in the comprehensive plan specifies actions, timelines, organizational responsibility, and funding necessary to achieve plan goals and objectives. An implementation action matrix was created to display this information. A "plan integration" column is inserted in the matrix that includes 48 references of action proposed by other plans.

Potential Obstacles and Limitations

- Small cities like Rockport with limited capacity for planning for resilience will likely need technical assistance to apply the scorecard. This condition is particularly problematic during a recovery effort from a catastrophic disaster event like Hurricane Harvey.
- At the time of writing this report, plan implementation actions by the city were put on hold due to the coronavirus pandemic. Consensus built through the planning process has a shelf life. If significant time passes between plan adoption and tangible implementation, support for the plan may begin to dissipate as leaders change and constituencies shift, new issues and priorities emerge, and local planners become preoccupied with other responsibilities.

Part 1: Background of the Resilience Scorecard Initiative

The Importance Integration of Resilience in Planning
Disaster events, ranging from catastrophic floods to extreme wildfires, have increased dramatically over the past two decades. The years 2016-2018 experienced historically high levels of losses, with the annual average number of billion-dollar disasters more than doubling the long-term average (NOAA 2019). Meanwhile, "nuisance events" that generate frequent minor impacts are on the rise. In coastal communities, for example, the number of nuisance flood days from sea level rise has risen from an average of 2.1 days per year during 1956–1960 to 11.8 during 2006–2010, and is projected to increase to 26 times per year by 2035 in 170 coastal communities (Union of Concerned Scientists 2017).

In this severe context, practitioners, policymakers, and affected communities have converged around the notion of "community resilience," in recognition that they need to take a more proactive approach to reducing vulnerability, and to an at-risk population growing in number and income inequality (Howell and Elliott 2018). The National Research Council has placed the goal of resilience at the center stage of urban planning by defining community resilience as "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events" (NRC 2012, p. 1).[1]

A major obstacle to building community resilience is that hazard mitigation planning usually occurs in isolation from other decisions dealing with land use and development in hazard areas. Little thought is given to coordination of a local mitigation plan among a community's network of plans that focus on, for example, housing, transportation and climate adaptation. Reasons for poor coordination include increasing specialization in government organizations, reluctance to share information to protect turf, beliefs and ideologies aligned with specialized missions, and organizational performance based on individual goals that ignore collective goals (Peters 2018). As a result, plans often pursue conflicting goals, fail to adequately focus on the most vulnerable areas, and ultimately increase vulnerability (Berke et al. 2020, Hopkins, Kaza and Pallathucheril 2005, Hopkins and Knapp 2016, NRC 2012).

We present results of a local government engagement project in three cities vulnerable to flood events and sea level rise. Our project includes partnerships of university experts and local agency staff to identify conflicts in local network of plans and reveal hidden opportunities for improving coordination and implementation of plans. The project includes the technical application of a *Plan Integration for Resilience Scorecard*™ and a local engagement strategy. The scorecard, first developed by Berke et al. (2015), generates critical technical information that community decision makers can use to better coordinate planning for resilience among different types of local plans and implementation practices. The engagement strategy aims to improve involvement in resilience planning among local agencies with responsibilities that affect vulnerability, to enable city staff to learn about each other's agencies' roles and responsibilities,

[1] Scientific, civic, and professional practice organizations alike now recognize that importance of urban planning in building integration of resilience across different urban sectors. Examples include the Hazards Planning Program of the American Planning Association 2020; Resilient America Program of the National Academies of Science, Engineering and Medicine 2020; and Planners for Climate Adaptation (P4CA) program of the United Nations.

and to improve knowledge of staff about how different types of plans can be integrated to achieve long-term resilience.

We chronicle and evaluate the impacts of *Resilience Scorecard*™ application process from the local prospective. Project objectives are: 1) To determine changes in *local capacity* to proactively plan, including changes in: skill to evaluate plans; level of inter-organizational communication and coordination; and ability to use new information to develop integrated mitigation policy solutions; and 2) To determine changes in *outcomes* including change in: integration of mitigation actions across local networks of plans; strength of land use and development regulations; public investments for mitigation; and physical and social vulnerability (e.g., housing units relocated from hazard area, number of low-income people exposed to floods).

Linking the Concept of Plan Integration to Practice

Communities are increasingly adopting different types of plans that affect land use and development patterns, each with its own constituency of interest groups both within and outside government (Hopkins and Knapp 2016). Such broader and more inclusive planning is a positive development, but may also present problems when plans are aimed at pursuing interests of individual groups. For example, a hazard mitigation plan proposes acquisition of homes in a floodplain that experience repeated losses, but a transportation plan locates a road extension in the same area, encouraging growth.

The core capability of the *Resilience Scorecard™* is to enable comparisons between the degree of integration of local plan policies in support of vulnerability reduction in different geographic areas of a community. The scorecard identifies the level of coordination among plans, as well as conflicts that exacerbate existing, or create new, vulnerabilities in places such as a residential neighborhood, a downtown, and a waterfront. Information generated by the research allows planners and decision-makers to better focus their efforts on areas of greatest need and keep track of their progress toward integration and resilience goals. Applications of the scorecard have been cross-cultural ranging from cities in the United States (Berke et al. 2015, 2019, 2020, Newman et al. 2019), to the Netherlands (Malecha et al. 2018, Yu et al. 2020) and China (Ka et al. 2020).

The new information gives communities the ability to ask crucial policy questions about goals and priorities and how to improve the integration of resilience across multiple local plans. Examples of questions might include: Should policies in comprehensive plan that promote extensive waterfront development better integrate vulnerability reduction? Should policies in all plans be revised to give priority in districts with the highest physical and social vulnerability? Can the land acquisition program of the parks plan be coordinated with the buyout program of the hazard mitigation plan to produce co-benefits that reduce vulnerability and improve amenities? Table 1.1 illustrates a range of potential community benefits supported by application of the scorecard.

Table 1.1: Benefits of the *Plan Integration for Resilience Scorecard*

---

1. **Provide a tool to foster collaboration essential for addressing on-the-ground needs.** Each community has a specific set of challenges and opportunities. The results of the evaluation can be used to inform meaningful conversations among planners, emergency management staff and other local officials, and

residents about new policy priorities and areas to invest. The process by which communities self-evaluate local plans raises knowledge about the heterogeneous effects of plans, and enhances prospects for co-creating shared solutions.

2. **Uncover conflicts among different plans**. The scorecard reveals inconsistencies between plans and uncovers conflicts can exacerbate existing vulnerabilities or create new vulnerabilities. For example, land use plans that designate a floodplain land acquisition strategy for open space is at odds with transportation plans that locate roads in the same floodplain, inducing growth. By identifying conflicts communities can revise land use and development regulations and proposed public investments to improve spatial coordination that strengthens mitigation practices.

3. **Identify opportunities to create co-benefits.** The scorecard can expand prospects for seeking new opportunities to produce co-benefits by better aligning plans. Co-benefits have a positive effect on multiple interests rather than having narrowly defined benefits that suit individual interests. A parks plan, for example, includes a land acquisition policy to acquire greenway corridors for walking and biking along waterways can be coordinated with a hazard mitigation plan that designates buyouts for homes along the same flood prone waterways.

4. **Fill gaps in plans.** The scorecard highlights gaps in plans that do account for important areas that have been overlooked in current plans. This is especially important to ensure that critical issues dealing with hazards and climate change have been addressed across plans. Affordable housing plans, for example, that include polices that frequently prioritize redevelopment of poor neighborhoods that are exposed to multiple types of hazards, but fail to include mitigation policies.

5. **Provide communities developing new plans or updating existing plans with a guidance framework to reduce future hazard exposure through smarter and more consistent policies.** The methodical approach can be used to monitor and assess progress of the coordination of networks of plans for hazard vulnerabilities. A community can also evaluate the progress and performance of resilience investments and ensure continuity of decisions.

Source: Malecha et al. (2019)

This project necessitates the expansion of the concept and methods of the *Resilience Scorecard*^{TM} used by researchers to a tool that can be used by local practitioners active in urban planning. The next step is to examine the process by which communities use the scorecard to self-evaluate local plans, how the results influence knowledge about the heterogeneous effects of plans, and whether the process enhances prospects for co-creating shared solutions. Using the scorecard, we piloted application with three cities. The pilot cities applied the scorecard to their own plan-making efforts. We chronicle the process and tracked change in local capacity to coordinate multiple planning efforts, as well as change in outcomes in the form of revisions to plans, and adoption of land use and development regulations and public investments consisted with revised plans. Each city provided feedback on their experience throughout the process.

Engagement Strategy Applied to Planning Practice

The Institute for Sustainable Communities (IfSC) at Texas A&M University obtained funding from the Department of Homeland Security to conduct a four-year project (2016-20) entitled, *Application of the Plan Integration for Resilience Scorecard to Practice*. The authors of this paper were affiliated with IfSC and were the key participants in working with the pilot cities throughout the duration of the project. IfSC has expertise in research on hazard mitigation and climate adaptation planning, as well as in assisting local governments "to facilitate the

transformation of communities from high risk/low opportunity to equitable, resilient, and adaptive by mitigating threats to the economy, environment, and culture" (IfSC 2020).
To validate the *Resilience Scorecard™* and its translation to practice, the IfSC team invited subject matter experts to participate on an advisory board composed of national leaders with significant expertise in hazard and climate adaption planning practice. Members were primarily drawn from the Hazard Mitigation and Disaster Recovery Planning Division of the American Planning Association. The IfSC team developed a *Plan Integration for Resilience Scorecard Guidebook™* and software tool to assist local plan evaluators to track scoring. Board members gave critical guidance to IfSC in crafting the guidebook and tool to ensure that the scoring procedures are coherent and applicable to practice. After the scorecard was vetted by experts, IfSC began recruiting flood-vulnerable cities as potential pilot communities to further test the scorecard and guidebook.

IfSC provided technical assistance services to the pilot cities that agreed to apply the *Resilience Scorecard*. IfSC conducted several core activities for each pilot city. A kickoff webinar that involved local leaders and several local agency directors to explain the basic concepts of the scorecard and to identify links to ongoing resilience planning initiatives. A follow-up half-day workshop attended by agency staff focused on the data requirements and procedures to spatially evaluate plans. Attendees were provided with copies of a *Plan Integration for Resilience Scorecard Guidebook™* and a user-friendly software tool prepared by IfSC that is online and freely available.[2] Finally, IfSC experts acted as facilitators by conducting regular tele-conference meetings with local teams of plan evaluators over a duration of each city's evaluation process (6 to 9 months). IfSC responded to queries from local agency staff, such as assisting the local team by reviewing initial plan evaluations and offering advice on interpretations of how specific policies affect vulnerability.

Throughout this interactive process with the cities, the scorecard tool and guidebook were evaluated and refined. Several small revisions were suggested as well as some amendments of concept definitions. One serious issue involved the plan policy-scoring procedure because staff with diverse types of professional expertise (urban planning, emergency management) could not uniformly understand how to identify and classify different types of policies (e.g., development regulations, public infrastructure investments) that affect hazard vulnerability. This issue was resolved by developing clear definitions of policy categories to help the evaluators classify and score each policy. Overall, local agency staff engaged in applying the scorecard in the pilot cities supported the basic structure of the scoring system.

Pilot City Selection

The three cities selected for this effort are Nashua, New Hampshire; Norfolk, Virginia; and Rockport, Texas. Table 1.2 identifies the selection criteria. In all instances, local agency staff expressed a willingness to partner with IfSC, and they considered the project to be good fit with the timing of ongoing planning efforts. Additional rationale in making the selection is to demonstrate the applicability of the scorecard in diverse contexts. Study cities were selected based on geography and population size. We divided the US into geographic zones consistent with Federal Emergency Management Agency (FEMA) national planning regions. One city was

[2] http://mitigationguide.org/scorecard-guidebook/

selected from each of three of the six FEMA regions along the Atlantic and Gulf coasts in the US. Variation in geographic location and population characteristics is beneficial from a sampling perspective. Selection of cities from different coastal regions of the United States reflects variation in socio-economic, political, and biophysical characteristics, and thus is more likely to reflect differences in networks of plans and how well they target areas most vulnerable to hazards (Lyles, Berke, and Smith 2014). Further, different population sizes and income offer a preliminary understanding of how cities that vary in resource levels are responding to hazard vulnerability. An additional motivation was to select cities that experience significant vulnerability to coastal or riverine floods, and precipitation events and sea levels exacerbated by climate change. Vulnerability is a salient planning issue for the selected cities since they experience high levels of threat from flood hazards.

The selected cities have a range of population sizes: 82,246 (Manchester); 244,076 (Norfolk); and 10,759 (Rockport). Compared to the Norfolk and Rockport, Manchester has the highest income, lowest poverty rate, and least diverse in race. Norfolk is economically dominated by the largest Naval base in the world, and many areas are threatened by significant sea level rise rates at twice the global average. Rockport is highly vulnerable to coastal hazards and was devastated by Hurricane Harvey in 2017. Manchester is subject to riverine flooding and faces prospects for increase of severity from flooding due to climate change, especially in the downtown area.

Table 1.2: Selection Criteria for Pilot Cities

Selection Criteria	**Manchester, NH**	**Norfolk, VA**	**Rockport, TX**
Population characteristics (2018) **Size** **Growth rate (2010-18)** **Race(white alone, non-Latinex)** **Median HH income** **Poverty rate**	86,246 3.2% 73.4% $73.022 9.9%	244,076 0.5% 43.5% $49,146 19.7%	10,759 7.3% 64.0% $53,803 26.4%
Location by FEMA planning region	Region I: New England	FEMA Region III: Mid-Atlantic coast	FEMA Region VI: Western Gulf of Mexico coast
Major vulnerability issues	Flooding due convergence of two major rivers; future increase in severity of precipitation events due to climate change; threats to downtown area	Sea level rise at 2X global mean; coastal storm surge; threats to largest Naval base in world, downtown and multiple neighborhoods	Severe damage from Hurricane Harvey-2017; sea level rise
Timing with key ongoing planning efforts related land use and development patterns	Resilient Nashua Initiative; Resilience Dialogues; Downtown Riverfront Development Plan; Climate and Health	Norfolk Resilience Strategy; Vision 2100; plaNorfolk2030	Create new post disaster comprehensive plan; Recovery Planning Assistance Team Report; Aransas Count

	Adaptation Plan; Hazard Mitigation Plan		Long-Term Recovery Plan

Methods for Tracking Change

We derived data to track changes resulting from application of the *Plan Integration for Resilience Scorecard*^{TM} from several sources. We took notes during on-site training sessions, monthly teleconference meetings, and public hearings. As mentioned, these meetings dealt with queries raised by city staff as they completed the phases of the scorecard application process. We supplemented the notes with responses to interviews we conducted with staff who participated in the plan evaluation at the end of the process. Interview questions asked staff to assess their experience in applying the scorecard and identify actions taken by the city, civic groups, and the private sector resulting from the engagement process and information produced by the scorecard.

To guide our assessment of change, we used a logic model to track the effects of this project for each pilot city. Logic models are frequently used in the public health field to depict the relationship between a project's activities and its intended effects (CDC 2020). We believe that logic models have applicability to monitor and evaluate changes from urban planning initiatives. As shown in Figure 1.1, a logic model is a graphic depiction that presents the relationships among *inputs* (resources, training), *outputs* (change in organizational capacity to plan), and *outcomes* including changes in plans, development standards and public investments, and level of vulnerability (housing units relocated from hazard area, acres of hazard area conserved as open space). Although the boxes of the model are shown in a linear fashion, the relationships among them are expected to be complex and interactive over time.

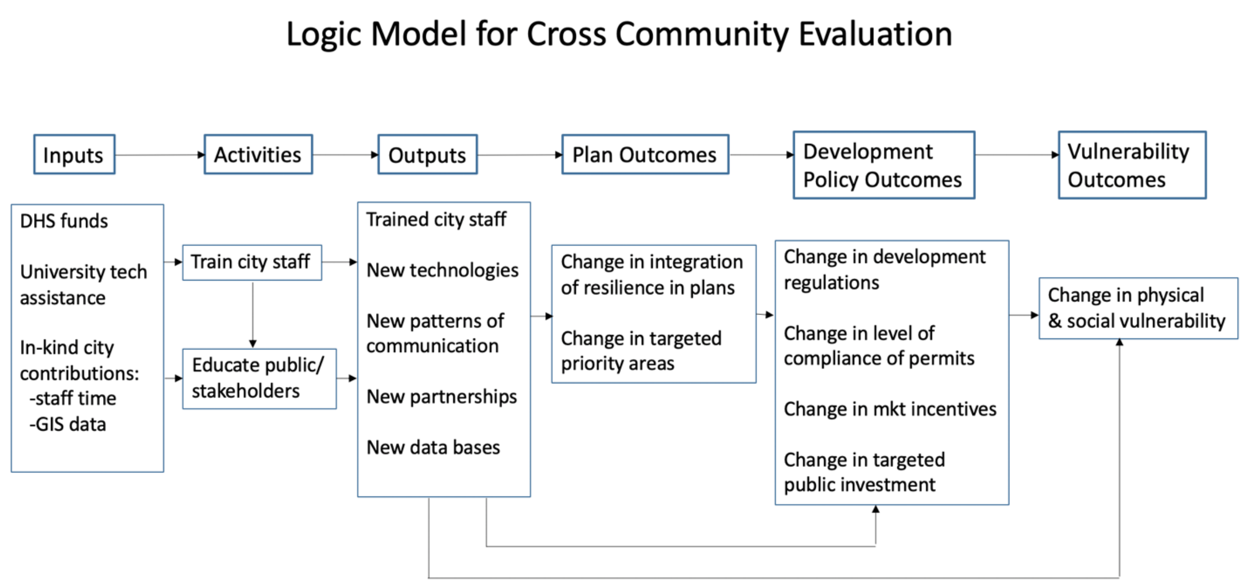


Figure 1.1: Logic Model of Relationships: Inputs, Activities, Outputs and Outcomes

Plan Scoring: A Four-Phase Procedure

The *Resilience Scorecard*^{TM} enables communities to determine coordination, conflict, and gaps in a local network of plans and to use that information to improve integration of mitigation across plans to more explicitly reduce vulnerability. Use of the *Resilience Scorecard*™ requires community actions across four phases.

Phase 1: Form a team. An interdisciplinary team of staff from local government agencies charged with implementation of relevant plans should be established to oversee the scorecard evaluation process to ensure that plan evaluation is not conducted in silos. Core activities of the team are to evaluate plans, communicate across agencies to better understand the contents of plans, and foster consensus in making adjustment based on results of the network of plan evaluation.

Phase 2: Select plans. Plans adopted by local government that influence land use and development in current and future hazard areas should be selected for evaluation. Table 1.3 shows a range of types of plans. Among these plans, the comprehensive plan represents the principal form of general governmental planning and is the primary planning policy instrument that coordinates land use and development across multiple urban sectors. Hazards mitigation practices can also be integrated into other more specialized planning activities (e.g., parks, housing, transportation). Notably, the hazard mitigation plan is one of the most frequently adopted specialized plans. The Disaster Mitigation Act (DMA) enacted by Congress in 2000 requires all local governments to adopt a mitigation plan approved by FEMA to be eligible for federal pre- and post-disaster mitigation funds. Other specialized plans (e.g., transportation, open space, climate action, hazard mitigation) are sometimes prepared at the regional scale and have direct influence on local land use and development.

Table 1.3: Examples of Types of Plans in a Community Network of Plans

Plan Type	Purpose	Contribution (+/-) to Vulnerability
Comprehensive/General Plan	Main community planning document	Policies can guide future development into or away from hazard zones.
Hazard Mitigation Plan	Reduce long-term risk to human life and infrastructure	Supports vulnerability reduction and resilience building, often via general policies or specific "action items".
Disaster Recovery Plan	Address disaster recovery-related needs to be activated during recovery	Supports vulnerability reduction and resilience building post-disaster. Coordinates agencies to assist people post-disaster.
Climate Change Adaption Plans	Adjust to actual or expected climate and its effects	Supports flexibility of strategies to address uncertainty of potential loss, and mainstreaming adaptive actions into other sectors of planning
Small Area Plans: Downtown (Redevelopment) Neighborhood District	Address planning issues pertaining to a portion of the community	Targeted policies may increase or decrease vulnerability, depending on purpose and location. Area plans may

Waterfront		also contribute to policy district delineation.
Corridor		
Functional or Sector-specific Plans:	Focus on individual or related functions or sectors in need of specialized planning	Individual plan policies (or objectives, action items, etc.) may increase or decrease vulnerability, and are often distinct from those found in comprehensive or hazard mitigation plans. Applicability to individual policy district(s) may be aided by additional functional or sector-specific maps.
Transportation (or Transit)		
Parks / Open Space		
Economic Development		
Environmental Management		
Climate Adaptation/Mitigation		
Housing (Consolidated/Strategic)		
Wildlife Management		
Wildlife Protection		

Source: Malecha et al. (2019)

Phase 3: Delineate district hazard zones. The basic unit of analysis for scoring the degree of integration of mitigation practices among plans are district hazard zones. Most community planning programs divide the community into planning districts based on geographic areas that encompass residential neighborhoods, downtowns, and commercial, industrial, and conservation places. To delineate the district hazard zones, intersect the planning districts with the hazard zones using GIS (Geographic Information Systems).

Phase 4: Spatially evaluate the network of plans. Evaluation of plans includes three step procedure. *First*, local plan evaluators extract applicable policies in each plan that influences land use and development. Classify each policy based on different categories of land use policy instruments (e.g., zoning regulations, land acquisition, public investments programs for infrastructure, market incentives like tax abatement and housing density bonuses) that influence the type, location, and amount of development. *Second*, evaluators score each policy based on the intended vulnerability outcome linked to the policy, that is, whether a policy has no effect on vulnerability (score = 0), increases vulnerability (score = –1) or decreases vulnerability (score = +1). Table 1.4 presents examples of how we apply the scoring method. *Third*, evaluators spatially assign each policy score to one or more district hazard zones, and then sum the scores from all plans by vulnerability outcome for each zone. Higher total scores indicate the use of more policies aimed at decreasing vulnerability, while lower scores indicate that use of more policies that actually increase vulnerability. Figure 1.2 visually illustrates the mapped data outputs of the scoring process.

Table 1.4: Examples of Plan Policy Classification and Scoring Method

Example 1. A policy in the infrastructure element of a Comprehensive Plan states, "Assure the provision of public and private parking in support of increased development and activity." The rationale is to expand infrastructure capacity to foster physical development of the downtown, which is entirely in the 100- year floodplain and in the projected area to be inundated by sea-level rise by 2100. Thus, for the downtown district this policy linked to *infrastructure capacity* received a score of –1 for vulnerability for the 100-year flood zone and a –1 for the zone covered by additional sea-level rise zone.

Example 2. A policy in the hazard mitigation plan states the need for "acquisition of properties located in the city's repetitive loss areas...including areas passing through areas largely utilized for public housing." The rationale is to reduce vulnerability inside the 100-year flood- plain. The policy of *acquisition* received a score of +1 for social vulnerability for each of the three districts.

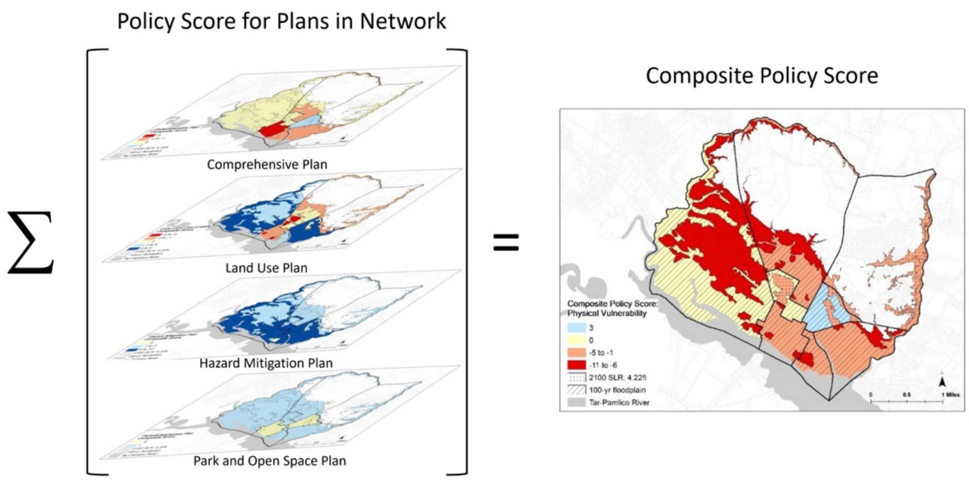


Figure 1.2: Scoring of Networks of Plans by District Hazard Zones

References

Berke, Philip, Galen Newman, Jaekyung Lee, Tabitha Combs, Carl Kolosna, and David Salvesen. 2015. "Evaluation of Networks of Plans and Vulnerability to Hazards and Climate Change: A Resilience Scorecard." *Journal of the American Planning Association* 81 (4): 287–302. https://doi.org/10.1080/01944363.2015.1093954

Berke, P.R., Malecha, M.L., Yu, S., Lee, J., Masterson, J.H., 2018. Plan integration for resilience scorecard: evaluating networks of plans in six US coastal cities. *Journal of Environmental Planning and Management.* Published electronically June 1. http://dx.doi.org/10.1080/09640568.2018.1453354

Howell, Junia, and James R. Elliott. 2018. "Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States. *Social Problems*. Published electronically August 14. doi:10.1093/socpro/spy016.

Kunetz, Nicholas. 2019. Coastal Flooding Is Erasing Billions in Property Value as Sea Level Rises. That's Bad News for Cities. *Inside Climate News*, February 28, 2019. [https://insideclimatenews.org/news/28022019/coastal-flooding-home-values-sea-level-rise-climate-change-ocean-city-miami-beach]

Intergovernmental Panel on Climate Change (IPCC). 2019. *Climate Change and Land*: *An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land*

Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems: Summary for Policymakers. https://www.ipcc.ch/report/srccl/

Lindsey, Rebecca and Dahlman, LuAnn. 2019. Climate Change: Global Temperature. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Malecha, Matt, Jamie Masterson, Siyu Yu, and Philip Berke 2018. Plan Integration for Resilience Scorecard Guidebook: Spatially Evaluating Networks of Plans to Reduce Hazard Vulnerability Version 2.0 [http://mitigationguide.org/scorecard-guidebook/]

National Oceanic and Atmospheric Administration (NOAA). 2019. 2018's Billion Dollar Disasters in Context. https://www.climate.gov/news-features/blogs/beyond-data/2018s-billion-dollar-disasters-context

National Research Council (NRC). (2012). *Disaster Resilience: A National Imperative.* Washington, DC: National Academies Press. https://doi.org/10.17226/13457.

Newman, Galen, Matthew Malecha, Siyu Yu, Zixu Qiao, Jennifer A. Horney, Jaekyung Lee, You Jung Kim, Ryun Jung Lee, and Philip Berke. 2018. Integrating a resilience scorecard and landscape performance tools into a Geodesign process. *Landscape Research*, 45(1): 63-80 DOI: 10.1080/01426397.2019.1569219

Peters, Guy. 2018. The challenge of policy coordination. *Policy Design and Practice*, 11(1); 1-11.

Rubin, Claire. 2019. Ch.1: Introduction, In Claire Rubin and Susan Cutter (Eds.), *US Emergency Management in the 21st Century: From Disaster to Catastrophe*, Philadelphia, PA: Routledge.

United Nations General Assembly. 2015. United Nations World Conference on Disaster Reduction: Sendai Framework for Disaster Reduction 2015-2030. Sendai, Japan: United Nations Office for Disaster Risk Reduction (UNISDR). http://www.preventionweb.net/files/43291_sendaiframe workfordrren.pdf

Part 2: Pilot City Experiences

City of Norfolk, Virginia

The Setting

Norfolk is a good fit to serve as a pilot community with estimated population of 244,707 in 2017. Norfolk is experiencing increasing frequency of floods due to coastal storm surge and sea level rise. Norfolk floods not just from heavy rains or hurricanes. Flooding occurs during blue skies, at high tide, or when the winds come from the right direction. The seas are rising at twice the global average, due to ocean currents and subsidence that involves the loss of coastal lands due to sinking subsurface geology that is not related to rising sea levels caused by climate change. About 16% (8.3 square miles) of the total geographic area (52 square miles) is within the 100-year (1% occurrence probability per year) floodplain boundaries as defined by the Digital Flood Insurance Rate Maps (DFIRM) of the National Flood Insurance Program (NFIP). An additional 32% (16.6 square miles) of the city's area could be exposed to the 100-year floodplain due to sea level rise by 2100 (City of Norfolk 2017a).

Norfolk has taken a longstanding leadership role in community resilience. According to Paula Shea, Chief Planner, inspires to be a "model community on resilience." The city is a participant in the Rockefeller Foundation's 100 Resilient Cities program that resulted in adoption of the Norfolk Resilience City Strategy and the hiring of a city Chief Resilience Officer in 2014. Norfolk hosted the Dutch Dialogues workshop in 2015 to brought together Dutch engineers and city planners with local counterparts to explore creative and innovative solutions to the challenges inherent in living in a coastal city (WPA 2015). The focus of the workshop was to extend beyond the conventional structural approach of building higher barriers, but to determine how to live more naturally with water. These activities culminated into the preparation of a forward-looking Norfolk Vision 2100, which responds to sea level rise and coastal storm hazards, and includes principles to guide the development of a new comprehensive plan during the years 2020-2021.

Forming a Team

The primary goal of establishing the team is to communicate across departments or entities to better understand the contents of the city's network of plans. Thus, Norfolk planners created a team of six members that represent a diverse set of agencies active and influential in the city's resilience program – the planning director, two planning staff within the department of city planning, one emergency manager, their chief resilience officer (from the 100 Resilient Cities initiative), and a GIS analyst. The main points of contact included the Chief Planner, Paula Shea. All members participated in collecting and evaluating Norfolk's network of plans. Core activities included a kickoff webinar, and a 2-day on-site training visit (November 2016), and monthly tele-conference meetings throughout the process (between December 2016 and September 2017) to respond to queries by city's team members.

Selecting Plans

Norfolk has adopted a diverse network of plans that influence on land use and development decisions in areas exposed to coastal flooding and sea level rise. Among the 16 official plans adopted by the City, plan evaluators originally attempted to assess all plans but soon realized that the effort was too time consuming. Local team then identified six plans (five citywide and one regional) to be included in the study as these plans were considered to have the most significant influence on development decisions in the city (see Table 2.1). Plans excluded from the study did not intersect with the hazard zones, were out of date, or were already integrated in the city's comprehensive plan, which incorporates as chapters several of the stand-alone small area and functional plans. Each of these plans are independently prepared by distinct government agencies and interest groups. The city staff felt that the combined impact of the selected plans has a strong effect on the level of vulnerability to community hazards.

Table 2.1: Selected Norfolk Plans

Comprehensive Plan: Norfolk 2030: The General Plan for the City of Norfolk (2013)
Hazard Mitigation (Regional) Plan: Hampton Roads Hazard Mitigation Plan (2016)
Shoreline Plan: Sand Management Plan Guidance Document (2016)
Resilience Plan: Norfolk Vision 2100 (2016); selected by the 100 Resilience Cities program.
Small Area Plan I: Downtown Arts and Design District Plan Revitalization Strategy (2013)
Small Area Plan II: Military Circle/Military Highway Urban Development Area: A Vision for the Future (2017)

The process of selection required that the team initiate cross agency staff discussions about the presence and influences of different plans. Urban planning staff, for example, were unaware how the hazard mitigation plan reduced vulnerability of built and social environments. The city's emergency management department prepared the city's element in the regional mitigation plan, but communication across emergency management and planning agencies was limited. The Norfolk team thus included the city's element in the regional mitigation plan in the evaluation when it might otherwise have been excluded if city's urban planning staff had not collaborated with emergency management staff.

Delineating District Hazard Zones

The first step in identifying the district hazard zones was to identify the parts of the city subject to flooding. The Norfolk team decided to focus on the 100-year floodplain since it is used in formulating local hazard mitigation policy to administer and enforce NFIP policy goals. The team also prioritized sea level rise given the potentially catastrophic consequences of this hazard. Sea-level rise forecasts were added to inundation surfaces indicated by the 100-year flood elevations on NFIP maps.[3]

Next, the Norfolk team debated about the appropriateness of how to delineate planning districts. The team was concerned about the appearance of bias when presenting the scorecard results to city decision-makers, and thus wanted to use districts that were more 'objective' than the official

[3] We add sea-level rise forecasts to inundation surfaces indicated by the 100-year flood elevations on DFIRM maps, consistent with the method used to guide rebuilding of structures that received FEMA's public assistance funds after Hurricane Katrina (U.S. Army Corps of Engineers [USACE], 2018a). Our aim is to delineate the extent of flooding using the same 1% probability of occurrence as FEMA uses, to which we add the level of sea rise. Recent advances in downscaling the effects of global climate change on sea-level rise have made it possible to delineate areas exposed to sea-level rise (Climate Central, 2014). We use data derived from USACE's sea-level rise calculator, which provides alternative scenarios in 10-year increments up to 2100 for relative local sea-level rise along the U.S. coast (USACE, 2018b). The intermediate-high scenario for the year 2100 from a range of possible sea-level rise scenarios (low, intermediate low, intermediate, inter- mediate high, and high) generated by the USACE sea-level rise calculator for the coastal region that includes Norfolk.

neighborhoods (which are closely linked to city council districts). In the end, they chose to use the 80 U.S. Census Tracts located entirely or partially in the hazard areas to serve as the planning districts. Smaller-scale units of analysis (e.g., Census Block Groups) would offer a more fine-grained analysis of policy coordination, but the time and effort required to spatially evaluate policies in a greater number of districts was beyond available time and staff resources. Even the 80-census tract were considered by plan evaluators to be excess in number and too cumbersome in terms of spatial identification of the locations where each policy has an effect. Plan evaluators indicated that wherever possible tracts could be combined in cases where hazard exposure, development patterns and social and economic conditions are roughly equivalent. Next, GIS was used to intersect the hazard zones with the census tracts to delineate the district hazard zones.

Findings: Spatial Evaluation of the Network of Plans

The Norfolk team followed the three-step procedure for spatially evaluating the plans: extracting policies in plans; scoring each policy based on vulnerability outcomes; and spatially assigning and summing policy scores to district hazard zones. The Norfolk team created and mapped a composite index score for each hazard district zone in the city. Figure 2.1 shows the resulting district hazard zones (and composite plan policy scores from all plans) for the Norfolk *Resilience Scorecard* analysis.

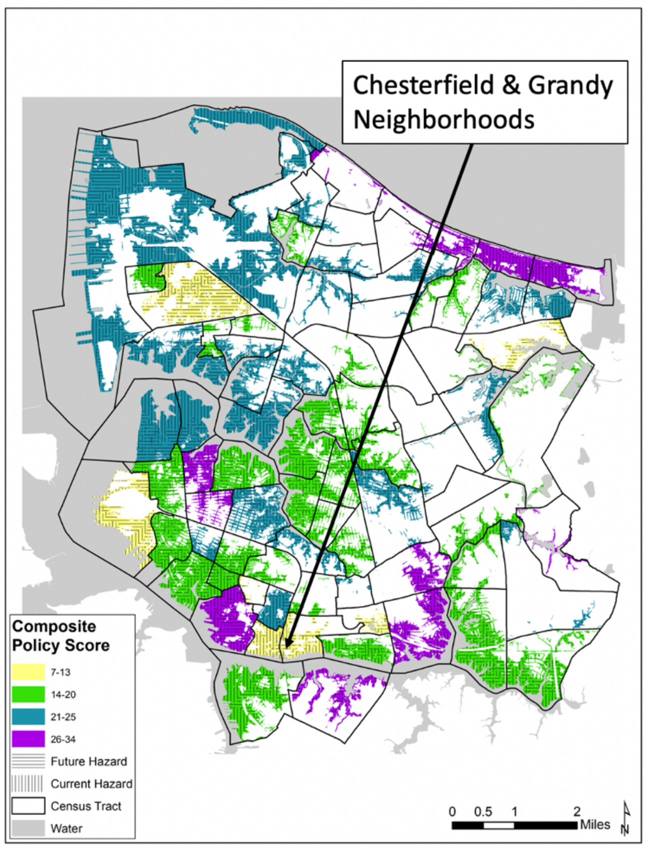


Figure 2.1: Composite Plan Policy Score by District Hazard Zone: City of Norfolk

The Norfolk team was surprised to find some weaknesses and inconsistencies in the city's network plans. Examples include:

- The city's comprehensive plan contained a major gap in hazard mitigation policy as the Norfolk planning staff had unintentionally excluded the hazard mitigation plan in all other prior plan making efforts in the city.
- Plans are unjust in policy attention aimed at socially vulnerable neighborhoods; poor areas of the city received lower composite policy scores, as illustrated by the Chesterfield Heights and Grandy neighborhoods.
- Prominent themes in the Vision 2100 to guide the city's long-term response to sea level rise were not integrated into the current comprehensive plan.
- Location criteria in several plans only focused on accessibility city services and facilities to different population groups but did not factor in location and design criteria for community facilities in flood hazard areas.
- The hazard mitigation plan lacked spatial specificity; notably, it did not specify strategies to mitigate vulnerability to existing development in areas exposed to sea level rise and the 100-year regulatory floodplain.

Results of the evaluation were shared with the city council at a public hearing and with staff across city agencies charged with preparation and implementation of different plans. Local planning staff pointed out that this action proved important for raising awareness about the threats posed by sea level rise and gaining support for better integration of vulnerability reduction policies throughout the city's network of plans.

Tracking Change in Local Capacity and Outcomes

We tracked changes in local government capacity (outputs) to support resilience planning and changes in plans, development regulations/spending, and level of vulnerability (outcomes) in the City of Norfolk as a result of the scorecard application process. Figure 2.2 illustrates these changes.

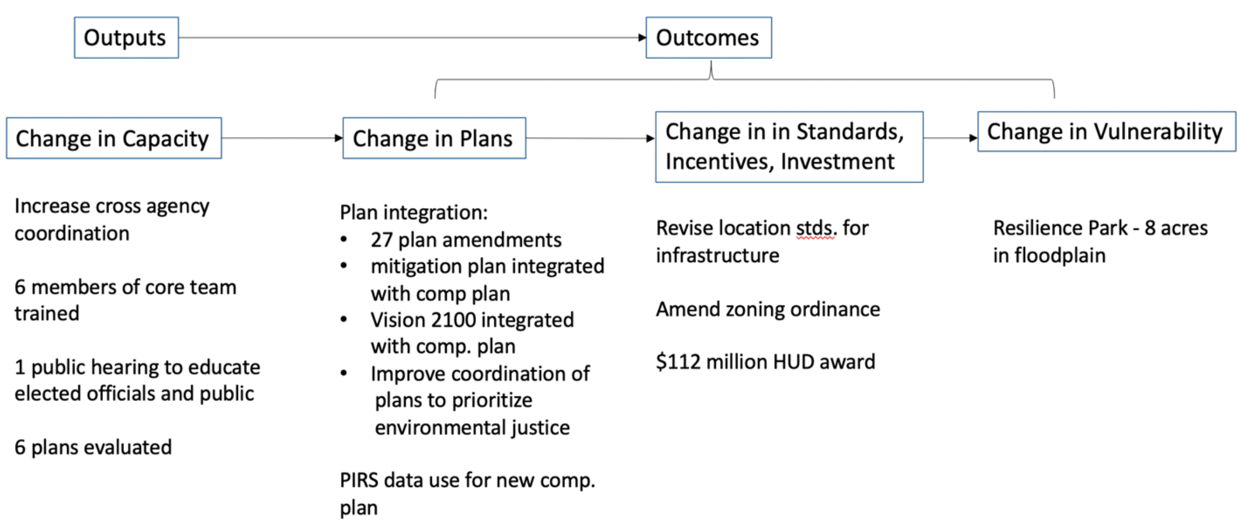


Figure 2.2: Changes Linked to the Scorecard Process in Norfolk

Outputs: Capacity Building
Norfolk's capacity to support resilience improved in serval ways due to the scorecard application process. George Homewood (FAICP, CFM, Norfolk Planning Director) summed up the city's overall experience with the process indicating that the "The Resilience Scorecard was a great tool to allow us to evaluate our existing plans and policies…we undertook a major plan amendment to more fully incorporate our Hazard Mitigation Plan and Vision 2010 as key elements in our comprehensive plan." Comments by city staff team members reveal the benefits of the *Resilience Scorecard* process. One member indicated that the, "process offers an unbiased and impartial look at policies and plans…it helps reveal how we need to spread our energy to other areas of the community." Another stated "We were very intrigued by the spatiality of our policies and hadn't thought about our policies spatially before."

Team members universally agreed that the process strengthened the city's capacity to plan for resilience. Six staff members improved their skills to conduct spatial evaluation of plans and to identify weaknesses, gaps and conflicts among plans, which resulted in a deeper under- standing of the network of plans by community staff and decision-makers, increased awareness of the connection between plans and vulnerability to natural hazards. Cross agency communication improved, notably between the emergency management and planning. The new data base provides the motivation and information that staff and decision-makers need to better integrate their network of plans.

Outcomes: Plans, Regulations, and Public Investments
Significant revisions of plans were made to address major gaps and conflicts in coordination, significant revisions of the comprehensive plan, including council approved 27 policy amendments (City of Norfolk, 2017b), were made to address major gaps in coordination. As noted, key policies and implementation actions in the hazard mitigation plan were incorporated into the city's comprehensive plan. The comprehensive plan was also amended to incorporate the Vision 2100 strategy that identifies major elements for a citywide resilience strategy. Figure 2.3 shows the key themes and a mapped illustration of Vision 2100:

- *Yellow low elevation areas* prone to flooding from sea level rise for gradual retreat by applying land acquisitions and limiting expansion of infrastructure;
- *Green high elevation areas* for new urban centers that increase densities, shifting single-use to mixed-use development, expand infrastructure investments; and
- *Red low elevation areas* for major structural flood protection projects to protect significant economic and cultural assets essential to the city's future (downtown, seaport, several historic neighborhoods).
- *Purple high elevation areas* for establishing neighborhoods of the future.

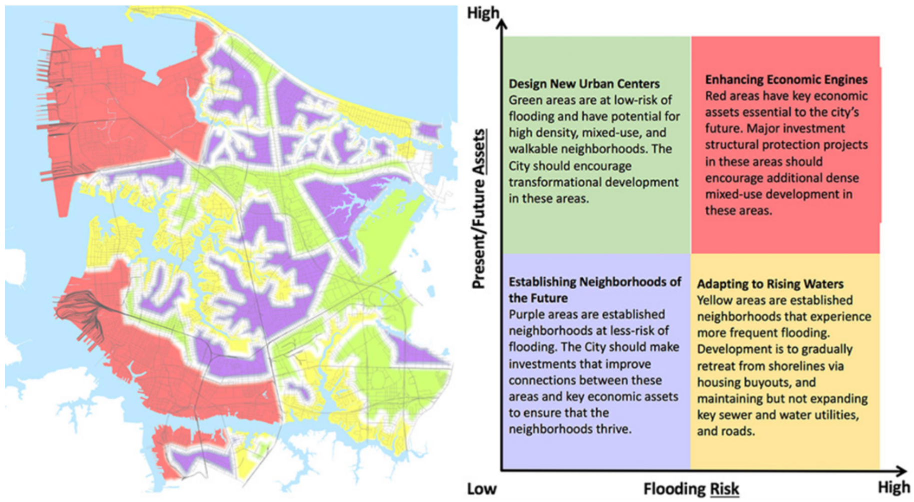


Figure 2.3: Norfolk's Vision 2100 includes land use strategies to address long-term vulnerability to coastal hazards and sea level rise.

Resilience metrics in the zoning ordinance were added to location criteria for community facilities in the hazard mitigation plan and comprehensive plan. Prior versions of the plans only included conventional metrics based on accessibility of populations to community facilities. In addition, information generated by the *Resilience Scorecard*^{TM} helped create a new zoning ordinance to better account for the variations in the "geography of resilience." Official notes from a public hearing initiated by the City Planning Commission indicated the information will be used to update development regulations and building standards, to strengthen stormwater infrastructure requirements, and to serve as a component of the fact base for preparation of a new comprehensive plan in 2020 (City of Norfolk 2017b).

The new data base for plan integration lead to increased public investments targeting flooding and environmental justice problems within the city. The city staff used the data to improve coordination among plan policies to be consistent with Vision 2100 and the hazard mitigation plan, and then to prepare proposals for external funding. As noted, a major need revealed by the scorecard was unjust policy attention aimed at socially vulnerable neighborhoods; that is, poor areas of the city received lower composite policy scores. In 2018, the city competed and won a $112 million award, sponsored by the U.S. Department of Housing and Urban Development's National Disaster Resilience Competition, that targets the historic Chesterfield Heights and Grandy neighborhoods -- poor neighborhoods comprised of a majority percentage of African Americans with 700 houses on the National Historic Register. Figure 2.1 shows that these two neighborhoods had the lowest composite policy scores in vulnerability reduction for the entire city. The city's proposal demonstrated that the award would be used to redress the historic legacies of under-investment and disproportionate impacts from floods by enhancing the city's ability to make public investments, improve quality of life and to stimulate market incentives for local job creation. In reflecting on the award, Paula Shea observed that, "when we go after grants for resilience…a fact base that demonstrates that plans are not at odds makes it clear that we know where we want to go in the future…we have our act together." Projects funded by the award, such as Resilience Park that covers eight acres (see Figure 2.4), must meet multiple goals framed from an equity perspective. Examples of the goals for the new park include more resilient neighborhoods to floods, better educational opportunities about the role of natural systems, and improve neighborhood-based economic opportunities (City of Norfolk 2018).

Figure 2.4: Norfolk Resilience Park*

*The HUD award includes investments in the park to serve as an education center, and to connect the neighborhoods of Grandy and Chesterfield Heights with 10 acres of open space that integrates a flood berm, a restored tidal creek and wetland, and multiple amenities for community gathering, sports, exercise and play (City of Norfolk 2018).

Future Steps

Norfolk planners indicated several next steps for building city resilience. The city will use the data base and learning outcomes generated by the *Plan Integration for Resilience Scorecard*^{TM} to support resilience initiatives that are woven across urban sectors. The results in Norfolk exemplify how the resilience scorecard framework can be applied at different stages of plan development—from evaluating an existing network of plans, to guiding the development of new plans to coordinate with existing plans, and to changing development ordinances tools to be consistent with revised networks of plans. Future work will focus on all these stages.

Information generated by the scorecard will be used to inform the preparation of a new comprehensive plan starting in the year 2020. They will extend the city's prior experience that has been confined to strengthening resilience from the perspective of stand-alone efforts (e.g., hazard mitigation planning, resilience strategy and Vision 2100).

Norfolk planners learned from the scoring process that they need to place more emphasis on leveraging the uniquely central role that urban planning plays in local government policy making. They see that the information generated by the scorecard supports their key coordinating role in helping communities pose critical questions and devising holistic solutions to rising threats.

Norfolk planners believe that it is critical that the city continues to learn and share its experience with other communities. Planners identified the professional training and educational resources of the American Planning Association as a critical resource. They recommend that APA support educational opportunities for local practitioners that focus on proven best practices for integrating resilience into local planning practices. They also pointed out that the city continue participation in the Dutch Dialogues (WPA 2015) would be an important venue to continue learning and sharing experiences about how to live more naturally with water.

References

City of Norfolk. 2017a. *Norfolk Vision 2100*. https://www.norfolk.gov/DocumentCenter/View/27768/Vision-2100---FINAL?bidId=

City of Norfolk, 2017b. *plaNorfolk2030* Amendments to be Initiated by City Planning Commission: May 25, 2017.

City of Norfolk. 2018. *Norfolk Resilience Park* https://www.norfolk.gov/3867/Ohio-Creek-Watershed-Project

U.S. Army Corps of Engineers. 2018a. *Application of flood risk reduction standard for Sandy rebuilding projects: Sea-level Change Curve Calculator Using the Flood Risk Reduction Standard for Sandy Rebuilding Projects.* http://www.corpsclimate.us/ccaceslcurvesECB

U.S. Army Corps of Engineers. 2018b. *Climate Change Adaptation: Comprehensive Evaluation of Projects with Respect to Sea-level Change.* http://www.corpsclimate.us/ccaceslcurves.cfm

Work Program Architects (WPA). 2015. Dutch Dialogues VA; Life at Sea Level. https://wparch.com/dutch-dialogues-va-life-at-sea-level/

City of Nashua, New Hampshire

The Setting

Nashua is the second largest city in New Hampshire and home to over 85,000 residents in 2018. It is an inland city situated at the confluence of the Merrimack and Nashua Rivers, and located approximately 45 minutes north of Boston, Massachusetts. Nashua has a significant risk of riverine flooding with the most devastating effects of flooding seen during the 1936 and 1938 flood events causing parts of the city to flood nearly 17 feet. Nashua also experiences flooding from precipitation events that are increasingly overwhelmed due to expansion of impervious cover from urban development and under capacity of stormwater infrastructure. The city has recognized that climate-sensitive hazards linking to flooding poses a future significant threat (City of Nashua 2019a).

Nashua is committed to build community resilience into the City's operations as indicated by several pioneering resilience initiatives. Nashua signed on to the Mayors National Climate Action Agenda in 2017. The city is incorporating resilience and adaptation into multiple planning initiatives, including a Downtown Riverfront Development Plan, a Climate and Health Adaptation Plan, and a Hazard Mitigation Plan. Nashua hired its first Community Resilience Coordinator in 2017 to spearhead citywide resilience efforts, and is partnering with the National Institute of Standards and Technology (NIST) in its first attempt to develop a proactive resilience plan (NIST 2019).

Nashua recognized that more must be done to coordinate its impressive array of diverse resilience initiatives. Priority concerns raised by city staff and leaders from outside government (particularly vulnerable populations and business interests) center on inconsistent prioritization of climate change across city government departments, variable stakeholder engagement, a climate resilience and hazard mitigation portfolio that is more reactive than proactive, and urban planning and emergency management processes that are poorly coordinated (City of Nashua 2018a). The city's Office of Emergency Management (OEM) took up this challenge by leading the development of a successful grant from the National League of Cities in 2018 to support a plan review process that uses the *Plan Integration for Resilience Scorecard*™. Objectives of the process are to: identify inconsistencies and conflicts across plans; prioritize resilience through use of green infrastructure, and climate adaptation and disaster mitigation plan policies; and build community partnerships to improve representation and strengthen engagement (National League of Cities 2018).

Forming a Team and Building a Resilience Coalition

Application of the *Resilience Scorecard*™ was part of an ambitious citywide engagement program. A core team of plan evaluators worked in collaboration with an inclusive and diverse coalition of stakeholders called the Resilience Nashua Initiative (RNI). The core plan team included nine staff from municipal agencies (e.g., emergency management, urban planning, public health and community development) responsible for daily operations and planning that guide development and land use in hazard areas. Staff were selected from agencies that could make changes to land use regulations, building standards, and infrastructure investments that influence the safety of development. Justin Kates, Director of Office of Emergency Management, served as the main point of contact on the core team.

The RNI is a coalition of 40 representatives from multiple stakeholder groups, including utilities, businesses, conservation groups, and local government agencies. This coalition was formed with assistance from the National Institute of Science and Technology (NIST) that was supporting the city in risk-informed planning and decision-support for mitigating the impacts of natural hazards.

The broad aims of the RNI are to help the city lay the groundwork for long-term resilience to climate change and hazards by building a network of leaders that support resilience initiatives that extend beyond local government (City of Nashua 2018, p. 6). Justin Kates referred to the network as "ambassadors for resilience," who are looked to as both leaders and respected peers. By performing and endorsing behaviors that support resilience, the ambassadors are viewed as important role models to cultivate buy-in to the resilience agenda from across the city.

The core team of plan evaluators and the RNI undertook joint activities that were supported by Institute for Sustainable Communities at Texas A&M University throughout the plan evaluation process. As noted, this process involves co-developing a shared understanding between city staff, RNI stakeholders, and the university experts about the city's experience in applying the *Resilience Scorecard*™. City staff from the plan evaluation team and university team conducted a 2-day on-site training visit in February 2019, and monthly tele-conference meetings throughout the process (between January 2019 and September 2019) to respond to queries about application of the scorecard.

Selecting Plans

Core team members were ambitious in their desire to learn about the diverse perspectives of the future reflected by the broad range of planning activities in the city. Members decided to evaluate all plans at multiple levels of governance that could influence land use and development in hazard areas. They recognized that evaluating all plans would create a truly comprehensive and integrated data base that could inform critical policy decisions in revising plans and implementation actions at multiple levels, as well as to ensure compliance with federal requirements for hazard mitigation plans. Team members discovered dozens of plans adopted at the state, regional, county, municipal, and small area scales, as well as plans jointly adopted by local governments within the same region that could be influential. The City of Nashua alone had a diverse network of over 50 plans adopted over past 20-years including, for example, climate adaptation, public health, water resilience, flood hazard mitigation, street trees, transportation, economic development, and riverfront development.

Core team staff recognized that including all plans requires time and staff resources that extend beyond the team's capabilities. A decision was made to focus the scorecard on the local network of plans. By concentrating on local plans, team members believe they could more deeply learn about the complexities of planning in Nashua, as well as develop baseline data that could assist in better coordination of local plans and planning activities across local government agencies. The team applied a set of criteria for selecting local plans that were particularly influential on support for economic development, location of infrastructure that provides community facilities, public health, emerging threats from climate change, and focus on neighborhoods (City of

Nashua 2018a, pp. 6-10). Many plans were over a decade old and are no longer relevant and influential, but core team members believed that evaluation of such plans yields a deeper understanding of the history success and failures in planning and policy in dealing with social, economic and environmental issues in the city. Local plans that did not intersect with the hazard zones were not selected. Ultimately, 14 local plans were selected for analysis that operate at both citywide and small area scales (see Table 1). Staff acknowledge the importance of evaluating external plans to generate data needed to strengthen vertical consistency with state and regional plans, and horizontal consistency other local governments, but that the evaluation should be done in the future.

Table 1: Selected Nashua Plans

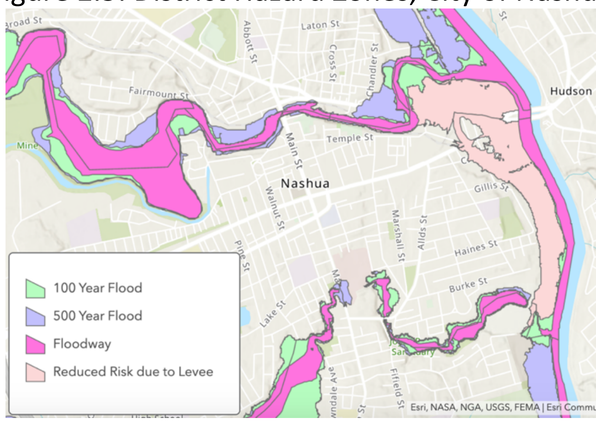
Nashua Master Plan (2000)
Consolidated Plan for CBDG and HOME (2015-2019)
Nashua Downtown Riverfront Development Plan (2017)
Beyond the Crossroads Positioning Nashua To Compete in the Global Economy (2005)
City of Nashua Hazard Mitigation Plan (2013)
Energy Plan for the City of Nashua (2011)
Exit 36 Study Area and Future Conditions (2014)
Nashua Economic Development Plan (2018)
Nashua Sanctuary Stewardship Plan (2003)
Nashua Tree Streets Neighborhood Analysis and Overview (2012)
Nashua Transit System Comprehensive Plan (2012-2025)
Complete Streets in Nashua (2016)
Small Area Plan: Nashua Downtown Master Plan (2003)
Small Area Plan: East Hollis Street Area Plan (2004)

Delineating District Hazard Zones

Nashua's approach to determining district hazard zones combined technical analysis with place-based narratives by residents. The first step in the technical analysis involved identifying geographic areas subject to current and future flooding. Four flood hazard zones were determined. The Nashua team decided to focus on the 100-year floodplain (1% occurrence probability per year) since it is used in formulating local hazard mitigation policy to administer and enforce NFIP (National Flood Insurance Program) land use and building standards. The team also prioritized climate change impacts on future flooding as future rainfall events are likely to be more severe relative to historical trends and that current flood hazard zones are likely to expand. The 500-year floodplain (0.2% occurrence probability per year) indicated on NFIP maps was used as a practical starting point to begin planning for future floods. By using the 500-year floodplains, the staff believed that this could serve as a projected expansion of current flood zones due to more extreme precipitation events linked to climate change and increased impervious cover from future urbanization of watersheds that traverse the city. Staff recognize that the 500-year flood does not account for specific changes in climate, but the intent is to begin to fill a gap in knowledge about current plan policies that influence population growth and development, and ultimately vulnerability of people and development in potential future hazard zones. Two additional flood hazard zones include the NFIP floodway and adjacent areas where all structures are restricted due high velocity flows, and reduced risk areas that are protected by levees.

The Nashua team then debated about the appropriateness of how to delineate district hazard zones. They chose to use the 43 U.S. Census Block Groups located entirely or partially in the hazard areas (see Figure 2.5). This small-scale unit of analysis would offer a fine-grained analysis of policy coordination across plans. GIS was then used to intersect the hazard zones with the block groups to define the district hazard zones.

Figure 2.5: District Hazard Zones, City of Nashua



Next, core team staff wanted to compliment the technical analysis used to determine district hazard zones with a place-based narrative of each zone. Place-based information on hazards can be particularly effective in building public awareness and action about hazards by shaping mitigation policy responsive to the needs and goals defined by local people. The narrative for each zone was created using crowdsourcing mapping technology that appears on the city's website, known as coURBANIZE. The coURBANIZE platform was utilized for the Resilient Nashua Initiative and proved useful in providing important information for the *Resilience Scorecard*™ plan review project (City of Nashua 2019b). A staff member on the core team observed that "This tool was innovative as it allowed community members who may not have been able to participate in public meetings to provide comments and input into all sectors of Nashua planning." The website enabled community residents to provide feedback on hazards they have experienced as well as community resources and facilities that are important to them. Figure 2.6 illustrates the riverfront area in downtown Nashua.

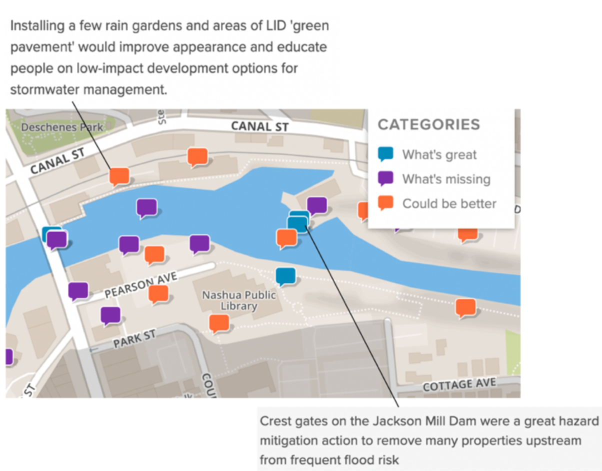


Figure 2.6. Downtown Nashua: Participatory Mapping using coURBANIZE and Comments
Source: City of Nashua (2019b)

Findings: Spatial Evaluation of the Network of Plans
The Nashua team spatially evaluated plans based on the 3-step procedure: extracting policies in plans; scoring each policy based on vulnerability outcomes; and spatially assigning and summing policy scores to district hazard zones. The Nashua team created composite index score for each district hazard zone in the city. Key findings revealed several strengths, gaps and inconsistencies in the city's network plans:

- A significant number of policies are included across all plans are aimed at reducing vulnerability, but many of these policies are reactive to addressing mitigation after a disaster event, rather than proactive policies aimed at reducing vulnerability before disaster events.
- The hazard mitigation plan primarily includes vague policies that lack spatial specificity in high vulnerability locations exposed to the 100-year and 500-year regulatory floodplains. Vulnerable areas include poor neighborhoods, historic districts, and areas with high potential for economic development.
- Multiple polices in the city's network of plans are inconsistent and in conflict. A notable example is the historic Millyard site located in the floodplain along the Nashua River. The Nashua Economic Development Plan includes land use and pubic investment policies that prioritize restoration and a high density, mixed use development project for this site. Yet, the mitigation plan includes specific policies aimed at strengthening building standards and limiting increased density on the most exposed parts of the site.

At the time of writing this report, GIS maps illustrating the distribution of policy scores had not been completed. Maps are to be completed and used as part of the fact base for preparing a new comprehensive plan during the year 2020.

Tracking Change: Building Capacity and Producing Outcomes
Application of the *Resilience Scorecard*™ produced multiple direct and indirect benefits. The plan review process supported local capacity building and outcomes to meet several of the city's highest resilience priorities, including: cross-departmental coordination on resilience; accessing and developing locally-relevant data to improve knowledge; and finding ways to plan for and design climate-resilient urban systems (see Figure 2.7).

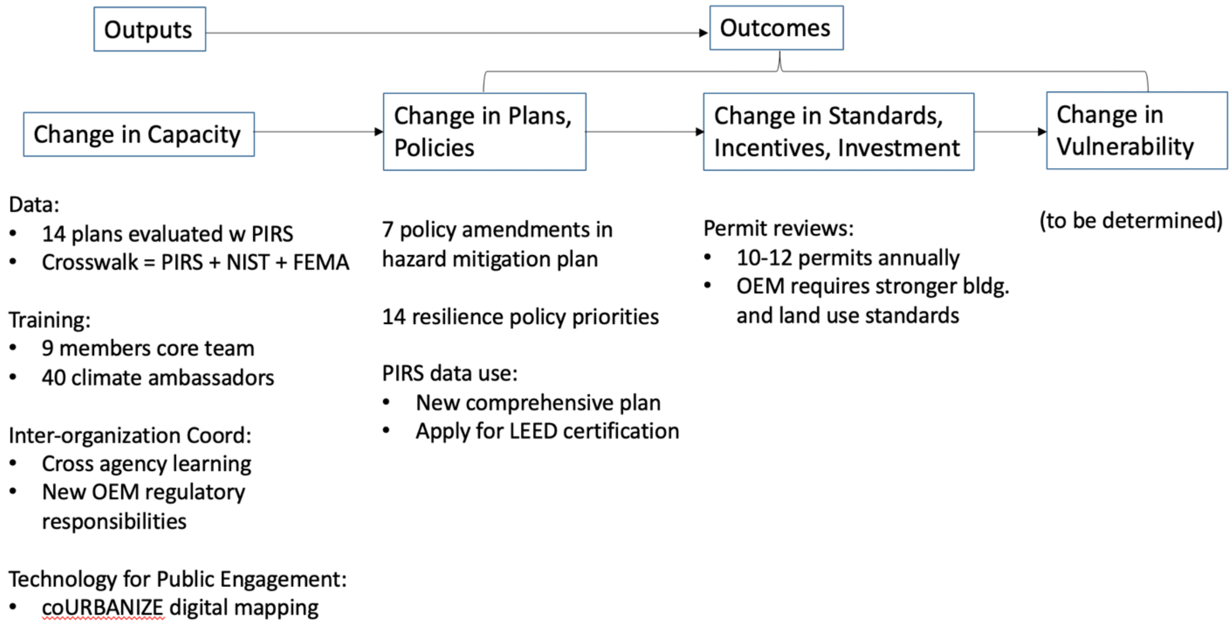


Figure 2.7: Changes Linked to the Scorecard Process in Nashua

Outputs: Building Change in Capacity
Learning about the depth and breadth of local planning initiatives is a critical output of the *Resilience Scorecard*^{TM} plan review process. As noted, the city has historically been active and committed to planning across a broad range of sectors from economic development and environmental conservation to climate adaptation and public health. However, these initiatives have frequently taken place in silos and have not been successful in institutionalizing resilience into city operations.

The scoring process enabled core team plan evaluators to learn about policies and plans of different agencies, and about the values and priorities of staff, as well as administrative rules and operations of diverse agencies. The general sentiment of learning is reflected by a comment by a team member, observing that "…using the scorecard was huge to help us understand what we had, what was out there." Another member noted that "The process required me to actually go through plans, understanding the history of planning…what exists and what doesn't." Working and learning together clearly increased capacity to identify congruencies, gaps and conflicts among the plans. As noted, information generated by the scorecard revealed a clear conflict between policies in the Nashua Economic Development Plan and policies in the Nashua Hazard Mitigation Plan focused on the riverfront Millyard district. This finding made it important to engage OEM and the Office of Economic Development throughout the process. As a result, consensus was reached between both agencies in revising policies for utilities and building codes in the local hazard mitigation plan to more explicitly focus on reducing vulnerability in Millyard (see Table A-1), and to give specific attention to vulnerability reduction in economic development initiatives in updating the new comprehensive plan during the year 2020.

Application of the *Resilience Scorecard*^{TM} generated a broader and more inclusive engagement effort beyond government. This included public engagement by residents in evaluating floodplain land uses and making suggestions for improvements through use of a participatory mapping technology, and leveraging 40 local leaders of interest groups to be the "ambassadors of resilience" based on resilience educational/visioning workshops. These initiatives helped the community to understand risks and lay the groundwork for strengthening support for long-term resilience to climate change and hazards.

Nashua strengthened its analytical and collaborative capacity for planning by developing a unique integration of multiple tools the city applied throughout the Nashua Resilient Initiative. Figure 2.8 illustrates a crosswalk developed by Justin Kates, Director of Nashua's OEM, that aligns tasks included in the *Resilience Scorecard*™ with resilience and mitigation planning tools and guidelines developed by federal agencies, including: the *FEMA Local Hazard Mitigation Planning Handbook* used by communities to guide preparation of local mitigation plans to meet 44 CFR 201 requirements; and the *NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems* that sets forth a multi-step process to assist communities in identifying critical structures and to set goals for maintaining essential services like education, food, shelter, and businesses.

By integrating these *Resilience Scorecard*™ with the planning tools, the crosswalk is an important contribution to creating a more comprehensive approach to community resilience planning than separately applying of each tool. Nahshua's approach takes advantage of the synergies among the tools, prevents confusion among planners and improves efficiency by minimizing duplication of tasks.

FEMA Local Mitigation Planning Handbook	NIST Community Resilience Planning Guide	TAMU Plan Integration for Resilience Scorecard Guidebook
Resources		Planning Districts
Task 2 - Build the Planning Team	Step 1 - Form a Collaborative Planning Team	Leadership and Forming Your Team
Task 3 - Create an Outreach Strategy		
Task 4 - Review Community Capabilities		Generate Lists of Policies, & Policy Task 3 - Validate and
Task 5 - Conduct a Risk Assessment	Determine Goals and Objectives	Combine Planning Districts and Hazard Zones to Form 'District-
Task 6 - Develop a Mitigation Strategy	4 - Plan Development	Change plans and development policy tools
Task 7 - Keep the Plan Current	Step 6 - Plan Implementation and Maintenance	
Task 8 - Review and Adopt the Plan	Step 5 - Plan Preparation, Review, and Approval	
Community	Step 6 - Plan Implementation and Maintenance	knowledge of planners and stakeholders

Figure 2.8: Crosswalk Resilient Nashua Inigtiative
Source: Kates (2019b)

Another positive output linked to the *Resilience Scorecard*™ plan review process is a stronger role for OEM in mitigation policy implementation. Prior to the process, OEM staff had limited, if any, input to permit reviews. Because the process fostered learning and greater interaction among core plan review team staff about diverse agency plans and priorities for the community, the lead local agency for permitting (Community Development) recognized the unique expertise of OEM related to resilience, and thus requested that OEM take a more direct role in the city's permit review committee. Greater involvement provides opportunities for OEM staff to scrutinize proposed developments to incorporate vulnerability reduction practices that are prioritized by OEM.

Outcomes: Changes in Plans and Regulations

Multiple positive outcomes were produced as a result Nashua's improved capacity to integrate resilience into the city's planning and implementation efforts. Core plan review team members consistently observed that the *Resilience Scorecard™* produced a more disciplined and spatially specific approach to improving plans. A member summed the general sentiment of team by stating that "the PIRS review helped us to more carefully think through the spatial impacts of policy scores across plans in different parts of the city. Prior attempts were aimless and undisciplined."

As noted, a notable example of the more focused approach is the update of the city's 2019 Hazard Mitigation Plan (City of Nashua 2019). The update exemplifies how the new information generated by the *Resilience Scorecard™* was used to revise vague policies that did not spatially target physically vulnerable and socially vulnerable locations. The revisions focused on district hazard zones that have negative policy scores and are highly vulnerable to floods -- Table A-1 in the appendix includes a complete list of the revised policies. Examples of revised policies include:

- voluntary land and property acquisition to remove structures in a flood-prone poor neighborhood near the downtown;
- green infrastructure investments to support stream restoration to ensure adequate drainage and diversion of stormwater in the downtown commercial areas; and
- proposed zoning amendments to limit or prevent new development on developable parcels adjacent to the Merrimack River (City of Nashua 2019, sec. 4.2, pp. 306-320).

The city will use information generated by the *Resilience Scorecard™* as integral part of the fact base for preparing a new master plan in the year 2020, and developing an application for LEED (Leadership in Energy and Environmental Design) certification. A major theme of the next master plan will be to build the city's resilience to hazards and climate change. To ensure that resilience will be a critical component of the master plan, the city included language requiring use of the information in a request for proposals by consultants to assist the city in preparing the plan. The request indicates that "the update of the hazard mitigation plan in 2019…and other community planning efforts [including the *Resilience Scorecard*™] are an essential resource to start building the new 2020 Master Plan" (City of Nashua 2019c, p. 6). In addition, Nashua is using the *Resilience Scorecard™* data base to be a LEED certified city. By receiving a LEED certification, a city receives international recognition for implementation of integrated planning for natural system resilience, energy, water, and other factors that contribute to quality of life. A key LEED credit category that aligns with the scorecard requires that cities develop "Integrative Processes" in the development of plans, development designs and sustainability strategies (LEED 2020).

Another outcome are the actual changes in permit review requirements, especially for proposed floodplain land use activities. As noted, OEM has a stronger role in providing input into development proposals during the permit review process. OEM staff estimated that compared to years prior to use of the scorecard, about 10 to 12 additional permits annually would be given more attention and scrutiny by OEM. We examined a recent set of permit reviews to identify examples of input by OEM (City of Nashua 2018b):

- require the design and upgrading of buildings to extend beyond basic damage reduction, but also to have the ability to maintain operations or quickly recover after disasters to reduce demands during recovery and speed the overall recovery process.
- point out that since Nashua participates in the Community Rating System (CRS), proposed developments are eligible for a CRS rating discount; and

- educate permit applicants by providing technical information on best practice examples of flood mitigation measures.

Next Steps

Justin Kates, Director or OEM, maintained that Nashua's future efforts to build resilience are threefold. First, future resilience planning initiatives must be integrated into a master (or comprehensive) planning effort, rather than be confined to stand-alone plans. Comprehensive planning offers a major opportunity to integrate information generated by the *Resilience Scorecard™* into policies and implementation practices across urban sectors. Prior experience in Nashua emphasized siloed, stand-alone plans has had limited implementation successes (City of Nashua 2019d). For example, OEM has historically been responsible for the completion of the hazard mitigation plan, but has limited authority and resources to carry forward the hazard mitigation and adaptation recommendations into implementation (City of Nashua 2019d). Thus, Kates believes that future resilience initiatives should be embedded into the comprehensive plan since this plan has the most legal standing and likely to generate the broader support relative to stand-alone planning.

Second, Nashua wants to improve monitoring plan performance in achieving resilience based on locally defined goals. Results from the *Resilience Scorecard™* require that emphasis should be placed on implementation and monitoring at the granular scale where integrated planning has considerable potential to impact neighborhood vulnerability. Change that is detected at the small scale is more directly felt by neighborhood residents compared to the conventional tracking of change at the citywide and regional scales.

Third, Nashua will strive to maintain engagement with national initiatives to share its experiences, and learn about readily available resources and proven best practices implemented elsewhere (City of Nashua 2018a). Participation in national conversations about local experiences like the Resilience Dialogues supported by the American Society of Adaptation Professionals, facilitates a local dialogue with subject matter experts external to the city in order to explore alternative ways to reduce vulnerability from climate change (Resilience Dialogues 2019). Nashua planners believe that the external review and feedback initiated by the Resilience Dialogues process can be extremely helpful to provide realistic alternatives to the city's resilience planning initiatives.

References

City of Nashua. 2018a. Resilience Dialogues - Synthesis Report, Nashua, New Hampshire.
https://drive.google.com/file/d/1tGs_U7s2d9jVi2mYja0mcvsrgrtww9us/view

City of Nashua. 2018b. Memo, Nashua Office of Emergency Management, October 10, 2018

City of Nashua. 2019a. *Hazard Mitigation Plan*.
https://docs.google.com/document/d/1E8uhIr8ECg4ZubiiHfFLkaJZ3vq_P5X584493mN-e5Q/edit

City of Nashua. 2019b. coURBANIZE website. https://courbanize.com/projects/nashua-riverfront/comaps/39

City of Nashua 2019c. Request for Qualifications: 2020 Master Plan Update. Document #RFQ0265-02140. Nashua Purchasing Department.

City of Nashua. 2019d. Resilient Nashua NAC Capacity Building Briefing. Office of Emergency Management, City of Nashua, NH.

Kates, Justin, 2019a. *Toward a Resilient Nashua, New Hampshire*. https://www.nist.gov/blogs/taking-measure/toward-resilient-nashua-new-hampshire

Kates, Justin. 2019b. Crosswalk of the Resilient Nashua Initiative, Office of Emergency Management, City of Nashua, NH.

Leadership in Energy and Environmental Design **(LEED). 2020.** https://www.usgbc.org/leed/rating-systems

National League of Cities. 2018. *Resilience in Nashua, New Hampshire*. https://www.nlc.org/resilience-in-nashua-nh

National Insititute of Scence and Technology (NIST). 2019. NIST Community Planning Guide Success Stories. www.resiliencedialogues.org/overview

Table A-1: Spatially Specific Policies in the 2019 Hazard Mitigation Plan Changed Based on Resilience Scorecard Plan Review

----

- *Infrastructure*. Improve drainage capacity of problem flood areas, particularly Wethersfield/Westwood, Shelly Drive and Browning Ave, Victor Ave at Emmett St, Westchester Dr, Wilmington Rd at New Searles Rd, Pemberton Rd at Belfast St, Park Ave/Lawndale Ave area, Courtland St/Hall Ave area; C, D, E Sts, Marshall St (Bowers to East Hollis), and Spaulding Ave., p. 308.
- *Land and Property Acquisition*. Remove structures from flood-prone areas to minimize future flood losses by acquiring and demolishing structures from voluntary property owners and preserving lands subject to repetitive flooding, particularly southern portions of 300 Main Street Marketplace, p. 312
- *Natural system protection*. Stream restoration to ensure adequate drainage and diversion of stormwater, particularly on Salmon Brook near Main Street. P. 312
- *Natural System Protection*. Prevent erosion with proper bank stabilization, sloping or grading techniques, planting vegetation on slopes, terracing hillsides, or installing riprap boulders or geotextile fabric, particularly on Nashua and Merrimack Rivers. P. 316.
- *Infrastructure*. Raise utilities or other mechanical devices above expected flood levels, particularly in areas likely to be redeveloped soon in the Millyard. P. 320.
- *Building code*. Wet floodproof basements residential and non-residential structures, which may be preferable to attempting to keep water out completely because it allows for controlled flooding to balance exterior and interior wall forces and discourages structural collapse, particularly in areas likely to be redeveloped soon in the Millyard, p. 320.
- *Zoning*. Identify best approach to prevent new development or to require flood-resilient site & building design in developable parcels adjacent to the Merrimack River, p.320.

City of Rockport, Texas

The Setting

The City of Rockport is the county seat of Aransas County and a notable tourist destination in the Texas Coastal Bend Region along the Gulf of Mexico. Residents and businesses are highly exposed to coastal storms as the majority of the city's geographic area (16.8 square-miles) is only seven feet above sea level, with 17% in 100-year floodplain and additional 10% in the extending from the 100-year to 500-year floodplain (Aransas County 2017). In August 25, 2017, Hurricane Harvey made landfall just to the south of the city as a Category 4 storm that inundated 45% of the city's land area. Rockport suffered major damage from wind and storm surge. Over 90% of homes experienced some level of damage and 30% of homes were destroyed entirely (City of Rockport 2020). The pre-Harvey population of 10,759 has declined by nearly 20% largely due to a displacement of low-income households. Affordable rental units sustained significant losses, but these units are less profitable to rebuild (City of Rockport 2020).

Community leaders were determined that rebuilding presented a "window of opportunity" that could transform the city to be safer, smarter, and more resilient. One local government official observed that recovery of the city was about "bouncing forward," rather than merely "bouncing back." Rockport initially engaged in the Aransas County Long-Term Recovery Plan to be eligible for federal recovery funds to start the arduous process on rebuilding of housing and the economy (Aransas County 2018). Soon after the disaster, the city invited a Recovery Planning Assistance Team (RPAT) from the American Planning Association to identify actions that can help the achieve the twin goals of an economically revitalized and disaster resilient downtown (RPAT 2020). Participation by Rockport in these activities forged a commitment to taking an integrated communitywide approach to recovery.

The next step was to incorporate the *Resilience Scorecard™* into the comprehensive planning and implementation process as a means to guide rebuilding and enhance resilience. Rockport planners considered the comprehensive plan to be the best vehicle to build in resilience across multiple sectors of planning for recovery. Among all types of local plans (e.g., climate change, hazard mitigation, transportation, housing), the comprehensive plan represents the principal form of local governmental planning and the primary planning policy instrument that coordinates land use and development across multiple urban sectors. Figure 3.1 illustrates the sequence of the planning process and role of *Resilience Scorecard™* used in Rockport.

Organizing a Core Team of Plan Evaluators for PIRS™

Application of the *Resilience Scorecard™* was guided by two key local agency staff who were associated with the comprehensive planning process. Amanda Torres, chief planner and certified floodplain manager, served as the main point of contact. Michael Donoho, Torres' supervisor, and Director of Building, Development and Public Works, was informed throughout the plan evaluation process and provided input in guiding development of the policy recommendations for the comprehensive plan.

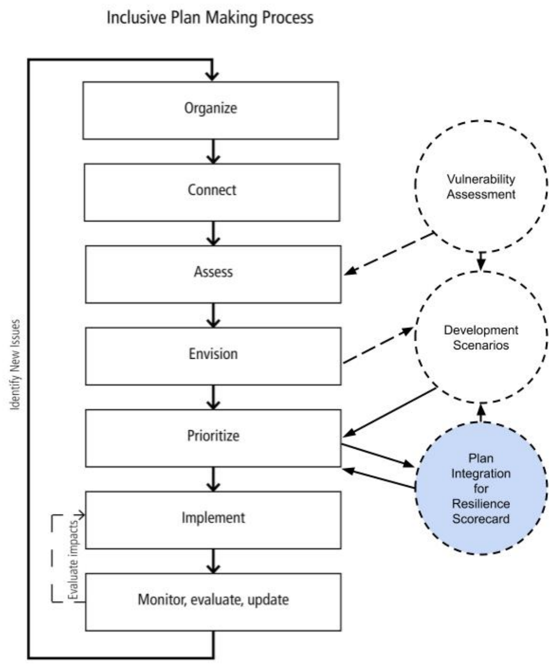


Figure 3.1: Expanding the Inclusive Plan-Making Model for New Plans (Masterson et al 2014)*

* The *Resilience Scorecard™* can be used in the development of new plans. As communities begin prioritizing goals, objectives, actions, and policies, the *Resilience Scorecard™* can be used to understand the range of policies across the network of plans, identifying opportunities to fold other plan's policies into the new plan, and pinpoint additional policy opportunities to be embedded into the new plan.

Because Rockport 's government has limited capacity and the city had to direct attention to the massive recovery effort, the staff needed significant technical assistance throughout the scorecard process. To facilitate application of the scorecard, Rockport requested and received additional funding from a local non-profit organization, The Harte Research Institute for Gulf of Mexico Studies. The additional support was used to employ a part-time planning expert from the Texas Sea Grant Program to lead in the evaluation of the network of plans. Torres participated on regular tele-conference meetings with the Texas Sea Grant planner and university experts between January 2019 and September 2019 to be informed about results generated by the scorecard and to seek advice on improving policy coordination of other plans with the comprehensive plan.

Selection of Plans

Rockport's team considered four plans and a zoning ordinance to be crucial in guiding land use and development decisions during the aftermath of Harvey (see table 3.1). A small area master plan and a zoning overlay code focused on restoration and preservation the city's historic downtown area. The county hazard mitigation plan emphasized mitigation practices funded by FEMA in the event of a federal disaster declaration, and the floodplain management plan prioritized improving policies to increase credits received under the National Flood Insurance Program's Community Rating System for household flood reduction premiums. The floodplain management plan was adopted a few months before the Hurricane Harvey disaster. Finally, the city participated in the development of the county long-term recovery plan that had an important role in guiding rebuilding after Hurricane Harvey by enabling the city (and county) to be eligible for federal and state disaster recovery funds. As the comprehensive plan development process entered its final stage, an additional evaluation was conducted on the draft version of the plan using the *Resilience Scorecard*™. The evaluation focused on how well the plan policies are coordinated with the selected plans and overlay zoning code.

Table 3.1: Selected Rockport Plans

A Vision for Rockport: A Master Plan for the Heritage District and Downtown Rockport (2006)
Rockport Heritage District Zoning Overlay Code (2014)
Aransas County Long Term Recovery Plan and Report (2018)
Aransas County Multi-Jurisdictional Hazard Mitigation Action Plan (2017)
Aransas County Multi-Jurisdictional Floodplain Management Plan (2017)

Delineating District Hazard Zones

The Harvey inundation area was used as the primary hazard zone for scoring plans. This area incurred widespread damages, and resonated emotionally with residents. Local residents thought of this devastated area as a worst-case future scenario that should be prioritized in the preparation of the comprehensive plan. The 100-year (1% annual chance) and 500-year floodplain (0.2% annual chance) also served as the hazard zones in formulating mitigation policy since these zones should be plan policies should be consistent with land use and building standards of the National Flood Insurance Program. But the NFIP boundaries were considered too abstract to serve as the primary basis for guiding planning and application of the scorecard.

Rockport decided to use Census block groups as the preferred planning district since the city did not formally delimit neighborhoods. The city's extra-territorial jurisdiction (ETJ) was included in the study area, given recent annexations and the potential for more in the near future (certainly within the 20-year time horizon of the comprehensive plan). District hazard zones were delineated by intersecting the hazard zones with 17 Census block groups that cover zones in the city and the ETJ.

Spatially Evaluating the Network of Plans

The scores generated by the *Resilience Scorecard*™ reveal several strengths, gaps and inconsistencies in Rockport's network of plans. Figure 3.2 illustrates the spatial distribution of composite plan policy scores by district hazard zone.

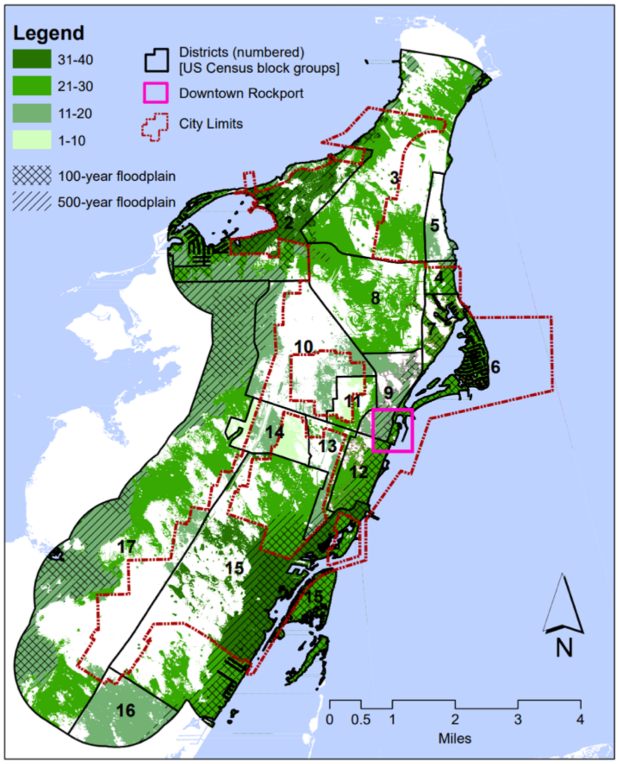


Figure 3.2: Composite Plan Policy Scores for All Plans by District Hazard Zone*
*Shaded areas outside of 100-year and 500-year floodplain indicate inundation by Hurricane Harvey

The analysis revealed several key findings. First, all district-hazard zones received positive composite scores, indicating that Rockport's network of plans support vulnerability reduction in three hazard zones (100-year, 500-year, Harvey inundation). As expected, the plans that specifically focus on mitigation -- hazard mitigation plan and floodplain management plan -- consistently received highest scores among all plans. The Master Plan for the Heritage District and Downtown Rockport had the lowest scores as the priority is to preserve historic structures, as well as support tourism and economic development.

Second, Districts 2 and 15 received the highest positive policy scores (see darkest green shades on Figure 3.2). Environmental protection policies received strong support as significant critical wildlife habitats and wetlands are present in both districts. District 2 is targeted by policies that support floodproofing of residential properties, acquisition of wetland areas, residential buyouts, and investment in stormwater drainage infrastructure. District 15 is targeted by policies aimed at reducing coastal erosion to preserve wildlife habitats, and bulkheads structures to protect economic assets of a marina.

Third, District 14 received the lowest policy scores. It is located inland of the downtown and was inundated by Hurricane Harvey. It does not contain 100-year and 500-year flood zones under the National Flood Insurance Program and is primarily a low-density development. As a result, it is subject to limited mitigation policy attention aimed at maintaining or improving drainage infrastructure for runoff generated by rainfall events, and city- and countywide policies for acquiring parklands and environmentally sensitive areas. Examples of policies that support increasing vulnerability include moderate density single family residential development and mixed-use development.

Fourth, hazard zones in District 9 that overlaps or is adjacent to the downtown has several conflicting policies from different plans. The district received the second lowest category of scores (see areas outlined in pink color on Figure 3.2). Examples of policies that increase vulnerability include:

- "Develop waterfront property along Water Street for condominium units, ground floor retail and restaurants..." in Master Plan for the Heritage District and Downtown Rockport (City of Rockport 2006, p. 3-9).
- "Secure funding for Heritage District & Downtown utility improvements, housing and economic development [to] help create a 'Developer-Ready' zone" in Aransas County Long Term Recovery Plan (Aransas County 2018, p. 49).

In contrast, examples of policies in the floodplain management plan that reduce vulnerability in the same location include:

- "Review and update zoning regulations to reduce population density in areas [including downtown] vulnerable to hazards" in Aransas County Multi-Jurisdictional Hazard Mitigation Action Plan (Aransas County 2017, p. 17-44)
- "Investigate grant opportunities for property buyouts, open space preservation, or other flood mitigation measures" in Aransas County Multi-Jurisdictional Floodplain Management Plan (Aransas County 2017, p. 65)

Tracking Change in Local Capacity and Outcomes

We tracked changes in Rockport's capacity (outputs) to support resilience planning, and the integration of resilience into the formation of the new comprehensive plan (outcomes) in the City of Rockport as a result of the scorecard application process. At the time of writing this report, plan implementation actions by the city were put on hold due to the coronavirus pandemic. Figure 3.3 illustrates the changes in capacity and outcomes influenced by the *Resilience Scorecard*™ plan evaluation process as of April 2020.

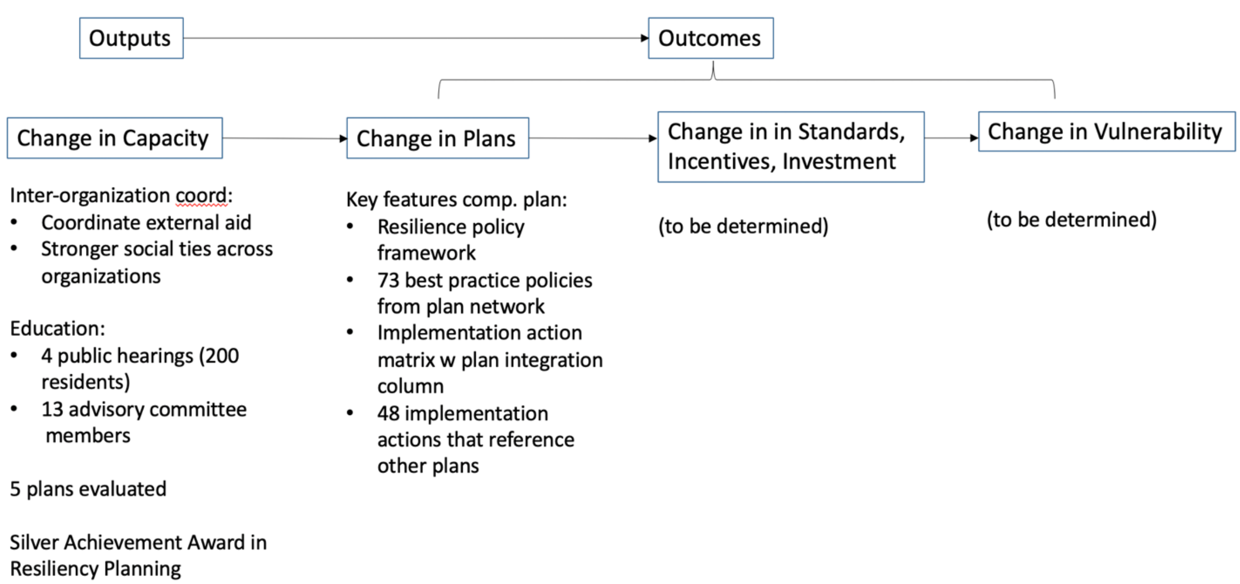


Figure 3.3: Outputs and Outcomes

Outputs: Change in Capacity
According to Torres, the *Resilience Scorecard*^{TM} served as a "filter to see how all the individual plans aligned" and enabled the city to "internalize resilience" across multiple sectors of disaster recovery. Similar to many local disaster recovery experiences (Olshansky and Johnson 2010), Rockport had to meet sometimes narrowly conceived requirements to qualify for different federal and state assistance programs ranging from affordable housing and public infrastructure restoration to property buyouts and structural flood protection works. The new information generated by the scorecard helped the city confront the dual demands of meeting local needs, as well as comply requirements for external disaster recovery funding. The city's commitment to resilience planning and recovery efforts was recognized by receiving a Silver Achievement Award in Resiliency Planning from the Texas Chapter of the American Planning Association in November 2019.

Although city staff did not directly evaluate local plans, the staff closely tracked the scorecard process throughout the comprehensive planning process. Results produced by the scorecard were disseminated through a range of plan making activities. Over 200 residents attended four public meetings associated with the new plan, and a 13-member advisory committee consisting of 9 residents that represent different stakeholder groups and 4 local government staff were regularly informed about purpose of the scorecard and gave feedback to findings.

Torres observed that the scorecard results increased the capacity of local officials to foster the development of an overarching policy framework that integrated resilience across all chapters (development, environment, housing, transportation, economy, facilities) of the new comprehensive plan. She maintained that the integrated policy framework serves to educate elected officials, agency staff, interest groups, and the general public about how diverse sectors of the community (tourism, heritage, hazard mitigation, environment) can work together to foster resilience. It also serves to guide city staff and elected officials in day-to-day decision-making by helping them stay on track toward achieving the long-range vision of resilience articulated in the plan.

The scorecard produced information that enabled staff to address two critical sets of issues. One set focused identifying best practice policies in the existing local network of plans that should be part of the policy framework of the new comprehensive plan. The other set focused on identifying specific policies and resources devoted to implementation of city's network of plans that could be leveraged in the implementation phase of the comprehensive plan. The county mitigation plan and county long-term recovery plan were prepared so that Rockport and Aransas County are eligible for federal recovery funds that flow through these plans. It was critical that the comprehensive plan policies and implementation actions be coordinated with the mitigation and recovery plans to achieve shared communitywide goals and priorities.

The connection to the county hazard mitigation plan and long-term recovery plan was important to the City in terms of motivating commitment to carry out comprehensive plan. One resident, after reading through the comprehensive plan said, "I was involved with the Long-term Recovery

Plan and I see it discussed here. Everything we worked on in that is not lost and is built on." Another active participant on the recovery plan representing the county government noted that "after the countless hours we put in…I am thankful to see that our work matters."

Outcomes: Innovations Integrated into the Comprehensive Plan

Several innovate measures within the comprehensive plan are included that demonstrate the benefits of the *Resilience Scorecard*^{TM}. A key measure involved integration of 73 policies into the comprehensive plan that were drawn from best practice policies included the local network of plans. The comprehensive plan document includes graphic illustrations using both icons to visually communicate and textboxes to describe how each policy coordinated with best practice policies from other plans. For example, Figure 3.4 illustrates a comprehensive plan policy drawn from the county multi-jurisdiction hazard mitigation plan (MHMP) that supports conservation easements and mitigation banking to protect wetlands that provide flood mitigation functions.

DISASTER PREPARATION AND COMMUNITY PROTECTION

Water retention methods need to be supported and managed throughout the city. The planning team recommends that Rockport amends the code of ordinances to include a land use tool, Transfer of Development Rights (TDR), to ensure wetlands ability to function and retain water. Sending areas should be established and outlined in the conservation management plan in places that have been identified as environmentally sensitive areas, critical habitats and wetlands providing flood mitigation functions. The lands need to be managed and protected properly so that the environmentally sensitive areas are preserved. The city needs to utilize tools such as a conservation easement or mitigation banking program so that conservation goals are achieved.

Directly coordinate with the Aransas County Navigation District to come up with strategies to strengthen the coastal shoreline to protect Rockport's residents and infrastructure from powerful storm surge. Coastal erosion can be mitigated through the construction of an artificial reef and marsh vegetation plantings; both will provide protection, filtration services and stabilization. Strengthening the coastal shoreline will protect Rockport's residents and infrastructure from powerful storm surge.

The Fulton Beach Road Project is a good model for future shoreline stabilization projects in Rockport. The city should continue striving to protect their shores by reaching out to nonprofits and advocacy groups for voluntary aid to help construct the artificial reef. Another example to use in the design and implementation of the erosion protection projects is the project along Shell Ridge Road, which is being funded by FEMA 404 mitigation dollars. The city should continue reaching out to nonprofits and advocacy groups for voluntary aid. Funding for construction and implementation can come from sources such as the FEMA Hazard Mitigation Grant, the Housing and Urban Development Community Development Block Grant Program for Disaster Recovery, and RESTORE Act Buckets. Regular community meetings conducted by local emergency managers and mitigation experts need to be held regularly to cover disaster preparedness and recovery efforts. The city's media methods and other marketing tools should be utilized and enhanced to promote educational meetings, seminars, tool sets etc. and encourage citizen engagement and outreach.

WETLAND MITIGATION

Wetland Mitigation is the practice of offsetting unavoidable impacts to aquatic resources at one site by restoring and/or enhancing wetlands on another site in the same or adjacent watershed.[35] The Wetland Mitigation Banking Program came out of the 2014 Farm Bill and can be a great strategy for conserving essential habitat. This approach uses a market-based system to restore/enhance wetlands in one place to compensate for unavoidable impacts to wetlands in another place. The process requires the replacement of all lost wetland functions, values and acres. Wetland Banking has been used in Georgia, Illinois, Iowa, Michigan, Missouri, Minnesota, Nebraska, North & South Dakota and Ohio.[36]

PLAN INTEGRATION

MHMP

MITIGATION

Evaluate best mitigation solution (i.e. buyouts, reconstruction) for repetitive loss properties. Evaluate list of repetitive loss properties for opportunities to partner with property owners regarding potential mitigation actions.

WETLAND MITIGATION

Wetland Mitigation is the practice of offsetting unavoidable impacts to aquatic resources at one site by restoring and/or enhancing wetlands on another site in the same or adjacent watershed.[35] The Wetland Mitigation Banking Program came out of the 2014 Farm Bill and can be a great strategy for conserving essential habitat. This approach uses a market-based system to restore/enhance wetlands in one place to compensate for unavoidable impacts to wetlands in another place. The process requires the replacement of all lost wetland functions, values and acres. Wetland Banking has been used in Georgia, Illinois, Iowa, Michigan, Missouri, Minnesota, Nebraska, North & South Dakota and Ohio.[36]

MHMP

PLAN INTEGRATION

MITIGATION

Evaluate best mitigation solution (i.e. buyouts, reconstruction) for repetitive loss properties. Evaluate list of repetitive loss properties for opportunities to partner with property owners regarding potential mitigation actions.

Figure 3.4: A page in the in the Rockport Comprehensive Plan illustrating a textbox of a Best Practice Wetland Mitigation Policy from the Aransas County Multi-jurisdiction Hazard Mitigation Plan (MHMP) (City of Rockport 2020, p. 125).

The practice of integrating policies from the network of plans into the comprehensive plan validates the work devoted the city's recovery. One resident described the importance of having a plan that encompasses the entire city. While there had been two city-wide comprehensive plans and a downtown plan in the past, the new one "includes more factors" that were identified by the entire community, which helped to expand the scope of the project as compared to the original plan. Several residents noted that it was a benefit to have a replacement plan for the one developed years earlier and were pleased that the new plan is "well-integrated" and offers balance solutions because of PIRS™.

Information generated by the scorecard fostered development of balanced solutions that meet multiple stakeholder values. Policies from the local network of plans were integrated into the comprehensive plan to simultaneously preserve the cultural heritage, promote equity and economic vitality, restore environmental systems, and enhance flood mitigation of the historic downtown. For example, policies from two plans integrated into the comprehensive plan attempt to achieve such balance. First, the Recovery Planning Assistance Team's plan calls for establishing a downtown tax incremental finance district to generate revenue to retrofit stormwater drainage to protect historic structures from flooding, and to invest in infrastructure improvements that support new development and attract tourists. It also includes a policy to use of FEMA post-disaster mitigation funds to create a living shoreline along the downtown waterfront to limit shoreline erosion and to improve amenities that bolster the tourist economy. Second, the County Long-term Recovery Plan includes policies to implement inclusionary zoning and financial incentives in the downtown district for developers to build affordable housing and to expand a market for businesses.

Consistent with recommendations for creating high quality implementation elements of comprehensive plans (Godschalk and Rouse 2015), the implementation chapter in the Rockport comprehensive plan specifies objectives, actions, and the timeline, organizational responsibility, and funding necessary for carrying out each action to achieve each objective. An implementation action matrix was created to display this information. A key feature in the matrix is "plan integration" column that includes references to other plans in the network associated with a given action. Information generated by the *Resilience Scorecard*™ was used to create the column that includes 48 references to other plans. Figure 3.5 shows an example of how actions aimed at expanding affordable housing after Hurricane Harvey are complimented by the long-term recovery plan (LTRP). By including the "plan integration" column, local officials are informed about resources and commitments from organizations in other planning domains that can be leveraged to improve prospects for successful implementation of the comprehensive plan. In so doing, the implementation matrix is designed to reinforce the overall theme of promoting policy alignment across the local network of plans. The implementation matrix is also used by city staff and city council to monitor progress. By including this column, it reminds staff and officials the consensus and greater impact of the policy ensuring future implementation.

Housing

Objectives	Action	Notes (Plan Integration)	Timeframe: On-Going	Timeframe: Short-Term	Timeframe: Mid-Term	Timeframe: Long-Term	Action Type: Capital Project	Action Type: Program	Action Type: Regulation or Standard	Action Type: Partnership or Collaboration	Action Type: More Targeted Planning	Action Leaders	Other Partners	Funding
Objective 4.1.2. Expand housing opportunities for low- and middle-income households	Action 4.1.2.2 Implement inclusionary zoning or financial incentives for developers to build affordable housing (affordable units can be a percentage of their overall development or a separate development) (except in SFHA)	LTRP		X					X			CS	Can the city work with the county to provide the same incentives in the ETJ?	Community Development Block Grant (CDBG), Capacity Building for Community Development and Affordable Housing Grants
	Action 4.1.2.3 Implement mixed use zoning in redevelopment areas, specifically downtown and "South Rockport," to provide greater accessibility to community facilities and amenities.					X								Choice Neighborhoods Planning Grants, Community Development Block Grant (CDBG)
	Action 4.1.2.4 Continue to apply for and prioritize state and federal funding for repairs, rebuilds, and maintenance to workforce and low income housing. Coordinate with the Aransas County Long Term Recovery Plan	LTRP										CS, ACLTRT	TDHCA, GLO, HUD, USDA	Housing Preservation & Revitalization Demonstration Loans & Grants, Community Development Block Grant (CDBG), Single Family Home Repairs (Section 504), Low-Income Housing Tax Credit (LIHTC),

Figure 3.5: Implementation Action Matrix and a Plan Integration Column

Next Steps

Amanda Torres observed that future efforts are aimed at implementing the comprehensive plan to build a stronger, more resilient Rockport. First, an immediate next step will involve development of a work plan to carry out the actions identified in the implement action matrix. Most actions will involve coordinating disaster recovery efforts across different sectors.

Second, the city's planning staff will be developing a parks and recreation plan consistent with the policy framework outlined in the comprehensive plan. This will involve identification of open space locations in floodplain hazard areas that are privately owned and likely to be developed. The locations most also be accessible to residents for recreational activities. The aim of the new park plan will be to guide use of parking funding in the most critical areas most exposed to coastal storm floods and sea level rise and increase community amenities.

Third, the city will initiate a project with the Nature Conservancy that ties parks and recreation planning with conservation and flood insurance. The Nature Conservancy has developed tools to help communities link conservation and restoration with the National Flood Insurance Program's Community Rating System. The aim is to create projects that generate CRS credits that reduce household flood insurance premiums, protect natural environment, and reduce risk to coastal storm floods and sea level rise.

References

Aransas County. 2017. Aransas County Multi-jurisdictional Floodplain Management Plan. Rockport, Texas https://www.cityofrockport.com/ArchiveCenter/ViewFile/Item/1441

Aransas County.2017. Aransas County Multi-Jurisdictional Hazard Mitigation Action Plan. Rockport, Texas https://www.aransascounty.org/harvey/uncategorized/public-service-announcement-aransas-county-multi-jurisdictional-hazard-mitigation-action-plan-proposed-annexation-of-the-aransas-county-navigation-district/

Aransas County. 2018. Aransas County Long Term Recovery Plan and Report. Rockport, Texas https://www.aransascounty.org/harvey/long-term-recovery-plan-elements/

City of Rockport. 2006. A Vision for Rockport: A Master Plan for the Heritage District and Downtown Rockport. Rockport, Texas.

City of Rockport. 2014. Rockport Heritage District Overlay Code. Rockport, Texas https://cityofrockport.com/DocumentCenter/View/13179/Rockport-Heritage-District-Overlay-code-final-?bidId=

City of Rockport. 2020. Rockport Strong: City of Rockport Comprehensive Plan 2020-2040. Rockport, Texas. https://cityofrockport.com/ArchiveCenter/ViewFile/Item/2916

Godschalk, David and David Rouse. 2015. *Sustaining places: Best practices for comprehensive* plans. APA Planning Advisory Service 578. Chicago, IL: American Planning Association.

Masterson, J., Peacock, W., Van Zandt, S., Grover, H., Schwarz, L., & Cooper, J. 2015. *Planning for community resilience: A handbook for reducing vulnerability to disasters*. Washington, DC: Island Press.

Olshansky, Robert and Laurie Johnson. 2010. *Clear as mud: Planning for the rebuilding of New Orleans*. Chicago: American Planning Association Planner's Press.

Recovery Planning Assistance Team (RPAT). 2020. Downtown Rockport: Strength, Vitality, and Resilience. American Planning Association. Chicago: 82 pp. https://cityofrockport.com/ArchiveCenter/ViewFile/Item/2907

DHS Coastal Resilience Center

Annual Project Performance Report

Project Title: Modeling the combined coastal and inland hazards from high-impact hypothetical hurricanes

Covers reporting period July 1, 2019 – June 30, 2020

Appendix

In this Appendix we provide some details of the project main accomplishments during this time period.

1. Modification of the ADCIRC mesh in coastal New England

During year 5, major progress was made in the modification and refinement of the ADCIRC mesh in New England to enable the simulation of river runoff induced flooding. As mentioned in the year 4 report, we were concerned that tides were not adequately simulated in the southwestern Gulf of Maine region (Boston in particular). We suspected that this could be due in part to deficiencies in the mesh in the larger region (beyond the southern New England region that is the focus of this project). For this reason, we collaborated with CRC colleague Casey Dietrich (NC State) to combine our high-resolution southern New England mesh with the existing NOAA Hurricane Surge On-demand Forecast System (HSOFS) mesh that covers roughly the same area as did the base mesh used to create our prior mesh. This new mesh provides better tidal simulations and preserves the high-resolution mesh that we have developed over the past several years.

The combined mesh was subsequently modified to include the lower portions of nine New England Rivers (Figure 1.1). In the Boston Harbor area these are the Mystic, Charles, and Neponset Rivers (Figure 1.2). For Narragansett Bay tributaries, the Taunton (MA) (Figure 1.3), Blackstone, Moshassuck, Woonasquatucket, and Pawtuxet Rivers (Figure 1.4) are included. In Connecticut, the modified mesh includes the Connecticut River (Figure 1.5). The river inflow locations are located at the upland boundary of the ADCIRC mesh, which is placed in the lower, tidally influenced reaches of the rivers. River discharge for specific tropical and extratropical storms was supplied by our colleague W. Huang using the PRMS model.

1.1 Testing of the modified ADCIRC mesh with river inflows

<u>Hurricane Diane (1955)</u>

The mesh was tested using river discharges for each of the configured rivers simulated for hurricane Diane (1955) from estimates of rainfall (see Section 4). The Connecticut River experienced significant flooding during Diane in the Hartford area (Kutschenreuter, 1956). As shown in Figure 1.6, the model simulated water surface elevation is in reasonable agreement with estimates of river stage presented in the Kutschenreuter (1956) report (note that the observed elevation was visually estimated from the stage plot in that publication with times assumed to have been in eastern daylight time). A sample map of the model simulated inundation in the Hartford region during hurricane Diane (Figure 1.7) shows the high level of spatial detail available in the model results.

Hurricane Sandy (2012)

Another test of the modified mesh was performed for hurricane Sandy (2012) with both meteorological (wind and sea level pressure) and river forcing. The meteorological fields were obtained from the ECMWF operational forecast archive (0.125 degree spatial resolution) and the river forcing was derived from historical data from USGS river gauging stations. ADCIRC simulations were performed with both meteorological and river forcing as well as with meteorological forcing only in order to quantify the effect of river inflow on the total water level in the river regions.

Model simulations of water surface elevation during Sandy generally under-predict the storm surge. For example, Figure 1.8, showing model and observed water level at Newport, RI, indicates that the peak model water level is about 0.75 m below the observed peak level. A portion of this difference appears to be due to an initial elevation offset, possibly resulting from wind-driven sea level setup prior to the start of the wind-forced simulation (10/27/2012). However, as Figure 1.9 shows, the ECMWF winds appear somewhat weaker than observed winds in Narragansett Bay and the peak in the ECMWF winds occurs slightly early in comparison to the observations. This suggests that some of the model-observation difference results from deficiencies in the wind forcing used, although with a relatively new model mesh, the impact of model parameter choices (e.g. bottom friction coefficient) cannot be ruled out. Further testing, including variation in the magnitude of the Mannings-n friction parameter, is underway at present to test this.

Overall, except for within the Connecticut River, the effects of river inflows during Sandy on total water levels were relatively minor in the areas we examined. Partly this was due to the fact that discharges in most of the rivers did not increase greatly during this storm (Table 1.1). The exception to this occurred in the smaller rivers (Mystic and Moshassuck) where discharges during Sandy were of the order of 10 times the median flows. However, even at high stages, the discharge of these rivers is still small compared to tidal and wind-driven surge transports so that the effect on water levels in the areas influenced by tides is small. To show the effects of river forcing, Figure 1.10 shows the ADCIRC water surface elevation just downstream of the Blackstone River inflow (See Figure 1.4 for the location of the Blackstone) for a model run with wind only and with wind and river forcing. The effects of the river (the difference between these two curves) are seen only in an increase in the low tide water level of 0.25-0.5 m, with the high tide (maximum surge) water levels unchanged.

Table 1.1. Comparison of maximum discharge during Sandy to long-term median discharge for the rivers configured for ADCIRC.

River	Long term median Q	Sandy Max. Q (m^3/s)	Ratio

	(m³/s)		
Mystic	0.57	5.0	8.8
Charles	7.65	10.7	1.4
Neponset	3.65	7.8	2.1
Taunton	11.2	18.8	1.7
Blackstone	17.3	52.7	3.0
Moshassuck	0.76	9.46	12.4
Woonasquatucket	1.59	4.0	2.5
Pawtuxet	7.25	17	2.3
Connecticut	464	455	0.98

The largest river, the Connecticut, did not exhibit a discharge increase during the Sandy period we simulated (10/27/2012 00:00 to 10/31/2012 00:00 UTC). The discharge of the Connecticut, a river with a very large drainage area, peaked several days later. However, because its discharge is so large (median discharge 27 times that of the next largest river we simulated, the Blackstone), the effects of the river are clearly visible (Figure 1.11). Inclusion of river discharge (red curve in Figure 1.11) results in approximately 1 m of additional water elevation above the wind-only simulation (green curve in Figure 1.11). Interestingly, the inclusion of river discharge appears to reduce the effect of the wind-driven surge (compare the increase around 10/30 in the red and green curves in Figure 1.11). As was seen at a non river-influenced location (Newport, RI), the observed water level peak at Hartford is under-predicted by approximately 0.5 m.

Hurricane Ram Simulations

With the new mesh enabling river inflows, a number of simulations of the hypothetical storm Ram (see Section 3) have been performed that focus on the effects of the Fox Point Hurricane Barrier (FPHB) on flooding in the Providence area. In these simulations, the FPHB is closed at a specific time during the period prior to the storm's landfall. Because the ADCIRC model does not have the capability to simulate the effect of the pumps in the FPHB, these simulations implicitly assume that during a high-impact storm the regional power grid is down. In this case, as might be expected, the region north of the FPHB rapidly floods as a result of the high discharge of the two rivers entering the model domain north of the FPHB (Moshassuck and Woonasquatucket Rivers).

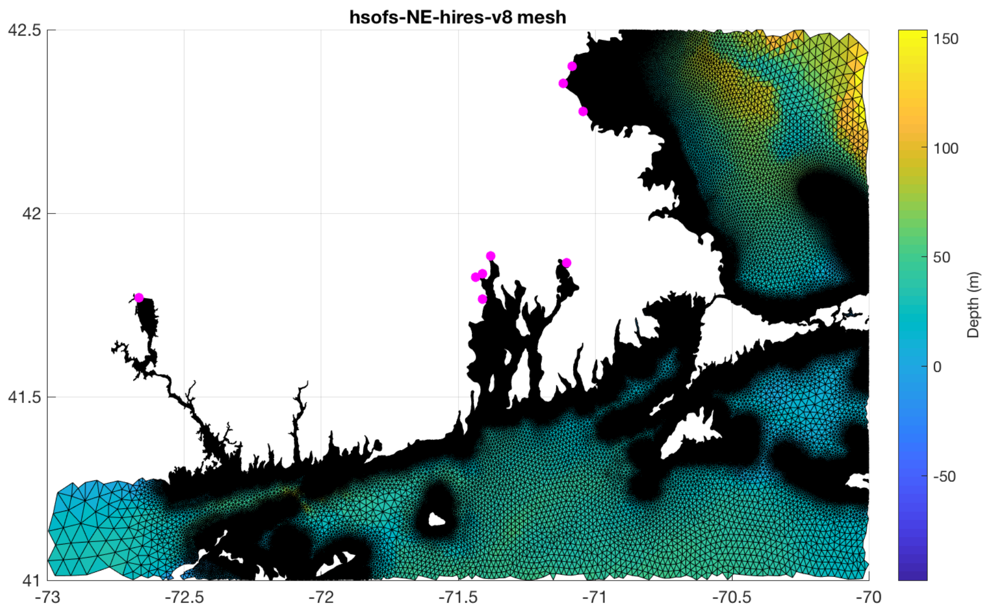


Figure 1.1. Revised ADCIRC mesh in the southern New England region showing the locations (magenta circles) where river transport is prescribed in order to simulate the effects of riverine flooding. The included rivers are the Mystic, Charles, and Neponset in the Boston area, the Taunton in Massachusetts, the Blackstone, Moshassuck, Woonasquatucket, and Pawtuxet in Rhode Island, and the Connecticut in eastern Connecticut.

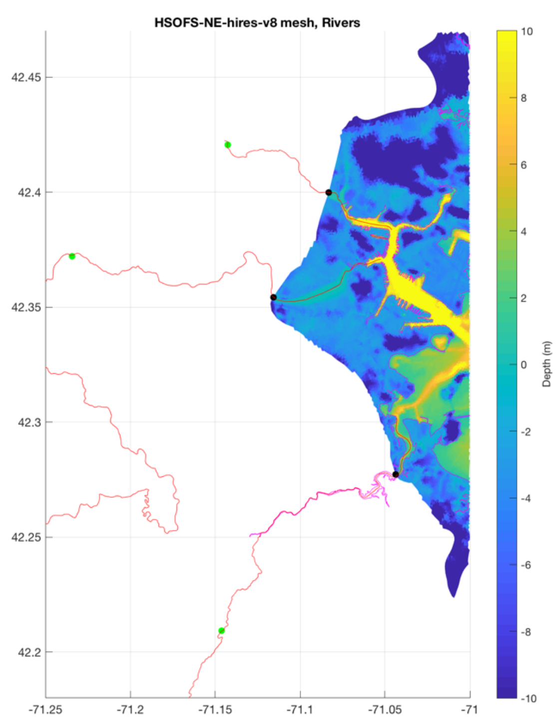


Figure 1.2. ADCIRC mesh in the Boston region showing the three area rivers that are configured in the mesh. The colored area is the ADCIRC mesh domain and the red lines denote the river courses (from north to south: Mystic, Charles, and Neponset Rivers). The green dots indicate the locations of the farthest downstream gauging stations. The black dots show the location of the model river inflows.

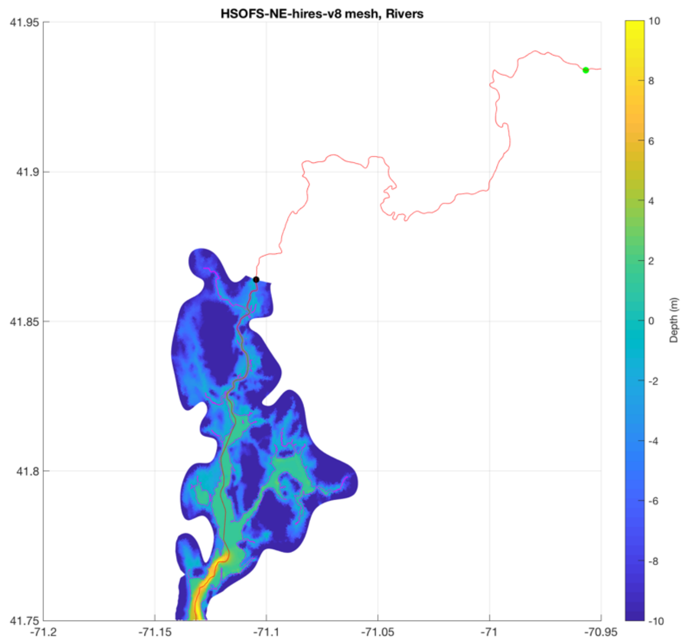


Figure 1.3. ADCIRC mesh in the Taunton River region showing the river configuration in the mesh. The colored area is the ADCIRC mesh domain and the red line denotes the river course. The green dot indicates the locations of the farthest downstream gauging station. The black dot shows the location of the model river inflow.

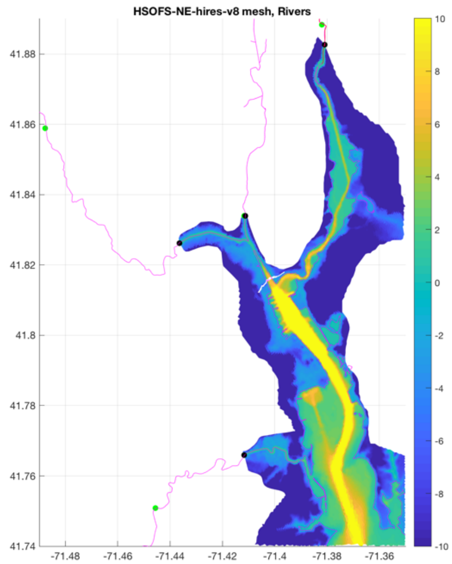


Figure 1.4. ADCIRC mesh in the northern Narragansett region showing the four area rivers that are configured in the mesh. The colored area is the ADCIRC mesh domain and the red lines denote the river courses (counterclockwise from upper right: Blackstone, Moshassuck, Woonasquatucket, and Pawtuxet Rivers). The green dots indicate the locations of the farthest downstream gauging stations (note that for the Moshassuck, the gauging station is at the model boundary location and is obscured by the black dot). The black dots show the location of the model river inflows. The thin white region (at approximate location 41.815 N, -71.4 W) is the Fox Point Hurricane Barrier at the southern end of downtown Providence.

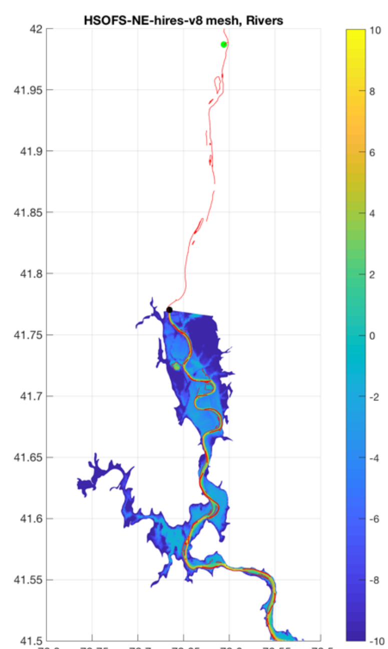


Figure 1.5. ADCIRC mesh in the Connecticut River region showing the river configuration in the mesh. The colored area is the ADCIRC mesh domain and the red line denotes the river course. The green dot indicates the locations of the farthest downstream gauging station. The black dot shows the location of the model river inflow.

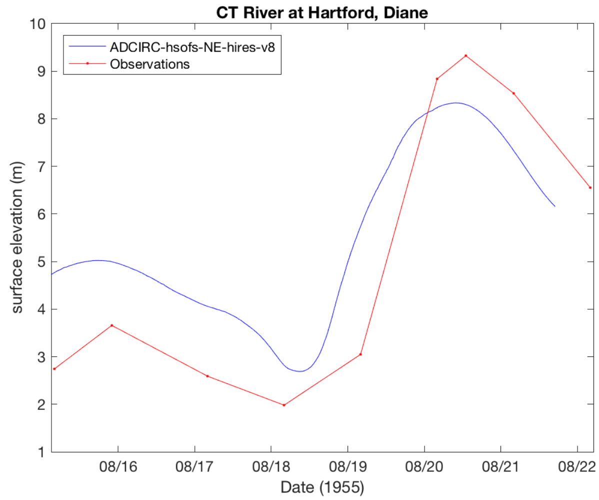


Figure 1.6. Water surface elevation (stage) at Hartford, CT during Hurricane Diane. The blue curve shows the ADCIRC-simulated elevation and the red line denotes the estimated elevation from Kutschenreuter (1956).

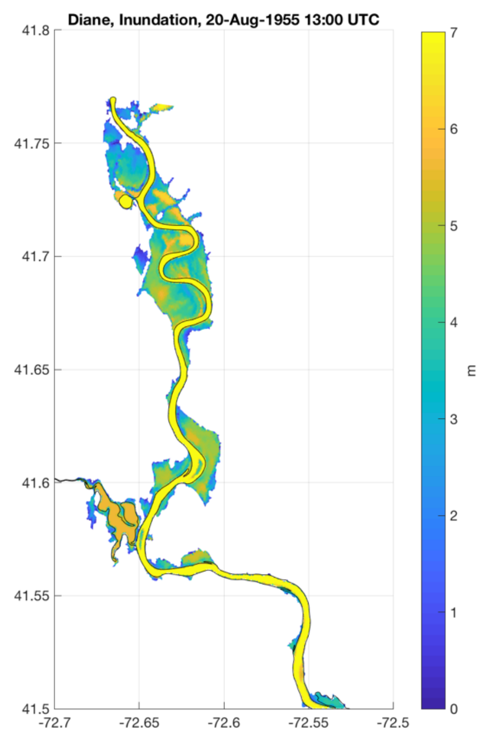


Figure 1.7. Inundation in the Hartford region of the Connecticut River during Hurricane Diane (1955). The black lines denote the main river channel.

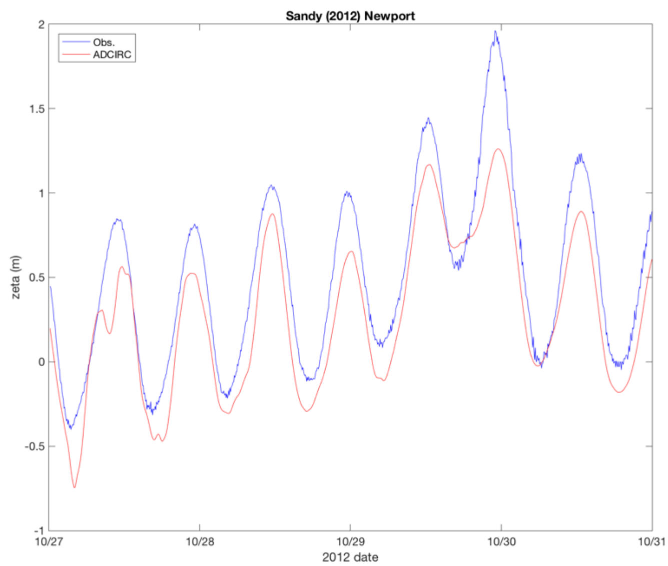


Figure 1.8. Water surface elevation at the NOS tide gauge in Newport, RI during hurricane Sandy. The observations are shown in blue and the ADCIRC results are shown in red.

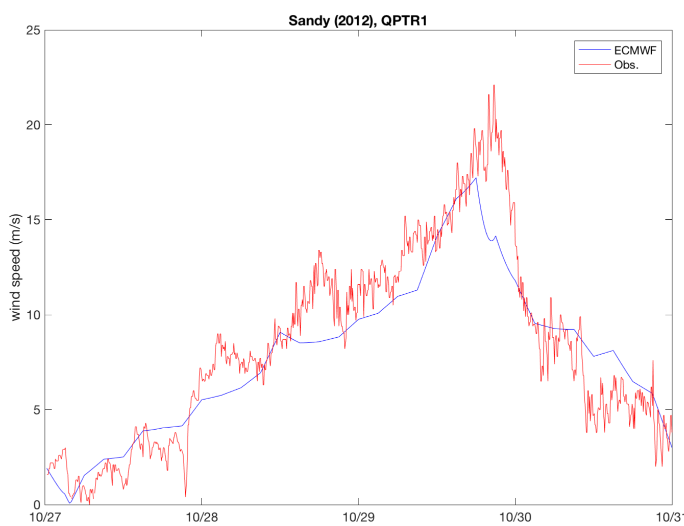


Figure 1.9. Comparison of observed wind speed at Quonset Point, RI with ECMWF winds spatially interpolated to that location.

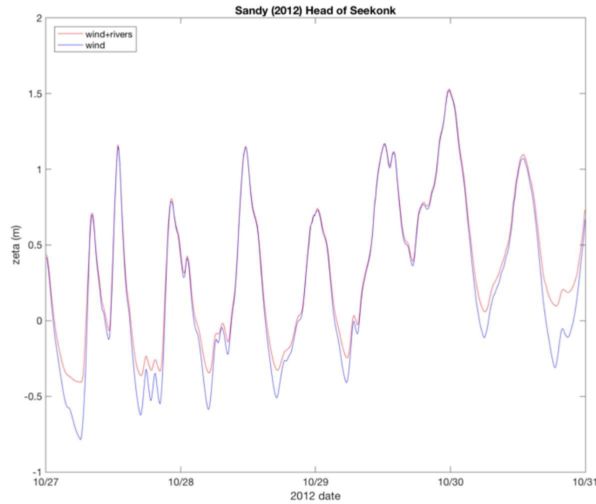


Figure 1.10. Water surface elevation in the Seekonk River just downstream from the Blackstone River discharge location during hurricane Sandy. The ADCIRC model results with wind and river forcing are shown in red and the results with only wind forcing are shown in blue.

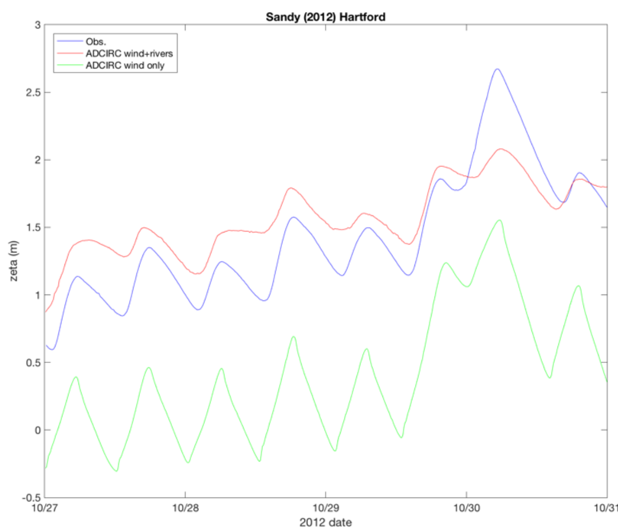


Figure 1.11. Water surface elevation at the USGS tide gauge in Hartford, CT during hurricane Sandy. The observations are shown in blue, the ADCIRC results with wind and river forcing are shown in red, and the ADCIRC wind-only forcing results are shown in green.

2. Evaluation and implementation of the sea state dependent drag coefficient in ADCIRC

During this report period, we have 1) finished the investigation of the sea-state dependent drag coefficient (Cd) and wind stress in coastal water with different bottom slopes under steady uniform wind and idealized hurricanes, and 2) performed idealized storm surge experiments to survey the impact of the sea state dependent drag coefficient on storm surge modeling. In these investigations, the WAVEWATCH III (WW3) model is used to simulate wave spectrum and to calculate wind stress and Cd based on the method developed in Reichl et al. (2014). The WW3 is chosen primarily because the two published wind stress modeling methods have already been implemented in the latest version of the model.

2.1 Impact of shoaling ocean surface waves on wind stress and drag coefficient in coastal waters under uniform wind and idealized tropical cyclones

2.1.1 Method

a. Simulation of Shoaling Wave Spectra with WAVEWATCH III

The WAVEWATCH III (WW3) model predicts wave spectra by solving wave-action equation. Version 5.16 of the WW3 code is used in this study. The wind input term (S_{in}) and the white-capping term (S_{dis}) are computed with the ST4 physics parameterization (Ardhuin *et al.*, 2010). Four-wave interaction (S_{nl}) is computed with the standard discrete interaction approximation (DIA). In shallow water, bottom friction (S_{btm}), depth-induced breaking (S_{db}) and triad interaction (S_{tr}) are activated. The wave action equation is solved with these 6 source terms to generate wave spectra during shoaling. Wave simulations are conducted with 40 frequency bins starting at 0.0125 with a logarithmic increment factor of 1.1, and 36 equally spaced directional bins.

This study focuses on medium to high wind speeds above 10 m/s (including hurricane conditions). Therefore, wind input and white-capping terms are tuned following the ST4 setup in Liu et al. 2017, which showed good agreement between model results and observations in Hurricane Ivan. The bottom dissipation S_{btm} is modelled with a simple linear JONSWAP bottom friction parameterization (Hasselmann *et al.*, 1973). The Battjes and Janssen (1979) parameterization is used for depth-induced breaking. Triad interaction is modelled with the Eldeberky (1996) Lumped Triad Approximation model. These three shallow water source terms are used with their default setting.

b. Empirical B_{sat} as a function of wind speed

In the sea-state drag coefficient models of Reichl et al. (2014), the full wave spectrum is constructed by merging the WW3 spectrum (in the resolved frequency range) and the parameterized saturation tail level B_{sat} (in the unresolved high frequency range). The drag coefficient is then calculated using two different wave boundary layer models (URI and Miami models). We parameterize the saturation tail level B_{sat} as a function of wind speed, so that the mean of the sea-state dependent Cd values is consistent with existing bulk parameterizations. The left panel of Figure 2.1 shows two different drag formula used in the ADCIRC and the Cd parameterization implemented in the Geophysical Fluid Dynamics Laboratory hurricane model in 2015 (Ginis et al. 2015, hereafter the GFDL Cd). The left panel shows the corresponding B_{sat} function. From here on we present the results based on the B_{sat} function tuned to the GFDL Cd.

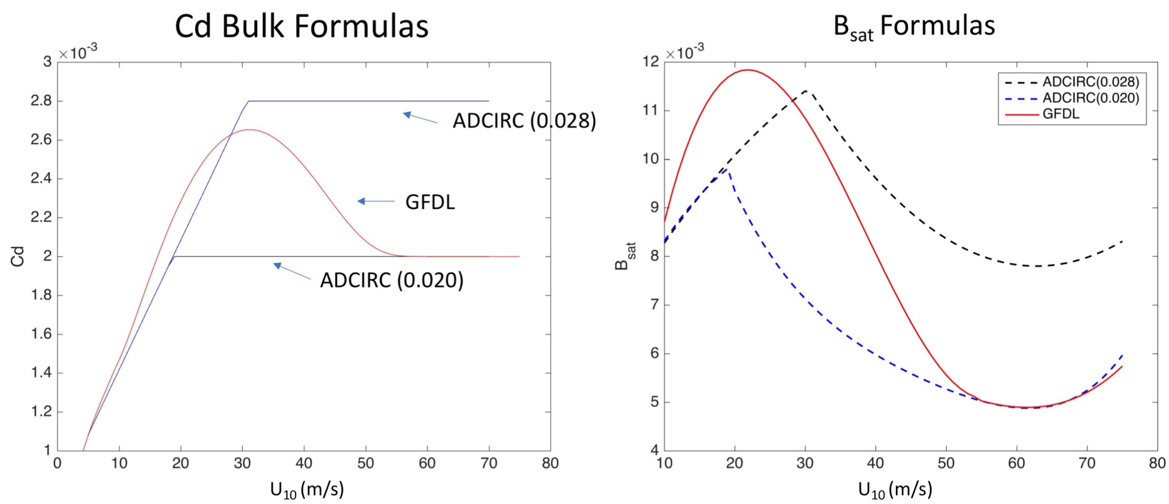


Figure 2.1 Examples of bulk Cd formulas used in different models (left panel) and the corresponding B_{sat} formulas (right) designed for the URI drag model. The result for the Miami model is similar and is not shown.

c. <u>Wind stress calculation</u>

Once the complete wave spectrum is constructed (from the WW3 resolved spectrum and the parameterized tail), two existing wind stress modeling methods, URI method (Reichl et al., 2014) and Miami method (Donelan *et al.*, 2012), are used to compute the sea-state dependent wind stress using the wave spectra. These two methods were used in Reichl et al. (2014) to investigate the sea-state dependent wind stress in deep water. Subsequently, both methods have been implemented into the WW3 model (in version v5.16) as diagnostic flux modules (FLD1/2) and are available for public use (The WAVEWATCH III Development Group, 2016).

2.1.2 Experiment setup

a. <u>Fetch-dependent shoaling waves under Uniform Winds</u>

Shoaling experiments of fetch-dependent wind waves are conducted on a sloped bottom under uniform and steady onshore wind. The wind speed spans from 10 m/s to 65 m/s with a 5 m/s increment. The bottom slope is set to 1:100, 1:200, 1:400, 1:1000, and 1:2000. These values are based on the range of bottom slope used in Irish *et al.* (2008) and Li *et al.* (2013). They are representative of realistic bottom slope conditions along the western north Atlantic coast (see Figure 2.2). The cross-shore domain length, which is also the wind domain length, is set to either 200 km, 400 km or 600 km. This parameter can be interpreted as the storm size or the effective fetch of a moving storm.

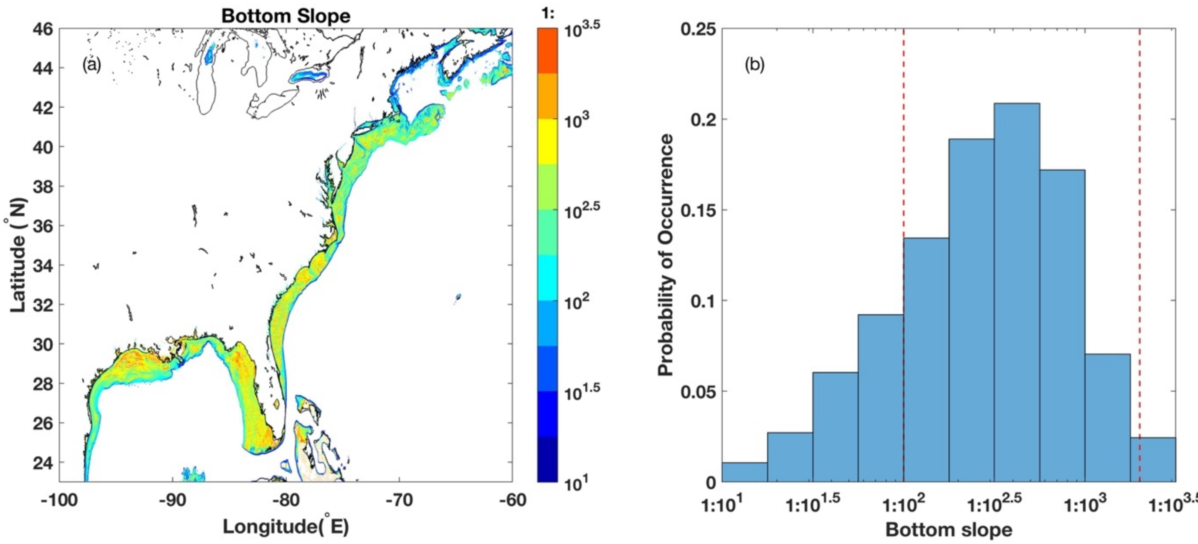


Figure 2.2 Estimates of bottom slope from ETOPO1 Global Relief Model along the western north Atlantic coast for water depth less than 100m. Left: spatial distribution of bottom slope in log scale; Right: probability distribution of bottom slope shown in the left panel. Two red dashed lines denote the range of our experimental slopes. Note that bottom slope is estimated in a 4 by 4 arc minutes grid box using central difference and less than 1:3000 values are excluded.

b. Shoaling waves under landfalling idealized hurricanes

Idealized tropical cyclone wind fields are generated using the Holland model (Holland, 1980). Inflow angle is specified and half the translation speed is added to the wind field above as in Moon *et al.* (2003).

Four idealized TCs with two maximum wind speeds V_{max}= 35m/s and 65m/s, corresponding to Category 1 and Category 5 hurricanes according to the Saffir-Simpson hurricane wind scale and two translation speeds, U_T= 5m/s and 10m/s, are used to force the wave model. The radius of maximum wind (R_{max}) is set 70km for all cases. These four idealized TC wind fields are shown in Fig. 2.3.

2.1.3 Results of Uniform wind experiment

a. Cross-shore variation of wave field and drag coefficient

We show results simulated under 35m/s uniform wind (Figure 2.4). Significant wave height (Hs), mean wave length (MWL) and drag coefficient (Cd) are displayed in two different coordinates, one is distance and the other one is depth. Since the wind blows onshore in our simulations, the wind fetch increases with decreasing cross-shore distance and depth. In all cases, we see that both Hs and MWL grow with the wind fetch in the same manner as in the deep water for some distances. At some point the Hs and MWL deviate from the deep water growth curves (dashed lines) as the waves start to feel the bottom and dissipated by bottom dissipation and also depth-induced breaking. Because at the same distance offshore the water depth is shallower with the gentle slope, the shallow water effects start to affect the wave fields in further offshore in the distance coordinate. However, when the results are shown in the depth space (lower panels in

Figure 2.4), the behavior of Hs and MWL on different slopes are more similar, suggesting the water depth exerts dominant controls on the magnitude of Hs and MWL. In general, we see two regimes of the depth impacts on the wave field. First, gradual decrease of Hs and MWL due to frictional dissipation. Then, a sharp drop of the wave energy due to depth-induced breaking. Interestingly, the magnitude of these two quantities are significantly dependent on the bottom slope even plotted against the water depth. As the slope decreases, the magnitude of both the Hs and the MWL reduces possibly because waves have more time to adjust to varying water depth.

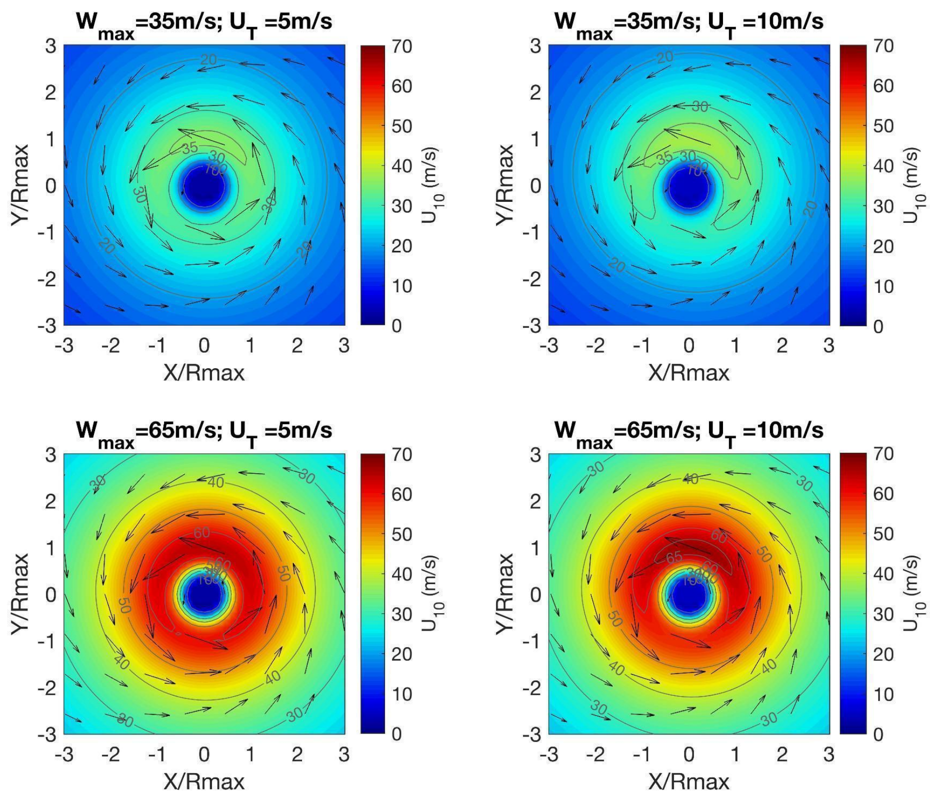


Figure 2.3 Wind fields of idealized tropical cyclones generated with the Holland model. Upper (lower) panels: TC with maximum wind speed V_{max}= 35m/s (65m/s), Category 1 (5) hurricane strength. Left (right) panels: translation speed U_T =5m/s (10m/s). Radius of maximum wind (R_{max}) is 70km. Distance in x-, y-axis is normalized by R_{max}. The TC propagate in the negative x direction.

The magnitude of the drag coefficient also displays similar dependence on the bottom slope. But unlike the consistent decay of the wave field, the drag coefficient gradually increases to a maximum and then reduces. The Cd peak occurs roughly at a location where depth-induced breaking begins. Again, the results are significantly dependent on the bottom slope. The steeper slope introduces more enhancement of the drag coefficient before waves start to break.

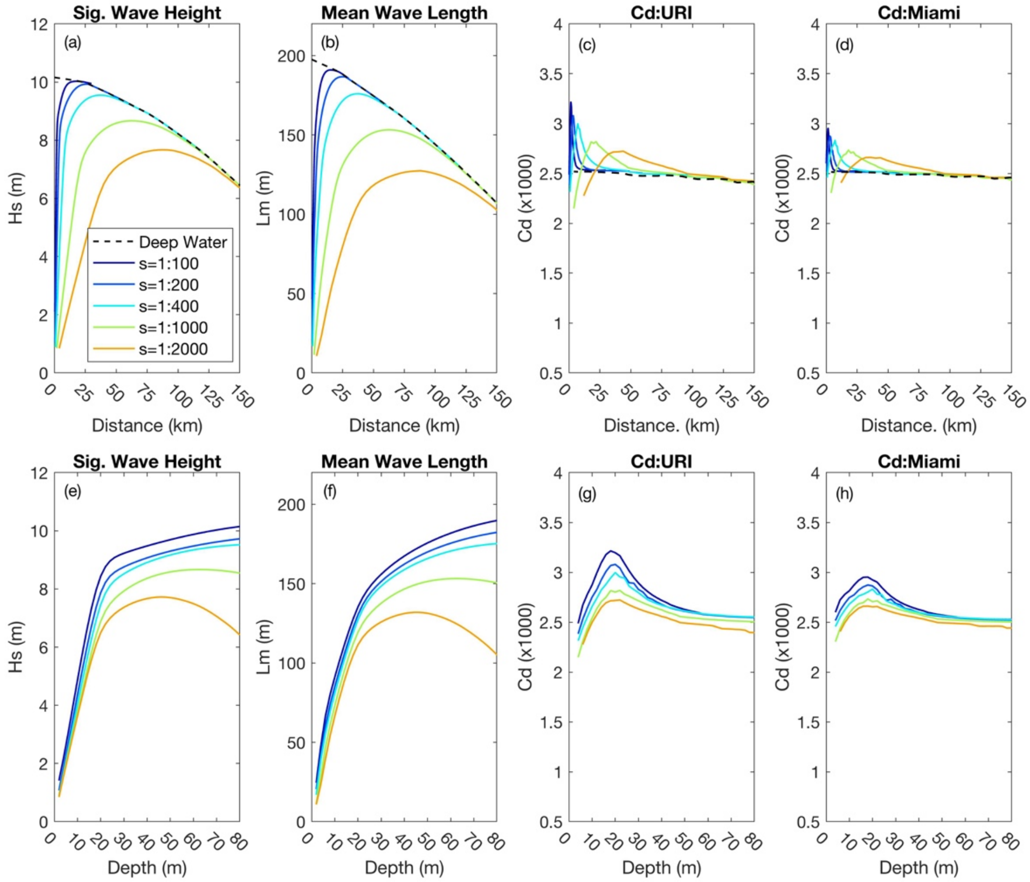


Figure 2.4 Significant wave height (Hs), mean wavelength (Lm) and drag coefficient (Cd) computed using the URI and Miami methods, simulated under 35m/s uniform wind on 5 different bottom slopes. The results are plotted against distance from the shoreline (upper panels) and against water depth (lower panels). In the upper panels dashed line represents fetch-dependent results in the deep water. Lines of different colors represent different bottom slopes as shown in the legend. Cross-shore domain length (fetch at the shoreline) is 200km.

b. Sensitivity of drag coefficient to bottom slope

We next focus on the maximum enhancement of Cd due to shoaling. The results are summarized in Figure 2.5, where the experiments with the larger wind domain lengths of 600km are also included. For a given tail level B_{sat}, as wind speed increases, the maximum Cd enhancement tends to increase first and then either decrease or saturate depending on the level of B_{sat}. The maximum Cd enhancement decreases with increasing B_{sat} except at the lowest wind speed. The sensitivity of the maximum Cd enhancement to the bottom slope is apparent in all experiments. Larger shoaling wave impacts on Cd are associated with steeper bottom slope values. Overall, the Cd enhancement is within ~40%.

The results are qualitatively similar between the URI and Miami methods. Both methods indicate significant Cd enhancement, particularly with higher wind speed and steeper bottom slope. There are some notable differences, however. The maximum Cd enhancement tends to be larger with the URI method and the Miami method shows less sensitivity to the changes in the cross-shore domain length.

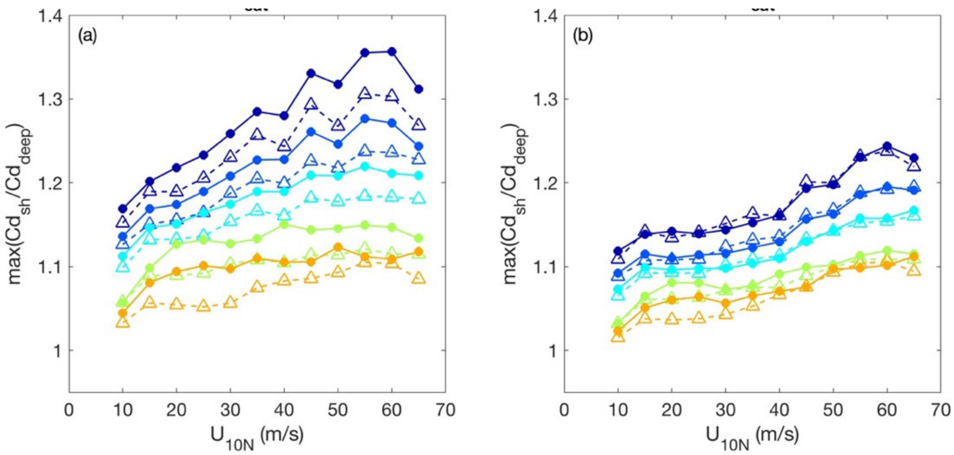


Figure 2.5. Maximum enhancement of drag coefficient as a function of wind speed on different slopes and with two different domain lengths computed with URI (left) and Miami (right) methods. Colors represent bottom slopes as used in Figure 2.4. Dashed and solid lines indicate the results with the 200km and 600 km domain lengths, respectively.

c. <u>Shoaling impact on Cd</u>

Figures 2.6 shows Cd ratio (ratio of shoaling Cd_{sh} to deep water Cd_{deep}), plotted against water depth for three different wind speeds, two different wind domain lengths, and four different bottom slope values. As wind speed increases, Cd ratio peak at a deeper water depth. The Cd peak moves to a deeper depth as the cross-shore wind domain length (WDL) increases from 200km to 600km in the 35m/s and 65m/s cases. This is because the longer WDL increases the fetch for wave growth and hence has the same effect as increasing wind speed. In the 15m/s case, however, the peak of Cd occurs at a similar depth because waves are approaching the fully grown state with both WDLs. In general, the URI and Miami methods yield enhancement up to 40% and 25%, respectively. The magnitude of enhancement always increases with steeper bottom slope, and it tends to increase with wind speed in both methods.

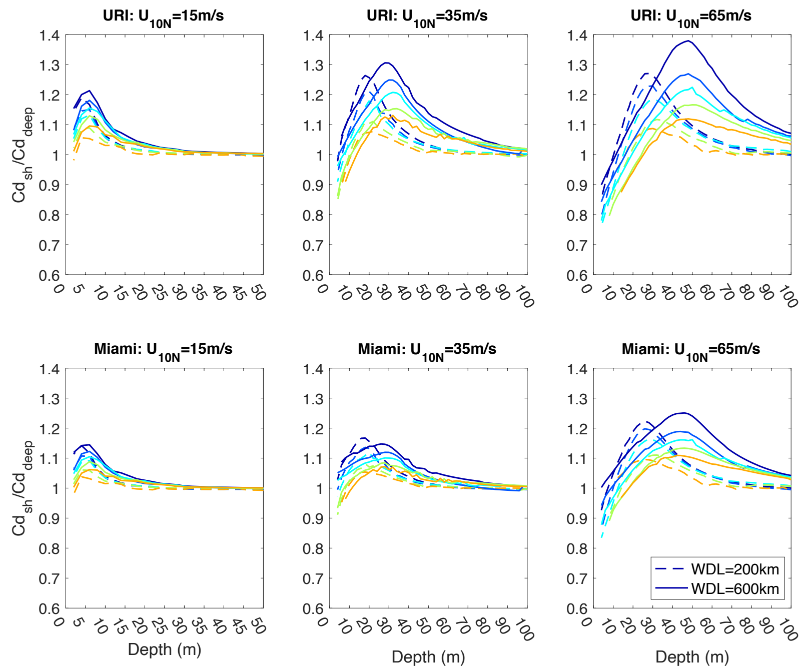


Figure 2.6 The ratio of shoaling impacted Cd to deep water Cd (Cd_{sh}/Cd_{deep}) as a function of depth under 15, 35, and 65 m/s wind speeds, using URI (top panels) and Miami (bottom panels) methods. Colors represent different bottom slopes as denoted in Fig. 2.4. Dashed and solid lines represent results with the 200 km wind domain length and 600 km wind domain length, respectively.

d. Enhanced variability of Cd by shoaling waves in shallow water

How is the Cd-U_{10} relationship affected by shoaling wind seas? To answer this question, sea-state dependent Cd values at water depths from 10m to 50m are aggregated from all shoaling wind sea experiments conducted at different wind speeds, on different slopes and with different cross-shore wind domain lengths. The results are then compared to those in deep water (Figure 2.7). It is evident that shoaling wind seas significantly increase variability of Cd for a given wind speed in shallow water. This variability is larger using the URI method than using the Miami method. It is interesting to note that at moderate wind speeds (<30m/s) Cd increases in shallower water (<30m) while at very high wind speeds (>50m/s) Cd increases in deeper water (>30m) and decreases in shallower water (<30m).

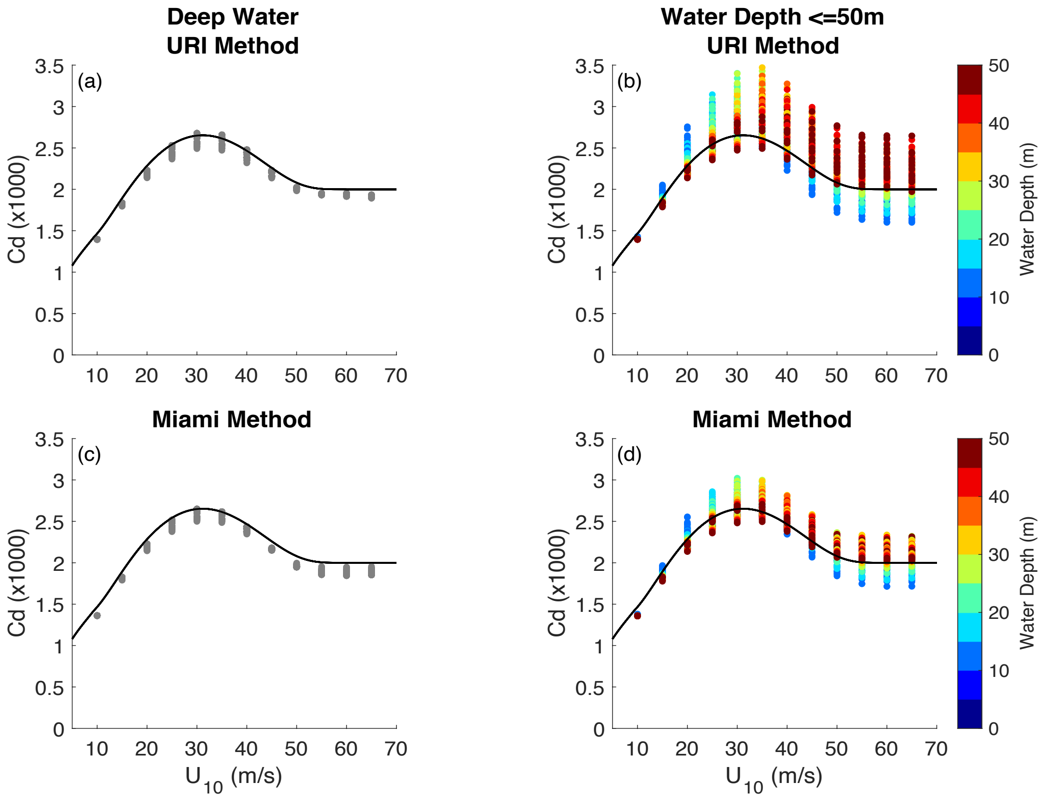


Figure 2.7. Drag coefficient as a function of wind speed in deep water (left panels) and at water depths less than 50 m (right panels). The water depths are color coded. The solid line shows the GFDL Cd bulk parameterization.

2.1.4 Results of Idealized hurricane experiment

When the quasi-steady wind/wave fields are established under a translating TC in deep water, the spatial distribution of a wind/wave variable (such as, significant wave height, sea-state dependent drag coefficient) also represents the temporal evolution of the same variable along a transect that is perpendicular to the storm track. (Since the storm propagates in the negative x direction, the x-axis of the spatial snapshot is equivalent to the time (t) axis, with a relation $x=U_T t$, where U_T is the storm translation speed.)

Once the storm enters the shoaling region, the wave field is not quasi-steady anymore. Nevertheless, it is beneficial to examine how a variable at a particular location (relative to the storm center) is modified due to depth change. In this section all the two-dimensional (2D) figures at a particular depth are constructed by first extracting results at that depth (i.e., along a y- transect perpendicular to the storm propagation) as time progresses. To enable comparison in the TC-centered spatial coordinates, time t is then converted to distance x using the same relation $x=U_T t$. Therefore, negative x values denote results prior to the TC center arrival at that depth and positive x values indicate results after the passage of the TC center. Only in deep water the 2D figures are true spatial snapshots in the quasi-steady state.

All the 2D figures shown in this section are generated under the intense TC with V_{max}=65m/s and U_T=5m/s or 10m/s. The results of the weaker TC (V_{max}=35m/s) are qualitatively similar and are not shown.

a. Characteristics of shoaling TC waves

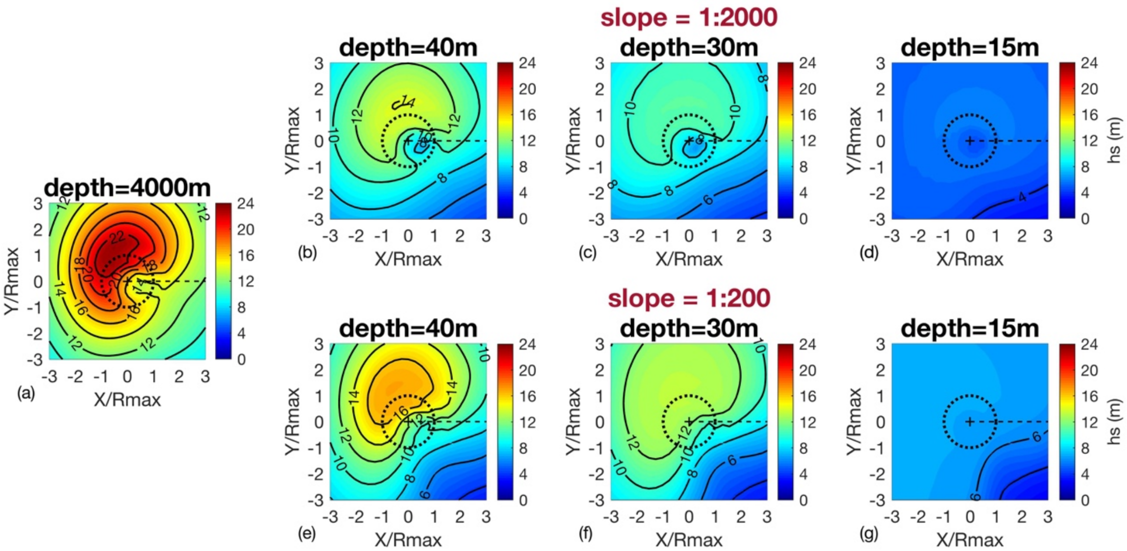


Figure 2.8 Spatial-temporal variation of significant wave height (Hs) in deep water (a) and at three different depths, 40m (b,e), 30m (c,f), 15m (d,g), under a strong fast-moving TC with V_{max} = 65m/s and U_T=10m/s. The upper panels (b-d) show results on 1:2000 slope, the lower panels (e-g) show results on 1:200 slope. Black solid contours are drawn every 2m in significant wave height. Dashed horizontal line is the TC track. Thin dotted circle marks R_{max}.

Shoaling wave fields generated by the strong fast-moving hurricane (V_{max} = 65m/s and U_T=10m/s) are shown in Figure 2.8. As expected, the significant wave height (Hs) is reduced everywhere as water depth decreases because of the enhanced wave dissipation. Even at the 40m water depth, the wave fields have already been modified significantly compared to those in the deep water. Hs is more strongly reduced at a given water depth with a gentler slope of 1:2000 than those with a steeper slope of 1:200. This is because waves propagate over a longer distance and are dissipated more efficiently with a gentler slope.

b. Enhanced variability of drag coefficient by shoaling TC waves

i. Spatial-temporal variability

The spatial-temporal variation of the shoaling wave-impacted drag coefficient during TC landfall is shown in Figure 2.9. The ratio of the shoaling-impacted Cd to the deep-water Cd for the corresponding cases is shown in Figure 2.10. Here, the drag coefficient is defined as the wind friction velocity squared divided by the 10-meter wind speed magnitude squared, even if the 10-meter wind direction and the wind stress direction are misaligned.

Fig. 2.9 shows the sea-state dependent Cd in the strong slow-moving TC (V_{max} = 65m/s and U_T=5m/s) case calculated using the URI method. The contours of the deep-water Cd (Fig. 2.9a) almost follow the circular wind speed contours, that is, Cd mainly depends on wind speed and its sea-state dependence is quite weak. Relative to the bulk GFDL Cd, the sea-state dependent Cd near Rmax is slightly lower on the front-right-hand side of the TC, where the waves are higher and more developed than those on the rear-left-hand side. Note that the sea-state dependence of Cd in deep water in this study is not as strong as those reported in Reichl et al. 2014. This is because the wave fields (simulated with the ST4 source term of WW3) in this study show reduced spatial variation (or reduced asymmetry) of Hs along wind speed contours, compared to those in Reichl et al. (2014) simulated with the ST2 source term of WW3.

As water depth decreases, the magnitude and spatial distribution of Cd is modified in a complex manner underneath the landfalling TC (Fig. 2.9b-2.9g). Interestingly, these Cd modifications show significant differences between the different bottom slopes. It is easier to interpret these results by examining the shoaling effect (Fig. 2.10), which is the ratio of Cd in shallow water relative to Cd in deep water at the same location relative to the storm center (for example, Fig. 2.10a shows the ratio of Cd in Fig. 2.9b and Fig. 2.9a).

Here, we mainly focus on the high wind area (the distance from the storm center roughly between R_{max} and $2R_{max}$). On the steeper bottom slope at a 40m depth (Fig. 2.10d), Cd is significantly increased (by more than 20%) in the right (toward right-rear) quadrant. It is also increased in the left (toward left-front) quadrant, but it is decreased in the front (toward front-right) and rear (toward rear-left) quadrants. As depth decreases from 40m to 30m (Fig. 2.10e), the increase/decrease of Cd is further enhanced. When depth decreases to 15m (Fig. 2.10f), the Cd increase on the right almost disappears, but the increase on the left and the decrease in the front/rear are significantly enhanced. On the gentler slope (Fig. 2.10a-c), the overall shoaling effect is much weaker. Significant Cd increase (more than 10%) is observed only on the right (toward right-rear) at 40m and 30m depths, and on the left (toward left-front) at 15m depth. No significant Cd decrease is observed.

In general, the Miami method shows very similar patterns of Cd and Cd ratio compared to those using the URI method. We have found that the results in other cases are also very similar between the two methods (not shown). This suggests that the shoaling impact on the sea-state dependent Cd is quite robust and is not dependent on how the sea-state dependent Cd is calculated.

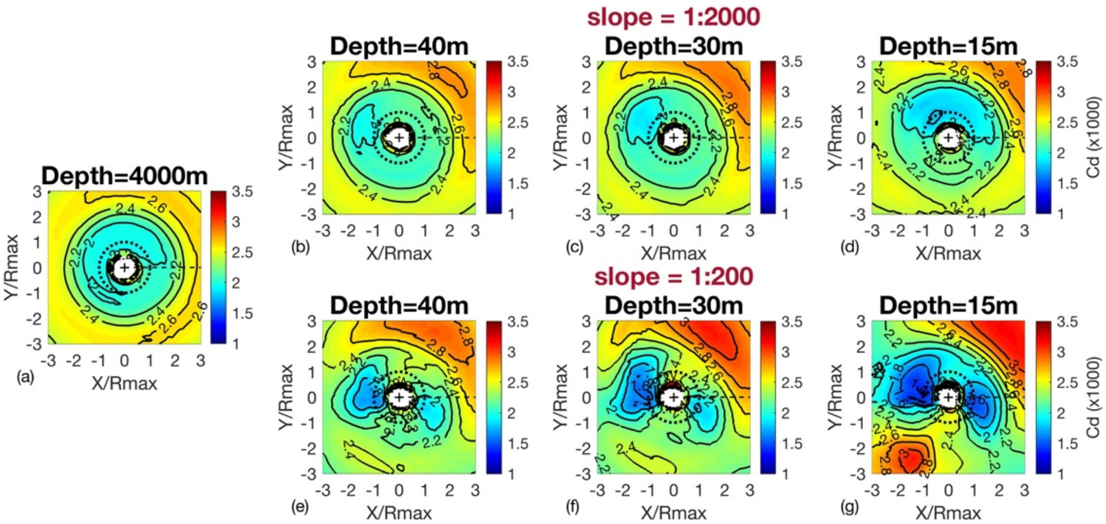


Figure 2.9 Spatial-temporal variation of Cd (calculated using URI method) in deep water (a) and at three different depths, 40m (b,e), 30m (c,f), 15m (d,g), under a strong slow-moving TC with V_{max} = 65m/s and U_T=5m/s. The upper panels (b-d) show results on 1:2000 slope, the lower panels (e-g) show results on 1:200 slope. Solid black contours are drawn every 0.2 in Cd(x1000). Dashed horizontal line is the TC track. Thin dotted circle marks R_{max}.

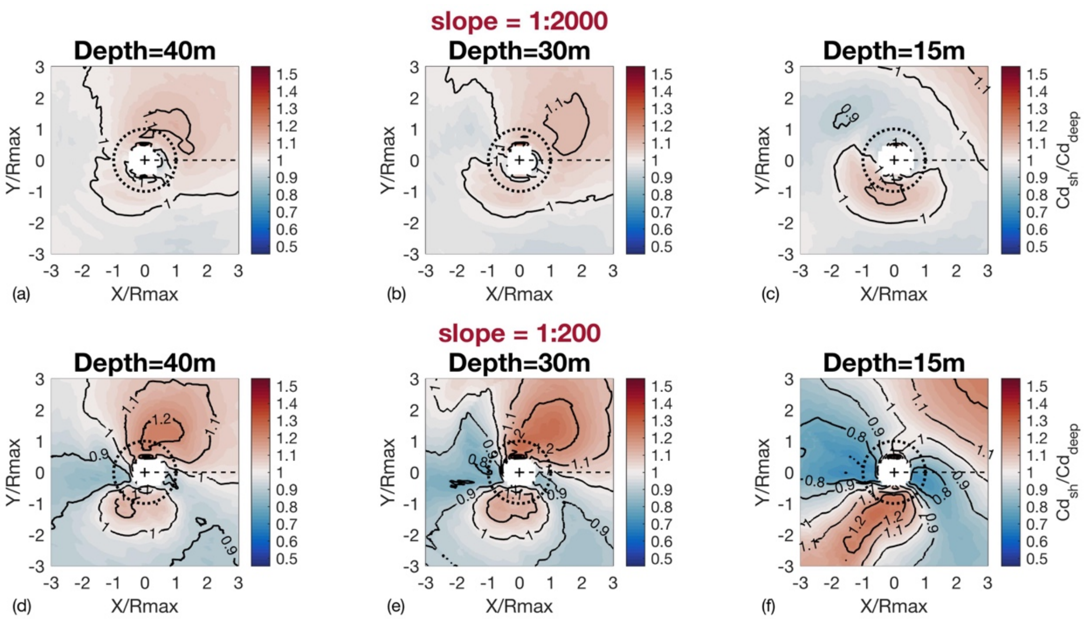


Figure 2.10 Spatial-temporal variation of Cd ratio (ratio of sea-state dependent Cd in shallow water to that in deep water, calculated using URI method) at three different depths, 40m (a,d), 30m (b,e), 15m (c,f), under a strong slow-moving TC with V_{max} = 65m/s and U_T=5m/s. The upper panels (a-c) show results on 1:2000 slope, the lower panels (d-f) show results on 1:200 slope. Solid black contours are drawn every 0.1 in Cd ratio. Dashed horizontal line is the TC track. Thin dotted circle marks R_{max}.

In summary, the shoaling impact on Cd is much stronger on a steeper bottom slope and with a faster propagating TC, and it varies significantly depending on the location relative to the storm center.

ii. Variability in the Cd-U_{10} relation

In this section, the results of the sea-stated dependent Cd with shoaling waves are presented as Cd - U_{10} scatter figures. The data are binned every 5m/s interval, and the statistical distribution of Cd in each wind speed bin is shown with a box-whisker plot, indicating its mean, median, as well as the lowest 2.5%, 25%, 75%, and 97.5% values. The data are color coded by the wave age, which is defined as $c_p\cos\psi/u_*$, where ψ is the angle between the dominant wave direction and the wind stress direction. Negative wave ages suggest presence of swell opposing wind, which generally occurs to the left of the TC.

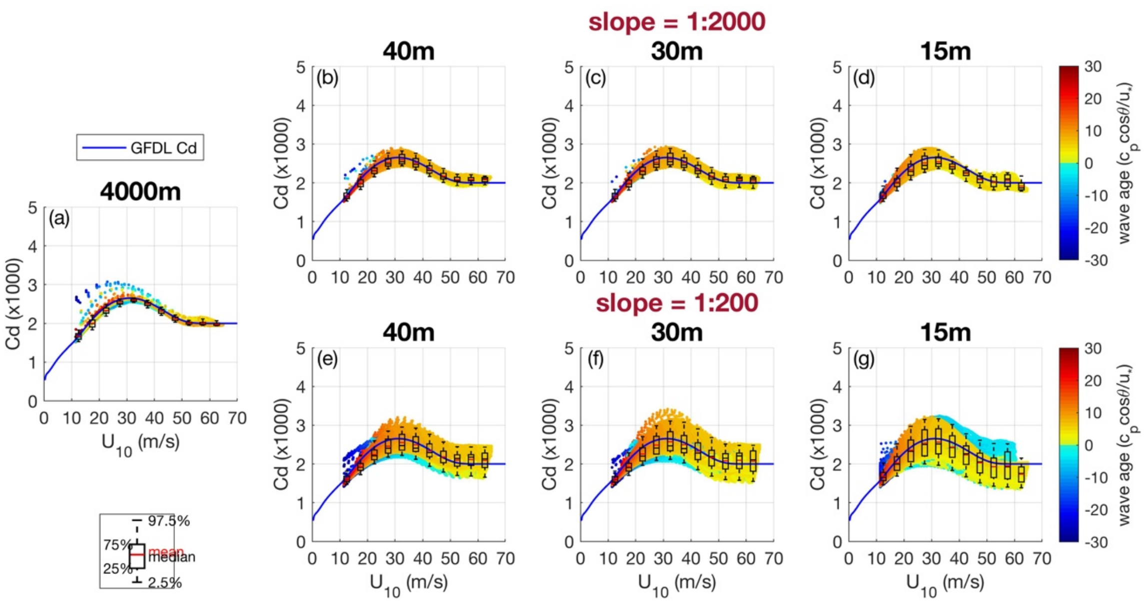


Figure 2.11 Cd - U_{10} scatter plots in deep water (a) and at three different depths, 40m (b,e), 30m (c,f), 15m (d,g), under a strong slow-moving TC with V_{max} = 65m/s and U_T=5m/s. Cd is computed using URI Method. The upper panels (b-d) show results on 1:2000 slope, the lower panels (e-g) show results on 1:200 slope. Data are color coded by wave age ($c_p\cos\psi/u_*$). The rectangular box with two whiskers shows data statistics in a given wind speed bin. The red and black lines in the box denote the mean and median Cd values respectively. The bottom and top of the rectangular box mark the 25th and 75th percentile of the Cd values. The lower and upper whisker levels indicate the 2.5th and 97.5th percentile of the data. The blue line is the GFDL bulk Cd.

Fig. 2.11 shows the results at all locations where wind speed exceeds 10m/s in the strong slow-moving TC case (Vmax = 65m/s, UT=5m/s). Here, Cd is calculated using the URI method. In deep water (Fig. 2.11a), sea-state dependence is generally weak. Although there are some outliers with high Cd values (over opposing swell), the 95% interval is quite small. As the water depth decreases, the variability of Cd significantly increases particularly with the steeper bottom slope. As discussed above, higher values of Cd in high wind region mainly occur on the right (positive wave age) at 30 to 40m depths and on the left (negative wave age) at 15m depth. The mean and median values of Cd still closely follow the GFDL bulk Cd parameterization.

c. Misalignment between 10-meter wind and wind stress directions

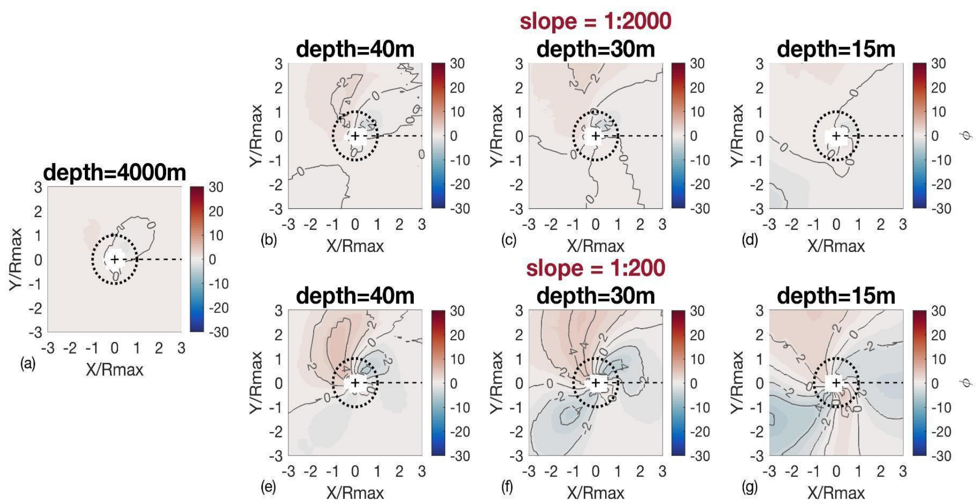


Figure 2.12. Spatial-temporal variation of misalignment angle (in degrees) between 10 meter mean wind direction and wind stress direction, in deep water (a) and at three different depths, 40m (b,e), 30m (c,f), 15m (d,g), under a strong fast-moving TC with V_{max} = 65m/s and U_T=10m/s. The upper panels (b-d) show results on 1:2000 slope, the lower panels (e-g) show results on 1:200 slope. Thin black contours are drawn every 2 degrees. Dashed horizontal line is the TC track. Thin dotted circle marks R_{max}. Wind stress is calculated using the URI method.

The misalignment angle (ϕ) between the 10-meter wind direction and wind stress direction for the strong and fast-moving TC, computed using the URI method, is shown in Figure 2.12. Positive (negative) values mean the wind stress direction turns clockwise (counter-clockwise) from the 10-meter wind direction. The misalignment is significantly increased in shallow water, particularly with the steeper bottom slope of 1:200. At all shallow water depths, the misalignment is positive in the TC front-right and negative in the rear-right. This is because part of the stress is supported by the misaligned dominant waves, hence, the wind stress direction turns toward the dominant wave direction (see Figure 2.8).

The misalignment angle is negative in the TC front-left, because part of the stress is supported by the swell opposing wind (swell whose direction is more than 90 degrees away from the wind direction). Since such swell is pushed backward by wind, the stress supported by the swell is in the opposite direction of the swell propagation. Hence, the wind stress direction turns toward the opposite of the swell direction (see Figure 2.8). At the 15m depth, the misalignment becomes positive in the TC rear-left for the same reason.

In summary, regardless of modeling methods, wind stress direction is steered toward the dominant wave direction wherever dominant waves misalign with wind by less than 90 degrees, and wind stress direction is steered toward opposite of the dominant wave direction wherever the dominant waves misalign with wind by more than 90 degrees. These patterns of rotation are mainly determined by the characteristics of our idealized TC wave fields and they are qualitatively consistent with the illustration in Grachev *et al.* (2003), who systematically investigated misalignment between wind and wind stress in different conditions.

2.1.5 Main findings

a. <u>Uniform steady onshore wind</u>

Two wave spectrum-based wind stress calculation methods (Miami and URI) are used to model the cross-shore variation of the drag coefficient under the influence of shoaling idealized wind seas. Our results show that the drag coefficient always increases with shoaling and peaks at a threshold depth, and then rapidly decreases, relative to its fetch-dependent deep-water value. The threshold depth is where the depth-induced breaking starts to dominate the dissipation. This variation of Cd is qualitatively consistent with the observational study (AD96). The relative Cd enhancement is within 25% with the Miami method and 40% with the URI method.

The enhancement of Cd is sensitive to the bottom slope, with a larger increase on a steeper bottom slope. This implies that the bottom slope needs to be considered as an important parameter in addition to water depth in the future use of drag coefficient in coastal waters.

Our results suggest a larger variability of the Cd-U_{10} bulk relation in shallow water compared to that in deep water. Specifically, at moderate wind speeds (<30m/s), shoaling wind seas can increase the slope of the Cd-U_{10} linear fit for water depth between 15-30m. This is qualitatively consistent with existing measurements in coastal waters. Our analysis indicates that the increase of Cd is mainly caused by a combination of wave steepening (increase of the slope spectrum) and decrease of the wave phase speed.

b. <u>Landfalling idealized hurricanes</u>

The effects of shoaling waves on the sea-state dependent wind stress and the drag coefficient (Cd) under landfalling TCs were investigated. Numerical experiments were conducted using idealized TCs with two intensities (Category 1 and 5) and two translation speeds, propagating toward and normal to the shoreline over two different bottom slopes. The shoaling wave spectra were simulated using the WW3 wave model, and the unresolved spectral tail (saturation level) was empirically parameterized and assumed to be unaffected by shoaling. The sea-state dependent wind stress was calculated using the two methods, URI and Miami.

The main findings are summarized as follows:

1. Shoaling TC waves can significantly modify the wind stress and Cd in a complex manner compared to those in deep water. The modification is stronger over a steeper bottom slope and is further enhanced with a faster moving TC. The overall results are similar between the URI and Miami methods.

2. The wind stress magnitude (or Cd) is enhanced relative to that in deep water in the right (toward right-rear) quadrant because of shoaling of fetch-limited waves - similar to the results of the uniform wind experiments in Part I. The wind stress is also enhanced due to opposing swell in the TC left (toward left-front) quadrant.

3. Over a steeper bottom the wind stress magnitude (or Cd) is reduced relative to that in deep water in the TC front (toward front-right) and real (toward rear-left) quadrants because wind seas are reduced due to the storm's proximity to the shoreline.

4. The variability of the drag coefficient at a given wind speed significantly increases due to shoaling waves, especially with a steeper bottom and a faster moving TC. However, the mean and median values of the drag coefficient are not significantly modified from those in deep water.

5. When dominant waves (swell) are misaligned with wind by less (more) than 90 degrees, the wind stress direction turns toward (opposite of) the dominant wave (swell) direction, hence, the 10-meter wind direction is misaligned with the wind stress direction. This misalignment angle significantly increases due to shoaling waves. The calculated misalignment angle is much larger with the Miami method than with the URI method.

Some of our findings (e.g., increased Cd on the TC right attributed to shoaling wind waves, increased Cd on the TC left due to swell opposing wind) are consistent with those of Chen and Curcic (2016) who conducted similar experiments using two historical TCs. However, our systematic study with idealized TCs have further clarified how the shoaling effects on Cd depend on storm intensity, storm translation speed, and, most importantly, bottom slope. In addition, this study has provided detailed explanations as to why the shoaling wave effect on Cd significantly varies depending on the location relative to the storm center.

Despite uncertainties remain regarding some assumptions made in our model approach, this study strongly suggests that the wind stress and Cd can be significantly modified under landfalling TCs in shallow water. Hence, predictions of landfalling TCs and their impacts (e.g., storm surge) are likely affected by the modified Cd as well.

3. Development in the Hurricane Boundary Layer Model for Landfall Forecasting

Over the last year, we made significant advancements in the development of the hurricane boundary layer (HBL) model to improve the surface wind forecast during hurricane landfall. Hurricane damaging winds are one of the main reasons behind the catastrophe caused by hurricanes during landfall. In most of the cases damaging wind occurs within the first few hours of landfall when the land roughness changes abruptly from ocean towards the land. The National Hurricane Center (NHC) currently relies on parametric wind field models (wind fields described by simple mathematical functions and a few storm parameters) with empirical over-land-decay formulas. These models are too simplistic to properly represent the rapid decay in wind speed which is one of the major characteristics of hurricane during landfall and surface friction is thought to be one of the major factors behind this feature.

The HBL model utilizes the physical balances in the dynamic equations to determine how the near-surface winds respond to local variability in the surface conditions during hurricane landfall. The governing equations for the mean wind components were similar to those described in Gao and Ginis (2014, 2016). The horizontal and vertical resolution in the model is currently 1-kilometer and 30-meters, respectively. The mean wind at the top of the boundary layer (3 km height) is assumed to be in gradient wind balance and doesn't vary vertically. The radial distribution of the gradient wind in the model is generated from the NHC hurricane best track archive or the Tropical Cyclone Vitals (TC-Vitals) Database (Trahan and Sparling, 2012). They typically include hurricane's center position, Maximum Wind Speed (MWS) at 10 m height, Radius of Maximum Wind (RMW) and radii of 18 m/s wind (R18) & 26 m/s (R26) wind at a 6-hour interval.

3.1 HBL model evaluation

During this time period, we have conducted a careful evaluation of the HBL model during hurricane landfalls and comparison with available observations. Here we summarize the main results.

3.1.1. Maximum sustained wind speed comparisons

(a) Hurricane Florence (2018)
The HBL simulated maximum wind swath of Hurricane Florence over land is shown in Figure 3.1 The modeled maximum sustained wind speed is compared with observations at 15 stations, and their differences are represented using colored markers. From these comparisons, it can be seen that at most of the stations HBL simulated wind agreed reasonably well with the observations. Stations that are located on the western part of the storm, i.e. Bald Head Island, Southport, and North Myrtle Beach, differences between HBL simulated wind and observations are within the range of 0-2 m/s. The rest of the 12 stations that are located on the eastern side of the storm, differences between modeled maximum and observed maximum sustained wind speed is within the range of -4 m/s to 7 m/s.

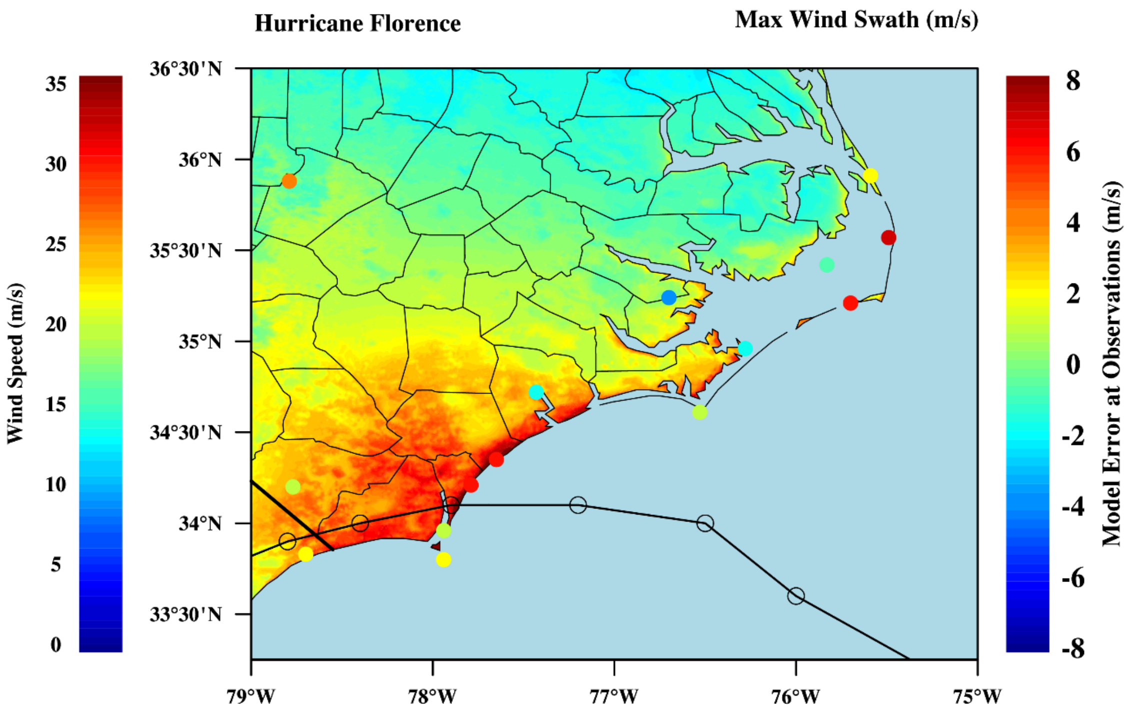


Figure 3.1 HBL simulated maximum wind swath for Hurricane Florence over land. The colored markers over land represent the differences of maximum sustained wind speed between HBL simulated wind and observed wind. The color bar on the left-hand side represents the magnitude (m/s) of HBL simulated maximum sustained wind speed and color bar on the right-hand side represents the magnitude (m/s) of errors between model and observations shown as colored markers over land. Track of Hurricane Florence is shown in the black colored line.

(b) Hurricane Irma (2017)

Similar to Hurricane Florence, the maximum wind swath of Hurricane Irma over land is shown in Figure 3.2, and the differences between HBL simulated and observed maximum sustained wind speed at 35 stations are represented using colored markers. Most of the observational stations are located on the east coast of Florida, and the differences between modeled and observed maximum sustained wind speed are within the range of -4 m/s to 6 m/s. Stations that are located on the west coast of Florida are within the range of -2 m/s to 5 m/s. These comparisons suggest that the HBL model simulated maximum sustained wind speed agreed reasonably well with the observations.

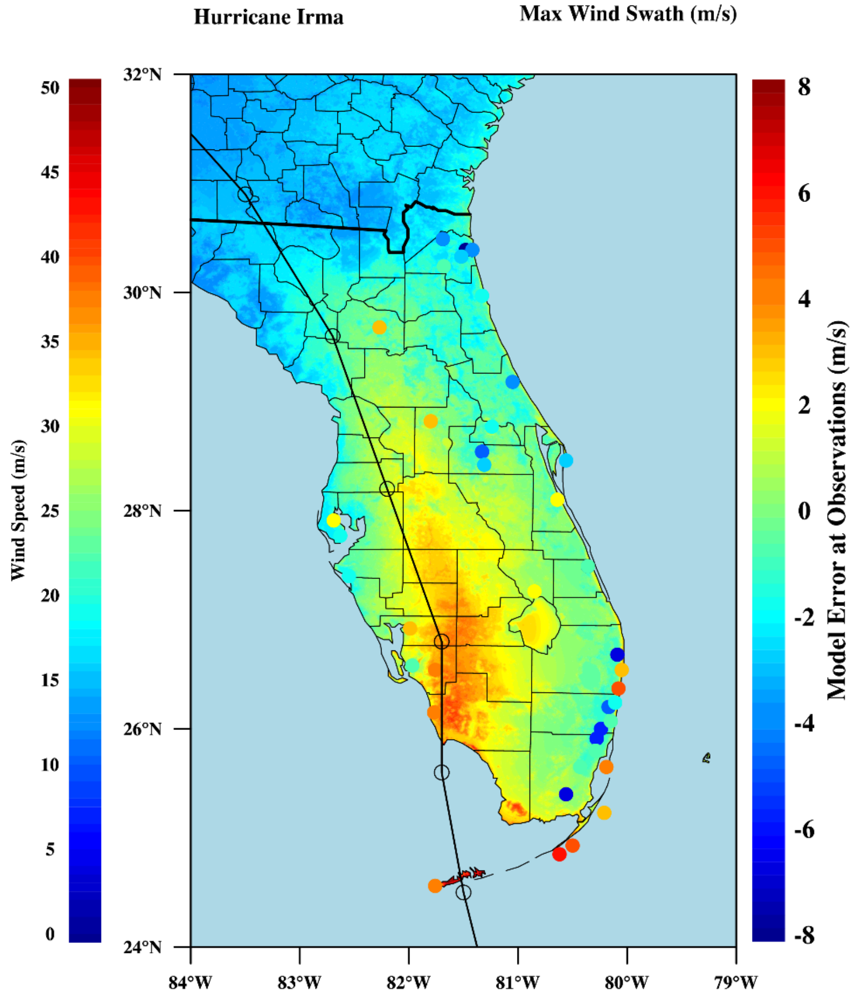


Figure 3.2 Same as Fig 1 but for the case of Hurricane Irma.

3.1.2 Comparisons of HBL simulated wind speed and direction with observations

Figure 3.3 and Figure 3.4 are showing the HBL simulated maximum wind speed distribution for the time 14th September 04H. The HBL simulated maximum wind speed and wind directions are also compared with observed wind speed and directions and shown in Figure 3.3 and Figure 3.4.

The black and white-colored vectors are representing the observed and HBL simulated wind vectors. The colored markers are showing the differences between HBL simulated maximum wind speed and observed maximum wind speed. Comparing the wind vectors between observations and model, we can see that HBL simulated wind directions are closely related to the observed wind direction. The differences between HBL simulated maximum wind speed and observed maximum wind speed at that time also shows a good agreement with differences ranging between -5 m/s to up to 6 m/s.

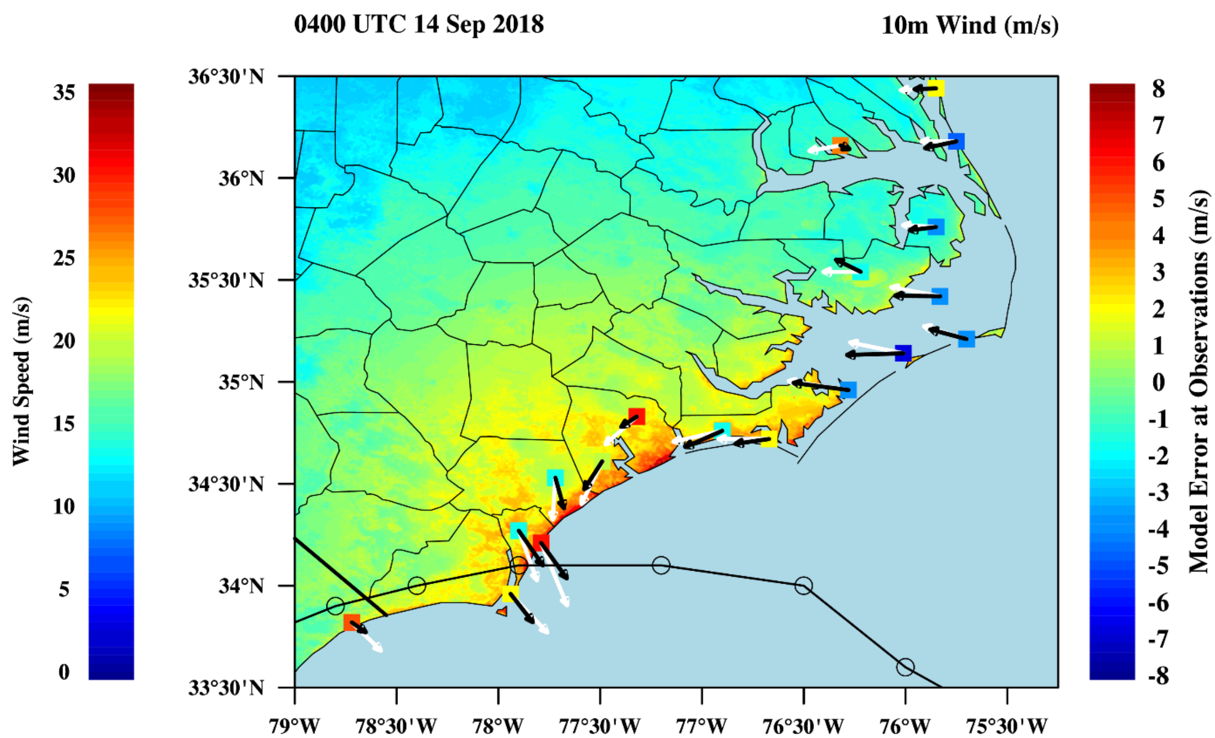


Figure 3.3 A snapshot of HBL simulated wind speed over land before the landfall of Hurricane Florence. The colored markers over land represent the differences in wind speed between HBL simulated wind and observed wind at those locations. Observed and modeled wind vectors are represented by black colored and white-colored vectors, respectively. The color bar on the left-hand side represents the magnitude of HBL simulated wind speed (m/s) and color bar on the right-hand side represents the magnitude of errors (m/s) between model and observations shown as colored markers over land.

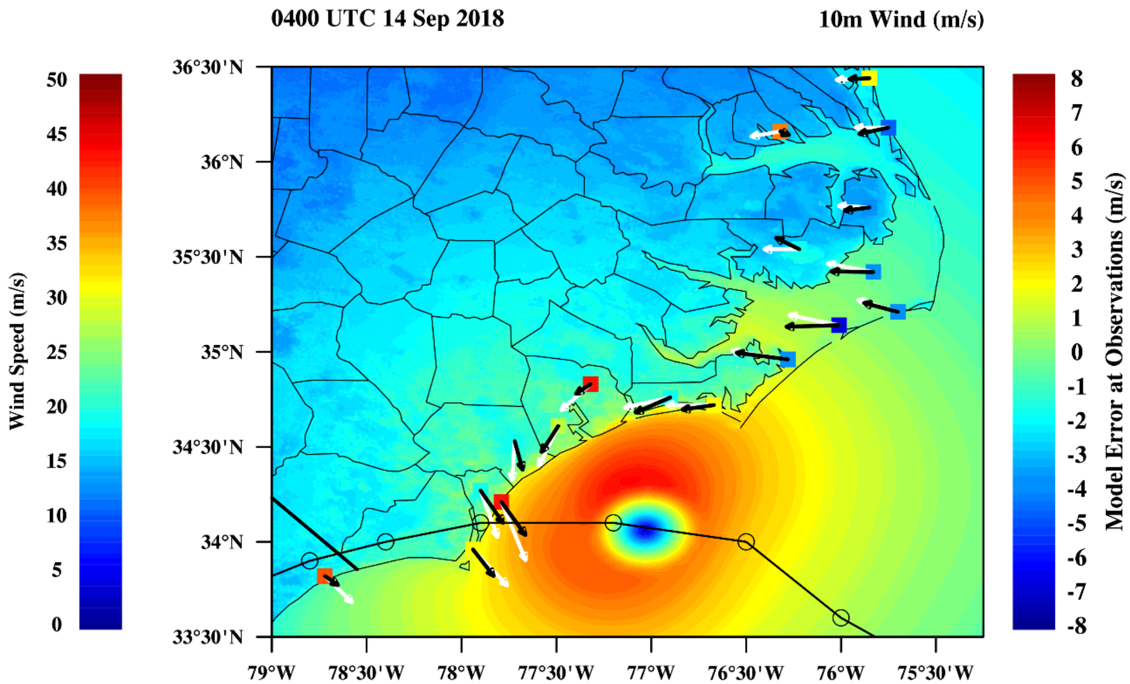


Figure 3.4 Same as Fig 3 but wind speed over both land and ocean are shown here.

3.1.3 Timeseries comparisons of wind speed

Time-series comparisons between HBL simulated wind speed and observed wind speed of Hurricane Florence at four observational stations are shown in Figure 3.5. The lines with blue colored markers represent the observed maximum wind speed, and the lines with red-colored markers represent the HBL simulated maximum wind speed. The calculated Root Mean Squared Error (RMSE) between the model and observations in those four stations is within the range of 3.15 m/s to 5.38 m/s which shows that the HBL simulated wind speed at these locations are in good agreement with the observations.

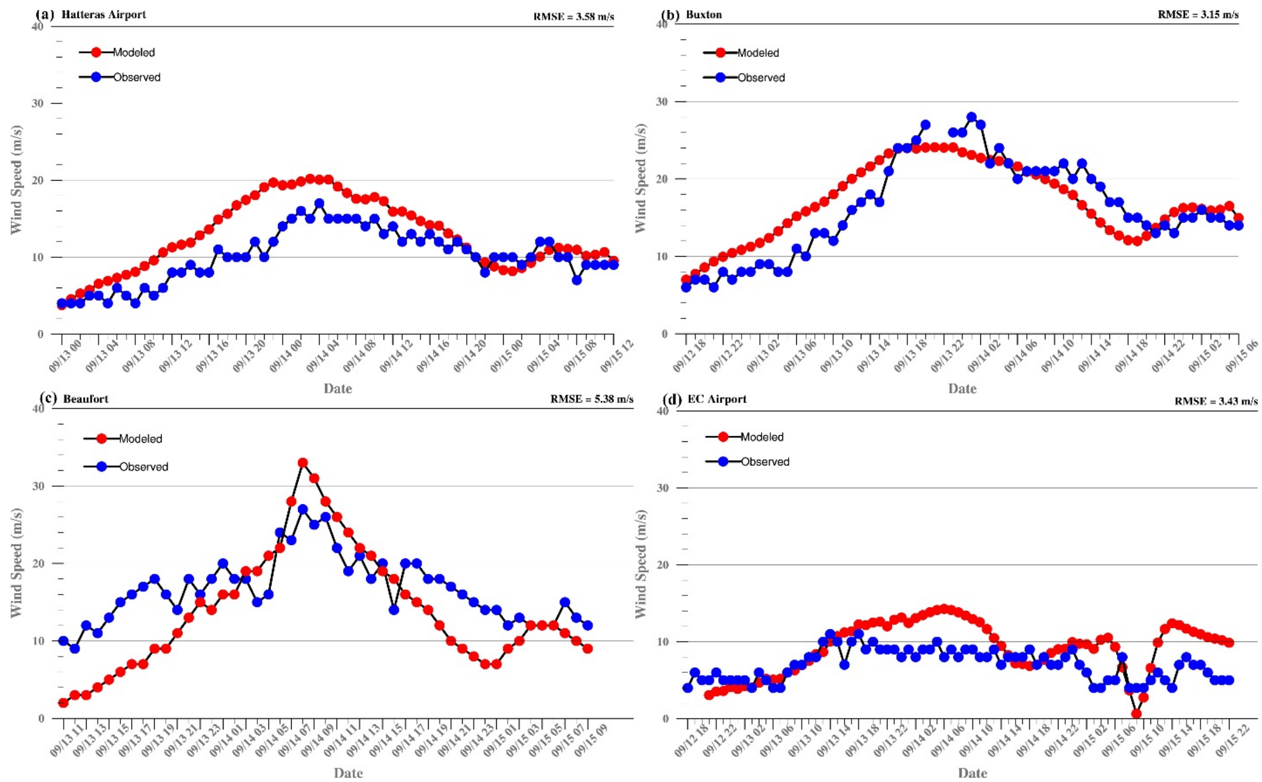
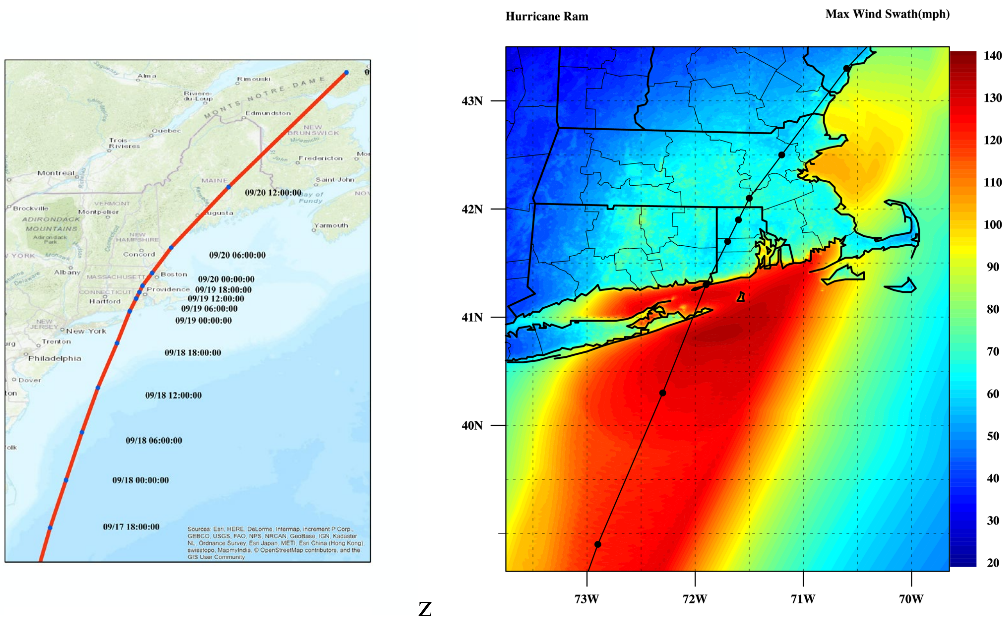


Figure 3.5 Timeseries comparisons of maximum wind speed between HBL simulated wind and observed wind at (a) Hatteras Airport (b) Buxton (c) Beaufort and (d) East Carolina Airport. The lines with red-colored markers represent the HBL simulated wind speed and lines blue colored markers represent observed wind speed.

3.2 Hurricane Ram

Hurricane Ram is a hypothetical, yet plausible hurricane scenario created to simulate the effect of a high-impact storm in Rhode Island. This scenario will allow the state and local agencies to better understand the consequences of coastal and inland hazards associated with extreme high impact landfalling hurricanes and to better prepare the Rhode Island communities for future risks. The Wind and rainfall simulated by the HBL and R-CLIPPER model in this scenario will drive multiple ocean circulation/storm surge prediction models to simulate coastal flooding, and hydrological models to simulate inland flooding. The Hurricane Ram scenario will be used for developing training material and web-based interactive software coupled with the Consequence Threshold (CT) database for RIEMA and other state agencies in Rhode Island (See section 5).

The Hurricane Ram scenario involves a major hurricane that starts near the Bahamas and propagates northward close to the U.S. East Coast. While staying close to the coast (like Hurricane Carol (1954)) it moves more quickly. Ultimately, the storm makes landfall in eastern Long Island and then in Rhode Island, as a strong Cat 3 hurricane causing a significant storm surge in Narragansett Bay and along the south shore of RI (Fig. 3.6). Then, shortly after its landfall, the storm slows down, producing heavy rainfall. The total rainfall reached more than 18 inches in some areas causing massive river flooding in Rhode Island, like Hurricane Diane (1955) and the March 2010 floods (Fig 3.7).



Z

Figure 3.6 Hurricane Ram track (left) and a swath of the maximum wind speed (right).

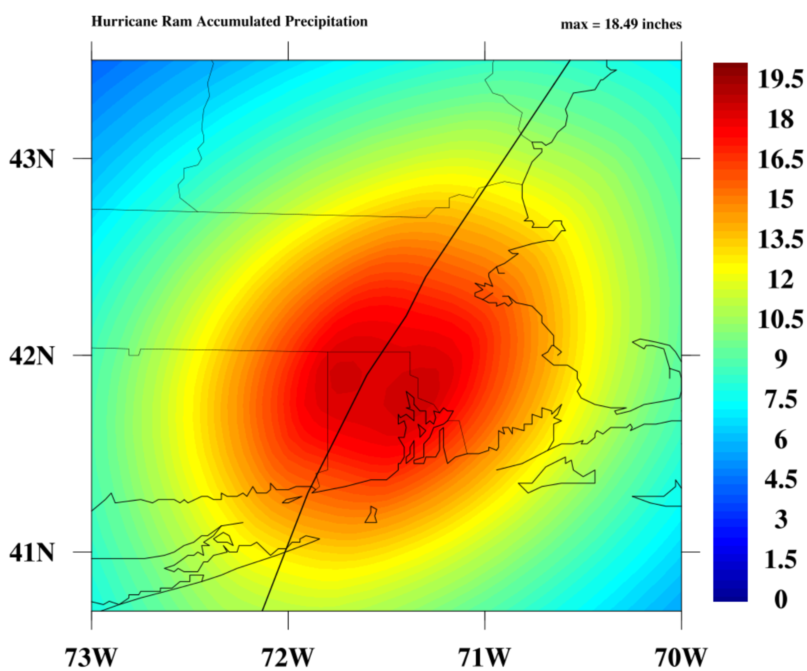


Figure 3.7 Hurricane Ram, total accumulated rainfall from Sep 19, 00:00 UTC - Sep 20, 06:00 UTC (in.) simulated with the R-CLIPER rainfall model.

4. Hydrological Modeling of Rainfall Runoff in Coastal Watersheds in Massachusetts during Hurricanes

(Wenrui Huang, Florida State University)

In Year 5 study, a hydrological model has been applied to Charles, Mystic, and Neponset river watersheds in Massachusetts (Figure 4.1). The Charles River is fed by approximately 80 streams and several major aquifers as it flows 80 miles (129 km), starting at Teresa Road just north of Echo Lake in Hopkinton, passing through 23 cities and towns in eastern Massachusetts before emptying into Boston Harbor (https://en.wikipedia.org/wiki/Charles_River). Thirty-three lakes and ponds and 35 municipalities are entirely or partially part of the Charles River drainage basin. Despite the river's length and relatively large drainage area (308 square miles, 798 km2), its source is only 26 miles (42 km) from its mouth, and the river drops only 350 feet (107 m) from source to sea. The Charles River watershed contains more than 8,000 acres (32 km^2) of protected wetlands, referred to as Natural Valley Storage. These areas are important in preventing downstream flooding and providing natural habitats to native species.

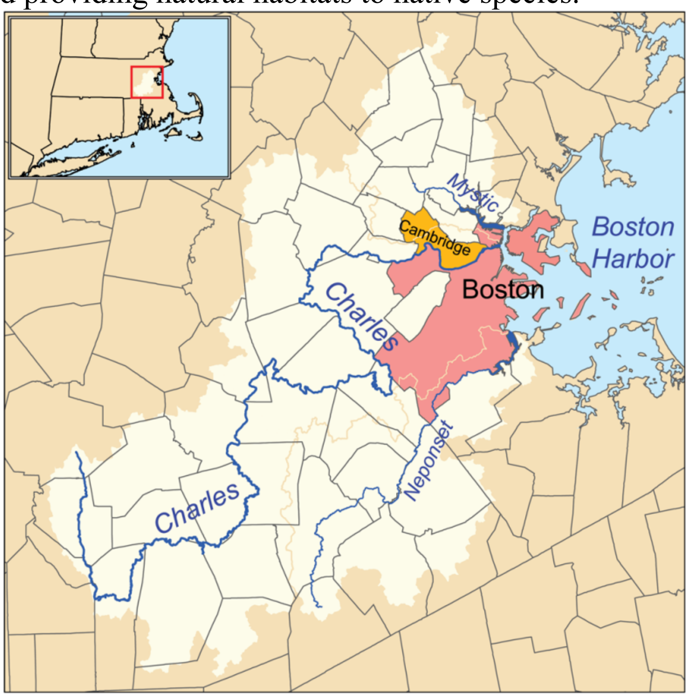


Figure 4.1. Charles, Mystic, and Neponset river watersheds in Massachusetts (https://en.wikipedia.org/wiki/Charles_River)

4.1 PRMS Hydrological Model

The hydrological model, the Precipitation-Runoff Modeling System (PRMS), is a deterministic, distributed-parameter, physical process-based modeling system developed by USGS to evaluate the response of various combinations of climate and land use on stream flow and general watershed hydrology (Markstrom et al., 2015). PRMS's modular design allows users to selectively couple the modules in the module library or even to establish a self-design model. It has been widely applied in the research of rainfall-runoff modeling. It was proved to be a reliable hydrological model. The model simulates the hydrologic processes of a watershed using a series of reservoirs that represent a volume of finite or infinite capacity. Water is collected and stored in each reservoir for simulation of flow, evapotranspiration, and sublimation. Surface runoff, interflow, and groundwater discharge simulate the flow to the drainage network segments, e.g. stream-channel and detention-reservoir. Surface runoff from rainfall is computed using a contributing-area concept. A reservoir routing method is used to compute subsurface flow which is a rapid movement of water from unsaturated zone to stream channel. The groundwater is conceptualized as a linear reservoir and is assumed to be the source of all base flow. Stream flow could be computed directly as the sum of surface runoff, subsurface flow, and groundwater discharge that reaches the stream network. However, a Muskingum flow-routing method computing stream flow to and from individual stream segments is also available in the module. PRMS uses the Muskingum method to calculate the stream flow route. Phase is determined by parameter Kinematic wave coefficient (K_coef) that represents the travel time of flood wave in each segment. PRMS includes climate, plant canopy, impervious-zone interception, surface runoff, subsurface flow, groundwater, streamflow routing, evaporation, and snowpack. Surface runoff is the most outstanding element of streamflow. The most influential elements of surface runoff and infiltration module in PRMS are subbasin area, surface storage depression, impervious area, and type of variable-source area. Subbasin area, impervious area, and type of variable-source area determine the water's transformation from precipitation to surface runoff. Depression parameters provide for water storage during and immediately after precipitation events.

The PRMS model has been successfully applied to some rainfall runoff and snowmelt modeling. Niswonger et al., (2014) applied the PRMS model to an integrated decision support system. Markstrom and Hay (2009) used the model to investigate watershed responses to climate change. Hay et al., (2006) applied PRMS to a snowmelt-dominant watershed. Hay et al., (2000) and Christiansen et al., (2011) evaluated climate change impacts on rainfall runoff by PRMS model simulations. Dressler et al., (2006) conducted an evaluation of snow water equivalent for mountain basin in the PRMS model. Markstrom et al., (2008) integrated PRMS model into a ground and surface water flow model GSFLOW. In these studies, PRMS was applied to perform long-term hydrological process in order to provide supports to the local water resource managements. Yates et al., (2001) applied PRMS in flood forecasting.

The hydrological model networks for sub-basins for Charles, Mystic, and Neponset river watersheds (Figure 4.2), were set up based on the geographic characteristics, precipitations, general situation of runoff stations, and the basin distribution. Basin's geographic characteristics such as DEM, land use, and soil type are obtained from EPA's BASINS model database, a multipurpose environmental analysis system developed by EPA, USA. Basin's geographic information (sub-basin's area, slope, aspect, latitude and elevation), reaches' topological structure (stream length, side slope and longitudinal slope) were calculated by EPA's BASINS.

After the models were setup, model parameters were calibrated by the USGS gage flow at Waltham, MA.

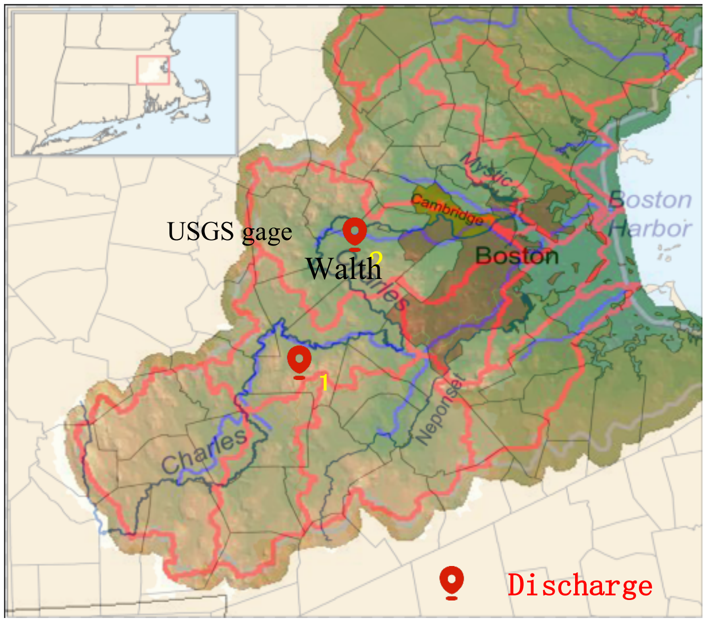


Figure 4.2. hydrological model sub-basins for Charles, Mystic, and Neponset river watersheds.

4.2 Hurricane Diane - August 15-19, 1955

Hurricane Diane was one of three hurricanes to hit the North Carolina coast during the 1955 Atlantic hurricane season (Figure 4.1). The system began as a tropical wave over the Atlantic Ocean, which developed into a tropical depression on August 7, 1955. Moving west-northwest, the depression became Tropical Storm Diane two days later. The storm turned north-northeast on August 11 and quickly developed into a hurricane about 400 miles northeast of San Juan, Puerto Rico. The hurricane reached its peak intensity at Category 3 status on August 12 with 120 mph sustained winds. It remained at Category 3 status for three days until cooler air behind Hurricane Connie, a Category 1 hurricane that struck the Outer Banks of North Carolina on August 12, became entrained in Diane's circulation. As a result, Hurricane Diane weakened to Category 1 strength with winds of 74 mph before making landfall near Wilmington, NC (Figure 2) on August 17, 1955 with estimated pressure at landfall (Figure 4.3) of 986 millibars (29.10 inches). At the time of landfall, Diane had sustained wind speeds of 50 mph, and the only areas that were experiencing hurricane force winds were a few exposed points on the coast between Cape Hatteras and Cape Fear, NC. Diane's landfall occurred just 150 miles southwest from Hurricane Connie's point of landfall near Cape Lookout five days earlier, leaving residents of these areas with little time to prepare due to the close proximity of the two storms https://www.weather.gov/mhx/HurricaneDiane1955.

Hurricane Diane affected the entire East Coast from North Carolina to Massachusetts. More than 100,000 New Englanders lost their jobs, as flooded mills and factories had to shut their doors in Diane's wake (http://www.newenglandhistoricalsociety.com/hurricane-diane-1st-1-billion-hurricane-wallops-new-england-1955/) . The hurricane injured 7,000 New Englanders and killed more than 100 people. It was the first hurricane to cost more than $1 billion in damage. Connecticut got hit the hardest. Near Torrington, Conn., a weather station recorded 16.86 inches of rain within 24 hours, the highest in the state's history.

The 1955 flood was arguably the greatest natural disaster in Massachusetts. This flood caused 12 deaths and damage of about $133 million (http://www.hope1842.com/hhist08-07-15.html). Much of southern Massachusetts, from its border with New York toward Worcester and to the ocean, experienced flooding (https://en.wikipedia.org/wiki/Hurricane_Diane). Most streams in western Massachusetts overflowed their banks, and in southeastern Massachusetts, which is largely flat terrain, streams flooded large areas along their channels; these streams moved slowly, while other areas in New England sustained damage due to the fast-moving nature of the floods. Record flooding was reported along 24 stream gauges in the state, including ones that surpassed the peak set by the 1938 New England hurricane. Both the Charles and Neponset rivers were among those that flooded. About 40% of the city of Worcester was flooded during Diane, and in Russell, the state police forced many residents to evacuate. In Weymouth, the floods were considered at least a 1 in 50 year event. The Little River in Buffumville, Massachusetts had a peak discharge of 8,340 ft^3/s (236 m^3/s), which was 6.2 times greater than the previous peak and 28.5 times the average annual flooding. Flooded rivers breached run-of-the-river dams and covered nearby roadways, although dams with reservoirs resulted in less flooding. Hurricane Diane caused flood in Hopedale, Uxbridge, Northbridge, Millbury, and Milford. As shown in Figure 4, many historical photos of flood during Hurricane Diane in MA can be found in http://www.hope1842.com/hhist08-07-15.html.

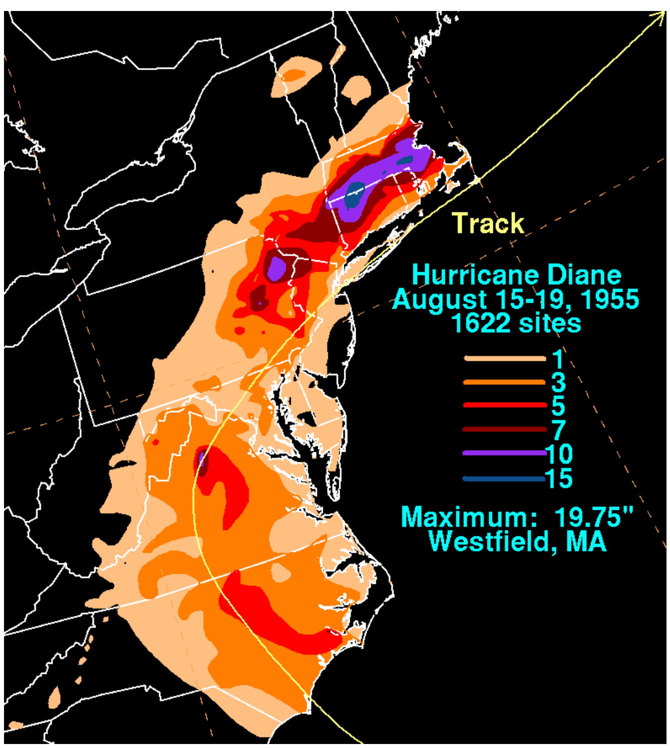


Figure 4.3. Rainfall totals from Hurricane (https://en.wikipedia.org/wiki/Hurricane_Diane)

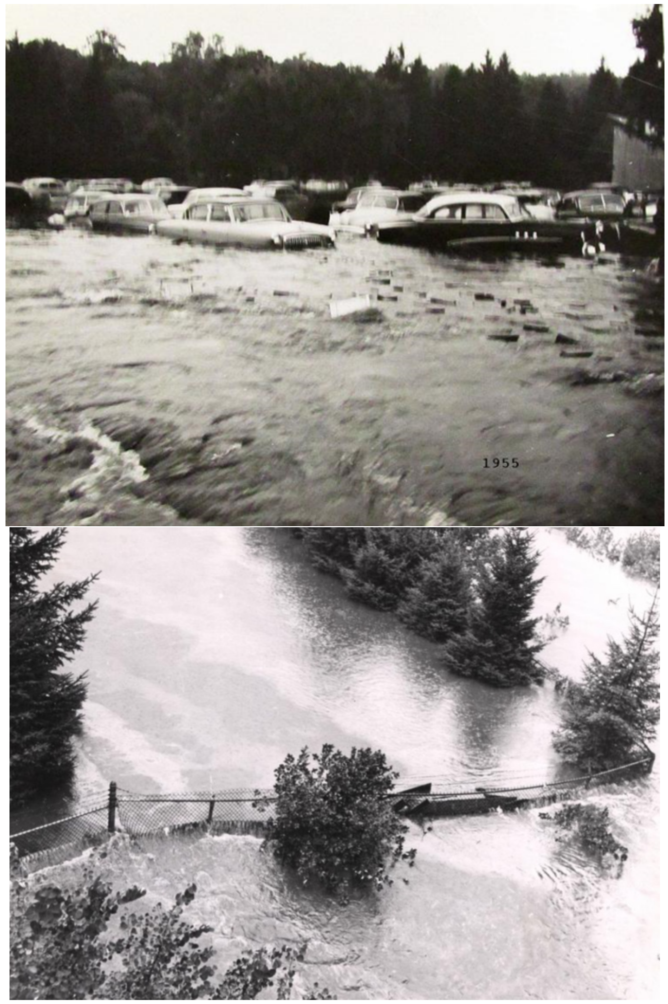


Figure 4.4. Flood in Hopedale (upper photo) and Uxbridge (lower photo), MA, during Hurricane Diane in August 1955 (http://www.hope1842.com/hhist08-07-15.html *)*

4.3 Modeling Rainfall Runoff Induced by Hurricane Diane

Based on the report of "Hurricane Rains and Floods of August 1995: Carolinas to New England" Weather Bureau of U.S. Department of Commerce, rainfalls in New England area are given in Table 4.1 below. It shows that the total rainfall is about 12 inches during August 18-19 in Boston area.

Table 4.1. Rainfall intensity during Hurricane Diane

Location/ Date (August 11-20, 1995)	11	12	13	14	15	16	17	18	19	20
Hartfort airport,CT	0.58	2.04	1.44	0.38	0	0	0.43	8.27	7.70	0
Boston Airport, MA, in	0.04	1.39	0.08	0	0	0	0.93	4.88	7.04	0
Providence Airport, RI, inch	0.04	2.39	0.72	0	0	0	0.94	3.88	3.89	0

By using the rainfall as inputs (Figure 4.5), model calibrations were conducted. Hydrological model parameters were adjusted until the model simulated rainfall runoff matches well with observation at USGS station at Waltham. Major model parameters include: dprst_flow_coef (Coefficient in linear flow routing equation for open surface depressions), sro_to_dprst (Fraction of pervious and impervious surface runoff that flows into surface depressions; the remainder flows to a stream network), smidx_coef (Coefficient in non-linear contributing area algorithm), pref_flow_den (Decimal fraction of the soil zone available for preferential flow), ssr2gw_rate (Linear coefficient in the equation used to compute gravity drainage to PRMS ground-watergroundwater reservoir or MODFLOW finite-difference cell), gwflow_coef (Linear coefficient to route water in ground-watergroundwater reservoir to streams), K_coef (Travel time of flood wave from one segment to the next downstream segment, called the Muskingum storage coefficient). As shown in Figure 4.6, the calibrated model simulations of storm runoff compare well with observations.

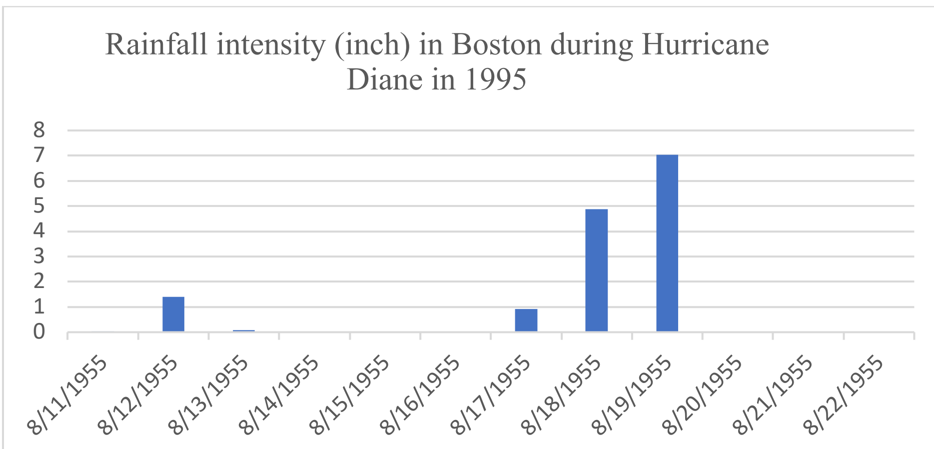


Figure 4.5. Rainfall intensity (inch) in Boston during Hurricane Diane in 1995.

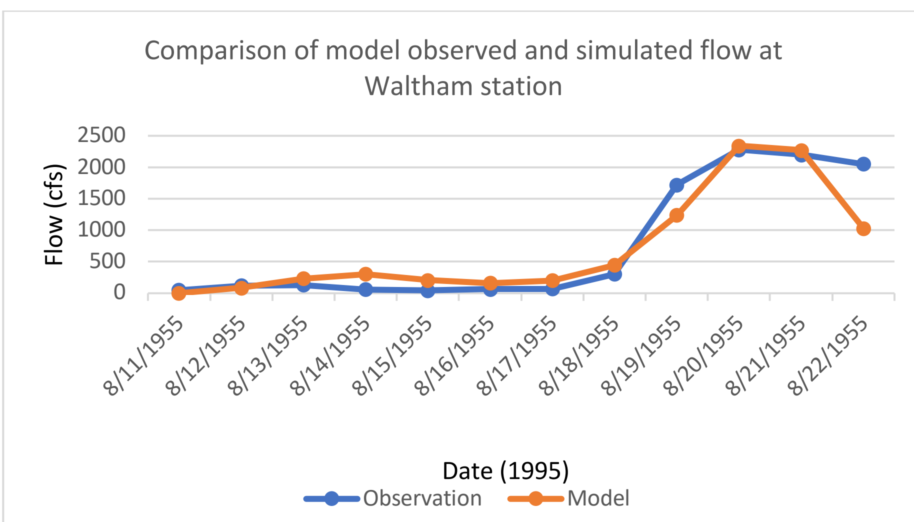


Figure 4.6. Comparison between model simulated rainfall runoff and USGS stream flow at Waltham station.

After satisfactory calibrations of the hydrological model by comparison with stream flow data at Waltham, the model was applied to simulate total rainfall runoff at river mouth for each river during Hurricane Diane. The total storm runoff will be provided to coastal hydrodynamic modelers as river input boundary condition to simulate the interactions between coastal storm tides and rainfall runoff. Total rainfall runoff for each river at the river mouth is given in Figure 4.7. The rainfall runoff at river mouth of Charles, Mystic, and Neoponset River will be used as river inputs coupling coastal hydrological-hydrodynamic modeling of rainfall runoff and storm surges.

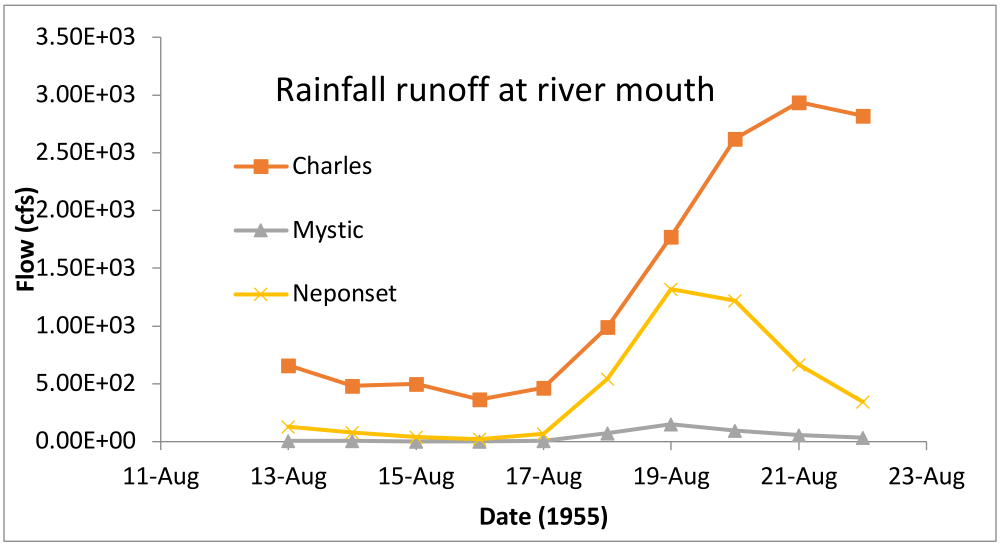


Figure 4.7. Rainfall runoff at river mouth of Charles, Mystic, and Neoponset River.

5. Hazard Consequence Threshold Models for Emergency Management and Response Decision Making

Emergency managers need relevant, local-scale, information about potential consequences of extreme events in *advance* of a storm's landfall. Building upon work completed in Year 1-4, we continued to target Rhode Island Emergency Management Agency (RIEMA) operations, for a real-time hazard and impact prediction system for hurricanes and nor'easters in Southern New England. The system integrates end-user concerns as model inputs into the ADCIRC-Surge Guidance System to provide predictions of cascading consequences of extreme weather impacting critical infrastructure (e.g., waste water treatment facilities, sewer systems, airports, and seaports).

Testimonials from our four Enduser Key Partners
Endusers have given our project an enthusiastic reception and are excited about the potential contribution that our tools can make for emergency response and decision making.

Work to date on this critical modeling and impact analysis tool is incredible. When fully functional, this tool has the potential to transform the very nature of emergency management relating to storm surge and other coastal inundation events. This project, even in its current unfinished state, has introduced capabilities that have long been sought yet remained unfulfilled due to a lack of understanding and belief that such a product could be made. It would be a travesty, and detrimental to the protection of the homeland if this project were to remain unfinished. Future funding for completion of this project is an absolute imperative.
Erik P. Ulmen, PMP, Protective Security Advisor, Rhode Island, US Department of Homeland Security, Cyber and Infrastructure Security Agency (CISA)

URI's Real Time 3-D Storm Impact Modeling will allow Emergency Managers to determine the potential impacts to critical infrastructure. It also will allow states to strategically plan to mitigate those storm impacts.
Tom Guthlein, Director, RI Emergency Management Agency

The predictive models of impacts on critical infrastructure are particularly essential to evaluating and prioritizing infrastructure investments with the goal of preserving and protecting vital lifelines.
Kevin Kugel, Director, Providence Emergency Management Agency

Over the past six months, RIDOH has worked to support the University of Rhode Island's important Hazard Consequence Threshold Modeling project, coordinating with facility operators of healthcare and public health critical infrastructure throughout the State. While work to complete the project is ongoing, RIDOH and its partners in the Healthcare Coalition of Rhode Island have deepened their understanding of the hazards and consequences that face this infrastructure. RIDOH and its partners are eager to continue participation in this project and to explore ways to leverage the data collected in support of Rhode Island's healthcare system.
Nicholas Larmore, Center for Emergency Preparedness and Response, RI Dept. of Health

emergency managers as they allocate resources and anticipate the challenges of an imminent storm at the Emergency Operations Center (EOC). Our approach allows critical facility managers' expertise about impacts to be integrated in model outputs in the same way that "damage functions" are traditionally utilized to model potential structural damages. By identifying wind/surge/flooding thresholds for critical infrastructure failure, the identified concerns may be directly linked to the storm prediction models. Our project developed a methodology for collecting meaningful data regarding local and regional consequences of infrastructure damage, at the site-specific scale, and integrating these data with real-time predictive storm models already in use at EOCs around the country.

Our pilot study conducted in Providence identified 321 "consequence thresholds" collected from managers of 45 critical infrastructure facilities located along the City's 500-year floodplain. Our approach addresses the challenges inherent in collection and dissemination of Protected Critical Infrastructure Information (PCII) data by partnering with critical lifeline sector leads, utilizing DHS PCII protocols, and leveraging existing technology in use at EOCs.

5.1 Consequence Threshold Data Collection Methodology

Study Area

Situated at the confluence of the Woonasquatucket and Moshassuck Rivers, Providence, Rhode Island’s capital city, Providence, hosts a significant portion of the state’s population and critical infrastructure, including nearly half of the state’s hospitals and the Port of Providence, designating it as an important study site for storm risk in Rhode Island. We defined the study area (Figure 5.2) in Providence using the Federal Emergency Management Agency (FEMA) Flood Zones plus a 100 meter buffer.

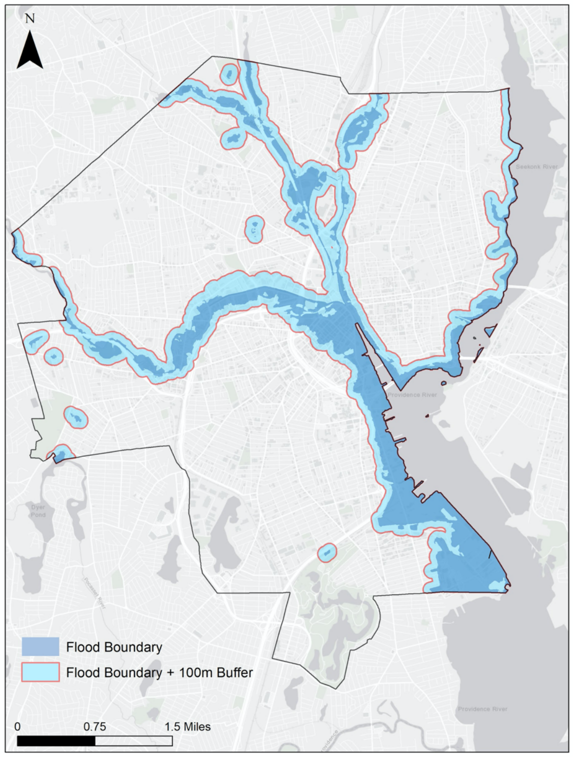


Figure 5.5 - Map of study area. Red line defines flood boundary and 100 meter buffer.

The flood boundary delineated for the Providence study consisted of the following FEMA flood zones:

- AE, Floodway
- AE, 1% Annual Chance Flood (100–year floodplain)
- AH, 1 % Chance Shallow Flooding (1–3 feet)
- VE, 1 % Annual Chance Flood Event due to storm-induced velocity wave action
- X, 0.2% Annual Chance Flood
- X, Area with Reduced Flood Due to Risk to Levee
- 100 meter buffer

I.Sampling approach

We collected CTs from FMs representing 10 critical infrastructure (CI) sectors as defined by the Department of Homeland Security (**Table 1**). These sectors included:

1. Emergency
2. Energy

3. Food, Water & Shelter
4. Government
5. Health & Medical
6. Port of Providence & Hurricane Barrier
7. Security
8. Transportation
9. University
10. Water &Wastewater

Table 5.1 - Participating facilities grouped by sector. Those with an asterisk (*) were contacted but either declined to participate in the study or were unresponsive to correspondence

Lifeline Sector	Facility
Emergency	Providence Firehouse
Energy	National Grid*
	Manchester Street Power Station*
	Starwood Energy Group*
Food	Al-Jacs Produce Inc.*
	American Food, Paper, and Poultry Co.*
	Portion Meats Associates Inc.*
	Price Rite Supermarket*
	Quality Food Company, Inc.*
	Save A Lot*
	St. Edward Food and Wellness Center*
	Super Stop & Shop Nos. 722 and 725*
	Walmart No. 3301*
Government	Licht Judicial Complex
	Providence City Hall
	Rhode Island Department of Public Works
	Department of Children, Youth, and Families
	Rhode Island Department of Health Capital Building
	Garrahy Judicial Complex
	Rhode Island Department of State
Health & Medical	Rhode Island Blood Center
	Rhode Island Department of Health Office of State Medical Examiner
	Charlesgate Nursing Center*
	Davinci Center for Community Progress*
	Providence Community Health Center at Chafee
Port of Providence & Hurricane Barrier	Hudson Asphalt
	Lafarge Holcim Cement
	ProvPort
	Schnitzer Northeast
	Fox Point Hurricane Barrier

	Sea-3 Terminal
Security	Rhode Island Fusion Center
	Providence Police Department
Transportation	Kennedy Plaza
University	University of Rhode Island Providence Campus
	Johnson & Wales Harborside Campus
	Brown University
	Rhode Island School of Design
	Johnson & Wales Providence Campus
Water & Wastewater	Fields Point Wastewater Treatment Facility

Critical infrastructure facilities were selected in consultation with the steering committee and through using the Providence Multi-Hazard Mitigation Plan and publicly available data from the Rhode Island Geographic Information System (RIGIS). Spatial data for Emergency Medical Services, Colleges and Universities, State Facilities, Fire Stations, Hospitals, and Law Enforcement were obtained from RIGIS and critical infrastructure within the study area were identified using geographic information systems (ArcMap, Version 10.5). Through a focus group, the steering committee helped researchers review and assign levels of importance for each facility (i.e., 1 = Most Important, 2 = Important, 3 = Least Important) and identified additional facilities that were not identified on the map provided during the workshop. Level 1 facilities were considered high priority to the EM community and were included in the interview process. Level 2 facilities were considered important, but not of high priority. Level 3 facilities were not engaged in the interview process. Spatial data for identified critical infrastructure were stored in a relational database.

End User Focus

The project engages key end-users in the development and dissemination of the tools to make them more relevant and usable for planning and response.

Federal partners: FEMA Region 1, US Coast Guard, NOAA National Weather Service (NWS) Northeast, Department of Homeland Security Science and Technology.

State and municipal partners: Emergency responders, facility managers and other critical decision-makers.
We partnered with the Rhode Island Emergency Management Agency (RIEMA), Rhode Island Department of Health (RIDOH), and Providence Emergency Management Agency (PEMA) to form a steering committee (Table 5.2) consisting of local and state partners. The steering committee members served as points of contact for key informant identification at each CI sector facility. Steering committee members were assigned to a sector so that they could subsequently aid the research team with identifying critical infrastructure points of contacts, and provide guidance and advisement throughout the course of the pilot project.

Table 5.2 - Steering committee members (Providence study)

Name	Organization	Title	Role

Tom Guthlein, Mike Previty, Christine Willett	Rhode Island Emergency Management Agency (RIEMA)	Operations Section Chief, Crisis Information Management, Software Coordinator, Critical Infrastructure/Key Resources Coordinator	Key partner
Alysia Mihalakos, Phil Sheridan, Nick Larmore	Rhode Island Dept of Health (RODOH)	Chief of Center for Emergency Preparedness and Response (CEPR), Deputy Chief (CEPR), and Response, Program Support Specialist	Key partner
Kevin Kugle and Clara Decerbo	Providence Emergency Management Agency (PEMA)	Director and Deputy Director	Key partner
Erik Ulman	Department of Homeland Security (DHS)	Protective Security Advisor, RI District, DHS Cyber Security and Infrastructure Security Agency	Key partner
Al Buco	Providence Department of Public Property	Public Property Coordinator	Steering committee, provide data, test results
Bill Patenaude	Rhode Island Dept. of Environmental Management (RIDEM) Office of Water Resources	Principal Engineer	Steering committee, provide data, test results
Dave Bowen	Narragansett Bay Commission	Engineering Manager	Steering committee, provide data, test results
Kevin Blount	US Coast Guard	Marine Transportation Recovery Specialist, Sector Southeast New England	Steering committee, provide data, test results
Marisa Albanese	North East National Grid	Senior Coordinator/Community Investment & Economic Development	Steering committee, provide data, test results
Peter LePage	Providence Water Supply Board	Director of Engineering	Steering committee, provide data, test results

Shaun O'Rourke	RI Infrastructure Bank	RI Chief Resilience Officer; Director, Stormwater and Resilience	Steering committee, provide data, test results
John McCoy	City of Providence	Division of Capital Asset Management & Maintenance	Steering committee, provide data, test results

Interviewing and Consequence Threshold Data Collection
Working with the steering committee, critical infrastructure managers from the identified facilities (Table 5.3) were invited via email or phone to attend a focus group interview at the Providence Emergency Management Agency. Due to the number of facilities identified, focus group interviews were conducted to engage with managers across all sectors. Prior to the interviews, attendees were asked to review and sign NDAs and IRB Consent Forms for Research to ensure confidentiality of all disclosed PCII (see "Data Security and Confidentiality" section above). The University of Rhode Island Institutional Review Board (IRB) reviewed and approved all methodologies and procedures for conducting four focus groups interviews with identified facility and emergency managers.

Interview Process
Collecting CT data requires conversation between FMs and researchers, especially when collecting complete data that accurately reflects the concerns provided by FMs. To collect useful information, the interviewing process adhered to the data collection process shown in Figure 5.3. Collecting consequence data began by asking FMs to inventory critical assets at their facility. To prompt FMs to identify critical assets, researchers would ask questions such as, "What assets at your facility would keep you up at night if damaged during a storm?". In most cases, this question was enough to get FMs to identify several at risk assets at their facility. FMs were asked to place the location of the asset on the map and provide the hazard (e.g. flooding) and hazard threshold (e.g. 6 inches) that would cause the consequence (e.g. flooding damages generator and power is lost) to occur. Once each consequence was inventoried, the CT was complete.

Focus Group Interviews
Focus group attendees were provided with a background on storm impact models, impacts of historic storms in Providence, and results generated from a pilot study in Westerly, Rhode Island (Witkop et al., 2019). The procedures of gaining participant consent and articulating the relevance of the study allowed researchers to facilitate a level of comfort and understanding amongst the FMs that would be integral to their participation. Attendees were then asked to identify the hazard threshold and consequences for an asset at their facility. Using one of the assets identified, researchers guided attendees through an example of how to properly input their CT data.

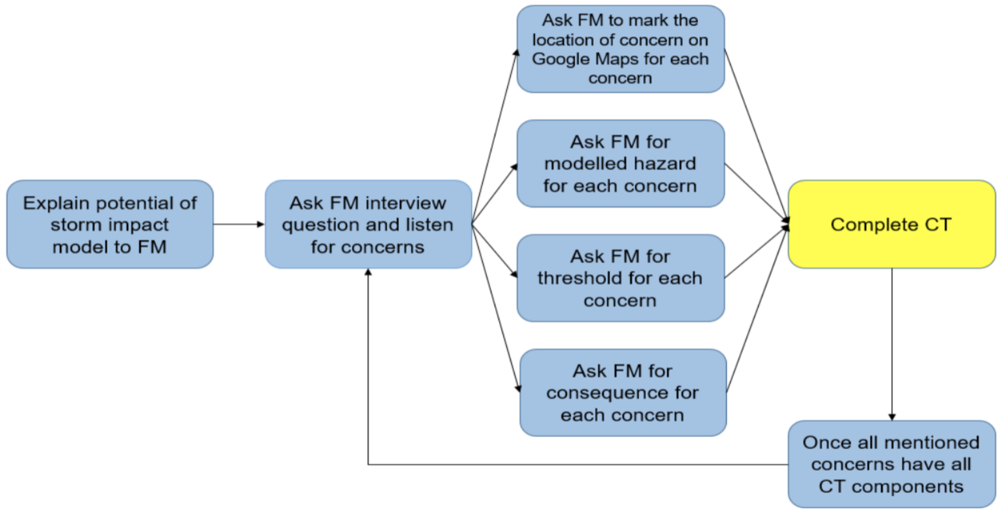


Figure 5.6 - A framework for collecting Consequence Threshold data from facility managers (Witkop et al., 2019)

Individual Interviews/Site Visits

In some cases, FMs were unable to provide the information during the focus group interview exercises due to their role at the facility. In addition to focus group interviews, researchers held individual interviews with participants that were unable to attend the focus group sessions or with previous focus group participants to collect additional CT information for facilities. Groups of two or three researchers conducted individual interviews at the participant's facility, where the participant could provide researchers with a tour of the facility's critical infrastructure. Interviews were semi-structured, and lasted approximately one hour. During the course of the interview process, researchers recorded PCII data on a CT Data Collection Sheet (see following section).

Table 5.3 - Respondent titles grouped by interview type.

Respondent Title	Interview Type (Focus Group, In Person/Phone, or Site Visit) or Did Not Interview
Assistant Canal Manager	
Battalion Chief	
Deputy Director	
Director of Elections	
Director of Emergency Management Services	
Director of Public Property and Capital Improvement	

Emergency Management Director	Focus Group
Local Government Records Coordinator	
Officer	
Operations Manager	
Program Support Specialist	
Programming Services Officer	
Project Manager	
Senior Intelligence Analyst	
Terminal Manager	
Director of Emergency Management	In Person
Director of Public Property and Capital Improvement	
Facilities Director	
Risk and Emergency Manager	
Associate VP, Center Operations at PCHC	Individual Interview (in person? On phone?)
Administrative Director	Site Visit
Operations Manager	
Regional Environmental Manager	
Senior Terminal Manager	
V.P of Terminal Operations	Site Visit & Focus Group

II.Consequence Threshold Data Description

CTs are comprised of the following data:

1. **Asset of concern:** An asset directly impacted by waves, wind, flooding, or surge

2. **Sensitivity[4] of asset:**

[4] Sensitivity levels were changed after a data validation meeting with steering committee members. Feedback from 5 experts from RIEMA and RIDOH suggested the sensitivity classification scheme needed to be changed to broaden access to level 2 data. Previously, security levels were defined as: Level 0 - Classified and available only to reporting facility

Level 1: Classified and available only to reporting facility
Level 2: Classified and available only to PEMA/RIEMA community
Level 3: Not sensitive, publicly available

3. **Geographic location of asset**: The latitude and longitude of the asset (X, Y)

4. **Hazard:** The storm hazard (wind, flooding, wave, or surge)

5. **Hazard Threshold:** The force threshold that the stakeholder perceives as a risk to the asset, can be quantified such as inundation depth or wind velocity, is modellable (wind, wave, surge, flooding).

6. **Consequence(s):** The outcome(s) if the storm force exceeds the threshold at the location of concern

7. **Recovery period:** The length of time needed for asset functionality to be restored
a. Short term - up to one week
b. Medium term - weeks or months
c. Long term - months or years

Data Security and Confidentiality
CT data contains protected critical infrastructure information (PCII), the collection of which is complicated by security threats and the sensitivity of information. This required researchers to adhere to various data security and confidentiality protocols as outlined on the Department of Homeland Security (DHS) PCII program website. Prior to data collection, all researchers completed the authorized user certification on the DHS PCII program website and signed non-disclosure agreements (NDAs). PCII data were collected and stored using PCII data handling protocols.

Transferring of PCII Information
PCII data were intermittently exchanged between researchers over a non-secured email channel for editing and conditioning purposes. Compliant with PCII protocol, email attachments containing PCII data were password-protected and passwords were provided in separate emails.

III. Incorporating Consequence Data into Storm Impacts Models

1. Data Conditioning
CTs collected were stored in a Microsoft Excel Spreadsheet and were conditioned for input into a numerical storm model. Data conditioning included the removal of all commas in string data, removal of space in column names, and removal of text in cells with numeric data. Whenever possible, syntax used for CT description was made consistent and hazard unit notations were standardized (e.g., Flooding(FT) vs. Flooding (FT)) Finally, all depth hazard thresholds (e.g., 1

Level 0 - Classified and available only to reporting facility
Level 1 - Classified and available only to reporting facility and critical infrastructure lead sector agency
Level 2 - Sensitive and available only to PEMA/RIEMA community
Level 3 - Not sensitive, publicly available

foot of flooding) were converted to meters and velocity thresholds (e.g., 70 mph winds) were converted to meters/second.

2. Data Validation

Following data conditioning, researchers emailed participants to provide feedback on the data they initially provided researchers. In compliance with PCII protocol, researchers encrypted an excel spreadsheet that contained data for each participant's facility, a map of their facility with assets, and a data dictionary for them to reference. If the participants didn't respond by the deadline, it was assumed that they were satisfied with the data collected.

5.2 Results

I.Interviews

1. Focus Group Interviews

We hosted four focus group interviews, three of which were hosted at PEMA and one at ProvPort for the Port of Providence Tenants. 19 FMs among all of the CI sectors were in attendance for the focus group interviews. 134 CTs were collected from the four focus group sessions as shown in Table 5.4.

2. Individual Interviews & Site Visits

187 CTs were collected during individual interviews and site visits. We decided to group these together as many of the individual interviews were hosted at the participants facility and were followed by a tour of the site to collect CTs. In total, we individually interviewed 6 FMs and visited 5 FMs facilities. In addition to interviews in which CTs were collected, we conducted site visits and individual interviews at additional facilities. However, after reviewing the NDA, they were unable to participate in this study.

II. Assets of Concern

We were able to collect location data for all of the 137 assets identified of concern as a point on a map. Many of the assets identified had cascading consequences, with one point on a map representing multiple consequences. The most common assets that were identified of concern at the facilities we interviewed included entrances to buildings, generators, and HVAC systems.

III. Consequence Thresholds

We collected a total of 321 consequence thresholds from 25 facility managers representing 33 critical infrastructure facilities in Providence. A majority of the consequence thresholds collected were from the Port of Providence and Fox Point Hurricane Barrier, Water and Wastewater, and Health and Medical.

IV. Hazard Type & Threshold

Of the 321 CTs we collected, 274 were triggered by flooding, 36% were triggered by wind, and the remaining 6 were triggered by storm surge (Figure 5.4). We did not collect any consequences for wave hazards due to the upriver setting of the study area. For some of the hazards collected, we asked the FMs to make an approximate guess at the hazard level that would trigger their concerns. For consequences collected during site visits, we were able to inspect the asset of concern and estimate the hazard level that would trigger the concern. For example, a facility manager identified 6” flooding as the hazard threshold that would damage a generator at their facility. Upon further inspection, we noted that the generator was on a 2” concrete slab and we adjusted the hazard threshold to trigger the concern when flooding reached 8” at the asset location. In some cases, we were able to use the design thresholds of assets as the hazard threshold. For example, a facility manager was concerned about several wind turbines at their facility being impacted by wind during a major storm but were unsure of the hazard threshold. In this situation, we used the design threshold for the winds turbines as the hazard threshold.

V. Sensitivity Level

239 of the consequences were Level 2, 64 were Level 3, and 18 were Level 1.

VI. Recovery Period

163 of the consequences had a medium-term recovery period, 129 had a short term recovery period, and 29 had a long term

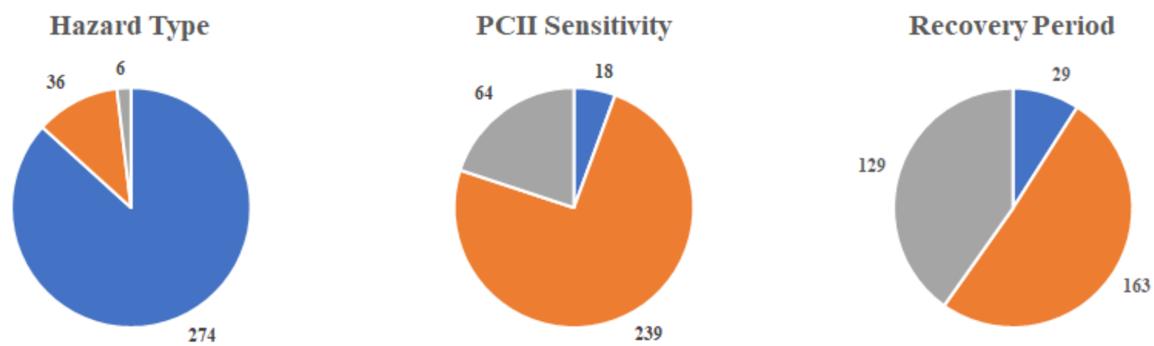


Figure 5.7 - Number of consequence thresholds collected by hazard type, PCII Sensitivity, and recovery period collected during Year 5.

Table 5.4 - Interactions with end-users in Year 5

Date	Type of Interaction	Study Participant(s)	Infrastructure Sector	Facility Studied	Researcher(s)
12/18/2019	FEMA briefing for FEMA Region 1	Dan McElhinney, Federal Preparedness Coordinator; Kerry Bogdan, Risk Analysis Branch Chief; Nathan Spad, Preparedness Branch Chief; Ryan Jones, FEMA Integration Team Lead; Paul Morey, Hurricane & Earthquake Program Manager; Arlene Magoo, Community Preparedness Officer; Sara Varela, Regional Preparedness Liaison	Other	N/A	Austin, Pam, Isaac, Sam Adams
07/11/2019	Focus Group	Cindy Vanner; Nick Larmore	Health & Medical	RIDOH	Austin Becker; Isaac Ginis; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
07/29/2019	Focus Group	Joe Mollis; Shaun Mitchell; Clara Decerbo; John Soscia; Matthew Mulligan; Sam Adams; Stephen Morin, Hana Haskell, Stephen Morin	Cross Sector	Providence Police, PEMA, RIDOH, PVD Fire, RI Courts, Brown University, URI	Austin Becker; Isaac Ginis; Pam Rubinoff; Noah

					Hallisey; Joyce Pak; Sam Radov
08/06/2019	Focus Group	Rob Rock; Tracey Croce; John Macpherson, David Polatty, Ben Davies, Kevin Blount	Cross Sector	Providence City Hall, RI State Archives, USACE, US Naval War College, RI Dept. of State, USCG	Austin Becker; Isaac Ginis; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
08/07/2019	Focus Group	Pamela Leary, Marissa Albanese, Julia Gold, Christine Willet	Cross Sector	National Grid, RIDOT, DI DCYF, RIEMA	Austin Becker; Isaac Ginis; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
08/26/2019	Focus Group	Kevin Blount; Michal Turbitt; Bill Kastin; Barry Nuggent; Chris Hunter; Keri Fitzpatrick; Dennis Leamy; Jeff Halliday; Steve Curtis	Port of Providence & Hurricane Barrier	USCG, Univar, Holcem Cement, PVD Working Waterfront Alliance, Schnitzer Steel, Hudson Terminals, Lehigh Cement, URI, ProvPort,	Austin Becker; Isaac Ginis; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
08/05/2019	Individual Interview	Ralph Chartier, Darlene Foley	Heath & Medical	Providence Community Health Center Chafee	Joyce Pak, Austin Becker
08/09/2019	Individual Interview	Michael Borg	Government	Department of Public Property & Capital	Noah Hallisey
08/09/2019	Individual Interview	Michael Borg	Government	City of Providence	Noah Hallisey
08/15/2019	Individual Interview	Christopher Harwood	University	Johnson & Wales University	Joyce Pak; Noah Hallisey
08/26/2019	Individual Interview	Keri Fitzpatrick	Port of Providence & Hurricane Barrier	Schnitzer Northeast	Noah Hallisey; Ellis Kalaidjian
8/29/2019	Individual Interview	David Marble	Government	OSHEAN, Inc	Noah Hallisey
09/04/2019	Individual Interview	Jeffery Anderson, Chris O'Connell, Henry Reis	Energy	Manchester Street Power Station	Austin Becker, Noah Hallisey, Sam Radov
10/16/2019	Individual Interview	Jennifer Howley	University	Rhode Island School of Design	Joyce Pak
10/09/2019	Indivudal Interview	Carlos Padilla	Transportation	Federal Highway Association	Noah Hallisey, Sam Radov
08/05/2019	Site Visit	Manuel Miguel	Health & Medical	Rhode Island Blood Center	Joyce Pak, Austin Becker
08/26/2019	Site Visit	Dennis Leamy	Port of Providence & Hurricane Barrier	Providence City Hall	Noah Hallisey; Ellis Kalaidjian
09/05/2019	Site Visit	William Bombard, Antonio Morabito	Port of Providence & Hurricane Barrier	Providence Public Works	Sam Radov, Austin Becker
09/26/2019	Site Visit	Bill Kastin	Port of Providence & Hurricane Barrier	Larfarge-Holcim Cement	Noah Hallisey; Ellis Kalaidjian
9/30/2019	Site Visit	Paul Desroiser	Port of Providence & Hurricane Barrier	Fields Point Wastewater Treatment Facility	Noah Hallisey; Pam Rubinoff
10/04/2019	Site Visit	Keri Fitzpatrick	Port of Providence & Hurricane Barrier	Schnitzer Northeast	Noah Hallisey; Ellis Kalaidjian
10/07/2019	Site Visit	Jennifer Howley	University	RISD	Joyce Pak
10/11/2019	Site Visit	Nancy Cicogna	Health & Medical	Apple Rehab	Joyce Pak

08/10/2019	Site Visit	Stephen Morin	University	Brown University	Joyce Pak
05/20/2019	Stakeholder kickoff meeting	Various	Cross Sector	N/A	Austin Becker; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
05/07/2019	Steering Committee Meeting	Phil, Nick, Christine Willet (others)	Cross Sector	N/A	Austin Becker; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
06/21/2019	Steering Committee Meeting	Tom, Phil, Alysia, Nick	Cross Sector	N/A	Austin Becker; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
09/13/2019	Steering Committee Meeting	Nick Larmore; Clara Decerbo; Bill Previty, Christine Willet	Cross Sector	N/A	Austin Becker; Isaac Ginis; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
11/22/2019	Steering Committee Meeting	Nick Larmore, Alysia, Jay Metzger	Cross Sector	N/A	Austin, Joyce
12/10/2019	Steering Committee Meeting	Eric Ulman, Mike Previty, Christine Willet	Cross Sector	N/A	Austin, Pam
05/15/2019	Technical Committee (RIEMA)	Tom, Armand, Ryan Jones (FEMA/RIEMA Integration Team)	Technical Committee (RIEMA)	N/A	Austin Becker; Pam Rubinoff; Noah Hallisey; Joyce Pak; Sam Radov
08/30/2019	Technical Committee (RIEMA)	Mike Previty	Technical Committee (RIEMA)	N/A	Austin, Pam, Peter, Isaac
11/21/2019	Technical Committee (RIEMA)	Christine Willet, Eric Ulman, Joe Dwyer	Technical Committee (RIEMA)	N/A	Austin Becker
12/02/2019	Technical Committee (RIEMA)	Tom Guthlein, Christine Wilet,	Technical Committee (RIEMA)	N/A	Austin Becker, Pam, Jason Flemming
01/21/2020	Technical Committee (RIEMA)	Chris Damon, Chuck LaBash, Mike Previty, Joe Dwyer, Peter Stempel	Technical Committee (RIEMA)	N/A	Austin, Pam
02/10/2020	Technical Committee (RIEMA)	Shane White, Mike Previty, Joe Dwyer	Technical Committee (RIEMA)	N/A	Austin, Pam, Sam Adams, Chuck Labash, Chris Damon

5.3. Hazard Consequence Database Development

I. *Leveraging Partnerships and Resource Among State Agencies*

We developed a hazard consequence database using an underlying secure database structure that provided an interface between the Environmental Systems Research Institute (ESRI) ArcGIS Enterprise GIS system used in EOCS and storm model outputs at the University of North Carolina or elsewhere (e.g., ADCIRC). The State of Rhode Island has invested in the

ArcGIS Enterprise system and currently maintains an active site that is utilized by all major agencies including RIEMA.

II. EOC Hazard Viewer Prototype

We partnered with the University of Rhode Island Environmental Data (EDC) center to develop the EOC Hazard Viewer Prototype using ArcGIS Dashboard Operations, a product offered as part of the Rhode Island ArcGIS Enterprise System. The EDC is a Geographic Information System (GIS) and spatial data analysis laboratory in the University of Rhode Island Department of Natural Resources Science, College of the Environment and Life Sciences (CELS). Since 1985, the EDC has been a center of expertise in GIS for the state of Rhode, including maintaining Rhode Island's geospatial data catalog. This partnership developed a real-time storm hazard interface with existing software platforms in use at RIEMA. The Emergency Operations Center (EOC) Forecast Viewer, as shown in Figures 5.5 & 5.6, contains an interactive display of Providence inundation and assets of concern collected during Year 5 activities. Using scenario-based storm events or real-time ADICRC outputs, the platform filters the attributes in the consequence database as a storm event advances to display the consequences triggered throughout the duration of a storm event.

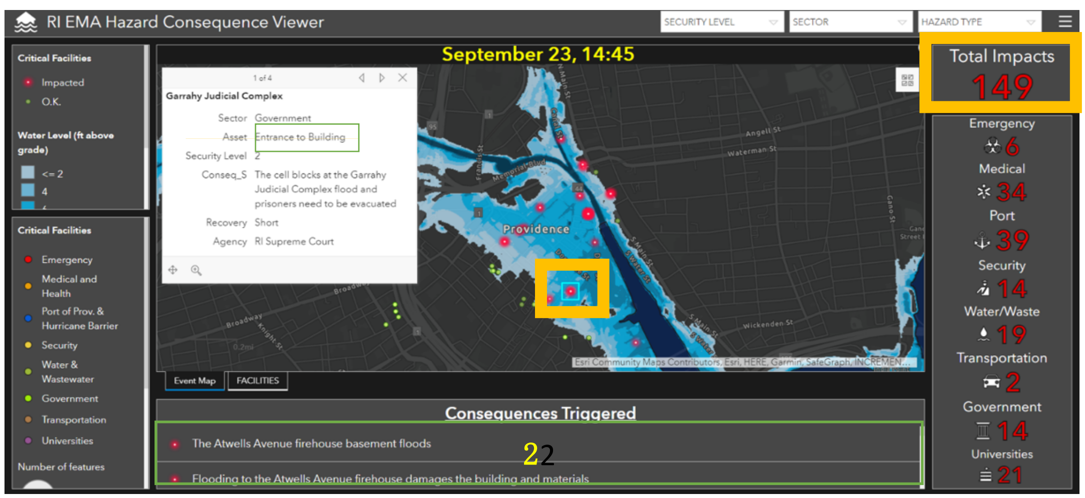


Figure 5.8 - EOC Forecast View Protype at Time Step 2.

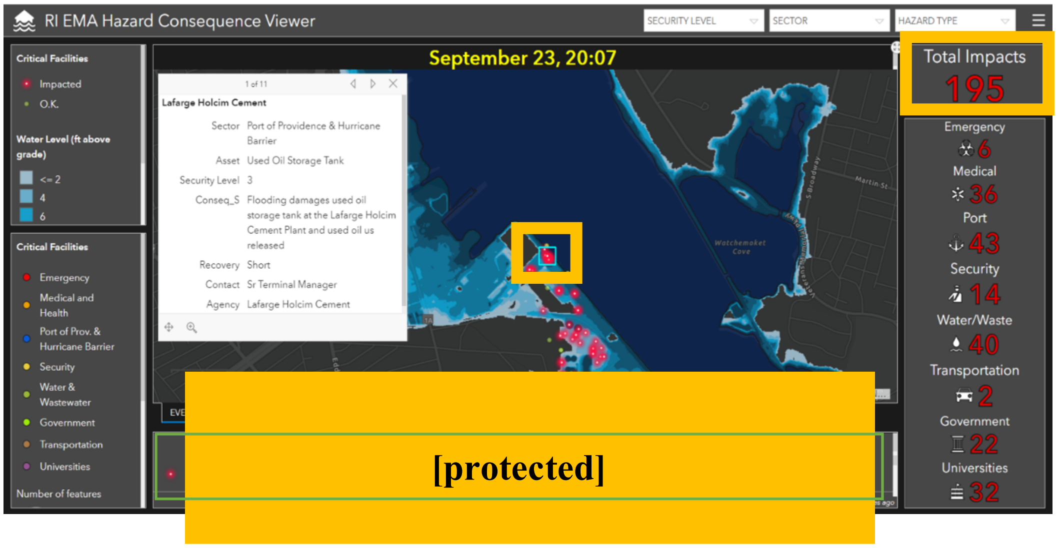


Figure 5.9 - EOC Forecast View Protype at Time Step 3.

5.4 Portsmouth and Newport Visualization

New visualization and model infrastructure have been created for Portsmouth and Newport Rhode Island. These infrastructures and the connection to extreme storm models has been used in preliminary public engagement processes and form a basis for expanding elicitation and analysis activities. This preliminary work has identified key infrastructure areas such as road connections, sewer, and drainage infrastructure that will be affected by changing sea levels and storm surge.

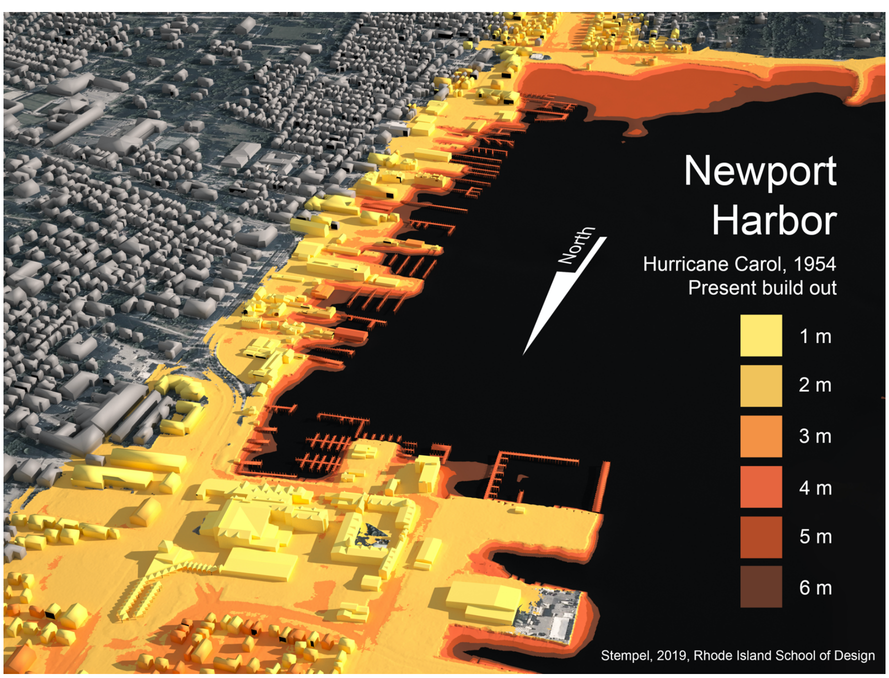


Figure 5.7. 3D visualization of Newport Harbor with simulated inundation during Hurricane Carol (1954).

Survey research employing visualizations of ADCIRC simulations showing preliminary impacts in Portsmouth Rhode Island has identified public priorities for modeled outputs, and perceptions of predicted scenario levels. New highly realistic outputs have been tested along side other forms of diagrammatic depictions of impacts, informing the development of future representations. Examples of 3D infrastructure visualizations with simulated inundation during Hurricane Carol (1954) are shown in Figure 5.7 & 5.8.

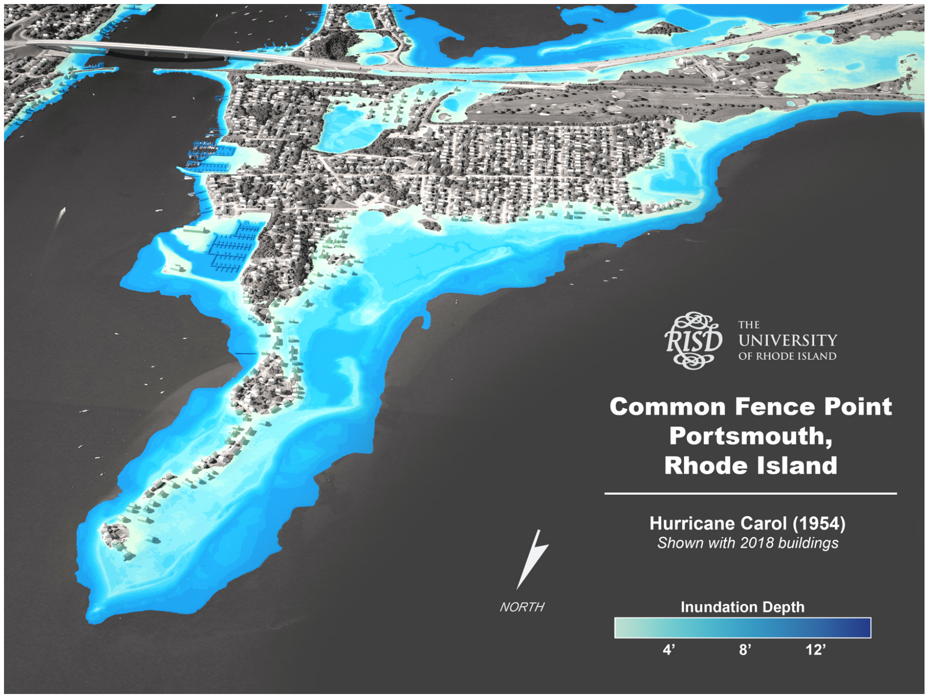


Figure 5.8. (top) 3D visualization of the Town of Portsmouth and (bottom) the same but with inundation during Hurricane Carol (1954).

References

Kutschenreuter, P. H., 1956. Hurricane rains and floods of August 1955, Carolinas to New England, Technical Paper no. 26, U. S. Weather Bureau, Washington, DC.

Ardhuin, F. *et al.* (2010) 'Semiempirical dissipation source functions for ocean waves. Part I: Definition, calibration, and validation', *Journal of Physical Oceanography*, 40(9), pp. 1917–1941.

Battjes, J. A. and Janssen, J. P. F. M. (1979) 'Energy Loss and Set-Up Due To Breaking of Random Waves.', in *Proceedings of the Coastal Engineering Conference*. New York, NY: American Society of Civil Engineers, pp. 569–587.

Chen, S. S. and Curcic, M. (2016) 'Ocean surface waves in Hurricane Ike (2008) and Superstorm Sandy (2012): Coupled model predictions and observations', *Ocean Modelling*. Elsevier, 103, pp. 161–176.

Christiansen DE, Markstrom SL, Hay LE (2011) Impacts of climate change on growing season in the United States. Earth Interactions 15(33):1-17.

Donelan, M. A. *et al.* (2012) 'Modeling waves and wind stress', *Journal of Geophysical Research: Oceans*. Wiley-Blackwell, 117(7), p. n/a-n/a.

Dressler KA, Leavesley GH, Bales RC, Fassnacht SR (2006) Evaluation of gridded snow water equivalent and satellite snow cover products for mountain basins in a hydrologic model. Hydrol Processes 20(4):673-688.

Gao, K., & Ginis, I. (2014). On the generation of roll vortices due to the inflection point instability of the hurricane boundary layer flow. Journal of the Atmospheric Sciences, 71(11), 4292-4307.

Gao, K. and I. Ginis 2016: On the Equilibrium-State Roll Vortices and Their Effects in the Hurricane Boundary Layer. J. Atmos. Sci., 73, 1205-1221.

Gao K, and I. Ginis, 2018: On the characteristics of roll vortices under a moving hurricane boundary layer, J. Atmos. Sci., 75, 2589-2598.

Grachev, A. A. *et al.* (2003) *Direction of Wind Stress Vector Over Waves*, *Wind Over Waves II: Forecasting and Fundamentals of Applications*.

Hay LE, Leavesley GH, Clark MP, Markstrom SL, Viger RJ, Umemoto M (2006) Step-wise, multiple objective calibration of a hydrologic model for a snowmelt-dominated watershed. Journal of American Water Resources 42(4):877-890.

Hay LE, Wilby RL, Leavesley GH (2000) A comparison of delta change and downscaled GCM scenarios for three mountainous basins in the United States. Journal of American Water Resources Association 36:387-397.

Hasselmann, K. *et al.* (1973) 'Measurements of wind-wave growth and swell decay during the joint North Sea wave project (JONSWAP).', *Erganzungsheft zur Deutschen Hydrographischen Zeitschrift*, 12(8).

Holland, G. J. (1980) 'An analytic model of the wind and pressure profiles in hurricanes.', *Monthly Weather Review*, 108(8), pp. 1212–1218.

Irish, J. L., Resio, D. T. and Ratcliff, J. J. (2008) 'The influence of storm size on hurricane surge', *Journal of Physical Oceanography*, 38(9), pp. 2003–2013.

Landsea, C. W. and Franklin, J. L. (2013) 'Atlantic hurricane database uncertainty and presentation of a new database format', *Monthly Weather Review*, 141(10), pp. 3576–3592.

Li, R. *et al.* (2013) 'On the sensitivity of hurricane storm surge simulation to domain size', *Ocean Modelling*, 67, pp. 1–12.

Liu, Q. *et al.* (2017) 'Numerical simulations of ocean surface waves under hurricane conditions: Assessment of existing model performance', *Ocean Modelling*, 118, pp. 73–93.

Markstrom SL, Niswonger RG, Regan RS, Prudic DE, Barlow PM (2008) GSFLOW—Coupled Ground-Water and Surface-Water Flow Model Based on the Integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005). Techniques and Methods 6–D1. Reston, Viginia, U.S. Geological Survey.

Markstrom SL, Hay LE (2009) Integrated watershed scale response to climate change for selected basins across the United States. Water Resources Impact 11(2):8-10.

Moon, I. J. *et al.* (2003) 'Numerical simulation of sea surface directional wave spectra under hurricane wind forcing', *Journal of Physical Oceanography*, 33(8), pp. 1680–1706.

Niswonger RG, Allander KK, Jenton AE (2014) Collaborative modelling and integrated decision support system analysis of a developed terminal lake basin. J Hydrology 517:521-537

Trahan, S., & Sparling, L. (2012). An analysis of NCEP tropical cyclone vitals and potential effects on forecasting models. Weather and Forecasting, 27(3), 744-756.

Weather Bureau, US. Department of Commerce, Hurricane Rains and Floods of August 1995: Carolinas to New England. Technical Paper No. 26, 1955.

Yates D, Warner TT, Brandes EA, Leavesley GH, Sun J, Mueller CK (2001) Evaluation of flash-flood discharge forecasts in complex terrain using precipitation. J Hydrol Eng 6(4):265-274.

Report to U. S. Department of Homeland Security
Coastal Resilience Center

Award to the Jackson State University's Community Resilience Project

By:Jessica L. Murphy, Ph.D.
Start: June 01, 2020
Conclusion: June 30, 2020

<u>Vision</u>: Our vision is to equip Mississippi's underserved communities with up-to-date skills for better preparedness of natural disasters to minimize loss of life and property; thus, building resilient communities.

<u>Mission</u>: Our mission is to provide contemporary emergency/disaster management and preparedness education and training related to natural disasters (i.e. weather and atmospheric events) for Mississippi's underserved communities; to mitigate loss through effective preparedness and response planning; and to building a pipeline from middle school to higher education that develops future Emergency/Disaster Management Professionals and Atmospheric Scientists.

<u>Description, Procedure, and End User</u>:

- Mississippi underserved (rural) communities near the Jackson Metro area (i.e. Hinds Madison, Rankin, etc.—community training and outreach)
    - Collaborate with National Weather Service to provide weather safety information (virtual events).
    - Provide virtual activities to local area to inform students about weather preparedness and careers in Emergency Management, Meteorology, Journalism, and Psychology.
    - Develop and conduct survey to solicit community input regarding weather preparedness.
    - Host virtual community meeting and/or virtual information session/video on weather preparedness—featuring tornadoes, hurricanes, and flooding.
- Emergency academic program promotion to community-Generation Next: Discipline Awareness and Workforce Development (developing next generation of Emergency Management specialists, Meteorologists/Atmospheric Scientists, and Psychologists and Social Scientists Psychology (focusing on Disaster Mental Preparedness)
    - Develop short video(s) to explain the disciplines, degree and professional requirements, career paths, etc.
    - Host "virtual" meeting with a sample of area community members to discuss emergency preparedness for community entities such as schools.

<u>Project Activity</u>:
The CR Leadership Project Team at Jackson State University (Drs. Jessica Murphy, Dawn McLin, Elayne Hayes Anthony, April Tanner and Professor Don Spann and Collaborators: Bill Parker & Latrice Maxie (National Weather Service) and Investigator Michael Ivy (JSU Public Safety)) met in May and June to prepare for June activities (e.g. outline promotional video, draft weather preparedness survey, and plan for 2 virtual town hall meetings) and complete IRB Application.

The IRB Application was submitted the first of June and approved by mid-June 2020. For this pilot phase of the CR project, the aim was to recruit 150 participants. There were 58 participants who completed the survey and 43 to participate in the virtual town hall meetings. The town hall meetings where hosted on the Google Meet platform without difficulty. The following provide additional milestones from the CR Project:

1) Developed two short video promos that were televised on JSU TV.
2) Developed and made available survey for community.
3) Marketed program through JSU TV, Radios, JSU Blast, and other community networks (overall recruitment of participants).
4) Conducted in-person interviews (voice and video) with participants impacted by weather events (specifically the Easter 2020 Tornado in south MS).

See forwarded emails (sent on Wednesday, July 8, 2020) for copy to promotional and interview videos and recording from the town hall meeting 2, Monday, June 29, 2020. Please note, town hall meeting 1 (June 25) featured more psychological and emotional recovery after weather events. Town hall meeting 2 (June 29) featured more cyber security in additional to weather preparedness. The premise of both meetings included Mississippi weather events, weather preparedness, COVID-19 considerations for shelters and evacuations, and response and recovery tips. See below for google announcement and survey link.

Google Meet (Thursday, June 25, 2020 at 6:00 p.m.)
meet.google.com/crx-svxt-mbz

Join by phone
(US) +1 984-355-1372 PIN: 580 559 656#

Survey: https://forms.gle/noGYYLm5HgQBiF5L9

Appendix B: Publications Years 1-5

CRC Publications – Years 1-5:

Year 5

BERKE:

Year 5 Publications

- Berke, P, M Malecha, S Yu, J Lee and J Masterson. 2019. Plan Integration for Resilience Scorecard: Evaluating Networks of Plans in Six US Coastal Cities, *Journal of Environmental Planning and Management*. 62(5): 901-92. DOI: /full/10.1080/09640568.2018.1453354 (published)

- Berke, P., S Yu, M Malecha, J Cooper. 2020. Plans that Disrupt Development: Equity Policies and Social Vulnerability in Six Coastal Cities. *Journal of Planning Education and Research* doi.org/10.1177/0739456X19861144 (published online).

Other Publications

- Berke, P., J Masterson, M Malecha, Matt, S Yu. 2020. Evaluation of Networks of Plans to Hazards and Climate Change: Application of Plan Integration for Resilience Scorecard™ in Norfolk, VA, *Carolina Planning Journal* (forthcoming).

- Berke, P., J Masterson, M Malecha, Matt, S Yu. 2020. A*pplying a Plan Integration for Resilience Scorecard to Practice: Experiences of Nashua, NH, Norfolk, VA, Rockport, TX*. pp. 40.

Year 4 Publications

- Newman, Galen, Malecha, Matt, Yu, Si, Qipao, Z., Horney, Jen, Lee, Daemyung, Kim, Young., Lee, R.J., & Berke, Philip. 2019. Integrating a Resilience Scorecard and Landscape Performance Tools into a Geodesign Process. *Landscape Research*. DOI: 10.1080/01426397.2019.1569219
(2020 Certificate of Research Excellence, Environmental Design Research Association)

Student theses and dissertations completed up through Year 5

- Zito, Fracesca. 2020. *Applying the Plan Integration for Resilience Scorecard™: New Bern, NC.* Master City & Regional Planning, University of North Carolina-Chapel Hill. Primary Advisor: Philip Berke

- Malecha, Matt. 2019-December. *Enhancing Community Resilience to Flooding through the Spatial Evaluation of Plans, Policies, & Regulation*. PhD, Urban and Regional Science, Texas A&M University. Primary Advisor: Philip Berke

- Yu, Siyu. 2019-August. *The Influence of Plan Integration on Community Vulnerability and Ecological Resilience to Natural Hazards*. PhD, Urban and Regional Science, Texas A&M University. Primary Advisor: Philip Berke

- Kim., You Jung. 2019-May. *Advancing Scenario Planning to Prepare for Uncertain Climate Change: Future Urban Growth Prediction and Flood Vulnerability*. PhD, Urban and Regional Science, Texas A&M University. Primary Advisor: Dr. Galen Newman, Committee Member, Philip Berke

BILSKIE:

- Bilskie, M.V., S.C. Hagen, S.C. Medeiros (2019), "Unstructured Finite Element Mesh Decimation for Real-Time Hurricane Storm Surge Forecasting," *Coastal Engineering*, 156. https://doi.org/10.1016/j.coastaleng.2019.103622.

- Santiago-Collazo, F.L., Bilskie, M.V., Hagen, S.C. (2019) "A comprehensive review of compound inundation models," *Environmental Modelling & Software*, 119, pp. 166-181. https://doi.org/10.1016/j.envsoft.2019.06.002.

- Bilskie, M.V., Asher, T.G., Fleming, J.G., Hagen, S.C., Kaiser, C., Luettich Ur., R.A., Twilley, R. (2020) "Real-time storm surge predictions during Hurricane Michael," *Weather and Forecasting*, In Progress (Previously submitted to *Geophysical Research Letters* and being revised).

- White, S.C., S.C. Medeiros, M.V. Bilskie, S.C. Hagen (2020) "Comparison of surface roughness parameterization methods for a storm surge simulation of Hurricane Michael (2018) in the Florida Panhandle," *Coastal Engineering*, In preparation.

COX:
Journal Papers

- Park, H., Do, T., Tomiczek, T., Cox, D.T., van de Lindt, J.W. (2018) "Numerical Modeling of Non-breaking, Impulsive Breaking, and Broken Wave Interaction with Elevated Coastal Structures: Laboratory Validation and Inter-Model Comparisons," *Ocean Engineering*, 158, 15, 78-98. DOI: 10.1016/j.oceaneng.2018.03.088
- Tomiczek, T, A Wyman, H Park, DT Cox (2019) "Modified Goda Equations to Predict Pressure Distribution and Horizontal Forces for Design of Elevated Coastal Structures," *J. Waterway Port Coastal and Ocean Engineerin*g 145, 6, doi.org: 10.1061/(ASCE)WW.1943-5460.0000527.
- Do, T, JW van de Lindt, DT Cox (2019) "Hurricane Surge-Wave Building Fragility Methodology for Use in Damage, Loss, and Resilience Analysis," *J. Structural Engineering* 146(1), 04019177, doi.org: 10.1061/(ASCE)ST.1943-541X.0002472.

Conference Papers

- Lomonaco, P., P. Arduino, A. Barbosa, D. Cox, T. Do, M. Eberhard, M. Motley, K. Shekhar, T. Tomiczek, H. Park, J. W. van de Lindt, A. Winter (2018) "Experimental Modeling of Wave Forces and Hydrodynamics on Elevated Coastal Structures Subject to Waves, Surge or Tsunamis: The Effect of Breaking, Shielding and Debris, *International Conference on Coastal Engineering*, ASCE.
- Park, H., Do, T., Tomiczek, T., **Cox, D., van de Lindt, J.W.** (2018) "Laboratory Validation and Inter-Model Comparisons of Non-breaking, Impulsive Breaking, and Broken Wave Interaction with Elevated Coastal Structures using IHFOAM and FLUENT," *International Conference on Coastal Engineering*, ASCE.
- Tomiczek, T., Wyman, A., Park, H., **Cox, D.T.** (2018) "Application and modification of Goda Formulae for Non-impulsive Wave Forces on Elevated Coastal Structures," *International Conference on Coastal Engineering*, ASCE.
- Tomiczek, T., Park, H., **Cox, D.T.**, Lomonaco, P., **van de Lindt, J.W.** (2018) "Application and modification of Design Formulae for Impulsive Wave Forces on Elevated Coastal Structures," *International Conference on the Application of Physical Modelling in Coastal and Port Engineering and Science (Coastlab18)*, IAHR.
- Do, T, JW van de Lindt W, DT Cox (2018) "Physic-Based Component Fragility Model for Near-Coast Residential Wood Building Subjected to Hurricane Wave and Surge" Engineering Mechanics Institute Conference 2018, Cambridge MA.

Thesis/Dissertation and Reports

- Jason Burke. *Design and Structural Testing of a 1:6 Scaled, Light-frame Construction, Near-coastal, Residential Structure*. (2018). MS Thesis, Oregon State University.
- Matt Karney. *Hydrodynamic Testing on a 1:6 Scale, Wood Framed Near-Coast Residential Structure*. (2018). MS Thesis, Oregon State University.
- Duncan, S. *Physical Modeling of Progressive Damage and Failure of Wood Framed Coastal Residential Structures Due to Waves and Surge Forces,* (2020), MS Thesis, Oregon State University

DIETRICH:

- A Gharagozlou*, JC Dietrich, A Karanci, RA Luettich, MF Overton (2020). "Storm-Driven Erosion and Inundation of Barrier Islands from Dune- to Region-Scales." *Coastal Engineering*, 158, 103674, DOI: 10.1016/j.coastaleng.2020.103674.

- A Thomas*, JC Dietrich, TG Asher, M Bell, BO Blanton, JH Copeland, AT Cox, CN Dawson, JG Fleming, RA Luettich (2019). "Influence of Storm Timing and Forward Speed on Tide-Surge Interactions during Hurricane Matthew." *Ocean Modelling*, 137, 1-19, DOI: 10.1016/j.ocemod.2019.03.004.

- R Cyriac*, JC Dietrich, JG Fleming, BO Blanton, C Kaiser, CN Dawson, RA Luettich (2018). "Variability in Coastal Flooding Predictions due to Forecast Errors during Hurricane Arthur." *Coastal Engineering*, 137(1), 59-78. DOI: 10.1016/j.coastaleng.2018.02.008.

Student Theses and Dissertations Completed in Year 5.

- Ajimon Thomas (2020). "Using a Multi-Resolution Approach to Improve the Accuracy and Efficiency of Flooding Predictions." PhD Dissertation, Department of Civil, Construction and Environmental Engineering, North Carolina State University, Raleigh, North Carolina, JC Dietrich (primary adviser).

- Carter Rucker (2020). "Improving the Accuracy of a Real-Time ADCIRC Storm Surge Downscaling Model." MS Thesis, Department of Civil, Construction and Environmental Engineering, North Carolina State University, Raleigh, North Carolina, JC Dietrich (primary adviser).

FAIK:

- Ying Bai & **Hang Chen**, "Build an Optimal Evacuation Contraflow Model for Natural Disasters by Using Fuzzy Inference System", to be appeared on Proceedings of the 2018 IEEE International Conference on Fuzzy System, July 8-13, Rio de Janeiro, Brazil, 2018.

- Cody Byrd, Jean-Marie Nshimiyimana, Ehije Idehenre, **Hang Chen** (Faculty Advisor), "Data Analysis of Haiti's Resiliency Post-2010 Earthquake". Presented at the 2017 Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM).

- NyJae Dickerson, Adonis Tillman, Desmond Taylor, Awatif Amin (Faculty Advisor) "Using Data Mining to analyze Natural Disasters at 10 countries". Presented at the 2017 Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM).

FLEMING:

- "Dynamic Water Level Correction in Storm Surge Models Using Data Assimilation." Authors: Taylor G. Asher, Richard A. Luettich Jr. and Jason G. Fleming. Submitted to Ocean Modelling. In revision.

- "Influence of storm timing and forward speed on tides and storm surge during Hurricane Matthew." Authors: Ajimon Thomas, JC Dietrich, TG Asher, M Bell, BO Blanton, JH Copeland, AT Cox, CN Dawson, JG Fleming, RA Luettich. Ocean Modelling. Published. https://doi.org/10.1016/j.ocemod.2019.03.004

- "Forecasting Model, Forecast Advisories and Best Track in a Wind Model, and Observed Data – Case Study Hurricane Rita." Authors: Abram Musinguzi, Muhammad Akbar, Jason G. Fleming, Samuel K. Hargrove. Journal of Marine Science and Engineering. Published. J. Mar. Sci. Eng. 2019, 7(3), 77; https://doi.org/10.3390/jmse7030077

GINIS:

Yr 4/5 Publications (Student authors are marked with an asterisk):

- Chen, X.*, T. Hara, and I. Ginis, 2020. Impact of Shoaling Ocean Surface Waves on Wind Stress and Drag Coefficient in Coastal Waters: Part I Uniform Wind, *J. Geophys. Res., In review.*
- Chen, X*., I. Ginis, and T. Hara, 2020: Impact of Shoaling Ocean Surface Waves on Wind Stress and Drag Coefficient in Coastal Waters: Part II Tropical Cyclones, *J. Geophys. Res., In press.*
- Huang, W., F Teng, I. Ginis, and D. Ullman, 2020. Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by International Journal of Structural and Civil Engineering Research (IJSCER), August V9N3.
- Stempel, P., Becker, A., 2020. Is it Scientific? Viewer perceptions of storm surge visualizations. *Cartographica (The Canadian Journal of Cartography). In Review*.
- Stempel, P., Becker, A., 2019. Visualizations out of context. Implications of using simulation-based 3d hazard visualizations. *ISPRS International Journal of Geo-Information*: Special issue on Natural Hazards and Geospatial Information. Vol 8, No 318; Doi:10.3390/ijgi8080318.
- Ullman D.S., I. Ginis, W.Huang, C. Nowakowski*, X. Chen*, and P. Stempel*, 2019: Assessing the Multiple Impacts of Extreme Hurricanes in Southern New England, USA, *Geosciences*, *9*(6), 265; https://doi.org/10.3390/geosciences9060265
- Witkop R.*, A. Becker, P. Stempel*, and I. Ginis, 2019: Developing Consequence Thresholds for Storm Models Through Participatory Processes: Case Study of Westerly Rhode Island. *Front. Earth Sci.* 7:133. doi: 10.3389/feart.2019.00133
- Bender, M.A., T. Marchok, R. E. Tuleya, I. Ginis, V. Tallapragada, and S. J. Lord, 2019: Hurricane model development at GFDL, 2019: A Collaborative success story from a historical perspective., *Bull. Amer. Met. Soc.*, September, https://doi.org/10.1175/BAMS-D-18-0197.1
- Wang, D.*, T. Kukulka, B. Reichl, T. Hara, I. Ginis, and W. Perrie, 2019: Wind-wave misalignment effects on Langmuir turbulence in tropical cyclones conditions, *J. Phys. Oceanogr*., https://doi.org/10.1175/JPO-D-19-0093.1
- Torres M.J.*, M. R. Hashemi, S. Hayward, M. Spaulding, I. Ginis, and S. T. Grilli, 2019: Role of hurricane wind models in accurate simulation of storm surge and waves. *Coastal, Ocean Eng.*, 2019, 145(1): 04018039. doi: 10.1061/(ASCE)WW.1943-5460.0000496

Conference papers, presentations:

Yr 4/5 presentations (student authors are marked with an asterisk):

- Becker, A., Rubinoff, P., Stempel, P., Ginis, I., Adams, S.*, Hallisey, N.*, Kalaidjian, E.*, (2020) Hazard Consequence Threshold Models for Emergency Management and Response Decision Making. Natural Hazards Center Researchers Meeting, Boulder, CO, July 15-16.
- Stempel, P., (2020). "Adaptation of low-lying neighborhoods in Portsmouth, RI. USA." International Geodesign Collaboration (IGC), Redlands, CA. February 22–24, 2020
- Chen, X.*, I. Ginis and T. Hara: Numerical Study of Wind Stress in Coastal Water Under a Tropical Cyclone, Ocean Sciences Meeting, Feb. 16-21, 2020, https://agu.confex.com/agu/osm20/meetingapp.cgi/Paper/644262
- Hara T., X. Chen* and I. Ginis: Impact of Shoaling Wind Waves on Drag Coefficient in Finite Depth, Ocean Sciences Meeting, Feb. 16-21, 2020, https://agu.confex.com/agu/osm20/meetingapp.cgi/Paper/646849
- Becker, A. (2019), "Coastal Hazard Impact Assessment." Climate Preparedness and Resilience Community of Practice Lead, CW Guidance Program US Army Corps of Engineers Headquarters, Washington, DC, Sept. 11.

- Becker, A. (2019), "Hazard Consequence Threshold Models for Emergency Management and Response Decision Making." CARIS (Climate Adaptation and Resilience Information Sharing Group, Sept. 13.
- Becker, A., Rubinoff, P., Ginis, I., Adams, S.* (2019) Hazard Consequence Threshold Models for Emergency Management and Response Decision Making. Presentation to FEMA Region 1, Dec. 18, Boston, MA.
- Stempel, P., (2019). "Rethinking model-driven realistic storm-surge graphics." Rhode Island Coastal Ecology, Assessment, Innovation, and Modeling (R C-AIM) Research Symposium 2019, Kingston RI. April 10.
- Ginis, I., and Il-K. Ma (2019): Impact of Warm-Core Ocean Eddies on Tropical Cyclone Intensification in the Northwest Pacific, International Workshop on Tropical Cyclone-Ocean Interaction in the Northwest Pacific, June 20, http://www.tcoi.co.kr/
- Ginis I. (2019): Advancing modeling capabilities to improve prediction of extreme weather events in the Northeastern United States, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, April 11.
- Ginis I. (2019): Improving Prediction of Extreme Weather and Its Impact in New England, RI Emergency Management Agency, Cranston RI, March 7.
- Ginis I. (2019): Modeling Combined Coastal and Inland Impacts from Extreme Storms, RI Department of Health, Providence RI, March 8.
- Becker, A, (2019). "Overcoming Barriers to Long-term Climate Adaptation," Lecture of Opportunity, US Naval War College, Newport, RI, April 29.
- Becker, A., (2019). "Climate risk adaptation for ports: Research for transformational thinking." UNCTAD Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future , Geneva, Switzerland, April 16-17.
- Stempel, P., Becker., A., Ginis, I., Ullman, D., Rubinoff., P., Overstrom, N. (2019). "Rethinking model-driven realistic storm-surge graphics." Rhode Island Coastal Ecology, Assessment, Innovation, and Modeling (RI C-AIM) Research Symposium, Kingston RI. April 10.
- Becker, A, Stempel, P.*, Menendez, J.* (2019). "Visualizing Risk: Dynamic 3d Models of Storm Impacts on Coastal Structures In Rhode Island." Poster presentation at the Infrastructure Climate Network Meeting, Portsmouth, NH, April 4-5.
- Huang, W., F Teng, I. Ginis, and D. Ullman (2019). Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by 8th International Conference on Civil Engineering (ICCEN 2019), November 19-20, Paris, France, 2019
-

<u>Student Theses/Dissertations</u>

- Bobby Witkop Master's thesis in Marine Affairs "Developing Consequence Thresholds for Storm Impact Models: Case Study of Westerly, Rhode Island", 2018, Primary advisor: Dr. Austin Becker, Committee member: Dr. Isaac Ginis
- Peter Stempel Ph.D. Dissertation in Marine Affairs: "Depicting consequences of storm surge, opportunities and ethics." 2018, Primary advisor: Dr. Austin Becker, Committee member: Dr. Isaac Ginis
- Xuanyu Chen Ph.D. Dissertation in Physical Oceanography: "Impacts of Shoaling Ocean Surface Waves on Wind Stress and Storm Surge" 2020, Primary advisors: Dr. Isaac Ginis and Dr. Tetsu Hara, Committee member: Dr. David Ullman

HAGEN:

- Bilskie, M.V., S.C. Hagen, S.C. Medeiros (2019), "Unstructured Finite Element Mesh Decimation for Real-Time Hurricane Storm Surge Forecasting," *Coastal Engineering*, 156. https://doi.org/10.1016/j.coastaleng.2019.103622.

- Santiago-Collazo, F.L., Bilskie, M.V., Hagen, S.C. (2019) "A comprehensive review of compound inundation models," *Environmental Modelling & Software*, 119, pp. 166-181. https://doi.org/10.1016/j.envsoft.2019.06.002.

- Bilskie, M.V., Asher, T.G., Fleming, J.G., Hagen, S.C., Kaiser, C., Luettich Ur., R.A., Twilley, R. (2020) "Real-time storm surge predictions during Hurricane Michael," *Weather and Forecasting*, In Progress (Previously submitted to *Geophysical Research Letters* and being revised).

- White, S.C., S.C. Medeiros, M.V. Bilskie, S.C. Hagen (2020) "Comparison of surface roughness parameterization methods for a storm surge simulation of Hurricane Michael (2018) in the Florida Panhandle," *Coastal Engineering*, In preparation.

HUANG:

- Huang, W., F Teng, I. Ginis, and D. Ullman, 2020. Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by International Journal of Structural and Civil Engineering Research (IJSCER), August V9N3.

- Ullman D.S., I. Ginis, W.Huang, C. Nowakowski*, X. Chen*, and P. Stempel*, 2019: Assessing the Multiple Impacts of Extreme Hurricanes in Southern New England, USA, *Geosciences*, *9*(6), 265; https://doi.org/10.3390/geosciences9060265

Conference Presentations:

- Huang, W., F Teng, I. Ginis, and D. Ullman (2019). Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by 8th International Conference on Civil Engineering (ICCEN 2019), November 19-20, Paris, France, 2019

LAIJU:
Year 4 Publications:

Long, J., Rose, S., Jwainat, A. & Hunter, F. (2019), Tougaloo Community Preparedness for Homeowners*,* abstract published in*Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1

Jones, T. Robinson, S. Boler, D.& Hunter, F. (2019) Disaster Preparedness: How Prepared Are They? An Assessment of Renters in Tougaloo Mississippi*,* abstract published in abstract publishedin*Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1
Kinkaid, D.,Ze'ronte, B.Sneed, H., &Banerjee, S., (2019), *Using GIS to Study*

Disproportionate Disaster Impact on Vulnerable Mississippi Population, abstract published in *Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1, & Presented at 83rd Annual Meeting in Hattiesburg, MS on February 21, 2019

Laiju, M. (2019), *A Framework: Address Vulnerability of Children and Current Policy of Disaster,*
abstract published in*Mississippi Academy of Sciences (MAS)* ISSN 0076 – 9436, Vol 64 # 1, &presented at 83rd Annual Meeting in Hattiesburg, MS on February 21, 2019

Laiju, M. (2019) *Career Pathway: Multidisciplinary Undergraduate Curriculum in Homeland Security's Coastal Resilience at a HBCU.* Abstract published in *Southern Sociological Society* (SSS) Journal and presented at SSS Conference on April 11, 2019, at Atlanta, GA.

Presentation:

Laiju, M. & Hunter, F. (2018), *Transforming the Curriculum: Adding Disaster Management and Coastal Infrastructure Management to the Curriculum,* abstract accepted and presented at the Historical Black Colleges &Universities(HBCU) Faculty Development Network Conference
in Jackson, Mississippi, November 2,2018

Senior Paper:

Jwainat, A. (2019), senior paper Knowledge and Attitudes Regarding Disaster/ Emergency Preparedness

Porter, J. (2019), New Orleans Residents' Awareness of Disaster Preparedness

Year 5 Publications:

Presentation and Senior Paper:

Thomas, C &Laiju, M (2020)*Natura Disaster Preparedness Among Undergraduate Students In Jackson, Mississippi,* abstract published in 84th MAS (ISSN 0076 – 9436, Vol 65 # 1) journal and presented the Paper at MAS conference on February 20, 2020. (Ms. Thomas's Senior Paper)

Hill, N., Randle, D.iMaya Randle, & Khan, S. (2020) *Assessment of Psychological Impact of Coastal Disaster,* abstract published in 84th MAS (ISSN 0076 – 9436, Vol 65 # 1) journal and presented the Paper at MAS conference on February 20, 2020

Tashana Irving, Desiree-Gift Mills, Jacory Clayton, MeherunLaiju, Santanu Banerjee, *Using GIS to Study Recent Past, Present and Potential Major Disaster Patterns' Impact on the Mississippi Demography*, supposed to be presented at the 8th International Conference on Flood Management in Iowa City, Iowa (postponed until August 2021 due to COVID-19)

Randle, D& Khan, S. (2020) *Time Management and Academic Adjustment among First Year African American Students,* abstract published in 84th MAS (ISSN 0076 – 9436, Vol 65 # 1) journal and presented the Paper at MAS conference on February 20, 2020 (Ms. Randle's Senior Paper)

LUETTICH:

- Bilskie, M.V., Asher, T.G., Fleming, J.G., Hagen, S.C., Kaiser, C., Luettich Ur., R.A., Twilley, R. (2020) "Real-time storm surge predictions during Hurricane Michael," *Weather and Forecasting*, In Progress (Previously submitted to *Geophysical Research Letters* and being revised).

- "Dynamic Water Level Correction in Storm Surge Models Using Data Assimilation." Authors: Taylor G. Asher, Richard A. Luettich Jr. and Jason G. Fleming. Submitted to Ocean Modelling. In revision.

- "Influence of storm timing and forward speed on tides and storm surge during Hurricane Matthew." Authors: Ajimon Thomas, JC Dietrich, TG Asher, M Bell, BO Blanton, JH Copeland, AT Cox, CN Dawson, JG Fleming, RA Luettich. Ocean Modelling. Published. https://doi.org/10.1016/j.ocemod.2019.03.004

MEDEIROS:

- Bilskie, M.V., S.C. Hagen, S.C. Medeiros (2019), "Unstructured Finite Element Mesh Decimation for Real-Time Hurricane Storm Surge Forecasting," *Coastal Engineering*, 156. https://doi.org/10.1016/j.coastaleng.2019.103622.

- White, S.C., S.C. Medeiros, M.V. Bilskie, S.C. Hagen (2020) "Comparison of surface roughness parameterization methods for a storm surge simulation of Hurricane Michael (2018) in the Florida Panhandle," *Coastal Engineering*, In preparation.

Thesis defense:

- White, Sky. 2020. *Use of lidar data to investigate the influence of bottom friction coefficients for storm surge modeling of Hurricane Michael in the Florida Panhandle.* Embry-Riddle Aeronautical University. Primary Advisor: Stephen Medeiros.

PAGAN:

- "Complexity Mapping for Resilient and Sustainable Infrastructure"; Manuscript Published as: López del Puerto, C., Suárez, L. Gransberg, D.D., and Montañez, J., "Complexity Mapping for Resilient and Sustainable Infrastructure, Proceedings, VII Conferencia Internacional de Ciencia y Tecnología de la Ingeniería, IESTEC-2019, Panama City, Panama, October, 2019. Peer reviewed.

- KEEP SAFE A GUIDE FOR RESILIENT HOUSING DESIGN IN ISLAND COMMUNITIES, All rights reserved. © Publiched by 2019 Enterprise Community Partners, Inc. Disclaimer: The PI's participated in the book development as Advisors, Workshop leaders, Reporters and Invited participants of the book presentation.

- Effects of Storm Surge Barriers on Estuary Ecosystems: A Comparison between Eastern Scheldt and Galveston Bay, Sofía N. Rivera Soto; University of Puerto Rico at Mayagüez, Mayagüez, P.R., sofia.rivera6@upr.edu; Dr. Samuel Brody; Texas A&M at Galveston, Galveston, Texas, brodys@tamug.edu; Dr. Yoonjeong Lee; Texas A&M at Galveston, Galveston, Texas, yoonlee@tamu.edu; Prof. Ismael Pagán Trinidad; University of Puerto Rico at Mayagüez, Mayagüez, P.R., ismael.pagan@upr.edu. A Final Technical Paper submitted as part of the requirement of her participation in the NSF PIRE Program. *2019 Summer Research Internship Program Partnership for International Research and Education – The Netherlands Texas A&M at Galveston, Jackson State University and University of Puerto Rico at Mayagüez.* September 2019.

- *Measuring Run-up on a Laboratory-Scale Beach Dune using LiDAR, Ihan-Jarek T. Acevedo González University of Puerto Rico at Mayagüez Dr. Meagan Wengrove, O.H. Hinsdale Wave Research Laboratory, Oregon State University, REU, Summer 2019. (Report presented as part of his Summer Internship at OSU)*

- *Erosion Analysis of Dune Types for a Typical East Coast Beach under Hurricane Conditions using Bathymetric and LiDAR Measurements. Authors: Robert Lewis1,2, Jeremy Smith3, Meagan Wengrove1; 1O.H. Hinsdale Wave Laboratory, Oregon State University, Corvallis, OR 97331; 2Department of Civil Engineering, University of Puerto Rico-Mayagüez, Mayagüez, PR. 00682; 3Department of Civil and Environmental Engineering, Stanford University, Stanford, CA94305, December 2019. (Report presented as part of his Summer Internship at OSU)*

Student Reports/Dissertations:

- A Decision Support System for Gate Operations at Clarence Cannon National Wildlife Refuge (CCNWR) in Pike County, MO., Oscar A. Vélez Ramos, A project report submitted in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING in CIVIL ENGINEERING UNIVERSITY OF PUERTO RICO, MAYAGUEZ CAMPUS. May 2020. Advisors: Ismael Pagán Trinidad, UPRM and Norberto Nadal, ERDC. Co-Advisors. UPRM-CHL ERDC Collaboration.

- STOCHASTIC SIMULATION OF TROPICAL CYCLONES FOR QUANTIFICATION OF UNCERTAINTY ASSOCIATED WITH STORM RECURRENCE AND INTENSITY; Efraín Ramos-Santiago; A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in CIVIL ENGINEERING, UNIVERSITY OF PUERTO RICO, MAYAGÜEZ CAMPUS, July 2019. Advisors: Ismael Pagán Trinidad, UPRM and Norberto Nadal, ERDC. Co-Advisors. UPRM-CHL ERDC Collaboration.

- ASSESSMENT OF HURRICANE VORTEX MODELS FOR THE DEVELOPMENT OF WIND AND PRESSURE PROFILES AND FIELDS, Nelson Y. Cordero-Mercado; Master's Progress Project Report Draft expected to be presented in Summer 2020 pending final submittal in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING In CIVIL ENGINEERING UNIVERSITY OF PUERTO RICO , MAYAGÜEZ CAMPUS, May 2020.

RESIO:

Student Theses and Dissertations

a) A dissertation by Amanda Tritinger was completed last June. She was supported by CRC funding for her entire dissertation and is now employed at the USACE ERDC. Her dissertation title is: The Influence of Vertical Structure on Open-Coast Surges and its Incorporation into Depth Averaged Models.

SMITH:

- **Smith, Gavin** and Wendy Saunders. 2020. A Comparative Study of Hazard-Prone Housing Acquisition Programs in the United States and New Zealand. Special Issue on Managed Retreat and Environmental Justice. Journal of Environmental Studies and Sciences. Perspectives on Managed Retreat: Environmental Justice and Beyond. A.R. Siders and Jola Ajibade, Editors. (under development).

- McGovern, Shannon, Ryan Scott, Gretchen Caverly, **Gavin Smith**. 2020. Disaster Resilient Policy, Engineering and Design Class Project: The Resettlement of three Hazard-Prone Communities. Special Issue on Managed Retreat and Environmental Justice. Journal of Environmental Studies and Sciences. Perspectives on Managed Retreat: Environmental Justice and Beyond (under development).

- **Smith, Gavin**. April, 2020. Best Practices and Lessons (Learned and Not Learned) in the United States Regarding the Role of States in Fostering Disaster Resilience at the Local Level through Program Design and Implementation. Report for the Queensland Reconstruction Authority and the Regional Resilience Strategies (Statewide Rollout) Project. Brisbane, Australia: Queensland Reconstruction Authority.

- **Smith, Gavin**, Allison Anderson and David Perkes. New Urbanism and the H-Transect: Improving the Integration of Disaster Resilience and Design (submitted for review).

- Saunders, Wendy and **Gavin Smith**. Global Principles Guiding the Acquisition of Hazard-Prone Housing. (under development).

- **Smith, Gavin**, Allison Anderson and David Perkes. New Urbanism and the H-Transect: Improving the Integration of Disaster Resilience and Design (submitted for review).
- Nguyen, Mai and **Gavin Smith**. Resilient Design Education in the United States (submitted for review).

- **Smith, Gavin**, Hurricane Matthew Disaster Recovery and Resilience Initiative: Achieving Rural Resilience through Research, Teaching and Engagement? (under development).

- **Smith, Gavin** and Wendy Saunders. A Comparative Review of Hazard-Prone Housing Acquisition Laws, Policies and Programs in the United States and Aotearoa New

Zealand: Implications for Improved Practice. In the Cambridge Handbook of Disaster Law: Risk, Recovery and Redevelopment. Susan Kuo, John Travis Marshall, and Ryan M. Rowberry eds. (forthcoming Cambridge, 2021).

- Saunders, W.S.A, and **G. Smith**. 2020. Spend to Save: reducing natural hazard risks through property acquisition in Aotearoa New Zealand. Lower Hutt (NZ): GNS Science.

- **Horney, Jennifer**, Carolina Dwyer, Bhagath Chirra, Kerry McCarthy, Jennifer Shafer and **Gavin Smith**. 2018. Measuring Successful Disaster Recovery. International Journal of Mass Emergencies and Disasters 36(1): 1-22.

WHALIN:

- **Ebersole, Bruce; Richardson, Thomas** and **Whalin, Robert**, "Minimize Hurricane Surge Penetration into West/Galveston Bays: It's Crucial!" Proceedings, 11th Texas Hurricane Conference, University of Houston, Houston, TX, Aug. 2, 2019.

- Hu, Guojing, Lu, Weike; Wang, Feng; and **Whalin, Robert**, "Macroscopic Fundamental Diagram Based Discrete Transportation Network Design," Journal of Advanced Transportation, February 2020

- **Whalin, Robert W**., "A PhD in Engineering Degree: Coastal Engineering Emphasis Area," Proceedings, 126th ASEE Conference, Tampa Bay, FL, June 2019.

- **Ebersole, Bruce; Richardson, Thomas W.; Whalin, Robert W.,** "Suppression of Hurricane Surge Forerunner and Peak Surge in Galveston and West Bays Achieved with a Western Segment of the Coastal Spine," 10th Annual Texas Hurricane Conference, University of Houston, Houston, TX; Aug. 3, 2018.

- "NSF-PIRE, Coastal Flood Risk Reduction Program, Authentic Learning and Transformative Education", Volume 1-2015-2017; Edited by Baukje "Bee" Kothius, Yoonjeong Lee and Samuel Brody, March 2018.

Years 1-4

Coastal Infrastructure Resilience

Wallace:

- Loggins, R. A., & **Wallace, W. A.** (2015). Rapid Assessment of Hurricane Damage and Disruption to Interdependent Civil Infrastructures Systems. J. Infrastruct. Syst., DOI: http://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000249.

Bennett:

- Amr Helal, **Victoria Bennett**, **Mo Gabr**, Roy Borden and **Tarek Abdoun**. *Monitoring and Modeling of Peat Decomposition in Sacramento Delta Levees.* Geotechnical Frontiers 2017, Orlando, Florida. DOI: 10.1061/9780784480458.054

- **Victoria Bennett**, Cathleen Jones, David Bekaert, Jason Bond, Amr Helal, **Joel Dudas, Mohammed Gabr, Tarek Abdoun**. Deformation Monitoring for the Assessment of Sacramento Delta Levee Performance. Geo-Risk 2017 (Geotechnical risk from theory to practice), Denver, Colorado. DOI: 10.1061/9780784480717.003

Conference papers, presentations

- **Victoria Bennett**, Chung Nguyen, **Tarek Abdoun**, Amr Helal, **Mohammed Gabr**, Cathleen Jones, David Bekaert, **Joel Dudas**. Use of remote-sensing deformation monitoring for the assessment of levee section performance limit state. Proceedings of the 19th International Conference on Soil Mechanics and Geotechnical Engineering, Seoul 2017.

- Rowshon Jadid, **Brina Montoya, Victoria Bennett**, and **Mo Gabr**. Deformation-based versus Limit Equilibrium Analyses to Assess the Effect of Repeated Rise and Fall of Water Level on the Stability of Princeville Levee. Dam Safety 2018, Seattle, Washington.

- Rowshon Jadid. Strain-Based Approach versus Limit Equilibrium Analyses: Assessing the Effect of Hydraulic Loading History on the Stability of Princeville Levee. DHS COE Summit 2018, Arlington, Virginia.

- Amr Helal. Analysis of Earth Embankment Structures using Performance-based Probabilistic Approach including the Development of Artificial Neural Network

Tool. PhD dissertation, Civil Engineering Department, North Carolina State University, June 2017.

Cox:

- Tomiczek, T, A Wyman, H Park, **DT Cox** (2019) Modified Goda Equations to Predict Pressure Distribution and Horizontal Forces for Design of Elevated Coastal Structures. Waterway Port Coastal and Ocean Engineering (accepted).

- Do, T, JW van de Lindt, DT Cox (2019) Hurricane Surge-Wave Building Fragility Methodology for Use in Damage, Loss, and Resilience Analysis. Structural Engineering (In Press).

- Tomiczek, T., Park, H., **Cox, D.T., van de Lindt, J.W.**, Lomonaco, P. (2017) Experimental Modeling of Horizontal and Vertical Wave Forces on an Elevated Coastal Structure. Coastal Engineering, 128, 58-74. DOI: 10.1016/j.coastaleng.2017.08.001

- Do, Trung, **van de Lindt, J., Cox, D.T.** (2016) Performance-Based Design Methodology for Inundated Elevated Coastal Structures Subjected to Wave Load Engineering Structures. Engineering Structures, 117, 250 – 262. DOI: 10.1016/j.engstruct.2016.02.046

- Park, H., Do, T., Tomiczek, T., Cox, **D.T., van de Lindt, J.W.** (2018) Numerical Modeling of Non-breaking, Impulsive Breaking, and Broken Wave Interaction with Elevated Coastal Structures: Laboratory Validation and Inter-Model Comparisons. Ocean Engineering, 158, 15, 78-98. DOI: 10.1016/j.oceaneng.2018.03.088

Conference papers, presentations, theses

- Lomonaco, P., P. Arduino, A. Barbosa, **D. Cox**, T. Do, M. Eberhard, M. Motley, K. Shekhar, T. Tomiczek, H. Park, J. W. van de Lindt, A. Winter (2018) Experimental Modeling of Wave Forces and Hydrodynamics on Elevated Coastal Structures Subject to Waves, Surge or Tsunamis: The Effect of Breaking, Shielding and Debris. International Conference on Coastal Engineering, ASCE.

- Park, H., Do, T., Tomiczek, T., **Cox, D., van de Lindt, J.W.** (2018) Laboratory Validation and Inter-Model Comparisons of Non-breaking, Impulsive Breaking, and Broken Wave Interaction with Elevated Coastal Structures using IHFOAM and FLUENT. International Conference on Coastal Engineering, ASCE.

- Do, T, JW van de Lindt W, DT Cox (2018) Physics-Based Component Fragility Model for Near-Coast Residential Wood Building Subjected to Hurricane Wave and Surge. Engineering Mechanics Institute Conference 2018, Cambridge MA.

- Tomiczek, T., Wyman, A., Park, H., **Cox, D.T.** (2018) Application and modification of Goda Formulae for Non-impulsive Wave Forces on Elevated Coastal Structures. International Conference on Coastal Engineering, ASCE.

- Tomiczek, T., Park, H., **Cox, D.T.**, Lomonaco, P., **van de Lindt, J.W.** (2018) Application and modification of Design Formulae for Impulsive Wave Forces on Elevated Coastal Structures. International Conference on the Application of Physical Modelling in Coastal and Port Engineering and Science (Coastlab18), IAHR.

- Do, T., Tomiczek, T., **van de Lindt, J. Cox, D.** (2017) Development of Physics-Based Building Fragility Surfaces for Near-Coast Community Modeling. International Conference on Coastal and Ocean Engineering, Osaka, Japan.

- Jason Burke. Design and Structural Testing of a 1:6 Scaled, Light-frame Construction, Near-coastal, Residential Structure. (2018). MS Thesis, Oregon State University.

- Matt Karny. Hydrodynamic Testing on a 1:6 Scale, Wood Framed Near-Coast Residential Structure. (2018). MS Thesis, Oregon State University.

- Trung Q. Do, Fragility Approach for Performance-Based Design in Fluid-Structure Interaction Problems, Part I: Wind and Wind Turbines, Part II: Waves and elevated Coastal Structures (2016), Ph.D. Dissertation, Colorado State University.

- William Short. A laboratory study of horizontal and vertical regular wave forces on an elevated structure. (2016). MS Thesis, Oregon State University.

- Benjamin Hunter. Exceedance Probabilities of Hurricane Wave Forces on Elevated Structures. (2016). MS Thesis, Oregon State University.

Building Resilient Communities

Horney:

- **Horney** et al (2018). Measuring Disaster Recovery. International Journal of Mass Emergencies and Disasters, March 2018, Vol. 36, No. 1. 1-22.

- Kirsch, K., & **Horney, J.** (2017). Steps toward recovery: A tool for disaster recovery planning, management, and tracking. Carolina Planning Journal, Vol.

42, 104-109.

- **Horney, J.**, Dwyer, C., Aminto, M., **Berke, P.**, & **Smith, G.** (2017). Developing indicators to measure post-disaster community recovery in the United States. Disasters, 41, 124-149. DOI: 1111/disa.12190

- **Horney JA**, Dwyer C*, Chirra B*, McCarthy K, Shafer J, **Smith G**. (2018) Measuring successful disaster recovery. International Journal of Mass Emergencies and Disasters. 36(1): 1-22.

- **Horney JA**, Dwyer C*, Aminto M*, **Berke P.**, & **Smith G.** (2017) Developing indicators to measure post-disaster community recovery. Disasters. 41(1):124-149. DOI: 10.1111.disa.12190

Conference papers, presentations, theses

- Chirra, B., & **Horney, J.** (2016, April). Measuring disaster recovery: A case study of six communities in Texas. Poster presentation at the 11th Annual Dr. Jean Brender Delta Omega Research Symposium and Student Poster Contest, Texas A&M University School of Public Health, College Station, TX.

- Chirra, B., & **Horney, J.** (2016, April). Measuring disaster recovery: A case study of six communities in Texas, United States. Oral presentation at the Texas Public Health Association's 92nd Annual Education Conference, Galveston, TX

- Kirsch, K., Sullivan, E., **Horney, J.**, and Goidel, K. (2018, July). Are slow-onset disasters well represented in hazard mitigation plans? Poster presentation at the 43rd Annual Natural Hazards Research and Applications Workshop, Broomfield, CO.

- Kirsch, K., & **Masterson, J.** (2017, September). Tool for tracking an equitable recovery [Blog post]. Retrieved from http://disasterphilanthropy.org/blog/hurricanes-typhoons/tool-tracking-equitable-recovery/

Berke:

- **Newman, Galen,** Malecha, Matt, Yu, Si, Qipao, Z., **Horney, Jen**, Lee, Daemyung, Kim, Young., Lee, R.J., & **Berke, Philip**. 2019. Integrating a Resilience Scorecard and Landscape Performance Tools into a Geodesign Process. Landscape Research. DOI: 1080/01426397.2019.1569219

- **Berke, Philip**, Siyu Yu, Matt Malecha, **John Cooper**. 2019. Plans that Disrupt Development: Equity Policies and Social Vulnerability in Six Coastal Cities.

Journal of Planning Education and Research. (forthcoming).

- **Berke, P.**, Lee, J., **Newman, G.**, Combs, T. Kolosna, C., Salvesen, D. 2015. Evaluation of Networks of Plans and Vulnerability to Hazards and Climate Change: A Resilience Scorecard. Journal of the American Planning Association 81(4): 287-302. DOI: 1080/01944363.2015.1093954

- **Berke P.**, Malecha M., Yu S., Lee J., **Masterson J.** (2018). Plan Integration Scorecard for Resilience: Evaluating Networks of Plans in Six US Coastal Cities. Journal of Environmental Planning and Management. DOI: 10.1080/09640568.2018.1453354.

- Malecha, M., Brand, A., & **Berke, P.** (2018). Spatially evaluating a network of plans and flood vulnerability using a Plan Integration for Resilience Scorecard: A case study in Feijenoord District, Rotterdam, the Netherlands. Land Use Policy, 78, 147-157. DOI: 10.1016/j.landusepol.201

Conference papers, presentations, theses

- **Masterson, J., Berke, P.**, Malecha, M., Yu, S., Lee, J., & Thapa, J. (2017) Plan integration for resilience scorecard: How to spatially evaluate networks of plans to reduce hazard vulnerability. College Station, Texas: Institute for Sustainable Communities, College of Architecture, Texas A&M. http://mitigationguide.org/wpcontent/uploads/2013/01/Scorecard_3Oct2017.pdf

Davidson:

- Wang, D., **Davidson, R. A., Trainor, J. E., Nozick, L. K.,** and **Kruse, J**. 2017. Homeowner purchase of insurance for hurricane-induced wind and flood damage. Natural Hazards 88, 221–245. DOI: 10.1007/s11069-017-2863-x

- Robinson, C., **Davidson, R. A., Trainor, J. E., Kruse, J. L.,** and **Nozick, L. K.** 2018. Homeowner acceptance of voluntary property acquisition offers. International Journal of Disaster Risk Reduction 31, 234-242. DOI: 10.1016/j.ijdrr.2018.05.002

Conference papers, presentations, theses

- Jasour, Z. (2017) Homeowner Decisions to Retrofit to Reduce Hurricane-Induced Wind and Flood Damage. Masters Thesis. University of Delaware.

- Slotter R. (2018) Hurricane Mitigation Decision-Making an Application of the Theory of Planned Behavior. Masters Thesis. University of Delaware

Prochaska:

- Mundorf, N., Redding, C.A., **Prochaska, J.O., Paiva, A.L.**, & **Rubinoff, P.** (2017). Resilience and Thriving in Spite of Disasters: A Stages of Change Approach. In A. Fekete & Fiedrich, F. Urban Disaster, Resilience and Security. Berlin: Springer.

Opaluch:

- **Becker, A.**; Hippe, A.; McLean, E., (2017), Cost and Materials Required to Retrofit US Seaports in Response to Sea Level Rise: A Thought Exercise for Climate Response. Journal of Marine Science and Engineering 5 (3), 44. DOI: 10.3390/jmse5030044

- **Becker, A.**, (2017), Using Boundary Objects to Stimulate Transformational Thinking: Storm Resilience for the Port of Providence. Sustainability Science. Vol. 12, No. 3, pp. 477-501. DOI: 10.1007/s11625-016-0416-y

- **Becker, A.**, Chase, N., Fischer, M., Schwegler, B., Mosher, K., (2016), A method to estimate climate-critical construction materials applied to seaport protection. Global Environmental Change. DOI: 10.1016/j.gloenvcha.2016.07.008

- Romelczyk, E.*, **Becker, A.** (2016), Missing the tide? Workplace cultural differences as a barrier to seafarer mobility in the U.S. workboat and sail training sectors. Maritime Policy and Management. (Nominated for Best Manuscript 2016) DOI: 10.1080/03088839.2016.1185182

- **Becker, Austin**, Pamela Matson, Martin Fischer, and Michael D. Mastrandrea, Forthcoming. Towards Seaport Resilience for Climate Change Adaptation: Stakeholder Perceptions of Hurricane Impacts in Gulfport (MS) and Providence (RI) Progress in Planning. DOI: 10.1016/j.progress.2013.11.002

- Touzinsky, K, Rosati, J., Fox-Lent, C., **Becker, A.**, Luscher, A., 2016. Advancing Coastal Systems Resilience Research: Improving Quantification Tools through Community Feedback. Shore and Beach 84 No. 4 · November 2016.

- Spaulding, M. L., Grilli, A., Damon, C., Crean, T., Fugate, G., Oakley, B., & Stempel, P. (2016). Stormtools: Coastal Environmental Risk Index (CERI). Journal of Marine Science and Engineering, 4(3). DOI: 10.3390/jmse4030054

Conference papers, presentations, theses

- Zhang, H., Ng, A., **Becker, A.** (In Press), Institutional Barriers in Adaptation to Climate Change at Ports, Regions, and Supply Chains. North American

Symposium on Climate Adaptation, New York, New York. Aug. 16-18, 2016. (Refereed Conference Paper)

- **Becker, A.,** (2016). Findings from a port vulnerability assessment. Dept. of Homeland Security Center of Excellence for Coastal Resilience and University of North Carolina Maritime Risk Symposium University of North Carolina, Chapel Hill, North Carolina, Nov. 14-15, 2016.

- **Becker, A.**, (2016). Adapting ports to climate change: Providence (RI) Case Study. AIVP Ports and Cities Conference, Netherlands, Oct 10-12, 2016.

- **Becker, A.**, (2016). Inspiring leadership for Adaptation. North American Symposium on Climate Adaptation, New York, New York. Aug. 16-18, 2016.

- **Becker, A.**, (2016). Inspiring resilience thinking for seaport systems. Transportation Research Board Conference for Committee on Maritime Transportation System (CMTS), National Academy of Sciences, Washington, DC, June 21-22, 2016.

- **Becker, A.**, (2016). Adapting ports to climate change: Providence (RI) Case Study. Adaptation Futures 2016, Rotterdam, Netherlands May 11-13, 2016.

- **Becker, A.**, (2016). Inspiring resilience thinking for seaport systems. Green Ports for Blue Waters Conference, University of Rhode Island April 4-5, 2016.

- Green, W., **Becker, A.**, (2016). Built environments and rising seas: Service learning recommendations for the future of the Port of Galilee. A presentation of student work resulting from a course on resilient planning, policy, and design. Keeping History Above Water Conference, Newport, Rhode Island, April 10-13, 2016.

- **Becker, A.** (2016). Hurricane Resilience and Impacts to Seaport Supply Chains. Invited Speaker for the 2016 Stu Clark Speaker Series at the University of Manitoba. March 4, 2016.

- McIntosh, R.*, Becker, A. (2016). Towards a Comparative Index of Seaport Climate-Risk: Development of Indicators from Open Data. Poster presentation at American Geophysical Union 2016 Ocean Sciences Meeting, New Orleans, LA, Feb. 21-26, 2016.

- Kretsch, E.*, **Becker, A.** (2016). Leadership and Responsibility for Long-term Hurricane Resilience: Stakeholder Perceptions in the Port of Providence, RI. Social Coast Conference. Charleston, SC, Feb. 11, 2016.

- **Becker, A.**, Burroughs, R. (2016). More holistic planning for long-term coastal resilience? Port of Providence Demonstration Project. Social Coast Conference.

Charleston, SC, Feb. 10, 2016.

- Stempel, P. (2016). Data Driven Visualization. Paper presented at the ECM14, Estuarine and Coastal Modeling Conference, South Kingstown, RI, June 14-17, 2016.

- Witkop, R., Stempel, P., **Becker, A.**, (2017). Coupling local scale, high resolution, qualitative data to interface with numerical storm models. Poster Presentation. American Geophysical Union Annual Conference, New Orleans, LA. December 12, 2017.

- Stempel, P., **Becker, A.** (2018). Perceptions of risk and legitimacy: how scenario selection and presentation of ocean models undermines disaster risk reduction. Paper presented at the ECM15, Estuarine and Coastal Modeling Conference, Seattle, WA, June 25-27, 2018.

- Witkop, R., Stempel, P., **Becker, A.** (2018). Incorporating facility manager knowledge into storm impact models: A case study of critical facilities in Westerly, Rhode Island. Oral presentation. 2018 Rhode Island Flood Mitigation Association Annual Conference. Smithfield, RI. Apr. 5, 2018.

- **Robadue, Donald D.** and Dawn Kotowicz (2018). Understanding resistance to resilience in coastal hazards and climate adaptation: three approaches to visualizing structural and process obstacles, opportunities and adaptation responses. Submitted to the 52nd Hawaii International Conference on System Sciences, Disaster Information, Technology, and Resilience Mini-Track of the Digital Government Track, June 16, 2017.

Coastal Hazards Modeling

Blanton:

Conference papers, presentations, theses

- Storm Surge Probabilities for Hurricane Events, J. Smith, **B. Blanton, R. Luettich**, 2017. Poster presented at AMS 2017 in Seattle WA (Jan 2017), DHS CRC Annual Meeting in Chapel Hill, NC (Feb 2017), and the annual Hurricane Awareness conference at East Carolina University (May 2017).

- Smith, J., **Blanton. B., and Luettich, R.** 2018. Probabilistic Hurricane Track Generation for Storm Surge Prediction. Presented at the American Meteorological Society 2018, Austin, TX.

- Smith, J. December 2017. Probabilistic Hurricane Track Generation for Storm Surge Prediction. Master's Thesis, UNC-Chapel Hill, Department of Marine Sciences.

Dietrich:

- A Thomas*, **JC Dietrich, TG Asher**, M Bell, **BO Blanton**, JH Copeland, AT Cox, **CN Dawson, JG Fleming, RA Luettich** (2019). Influence of Storm Timing and Forward Speed on Tide-Surge Interactions during Hurricane Matthew. Ocean Modelling, 137, 1-19, DOI: 1016/j.ocemod.2019.03.004.

- R Cyriac***, JC Dietrich, JG Fleming, BO Blanton, C Kaiser, CN Dawson, RA Luettich** (2018). Variability in Coastal Flooding Predictions due to Forecast Errors during Hurricane Arthur. Coastal Engineering, 137(1), 59-78. DOI: 1016/j.coastaleng.2018.02.008.

- A Gharagozlou*, **JC Dietrich**, A Karanci, **RA Luettich**, MF Overton. Storm-Driven Erosion and Inundation of Barrier Islands from Dune- to Region-Scales. Coastal Engineering, in review.

- R Cyriac*, **JC Dietrich, JG Fleming, BO Blanton, C Kaiser, CN Dawson, RA Luettich** (2018). Variability in Coastal Flooding Predictions due to Forecast Errors during Hurricane Arthur. Coastal Engineering, 137(1), 59-78. DOI: 10.1016/j.coastaleng.2018.02.008

Conference papers, presentations, theses

- A Thomas*, **JC Dietrich**, TG Asher, **BO Blanton**, AT Cox, **CN Dawson, JG Fleming, RA Luettich**. High-Resolution Modeling of Surge during Hurricane Matthew. 15th Estuarine and Coastal Modeling Conference, Seattle, Washington, 25 June 2018.

- A Thomas*, **JC Dietrich, JG Fleming**, **BO Blanton**, T Asher, **RA Luettich**. High-Resolution Modeling of Surge during Hurricane Matthew. ADCIRC Users Group Meeting, NOAA Center for Weather and Climate Prediction, College Park, Maryland, 13 April 2018.

- A Thomas*, **JC Dietrich, RA Luettich, JG Fleming, BO Blanton**, TG Asher, SC Hagen, **MV Bilskie**, P Bacopoulos. Hindcasts of Winds and Surge during Hurricane Matthew (2016): Balancing Large-Domain Coverage and Localized Accuracy. ADCIRC Users Group Meeting, Norwood, Massachusetts, 4-5 May 2017.

- A Thomas*, **JC Dietrich, JG Fleming, BO Blanton**, T Asher, **RA Luettich**. High-Resolution Modelling of Surge during Hurricane Matthew (2016). Graduate

Student Research Symposium, North Carolina State University, 21 March 2018.

- A Thomas*, **JC Dietrich, JG Fleming, BO Blanton**, T Asher, **RA Luettich**. High-Resolution Modelling of Surge during Hurricane Matthew (2016). Environmental, Water Resources, and Coastal Engineering Research Symposium, North Carolina State University, 02 March 2018.

Hagen:

- Santiago-Collazo, F.L., **Bilskie, M.V., Hagen, S.C.** (2019) A comprehensive review of compound inundation models. Environmental Modelling & Software, Volume 119, September 2019, 166-181. DOI: 1016/j.envsoft.2019.06.002
- **Bilskie, M.V.,** Asher, T.G., **Fleming, J.G., Hagen, S.C., Kaiser, C., Luettich Ur., R.A., Twilley, R.** (2019) Real-time storm surge predictions during Hurricane Michael. *Geophysical Research Letters*, In Progress
- Bilskie, M.V., **Hagen, S.C., Medeiros, S.C.** (2019) Unstructured finite element mesh development for real-time hurricane storm surge forecasting. Coastal Engineering, In Preparation.
- Tahsin, S., **S.C. Medeiros**, A. Singh, M. Hooshyar (2017), Optical Cloud Pixel Recovery via Machine Learning. Remote Sensing, Accepted. DOI: 10.3390/rs9060527
- Tahsin, S., **S.C. Medeiros**, A. Singh (2016). Resilience of coastal wetlands to extreme hydrologic events in Apalachicola Bay. Geophysical Research Letters, Vol. 43, DOI: 10.1002/2016GL069594.

Resio:

- **Resio, D.T.**, Asher, T.G., and J.I. Irish, 2017: The effects of natural structure on estimated tropical cyclone surge extremes, J. Nat. Haz., currently available online, Nat Hazards, DOI: 10.1007/s11069-017-2935-y
- Irish, J.L., Weiss, R. and **D.T. Resio**, Physical Characteristics of Coastal Hazards and Risks, Chapter 25, Springer Handbook of Ocean Engineering, Springer Dordrecht Heidelberg London New York, M. Dhanak and N. Xiros (Eds.), 549–562.
- **Resio, D.T.**, Tumeo, M.A., and J.L. Irish, Statistical Characterization of Hazards and Risk in Coastal Areas, Chapter 26, Springer Handbook of Ocean Engineering, Springer Dordrecht Heidelberg London New York, M. Dhanak and N. Xiros

(Eds.), 567–593.

Ginis:

- Stempel, P. and **Becker,** A., 2019: Visualizations Out of Context: Addressing Pitfalls of Real-Time Realistic Hazards Visualizations.

  ISPRS Int. J. Geo-Inf. **2019**, *8*(8), 318; DOI: 10.3390/ijgi8080318

- **Ullman D.S., I. Ginis, W. Huang**, C. Nowakowski*, X. Chen*, and P. Stempel, 2019: Assessing the Multiple Impacts of Extreme Hurricanes in Southern New England, USA. Geosciences 2019, 9(6), 265. DOI: 10.3390/geosciences9060265

- Witkop, R., **Becker, A.,** Stempel, P.*, **Ginis, I.** (2019). Developing Consequence Thresholds for Storm Models through Participatory Processes: Case Study of Westerly Rhode Island. Frontiers in Earth Science: Geohazards and Georisks. Vol. 7. DOI: 3389/feart.2019.00133.

- Gao K, and **Ginis**, 2018: On the characteristics of roll vortices under a moving hurricane boundary layer. J. Atmos. Sci., 75, 2589-2598. DOI: 10.1175/JAS-D-17-0363.1

- Chen*, X., **Ginis**, and T. Hara, 2018: Sensitivity of offshore tropical cyclone wave simulations to spatial resolution in wave models. J. Mar. Sci. Eng., 6, 116. DOI: 10.3390/jmse6040116

- Stempel, P.*, **Ginis, I., Ullman, D., Becker, A**., Witkop, R. (2018). Real-Time Chronological Hazard Impact Modeling. Journal of Marine Science and Engineering, Vol. 6, no. 134. DOI: 3390/jmse6040134.

- Teng, F., **Huang, and I. Ginis**, 2018. Hydrological modeling of storm-induced runoff and snowmelt in Taunton River Basin. Journal of Natural Hazards, 91, 179-199. DOI: 10.1007/s11069-017-3121-y

- **Liu, Q., L. M. Rothstein**, and Y. Luo, 2017. A periodic freshwater patch detachment process from the Block Island Sound estuarine plume. J. Geophys. Res. Oceans, 122, 570–586, DOI:10.1002/2015JC011546

- Gao, K., **I. Ginis**, J.D. Doyle, Y. Jin, 2017: Effect of boundary layer roll vortices on the development of the axisymmetric tropical cyclone J. Atmos. Sci. DOI: 10.1175/JAS-D-16-0222.1

- Whitney, M. M., **D. S. Ullman**, and D. L. Codiga, 2016. Subtidal Exchange in Eastern Long Island Sound. J. Phys. Oceanogr. 46, 2351-2371. DOI: 1175/JPO-

D-15-0107.1

- Gao, K. and **I. Ginis**, 2016: On the equilibrium-state roll vortices and their effect in the hurricane boundary layer. J. Atmos. Sci., 1205-1222. https://doi.org/10.1175/JAS-D-15-0089.1

- Liu, Q., L. **M. Rothstein**, Y. Luo, D. **S. Ullman**, and D. L. Codiga, 2016. Dynamics of the periphery current in Rhode Island Sound. Ocean Modelling, 105, 13-24. DOI: 10.1016/j.ocemod.2016.07.001

- Liu, Q., **L. Rothstein**, and Y. Luo, 2016. Dynamics of the Block Island Sound estuarine plume. J. Phys. Ocean, Accepted for publication. DOI: 10.1175/JPO-D-15-0099.1

- Reichl, B. G, D. Wang, T. Hara, **I. Ginis**, T. Kukulka, 2016: Langmuir turbulence parameterization in tropical cyclone conditions. J. Phys. Oceanogr., 46, 863-886. DOI: 10.1175/JPO-D-15-0106.1

- Reichl, B. G., **I. Ginis**, T. Hara, B, Thomas, T. Kukulka, and D. Wang, 2016: Impact of sea-state dependent Langmuir turbulence of the ocean response to a tropical cyclone. Mon. Wea. Rev. DOI: 10.1175/MWR-D-16-0074.1

- Sun, Y., C. Chen, R. C. Beardsley, **D. Ullman**, B. Butman, and H. Lin, 2016. Surface Circulation in Block Island Sound and Adjacent Coastal and Shelf Regions: A FVCOM-CODAR comparison. Progress in Oceanography, 143, 26-45. DOI: 10.1016/j.pocean.2016.02.005

- Spaulding, M. L., Grilli, A., Damon, C., Crean, T., Fugate, G., Oakley, B., & Stempel, P.*, (2016). Stormtools: Coastal Environmental Risk Index (CERI). Journal of Marine Science and Engineering, 4(3). DOI: 10.3390/jmse4030054

Conference papers, presentationsj

- **Huang, W., F Teng, I. Ginis, and D. Ullman**. 2019. Rainfall Runoff and Flood Simulations for Hurricane Impacts on Woonasquatucket River, USA. ICCEN 2019. Accepted by 8th International Conference on Civil Engineering (ICCEN 2019), November 19-20, Paris, France, 2019

- **Ginis I.** (2019): Advancing modeling capabilities to improve prediction of extreme weather events in the Northeastern United States, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, April 11.

- **Ginis I.** (2019): Improving Prediction of Extreme Weather and Its Impact in New England, RI Emergency Management Agency, Cranston RI, March 7.

- **Ginis I.** (2019): Modeling Combined Coastal and Inland Impacts from Extreme Storms, RI Department of Health, Providence RI, March 8.

- Fei, T., **W. Huang, I. Ginis**, Y. Cai, 2016. Characteristics of River Flood and Storm Surge Interactions in a Tidal River in Rhode Island, USA. Proceeding of IUTAM Symposium on Storm Surge Modelling and Forecasting, Oct 17-19, 2016, Shanghai, China

- Stempel, P.*, **Becker, A.**, (Accepted). Effects of localization on perceptions of storm surge risk depicted in model driven semi-realistic visualizations. International Conference on Sustainable Development, NY, NY. September 26-28, 2018.

- **Ginis I.** (2018): Advances in Predicting Hurricane Path and Intensity, Jamestown Philomenian Library, Jamestown RI, September 24.

- **Ginis I.** (2018): The 1938 Great New England Hurricane Looking to the Past to Understand Today's Risk, East Greenwich Historic Preservation Society, East Greenwich, RI, September 15.

- **Becker, A.** (2019). Overcoming Barriers to Long-term Climate Adaptation. Lecture of Opportunity, US Naval War College, Newport, RI, April 29.

- **Becker, A.** (2019). Climate risk adaptation for ports: Research for transformational thinking. UNCTAD Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future, Geneva, Switzerland, April 16-17.

- Stempel, P., **Becker., A., Ginis, I., Ullman, D**., Rubinoff., P., Overstrom, N. (2019). Rethinking model-driven realistic storm-surge graphics. Rhode Island Coastal Ecology, Assessment, Innovation, and Modeling (RI C-AIM) Research Symposium 2019, Kingston RI. April 10.

- **Becker, A**, Stempel, P., Menendez, J. (2019). Visualizing Risk: Dynamic 3d Models of Storm Impacts on Coastal Structures In Rhode Island. Poster presentation at the Infrastructure Climate Network Meeting, Portsmouth, NH, April 4-5.

- **Ginis, I., D. Ullman, T. Hara, W. Huang, A. Becker, and R. Luettich** (2018): Developing a Coastal and Inland Hazard and Impact Prediction System for Extreme Weather Events in the Northeastern United States, AGU Fall Meeting, December 14, https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/409069

- **Becker, A.** (2018). Stimulating Transformational Thinking for Long-Term Climate Resilience. University of Rhode Island Coastal Resiliency Symposium, Oct. 16, Narragansett, RI. (I)

- Peter Stempel Ph.D. Dissertation in Marine Affairs: Depicting consequences of storm surge, opportunities and ethics. 2018, Primary advisor: Dr. Austin Becker, Committee member: Dr. Isaac Ginis

- Stempel, P.*, **Becker, A.** (2018), Effects of localization on perceptions of storm surge risk depicted in model driven semi-realistic visualizations. International Conference on Sustainable Development, NY, NY. September 26-28, 2018.

- Bobby Witkop Master's thesis in Marine Affairs: Developing Consequence Thresholds for Storm Impact Models: Case Study of Westerly, Rhode Island. 2018, Primary advisor: Dr. Austin Becker, Committee member: Dr. Isaac Ginis

- Chen, X. *, **I. Ginis** and T. Hara (2018). Sea-State Dependent Drag Coefficient in Shallow Waters Under Tropical Cyclones. 21st Conference on Air-Sea Interaction, June 18 https://ams.confex.com/ams/23BLT21ASI/meetingapp.cgi/Paper/345222

- Chen, X.*, T. Hara, and **I. Ginis** (2018). Sea-state dependent air-sea momentum flux in a shallow water under a tropical cyclone. Ocean Sciences Meeting, February 14 https://agu.confex.com/agu/os18/meetingapp.cgi/Paper/303041

- **Ginis, I.**, C. Nowakowski*, and K. Gao (2018). A Hurricane Boundary Layer Model for Simulating Surface Winds during Hurricane Landfall. 33rd Conference on Hurricanes and Tropical Meteorology, April 18, https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339799.html

- **Ginis, I.**, **D. Ullman**, T. Hara, **C. Kincaid**, K. Rosa*, X. Chen*, B. Thomas, **A. Becker**, P. Stempel*, R. Witkop*, **P. Rubinoff**, **W. Huang**, M. Orr, R. Thomas, R. Thompson, M. Belk, P. Morey, and S. Conard (2018). Advancing Modeling Capabilities and Impact Analysis Tools to Improve Preparedness for Major Hurricane Hazard Events. 98th AMS Annual Meeting, January 11, https://ams.confex.com/ams/98Annual/webprogram/Paper336049.html

- Nowakowski, C.* and **Ginis I.** (2018): Advancing modeling of surface winds during hurricane landfall for predicting storm impacts. DHS Centers of Excellence Summit, May 30-31, 2018 https://cina.gmu.edu/coe-summit-2018/

- Witkop, R.*, **Becker, A.**, Stempel, P.*, (2018). "Incorporating facility manager knowledge into storm impact models: A case study of critical facilities in Westerly, Rhode Island," Rhode Island Floodplain Managers Association, Smithfield, RI, April 5.

- Rosa, K.*, **Kincaid, C.** (2018). "Transporting Nutrients Northward from Rhode Island Sound Bottom Water to the Upper Narragansett Bay Euphotic Zone", RI

C-AIM/RI NSF EPSCoR Symposium. Kingston, RI, April 9.

- Rosa, K., **Kincaid, C., Ullman, D**., and **Ginis, I.** (2017). Hurricane Rhody: How does Rhode Island Fare Against Hypothetical Superstorm?. URI Graduate Conference. Kingston, RI. 8 April.

- Rosa, K. *, **Kincaid, C., Ullman, D.**, and **Ginis, I.** (2017). Baroclinic Model of Narragansett Bay Post-Storm Shelf-Estuary Exchange. Estuary Research Workshop: Limiting Factors Beyond Nitrogen. Narragansett, RI. September 13.

- **Ginis, I., D. Ullman**, T. Hara, **C. Kincaid, L. Rothstein**, W. Hwang, B. Thomas, X. Chen*, K. Rosa*, A. Becker, P. Stempel*, R. Witkop*, P. Rubinoff (2017). Developing a mul.-model ensemble system for assessing hurricane hazards and impacts. URI Coastal Resilience Science and Engineering Workshop, December 4.

- **Ullman, D., I. Ginis, W. Hwang**, P. Stempel*, T. Hara, **C. Kincaid, L. Rothstein, P. Rubinoff**, B. Thomas, X. Chen*, K. Rosa* (2017). Assessing the Multiple Impacts of Extreme Hurricanes in Southern New England. URI Coastal Resilience Science and Engineering Workshop, December 4.

- Witkop, R.*, Stempel, P.*, **Becker, A.**, (2017). Coupling local scale, high resolution, qualitative data to interface with numerical storm models. American Geophysical Union Annual Conference, New Orleans, LA. Dec. 12.

- Stempel, P.* (2016). Data Driven Visualization. Estuarine and Coastal Modeling Conference 2016, Narragansett, RI, June 14-15.

Fleming:

- A Thomas*, **JC Dietrich,** TG Asher, M Bell, **BO Blanton**, JH Copeland, AT Cox, **CN Dawson, JG Fleming, RA Luettich** (2019). Influence of Storm Timing and Forward Speed on Tide-Surge Interactions during Hurricane Matthew. Ocean Modelling, 137, 1-19, DOI: 1016/j.ocemod.2019.03.004.

- Musinguzi, A.; Akbar, M.K.; **Fleming, J.G**.; Hargrove, S.K. Understanding Hurricane Storm Surge Generation and Propagation Using a Forecasting Model, Forecast Advisories and Best Track in a Wind Model, and Observed Data—Case Study Hurricane Rita. Mar. Sci. Eng. 2019, 7, 77. DOI: 10.3390/jmse7030077

- R Cyriac, **JC Dietrich, JG Fleming, BO Blanton, C Kaiser, CN Dawson, RA Luettich**. Variability in Coastal Flooding Predictions due to Forecast Errors during Hurricane Arthur. Coastal Engineering, 137(1), 59-78. DOI: 10.1016/j.coastaleng.2018.02.008

- Akbar, M.K.; Luettich, R.A.; Fleming, J.G.; Aliabadi, S.K. CaMEL and ADCIRC Storm Surge Models—A Comparative Study. J. Mar. Sci. Eng. 2017, 5, 35. DOI: 10.3390/jmse5030035

Education and Workforce Development

Whalin:

- "NSF-PIRE, Coastal Flood Risk Reduction Program, Authentic Learning and Transformative Education," Volume 1-2015-2017; Edited by Baukje "Bee" Kothius, Yoonjeong Lee and Samuel Brody, March 2018.

Conference papers, presentations, theses

- **Whalin, Robert W**., A PhD in Engineering Degree: Coastal Engineering Emphasis Area. Proceedings, 126th ASEE Conference, Tampa Bay, FL, June 2019.
- **Ebersole, Bruce; Richardson, Thomas W.; Whalin, Robert W.,** Suppression of Hurricane Surge Forerunner and Peak Surge in Galveston and West Bays Achieved with a Western Segment of the Coastal Spine. 10th Texas Hurricane Conference, University of Houston, Houston, TX; Aug. 3, 2018.
- **Ebersole, Bruce; Richardson, Thomas**; and **Whalin, Robert, W.**, Surge Suppression Achieved by Different Coastal Spine (Ike Dike) Alignments. 9th Texas Hurricane Conference, University of Houston, August 4, 2017, Houston, TX.
- **Whalin RW**, Pang Q, Latham J, Lowe LN. Assessment of a Summer Bridge Program: Seven Years and Counting. 2017 ASEE National Conference Proceedings, Columbus, OH, June 24-28, 2017.
- **Whalin RW**. HBCU Engineering Faculty and Graduates: Implications for Race, Retention and Graduation Linkages. NAAAS & Affiliates 2016 National Conference Proceedings, Baton Rouge, LA, published Oct. 2016.
- **Whalin RW**, Pang Q, Latham J, Lowe LN. Assessment of a Summer Bridge Program: Seven Years and Counting. 2017 ASEE National Conference Proceedings, Columbus, OH, June 24-28, 2017.
- **Whalin RW**, Brody SD, and Merrell WJ. The Galveston Bay Region as an International Test Bed for Flood Risk Reduction. 8th Texas Hurricane Conference, University of Houston, Houston, TX, August 5, 2016.

- **Ebersole B, Richardson TW**, and **Whalin RW**. Modeling Coastal Storms: Past, Present and Future. 8th Texas Hurricane Conference, University of Houston, Houston, TX, August 5, 2016

- **Whalin, Robert, W.; Pagan-Trinidad, Ismael**; Villanueva, Evelyn; and Pittman, David, W., A Quarter Century of Resounding Success for a University/Federal Laboratory Partnership. ASEE 123rd Annual Conference and Exposition, New Orleans, LA, June 26, 2016.

- **Ebersole, Bruce; Richardson, Thomas**; and **Whalin, Robert, W.**, Surge Suppression Achieved by Different Coastal Spine (Ike Dike) Alignments. 9th Texas Hurricane Conference, University of Houston, August 4, 2017, Houston, TX.

Chen/Faik:

Conference papers, presentations, theses

- Ying Bai & **Hang Chen**, Build an Optimal Evacuation Contraflow Model for Natural Disasters by Using Fuzzy Inference System. Proceedings of the 2018 IEEE International Conference on Fuzzy System, July 8-13, Rio de Janeiro, Brazil, 2018.

- Cody Byrd, Jean-Marie Nshimiyimana, Ehije Idehenre, **Hang Chen** (Faculty Advisor), Data Analysis of Haiti's Resiliency Post-2010 Earthquake. Presented at the 2017 Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM).

- NyJae Dickerson, Adonis Tillman, Desmond Taylor, Awatif Amin (Faculty Advisor) Using Data Mining to analyze Natural Disasters at 10 countries. Presented at the 2017 Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM).

Laiju:

- Long, J., Rose, S., Jwainat, A. & Hunter, F. (2019), Tougaloo Community Preparedness for Homeowners. Mississippi Academy of Sciences (MAS) ISSN 0076 – 9436, Vol 64 # 1

- Jones, T. Robinson, S. Boler, D.& Hunter, F. (2019), Disaster Preparedness: How Prepared Are They? An Assessment of Renters in Tougaloo Mississippi.

Mississippi Academy of Sciences (MAS) ISSN 0076 – 9436, Vol 64 # 1

- Kinkaid, D.,Ze'ronte, B.Sneed, H., &Banerjee, S., (2019), Using GIS to Study Disproportionate Disaster Impact on Vulnerable Mississippi Population. Mississippi Academy of Sciences (MAS) ISSN 0076 – 9436, Vol 64 # 1, and presented at 83rd Annual Meeting in Hattiesburg, MS on February 21, 2019

- Mage, D. Reed, S. Hokins, A. Mangum, C. & Banerjee, S. (2018) Using Arc GIS to Map Disaster Effects on Mississippi. Abstract published in The journal of Mississippi Academy of Sciences (ISSN 0076-9436) vol 63, 1 February edition

- Bryant, J. Hill, C. Bibbs, M. Boler, D. & Khan, S. (2018) Role of Effective Communication in Disaster Preparedness. Abstract published in The journal of Mississippi Academy of Sciences (ISSN 0076-9436) vol 63, 1 February edition

- Ball, I & **Laiju, M.** (2017) Sociodemographic Characteristics and Natural Disaster Preparedness among Mississippi Residence,. Abstract published in The journal of Mississippi Academy of Sciences (ISSN 0076-9436) April edition.

- **Laiju, M.** (2017) A Global Issue: Natural, Manmade Disaster, and Exploitation of Children. Pardee RAND Faculty Leaders Fellowship, manuscript under review.

- **Laiju, M.** (2016) Natural Disaster and Child Trafficking. Mellon Fellowship

<u>Conference papers, presentations, senior papers</u>

- Laiju, M. (2019), Career Pathway: Multidisciplinary Undergraduate Curriculum in Homeland Security's Coastal Resilience at a HBCU. Abstract published in Southern Sociological Society (SSS) Journal and presented at SSS Conference on April 11, 2019, at Atlanta, GA.

- Laiju, M. & Hunter, F. (2018), Transforming the Curriculum: Adding Disaster Management and Coastal Infrastructure Management to the Curriculum. Abstract accepted and presented at the Historical Black Colleges &Universities (HBCU) Faculty Development Network Conference in Jackson, Mississippi, November 2, 2018

- Jwainat, A. (2019), senior paper Knowledge and Attitudes Regarding Disaster/ Emergency Preparedness

- Porter, J. (2019), New Orleans Residents' Awareness of Disaster Preparedness

- **Laiju, M.** & Banerjee, S. (2017) Innovative Interdisciplinary Undergraduate Curriculum in Homeland Security at a HBCU. Presented at the 10th Anniversary

Homeland Defense & Security Education Summit on March 23, 2017

- Young, K, & Hunter, F. (2017) Hurricanes, Mudslides, and Drought: Considering the Public's Perceptions of the Role Governments Should Play in Providing Aid Using the NORC General Social Survey (GSS). Presented at Mississippi College & Tougaloo College (MCTC) Research Symposium

- Hopkins, A. & Banerjee, S. (2017) Using ArcGIS to Map Natural Disasters in Mississippi. Presented at Mississippi College & Tougaloo College (MCTC) Research symposium.

Keim:

- Xue, G.Z., D.J. Gochis, W. Yu, **B.D. Keim**, R.V. Rohli, Z. Zang, K. Sampson, A. Dugger, D. Sathiaraj, and Q. Ge. 2018. Modeling Hydroclimatic Change in Southwest Louisiana Rivers. Water 10(5), Article No. 596. https://doi.org/10.3390/w10050596.

- **Keim, B.D.**, W.D. Kappel, G.A. Muhlstein, D.M Hultstrand, T.W Parzybok, A.B. Lewis, E.M. Tomlinson, and **A.W. Black**. 2018. Assessment of the Extreme Rainfall Event at Nashville, Tennessee and the Surrounding Region on May 1-3, 2010. Journal of American Water Resources Association. https://doi.org/10.1111/1752-1688.12657.

- Gilliland, J.M., and **B.D. Keim**. 2018. Position of the South Atlantic Anticyclone and its impact on Surface Conditions across Brazil. Journal of Applied Meteorology and Climatology 57(3):535-553. DOI: 10.1175/JAMC-D-17-0178.1

- **Black, A.W.**, and G. Villarini. (2018) Effects of Methodological Decisions on Rainfall-Related Crash Risk Estimates. Accident Analysis and Prevention. DOI: 10.1016/j.aap.2018.01.023

- Gilliland, J. M., and **B.D. Keim**. Surface Wind Speed: Trend and Climatology of Brazil from 1980–2014. International Journal of Climatology. DOI: 10.1002/joc.5237

- **Black, A.W.**, G. Villarini, and T.L. Mote. 2017. Effects of Rainfall on Vehicle Crashes in Six U.S. States. Weather, Climate, and Society **9**: 53–70. DOI: 10.1175/WCAS-D-16-0035.1

- Shao, W., S. Xian, **B. Keim**, K. Goidel, N. Lin. 2017. Understanding Perceptions of Changing Hurricane Strength Along the U.S. Gulf Coast. International Journal of Climatology **37(4)**:1716-1727. DOI: 10.1002/joc.4805

- Allard, J.M., J.V. Clarke, and **B.D. Keim**. 2016. Spatial and Temporal Patterns of In Situ Sea Surface Temperatures within the Gulf of Mexico from 1901–2010. American Journal of Climate Change **5**:314-343. DOI: 10.4236/ajcc.2016.53025

- Shao, W., J.C. Garand, **B.D. Keim**, and L.C. Hamilton. 2016. Science, Scientists, and Local Weather: Understanding Mass Perceptions of Global Warming. Social Science Quarterly **97(5)**:1023-1057. DOI: 10.1111/ssqu.12317

- Hamilton, L.C, J. Hartter, **B.D. Keim**, A.E. Boag, M.W. Palace, F.R. Stevens, M.J. Ducey. 2016. Wildfire, Climate and Perceptions in Northeast Oregon. Regional Environmental Change **16**:1819-1832. DOI: 10.1007/s10113-015-0914-y

- Shankman, D., and **B.D. Keim**. 2016. Flood Risk Forecast for China's Poyang Lake Region. Physical Geography 37(1): 88-91.

Pagán-Trinidad:

- **Pagán Trinidad, Ismael, López-Rodríguez, Ricardo** and Ernesto Diaz, Education and Building Capacity for Improving Resilience of Coastal Infrastructure. Proceedings, ASEE 126th Annual Conference & Exposition: June 16-19, 2019, Tampa FL.

- Morales-Velez, A. C., and Hughes, K.S., Comprehensive Hurricane María Mass Wasting Inventory and Improved Frequency Ratio Landslide Hazard Mapping. Revista Dimensión Year 32, Vol 1, 2018

- Aponte Bermúdez, Luis D., Huracán María,: Sinopsis y Análisis Preliminar del Impacto en la Infraestructura de Puerto Rico. Revista Dimensión Year 32, Vol 1, 2018

- Martínez-Cruzado, José A. Huerta-López, Carlos I. Martínez-Pagán, Jaffet, Santana Torres, Erick X,and Hernández-Ramírez, Francisco J., Destrozos, Recuperación, y Planes en la Red Sísmica de Movimiento Fuerte a Raíz de los Huracanes Irma y María. Revista Dimensión, Year 32, Vol 1, 2018

- Acosta, Felipe J, Esquilín-Mangual, Omar, Wood, Stephanie G., Long, Wendy R. and Valdés, Didier, Lessons Learned from the Evaluation of Concrete Pole Failures Following Hurricane María. Revista Dimension Year 32, Vol 1, 2018

Conference papers, presentations, theses

- **Ismael Pagán Trinidad** and **Ricardo López**, Education and Building Capacity for Improving Resilience of Coastal Infrastructure. ASEE 126th Annual Conference & Exposition: June 16-19, 2019, Tampa FL, Presentation

- **Ismael Pagán Trinidad** and **Ricardo López**, Improving Resilience of Coastal Infrastructure through Education and Building Capacity. 2019 NLTAPA Southeast Region Meeting, April 30, 2019 San Juan PR, Presentation

- **Ricardo López** and Juan Rodríguez, Análisis tridimensional no lineal de estructuras de concreto (Non-Linear Tridimensional Analysis of Reinforced Concrete Structures). CIAPR –Mega Viernes Civil (Island wide meeting of Civil Engineers), April 5 2019, San Juan PR, Presentation.

- Carla López del Puerto, **Ismael Pagán Trinidad** and **Ricardo López**, Hurricane Maria in Puerto Rico: Assessment of the Damages, Reconstruction Efforts and Beyond Recovery. ASCE Construction Summit in Atlanta, March 7 to 9, 2019, Presentation Panel.

- **Ismael Pagán Trinidad** and **Ricardo López**, Overview of Damage Caused by Hurricane Maria in PR at Gavin Smith's Seminar at UNC, February 27, 2019, Remote Presentation

- **Ismael Pagán Trinidad** and **Ricardo López**, Overview of Damage Caused by Hurricane Maria in PR at Gavin Smith's Seminar at NCSU, February 27, 2019, Remote Presentation.

- Low Impact Development and Green Alternatives for Urban Projects: Sponsors FEMA, CRC; Speaker **Ismael Pagán Trinidad**, Aguadilla FEMA Headquarters, February 8, 2019.

- Benjamín Colucci, Alberto Figueroa and Alexander Molano,(Graduate student supported by the CRC project), Paper and Presentation, Lessons Learned for the Puerto Rico Transportation Infrastructure after Hurricane María. ITE, October 2018.

- Re-Imagine Puerto Rico: A discussion panel on solutions to rebuild PR, co-sponsored with Resilient Puerto Rico Advisory Commission. 11 speakers including **Ismael Pagán Trinidad**, UPRM, August 14, 2018

- Benjamín Colucci, Alberto Figueroa and Alexander Molano, (Graduate student supported by the CRC project), Paper and Presentation, Impacts and Lessons Learned as a Result of the Passage of Hurricane Maria on the Transportation Infrastructure of the Caribbean Island of Puerto Rico. UPADI, August 2018.

- Hector Colón, (SUMREX student 2017), Paper and Presentation, ASCE Coastal Engineering International Conference, Numerical Modelling of Tsunami

Inundation Considering the Presence of Offshore Islands and Barrier Reefs. Baltimore, MD, July 2018.

- **Ismael Pagán-Trinidad, Ricardo López-Rodríguez**, Education, Resilience and the Built Environment: Impacts and Some Lessons Learned on Infrastructure for Improvement of Coastal Infrastructure in PR. Symposium: Planning and Resilient Recovery in Puerto Rico, Graduate School of Planning – University of Puerto Rico – Río Piedras, May 18-19, 2018. Presentation.

- Angel Alicea (PhD Dissertation): Dynamic Identification and Nonlinear Modeling for the Structural Health Assessment of Aged Coastal Infrastructure in Puerto Rico. PhD dissertation completed in December 2018, Department of Civil Engineering, advisor Ricardo López

- Efrain Ramos (MSCE Thesis): Stochastic Simulation of Tropical Cyclones for Quantification of Uncertainty associated with Strong Recurrence and Intensity. July 8, 2019 (already submitted, pending final oral presentation); Dept. of Civil Engineering and Surveying; Advisor Ismael Pagán Trinidad-UPRM; Co-Advisor Norberto Nadal ERDC-UPRM.

- Kevin Cueto (MSCE Thesis): Modeling considering Computational Fluid Dynamics of hydraulic pressure exerted on coastal structures. July 8, 2019 (already submitted, pending final oral presentation); Dept. of Civil Engineering and Surveying, Advisor-Ricardo López, UPRM.

- Digital proceedings of the conference Lessons Learned and Best Practices: Resilience of Coastal Infrastructure.

- The following two presentations were given by Dr. Ricardo López at the World Engineering Conference on Disaster Risk Reduction. More information at http://www.wfeo.org/events/world-engineering-conference-disaster-risk-reduction-wecdrr-2016/
  - **Ismael Pagán-Trinidad, Ricardo López-Rodríguez,** Agustín Rullán, Oscar Perales-Pérez, John Fernández-Van Cleve, THE ROLE OF UNIVERSITIES ON DISASTER RISK REDUCTION IN THE COMMUNITY: UPRM CASE STUDY. World Engineering Conference on Disaster Risk Reduction, Peruvian Association of Professional Engineers, Lima Perú, December 5-6, 2016.
  - **López-Rodríguez, Ricardo R., Pagán-Trinidad, Ismael**, Structural Vulnerability to Natural Hazards in Puerto Rico. World Engineering Conference on Disaster Risk Reduction, Peruvian Association of Professional Engineers, Lima Perú, December 5-6, 2016.

- **Robert W. Whalin, Ismael Pagán-Trinidad**, Evelyn Villanueva and David Pittman, A Quarter Century of Resounding Success for a University/Federal Laboratory Partnership. Proceedings, 123rd ASEE Annual Conference and

Exposition, Vol 1, presented June 27 2016 in New Orleans, LA. ISBN: 978-1-5108-3480-4

- **Ismael Pagán-Trinidad, Ricardo López-Rodríguez**, Education, Resilience and the Built Environment: Impacts and Some Lessons Learned on Infrastructure for Improvement of Coastal Infrastructure in PR. Symposium: Planning and Resilient Recovery in Puerto Rico, Graduate School of Planning – University of Puerto Rico – Río Piedras, May 18-19, 2018

- Benjamín Colucci Ríos (Presenter), Alexander Molano Santiago, Ismael Pagán Trinidad and Didier. M Valdés Díaz. Impact of Extreme Climate in Coastal Transportation Civil Infrastructure in the Caribbean. World Engineering Forums November 26 to December 2, 2017, Rome, Italy

- Benjamín Colucci Ríos (Presenter) and Alexander Molano Santiago, Impact of Hurricane Maria on Puerto Rico's Transportation Infrastructure: Lessons Learned. 97th Transportation Research Board Annual Meeting, AHB55 Committee, *Work Zone Traffic Control Committee Meeting,* January 9, 2018.

- Benjamín Colucci Ríos (Presenter) and Alexander Molano Santiago, Impacto del Huracán María en la infraestructura de transportación de Puerto Rico (Impact of Hurricane María in Puerto Rico's Transportation Infrastructure). Conversatorio para un Puerto Rico Resiliente. February 20, 2018

- Benjamín Colucci Ríos (Presenter), Alexander Molano Santiago and Joel F. Alvarado López, El impacto del Huracán María en la infraestructura de transporte de Puerto Rico:Lecciones aprendidas (The Impact of Hurricane Maria in Puerto Rico's Transportation Infrastructure: Lessons Learned). Mega Viernes Civil 2018: Resiliencia Aplicada, College of Engineers and Surveyors of Puerto Rico, San Juan, April 6, 2018

- Benjamín Colucci Ríos (Presenter), Alexander Molano Santiago, Luis Sevillano García, Launelly M. Rosado Rosa and Joel F. Alvarado López, Transportation Engineering Innovation Spearheading the Economic Development of Puerto Rico after an Extreme Natural Disaster. XXX Congress of Engineering and Surveying, COINAR 2018, San Juan, April 17, 2018.

Smith:

- **Horney, Jennifer**, Carolina Dwyer, Bhagath Chirra, Kerry McCarthy, Jennifer Shafer and **Gavin Smith**. 2018. Measuring Successful Disaster Recovery. International Journal of Mass Emergencies and Disasters 36(1): 1-22.

- **Gavin Smith**, Lea Sabbag and Ashton Rohmer. A Comparative Analysis of the Roles Governors Play in Disaster Recovery. Risk, Hazards & Crisis in Public Policy. 9(2): 205-243. DOI: 10.1002/rhc3.12133.
- **Horney, J.**, Dwyer, C., Aminto, M., **Berke, P., & Smith, G.** (2017). Developing indicators to measure post-disaster community recovery in the United States. Disasters, 41, 124-149. DOI: 1111/disa.12190

- **Smith, Gavin**. The Role of States in Disaster Recovery: An Analysis of Engagement, Collaboration, and Capacity Building. 2019. In Building Community Resilience to Disasters: The Handbook of Planning for Disaster Resilience, Routledge Press.

- **Smith, Gavin**, Amanda Martin and Dennis Wenger. Disaster Recovery in an Era of Climate Change: The Unrealized Promise of Institutional Resilience. 2017. In Handbook of Disaster Research, Second Edition, Eds. Havidan Rodriguez, Joseph Trainor and William Donner. New York: Springer.

- **Smith, Gavin**. Pre- and Post-Disaster Conditions, their Implications, and the Role of Planning for Housing Recovery. 2017. Chapter 18, pp. 277-292. In Coming Home After Disaster: Multiple Dimensions of Housing Recovery, Eds. Ann-Margaret Esnard and Alka Sapat. Boca Raton, Florida" CRC Press.

- **Smith, Gavin**, Mai Thi Nguyen, Colleen Durfee, Darien Williams, Ashton Rohmer. September, 2018. **Resilient Design Education in the United States.** Chapel Hill, North Carolina: Department of Homeland Security Coastal Resilience Center of Excellence.

- **Smith, Gavin**, Barry Hokanson, Link Walther, **Jessica Southwell**. 2017. Hurricane Matthew Disaster Recovery and Resilience Initiative. A Project of the North Carolina Policy Collaboratory. Chapel Hill, North Carolina: Hurricane Matthew Recovery and Resilience Initiative.

- **Smith, Gavin**, Lea Sabbag, Ashton Rohmer. Role of States in Recovery Video Training Guide. March, 2016. Chapel Hill, North Carolina: Department of Homeland Security, Coastal Resilience Center of Excellence.

- **Smith, Gavin**, Sabbag, Lea, and Rohmer, Ashton. **A Comparative Analysis of the Roles Governors Play in Disaster Recovery**. 2018. Risk, Hazards & Crisis in Public Policy.

- **Smith, Gavin**. The Role of States in Disaster Recovery: An Analysis of Engagement, Collaboration, Leadership, and Capacity Building. 2017. In Building Community Resilience to Disasters: The Handbook of Planning for Disaster Resilience, Routledge Press.

- **Smith, Gavin**. Pre- and Post-Disaster Conditions, their Implications, and the Role of Planning for Housing Recovery. 2017. In Coming Home After Disaster: Multiple Dimensions of Housing Recovery, Eds. Ann-Margaret Esnard and Alka Sapat. Boca Raton, Florida" CRC Press.

- **Smith, Gavin**, Amanda Martin and Dennis Wenger. Disaster Recovery in an Era of Climate Change: The Unrealized Promise of Institutional Resilience. 2017. In Handbook of Disaster Research, Second Edition, Eds. Havidan Rodriguez, Joseph Trainor and William Donner. New York: Springer. (accepted/submitted)

- **Smith, Gavin**. 2016. Remembrances of the Past, Concerns for the Future, and the Potential Resilience of a Small Coastal Town. Southern Cultures. Summer: 64-87. DOI: 10.1353/scu.2016.0022