COMMENTARY

# Building Resilience in Vulnerable Coastal Communities With the Southeast Water Level Network Initiative


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## ABSTRACT

Coastal communities in the Southeast U.S.A. face increasing risks from storm surge, extreme rainfall, and rising sea levels, highlighting the need for effective monitoring and response systems. Southeast Coastal Ocean Observing Regional Association launched the Southeast Water Level Network in 2021 to address these challenges, partnering with academic, federal, nonprofit, and commercial organizations to install and operate lower-cost, real-time water level stations. This initiative, focused on communities vulnerable to flooding, enhances resilience by providing critical data for flood alerts and planning. The project underscores the role of strategic partnerships, innovative sensor technologies, and comprehensive planning in safeguarding vulnerable coastal regions.


Keywords: water level, flooding, coastal inundation, community engagement, sea level rise

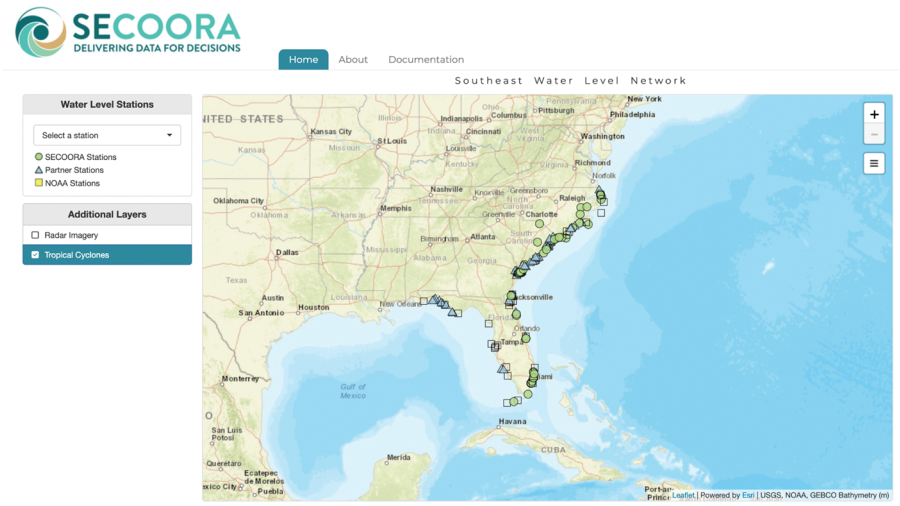

## Introduction and Background

Coastal communities face compounding threats from storm surges, extreme rainfall, and rising sea levels (Sweet et al., 2022). Real-time water level (WL) data are vital for communities to prepare for and respond to flooding related to these hazards. In 2021, the Southeast Coastal Ocean Observing Regional Association (SECOORA) initiated the installation and long-term operation of new community WL stations in the Southeast (SE; Figure 1), enabling access to real-time local WL data by town managers, emergency managers, design engineers, and the public. This regional sensor network supports localized flooding alerts, improved community resilience, and monitoring of flooding hazards. Compared to previous efforts to measure WL, which require expensive infrastructure and equipment investments, this equitable service model allows communities to partner with SECOORA to install affordable sensors and enhance their coastal resilience with reliable, timely data. This approach compliments the National Oceanic and Atmospheric Administration (NOAA) National Water Level Observation Network (NWLON), which provides high-quality, continuous WL observations and foundational measurements of sea level change at over 200 locations throughout the U.S.A. (NOAA, 2024). While lower-cost sensors are not as robust as NOAA NWLON stations, these community WL observations provide critical, local real-time coastal monitoring information in non-NWLON station locations. Further, the definitive observations of tidal datums, tide predictions, and sea level rise provided by the NWLON can be leveraged to enhance the capabilities of community WL observations beyond what would otherwise be possible.

SECOORA is one of 11 NOAA Integrated Ocean Observing System (IOOS) Regional Associations. The IOOS Regional Associations are essential for providing environmental, weather, and ocean observations. The Regional Associations have experience sustaining long-term sensor networks (i.e., high-frequency radar, buoys), expert knowledge of the needs within their geographic areas, and critical technological abilities,

## FIGURE 1

The SECOORA Water Level Network website with access to WL data across the SE (https://wl.secoora.org).




allowing them to develop products to meet regional and local needs (Snowden et al., 2019). SECOORA is the IOOS Regional Association that covers North Carolina, South Carolina, Georgia, and Florida.

## Partnerships Matter

The SECOORA and its partners install and operate WL stations across the SE. These partners include the American Shore & Beach Preservation Association, Hohonu, Coastal Carolina University, Georgia Institute of Technology, Florida International University, and Florida Atlantic University (Figure 2). Community outreach and engagement are led by Sea Grant offices within the region, who have provided valuable insight into identifying flood-prone areas and the impacted communities. The NOAA Center for Operational Oceanographic Products and Services (CO-OPS) has provided technical assistance to the SECOORA team, demonstrating a unique and powerful partnership between federal, academic, and nonprofit entities. Stations included in the SE WL Network must meet collaboratively established SECOORA Standard Operating Procedures (SOPs) for sensor installations, maintenance, and vertical elevation controls (via geodetic surveying and Global Navigination Satellite System [GNSS]). Through these partnerships, the SE WL Network has installed 121 community WL sensors to expand the WL data available to meet community needs. SECOORA worked with our state Sea Grant partners to determine how community members prefer to access WL data. Based on iterative feedback, SECOORA has developed an online and mobile-friendly website (SECOORA, 2024) that provides easy WL data access. Future iterations of this site will include WL text alerts, which individuals can sign up to receive.

## Goals and Objectives of the SE WL Network

The SE WL Network's goal is to provide real-time local WL data to town officials, emergency managers, design engineers, and the public for preparedness and real-time decision-making. The primary network objectives include: (1) substantially expanding real-time WL geographic coverage across NC, SC, GA, and FL; (2) partnering with coastal community stakeholders to provide access to WL data, products, and applications; and (3) contributing to state and local decision-support applications and alert systems. Another objective is understanding and documenting lessons learned during the network's development and evolution to inform other regional-scale WL monitoring enterprises.

SECOORA is also exploring how to standardize sensors and station installation processes, sampling rates, data-sharing requirements, and data products. This standardization better enables cost-efficient operations at scale and helps ensure consistency in data quality across the network. A test site was established in 2022 with one to two sensors from each partner co-located at the Fernandina Beach, FL, NOAA/National Ocean Service (NOS)/CO-OPS 8720030 NWLON station. This test site allows for analysis of the technical capabilities of each partner's sensor system and comparison to the NOAA NWLON standard, the results of which will be published in a follow-up report. Lessons learned from community collaboration and test sites like these will enable further refinement of the SE WL Network and support the transition of these methods to additional Regional Associations.

## Initial WL Network Design

SECOORA co-authored a paper that provides insights into previous efforts and technological evaluations to

**FIGURE 2**

A MaxBotix ultrasonic sensor integrated into a Hohonu station in Duck, NC.


establish a baseline for developing the WL network (Elko et al., 2023). However, there is a significant lack of literature on lower-cost WL monitoring, leaving few direct parallels. SECOORA leveraged NOAA CO-OPS' wealth of information on WL network technologies and practices (NOAA, 2014; NOAA 2022), which served as a cornerstone for the writing of SECOORA's three SOPs for station siting, installation and maintenance, and vertical control standards. SECOORA also drew inspiration from analogous endeavors such as the Alaska Water Level Watch and North Carolina's Flood Inundation Mapping and Alert Network, as these initiatives shed light on the broader landscape of community data needs and technological capabilities.

As part of the WL Network design process, SECOORA and its partners explored the cost spectrum of available WL sensor technologies. Ultrasonic and radar WL sensors are commonly used to meet community data needs. SECOORA primarily uses ultrasonic WL sensors (see Image 2) as they can be purchased: (1) as individual instruments to integrate into a local communications and data system, (2) from companies whose services include installation support and data management, or (3) custom-built. Sensor selection will depend on user needs and available funding for installation and long-term maintenance.

Specific cost considerations beyond the sensor include personnel to install, maintain, and operate the stations, installation and maintenance materials, communications systems (e.g., cellular, internet, satellite), monthly communication service fees, and other operational components such as data management infrastructure, including quality assurance (QA) and quality control (QC) protocols, and website development. There is also an additional cost for establishing a reference point, which allows the WL data to be presented relative to the surrounding land elevation and entails conducting vertical elevation surveys. The effort and precision required for these surveys can pose cost challenges.

After reviewing various station design and installation techniques by the project partners and evaluating the resulting data, SECOORA established a two-tiered system to differentiate WL data accuracy. Tier 1 includes long-term stations funded by SECOORA and installed directly by SECOORA or partners according to standards described in SECOORA SOPs. Defining the standards to which an organization will install a

WL station and how those standards can be met is necessary to mitigate and reduce human error. For example, SECOORA has two SOPs that guide the selection of appropriate sensor sites. The first defines desktop and field procedures related to site reconnaissance, and the second details station installation and maintenance requirements. WL accuracy for Tier 1 is +/– 5 cm. Tier 2 stations are installed in locations where community partners need relative WL information to help understand wet/dry conditions or for education purposes. Tier 2 stations differ from Tier 1 stations as the installation, maintenance, and vertical elevation surveys may not conform to SECOORA SOPs. Tier 2 stations often provide the height of the water below the sensor without being tied to a land elevation. The significant difference between the two tiers is whether the station is surveyed upon installation and during periodic maintenance to confirm accurate elevation control linked to known reference datums (i.e., NAVD88, Mean Higher High Water [MHHW]).

Finally, the co-development of the WL network and access to data are central to SECOORA's approach, emphasizing collaboration with our partners, community users, agencies, and organizations. After 3 years of collaboration to build the WL network, lessons have been learned regarding ways to more effectively collaborate to build community-based sensor systems, and are addressed in the Lessons Learned section. The collaborations are allowing SECOORA to tailor the network to specific community needs. For example, SECOORA has installed a WL sensor in Belhaven, NC, as a joint project between SECOORA, Beaufort County Emergency Management, NC Department of Public Safety, NC Sea Grant, and the Town of Belhaven, NC (Figure 3). Based on recommendations from the County and Town staff, the sensor was deployed overlooking a small waterway that floods the town during storms. Access to the data is free and open, and signage at the sensor and in town offices provides QR codes that help community members access the data and products. SECOORA and NC Sea Grant staff are also participating in county outreach events to broaden awareness of the availability of WL data.

**FIGURE 3**

WL sensor installed overlooking Wynn's Gut in Belhaven, NC. Wind-driven water piles into this waterway and then overflows into the town, causing flooding to area roads, businesses, and government offices.

## Data Management

Data QC steps outlined in the Water Level Quality Assurance and Quality Control of Real-Time Oceanographic Data (QARTOD) manual are essential for documenting the reliability of the collected real-time environmental data (U.S. IOOS, 2021). IOOS has developed authoritative QA/QC procedures for the U.S. IOOS core variables, such as WL, and has included detailed information about the sensors and procedures used to measure the variables. Accuracy concerns were the driver for establishing a two-tier system. However, both Tier 1 and 2 WL data undergo real-time QARTOD tests, which are custom set parameters of specific tests for each WL station. SECOORA personnel receive a daily email indicating the status of each WL station with QC flags that highlight good, suspect, and bad data based on QC tests. These flags reduce WL sensor downtime and accuracy issues since stations are monitored daily, alerting station operators to potential issues.

Relative changes in WL can be reported by WL sensors at stations that are installed and properly maintained. SECOORA Tier 1 stations have vertical elevation surveys with no more than +/– 5 cm of uncertainty tolerance, allowing maximum data utility since they are tied to a known datum (e.g., NAVD88). While Tier 2 stations are not required to meet the same standard, the data are beneficial for identifying flood conditions by providing relative changes in WL in real time. This tiered system clarifies the accuracy of the data flowing into the network for users.

## WL Network Products

SECOORA is working with Sea Grant to understand and document our region's community needs for WL data. This co-design process resulted in the SE WL Network webpage (SECOORA, 2024). The site uses open-source technology and is mobile-friendly. To improve awareness and access to the data, SECOORA is adding signs that include a QR code at Tier 1 WL stations in public areas so that anyone with a smartphone can scan the code and access the real-time data. Links to metadata on each station page provide information on accuracy.

## Lessons Learned

Developing the SE WL network was only possible through funding from NOAA IOOS and a partnership with NOAA CO-OPS, who provided expert advice at every stage of development. SECOORA's role has been to harmonize the differing approaches and methods of various partners into a cohesive network that can effectively serve a broad range of users, thereby maximizing the impact of the collective network. Lessons learned from the resulting collaboration include

1) Balance installation and operation requirements with user needs.The time and resources required to establish reliable vertical positions for Tier 1 stations can be substantial, even for lower-cost sensors. As some user needs may not require a well-defined vertical reference, SECOORA established Tier 1 and Tier 2 stations to better support a broad range of installations and user needs.

2) Lower cost does not mean inexpensive.The promise of very low-cost (i.e., > $500) sensor hardware is that many can be deployed throughout communities in coastal areas. SECOORA learned in the first 3 years of this effort that the non-sensor costs are significant and must be understood entirely at project initiation. Budgeting for the following components to establish and maintain stations should be included when estimating network costs:

- People hours for engagement with communities, to conduct WL station site reconnaissance, acquire necessary local, state, and/or federal permits or approvals, and travel to/from sites to install and maintain sensors.
- Backend data management (e.g., data assembly, metadata documentation, data QC) and visualization are as costly for lower-cost sensors as for any other real-time data stream type. Data management expertise and infrastructure are required, along with long-term capacity to support real-time operations and access to data.
- WL equipment/supplies such as GNSS/Real-Time Kinematic (RTK) equipment, computing software, and general tools for station maintenance. Supplies include mounting hardware, batteries, solar panels, and back up supplies in case of failing stations. Additional costs for complementary meteorological sensors should also be considered.

3) Partnerships often result in more robust solutions but take time and effort.Identifying technical solutions and standards that meet a broad spectrum of aims takes time and compromise. Having a good foundational standard for each attribute of the network in advance of any field deployments

will help reduce growing pains. In the instance of backend data management, having all teams understand/implement metadata standards, documentation, and data QA/QC from the beginning is crucial. Scheduling adequate time to collaborate on roles and responsibilities, technical solutions, and standards and training for all affected partners is critical to project success and efficiency.

## Final Recommendations and Considerations

Ensuring the long-term sustainability of the SE WL Network requires integrating comprehensive budget planning, strategic partnerships, and robust data management. Beyond the initial investment in sensors and stations, it is essential to account for ongoing operational expenses, such as ongoing maintenance, data management, system upgrades, and surveying. Implementing cost-effective maintenance protocols and establishing clear ownership roles will help address operational challenges and sustain the network's effectiveness over time. Transitioning this SE model to other regions will require collaboration at multiple levels, from local to national, to address standardizing protocols to ensure consistency, adaptability, and scalability across diverse regions.

Pursuing diversified funding strategies, including public-private partnerships, can help share the financial and operational burden while promoting data sharing and leveraging innovative technologies to maximize the network's value. The SECOORA team plans to continue collaboration to identify opportunities for the SE WL Network to benefit and complement existing NOAA coastal resilience science and products, such as integrating the network's sensors into NOAA's Coastal Inundation Dashboard and supporting coastal hydrodynamic model validation. By aligning station standards with stakeholder needs and expanding the network to engage more communities, the SE WL Network can maintain its long-term viability, provide valuable data, and support informed local and regional decision-making processes.

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