CREATING A RESILIENT MARINA

By Daniel Stapleton, Matthew Page, Jeff Taylor and Wayne Cobleigh

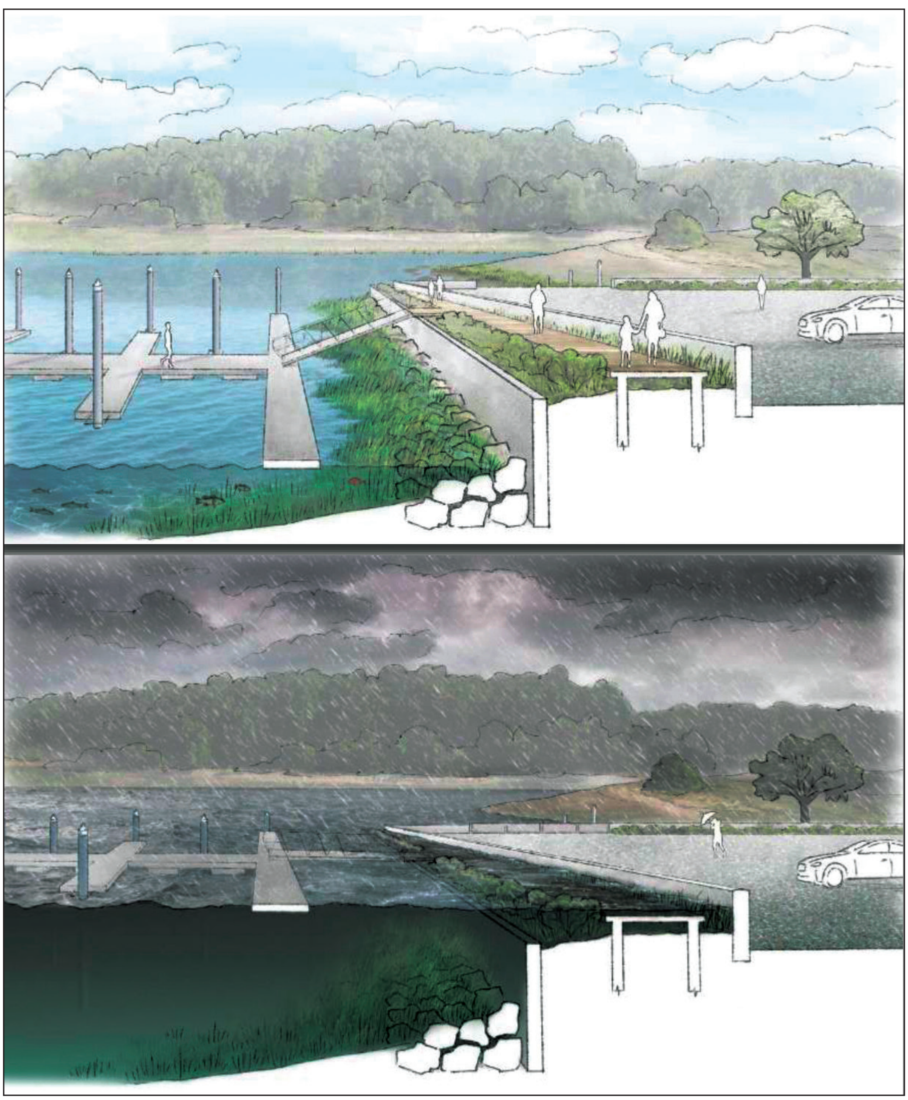

Figure 1: Example of Perimeter Flood Protection

Editor's Note: NOAA recently forecast the 2025 Atlantic Hurricane Season Outlook with a 60% chance of an above-normal season, a 30% chance of a near-normal season and a 10% chance of a below-normal season, predicting three to five major hurricanes of category 3, 4 or 5 with winds of 111 mph or higher. This article is the third in a series of three articles that discuss the objectives, practical implementation and benefits of creating "Resilient Marinas."

"Resilient Marinas" are marinas that have implemented specific measures to cost-effectively reduce the vulnerabilities, property damage and adverse consequences of severe weather events and the long-term effects of climate change. Additional benefits include remaining insurable at a reasonable cost and preserving property value. While marina owners, operators and customers cannot change the probability of a severe weather event occurring, they can take proactive measures to mitigate damage, minimize disruptions and accelerate recovery, ensuring a rapid return to business.

Resilience measures fall into four categories. The first two are:

- Physical improvements (capital investment) involving strategic site design and design and construction of resilient, fortified structures, systems and utilities
- Operational measures including Severe Weather Preparation Plans to reduce damage during a severe weather event by planning and preparation

The risks that remain are "residual risks" that are typically covered by insurance – the third category of resilience measures. The fourth is "recovery," which includes proactive management measures for timely and thorough insurance claim processing, vessel salvage, debris management and reconstruction.

Steps to Creating Resilience

Step 1. Hazard Characterization and Vulnerability Assessment: Characterize the environmental conditions including site-specific wind speeds, precipitation

By integrating design and risk management strategies, resilient marina developments can sustain property value, long-term market advantage and financial stability.

intensity, water levels (storm surge and tide) and waves that the marina is currently exposed to (and will be exposed to due to climate change effects) and assess what the marina vulnerabilities (e.g., damage) to these conditions are.

Step 2. Resilient Marina Design Benchmarks and Plan: Establish the resilient "design basis" benchmarks, for either new marina design or existing marina improvements. These benchmarks reflect design flood elevations, wind speeds, precipitation rates and wave heights and are aligned with probabilities of occurrence that reflect regulatory requirements, such as building codes and prudent, "beyond-code" conditions that will further reduce risk and increase return on investment. Develop a Resilient Marina Design Plan, which describes and prioritizes resilience improvements and measures, estimated costs and benefits (preventing loss of life and financial loss).

Step 3. Marina Physical Improvements: For new marinas, site development starts with site layout and includes resilient design of site features, marina building and harbor structures and systems. For existing marinas, this process involves retrofitting, replacement of critical structures and new construction.

Step 4. Severe Weather Preparation Plan: Develop and implement a "Severe Weather Preparedness Plan" to plan and prepare for the damaging severe weather effects of high winds, tidal surge, coastal flooding and waves. Respond during the severe weather event. Recover after the severe weather event.

Step 5. Residual Risk Management: Manage "Residual Risks" through marina commercial property and casualty insurance and customer vessel insurance.

Step 6. Rapid Recovery: Reduce disaster recovery time by proactively negotiating contracts and pricing rates with recovery and salvage contractors and documenting pre-and post-storm conditions for efficiently processing and optimizing your insurance claim eligibility.

Designing for Resilience

Set Design Benchmarks: Design benchmarks are site and asset-specific; a typical example of a Resilient Marina design basis could include the following design elements.

- Shoreline Flood Protection: protect against frequent flood events to 5-year Mean Recurrence Interval (MRI) flood.
- Buildings and Utility Elevation: protect buildings, accessory structures and electrical utilities including shore power to the 100-year MRI as required by building code (and beyond code for shore power components).
- Fortify Buildings and Other Structures: structural capacity to the 500- to 750-year MRI flood and wind loads, respectively.
- Incorporation of sea level rise to design flood levels, over a facility or structure design life (e.g., 50 to 75 years).
- Harbor Wave Attenuation: design wave attenuation to limit harbor waves to a maximum 1.5- to 2-foot wave height during the 100-year MRI flood and wind event and 0.5- to 1.5-foot wave height during a 50-year MRI event.
- Design of fixed docks and floating docks (including guide and mooring piles) to the attenuated 100-year MRI wave heights and periods, including wave crest elevation plus 2-feet freeboard (for guide piles and fixed docks and piers).

Site Design: Resilient site design considerations include these elements.

- Delineation of current and anticipated future FEMA flood hazard zones, in particular Coastal High Hazard Areas and Coastal A zones that have significant use and building limitations, and use of setbacks (distance from shoreline) to create buffer zones excluding permanent building construction and/or mitigating flood and wave loads, in particular within FEMA Coastal High Hazard Areas and Coastal A Zones.
- Waterfront perimeter flood protection against frequent flood events using minor elevation increase, low floodwall and boardwalks and deployable flood measures at perimeter gaps.
- Overland wave and flow velocity attenuation using landscaping features and native, coastal plantings.
- Dry ground and stacked boat storage

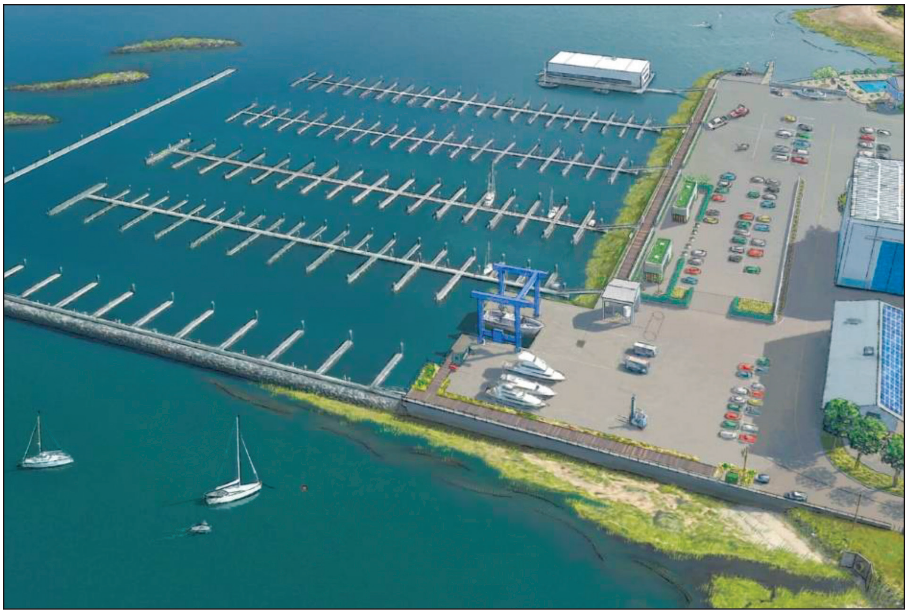

Figure 2: Integration of Natural and Nature-Based Features (image by GZA)

layout and design, including elevated pads to prevent flotation of stored boats during floods. Use of paved (concrete) surfaces to maximize vessel support during flood conditions.

- Site grading and elevation to facilitate post-flood stormwater run-off and to provide elevated site areas above flood elevations.
- Flood resistant (scour, salt) and free draining pavements and gravel surfaces.
- Stormwater infrastructure to improve post-storm drainage capabilities, flood surcharge protection and maximize use of green infrastructure such as swales vegetated with native coastal species to provide stormwater treatment prior to discharge.
- Building and dock orientation to reduce exposure to the prevailing coastal storm wind and wave direction. In areas within FEMA flood zones, structures and site grading will also need to conform to regulatory restrictions, in particular “Free of Obstruction” and limited fill restrictions within FEMA VE and Coastal AE zones.

Figure 1 illustrates an example of waterfront, perimeter flood protection. Normal conditions (top) and flooded conditions (bottom). Using: Bulkhead with a rip-rap revetment and adjacent fringe marsh for attenuation of waves’ reflection of wave energy and enhancement of habitat and water quality; Elevated embankment and boardwalk with native plantings; A low seawall for mitigation against frequent flood events, and Deployable flood mitigation measures at perimeter gaps.

Shorelines

Marina shorelines form the interface between harbor and open waters and landside features and serve several purposes, including prevention of shoreline erosion, providing access to docks and vessels, transition marina systems from land to docks and often include stormwater outfalls. Marinas typically include a range of shoreline features from bulkheads and revetments (armored shorelines) to beaches and marshes within adjacent undeveloped areas. The integration of Natural and Nature-Based Features (NNBFs) will attenuate wave energy and reduce shoreline erosion, including living shorelines along adjacent beach and marsh areas and fringe marshes adjacent to bulkheads and revetments. In addition to their resilience benefits, NNBFs enhance habitat and ecology, improve water quality, create desirable aesthetics and improve customer experiences.

Figure 2 illustrates the use of Natural and Nature-Based Features to protect against erosion.

- Living Shorelines for protection against shoreline erosion, wave attenuation, habitat enhancement and improved marina aesthetics and customer experience
- Perimeter fringe marsh along armored slopes and bulkheads
- Native plantings for reduction in flood flow and wave velocity, habitat enhancement and improved marina aesthetics and customer experience
- Landside vegetated areas for stormwater treatment prior to discharge as well as mitigating flood flowage and wave velocity and improved marina aesthetics and customer experience
- Living Breakwaters for harbor wave attenuation, habitat enhancement and improved marina aesthetics and customer experience

Wave Attenuation

Wave attenuation is one of the most important factors in marina resilience but is also one of the single largest marina investments. The goals of wave attenuation features are to reduce wave heights and wavelengths within the harbor to tolerable levels consistent with safe vessel mooring and minimal to no dock damage during the design basis event water levels, waves and wave overtopping. Wave attenuation features include breakwaters, wave fences/ screens and floating wave attenuators. The design of wave attenuation features should consider both the prevailing and storm wind and wave conditions, wave fetch directions, etc. as well as the natural coastal processes and coastal resources in the site vicinity. A desirable NNBF for wave attenuation includes the use of Living Breakwaters, which are aligned with the natural shoreline and area’s coastal processes and integrate breakwater armor stone with features to enhance ecology and marine habitat. Floating wave attenuators can be used as standalone features or integrated with breakwaters and wave fences as part of a tiered or multi-stage wave attenuation system.

Harbor Structures

Floating docks are appropriate in areas with tidal flooding and at other locations where accommodation of storm surge is expected. Innovative dock design for resilience against dock and vessel damage is an area warranting industry attention, with significant opportunity for operational and loss prevention benefits. Resilient dock design considerations include: 1) orientation relative to expected prevailing and storm wind and waves; 2) material type, stiffness and connectivity relative to design wavelengths and dock and vessel motion; and 3) most importantly, using guide piles that are elevated above the design flood elevation, including wave crest and freeboard, and with structural pile capacity under conditions of elevated water levels and with increased loads due to vessels.

Buildings and Accessory Structures

There are several general approaches to creating resilient buildings and accessory structures.

- Relocation: Locating the structure to higher ground and outside the limits of the current (or anticipated future) FEMA flood zones, in particular Coastal High Hard Areas and Coastal A Zones
- Elevation: Elevating the first building level to the design flood elevation, including wave crest and freeboard. The design elevation will, at a minimum, conform to building codes. Per ASCE/SEI 7-22 Minimum Design Loads and Associated Criteria for Buildings and Other Structures and ASCE 24-24 Flood Resistant Design and Construction for typical marina buildings (Flood Design Class 2), this elevation is the FEMA Base Flood Elevation (BFE) plus 1-foot of freeboard. Predicted sea level rise over the design life of the building should also be added to the design flood elevation.
- Dry and Floodproofing: Dry floodproofing involves a combination of measures that results in a structure, including utilities and equipment, being watertight with all elements “substantially impermeable” and with structural components having the capacity to resist flood loads. Wet floodproofing is a method that relies on the use of flood damage-resistant materials and construction techniques in areas of a structure that are below the design of flood elevation to allow those areas to flood. Dry floodproofing of non-residential buildings (typical of marinas) is not allowed within FEMA High Risk Hazard Areas or Coastal A Zones. Wet floodproofing of enclosed areas is limited to Flood Design Class 1 structures, which includes most marina accessory structures; enclosures used solely for parking of vehicles, building access, or storage and structures that are functionally dependent on proximity to water, which includes most marina buildings.
- Structural reinforcement to the design wind and flood (hydrostatic, hydrodynamic, wave and debris) loads in compliance with applicable building codes, with MRIs for typical marina buildings of 700-years (3-second gust wind) and 500-years (flood)
- Retrofitting to fortify existing buildings for wind and flood loads to ensure properly supported continuous load paths, cladding and roof covers and sheathing in accordance with FEMA guidance for coastal construction
- Use of aerodynamic building design, such as arched roof style, to reduce wind loads
- Use of flood resistant building materials per FEMA guidance
- Scour protection adjacent to building foundations

Marina Systems

Marina systems, including fuel stations, shore power, communication, water, sanitary pumpout and boat washdown and treatment, each have unique vulnerabilities. There are several examples of marina system resilience measures.

- Design land-based electrical components located within floodplains using an electric plane datum that is consistent with ASCE 24-24, which may have a higher design flood elevation than typically required by the local or state electrical and fire codes.
- Elevate land-based electrical components or use waterproof encasements anchored to resist wave loads.
- Provide adequate conduit and hose scope and attachments to accommodate displacement and rotation of docks and gangways.
- Locate fuel dispensary pumps on land, rather than docks, and utilize power shutoffs and transition sumps with fuel line shutoffs.
- If dispensary pumps are located on docks, utilize flexible fuel lines with adequate scope to accommodate dock and gangway movement.
- If using aboveground tanks, utilize vault type contained systems that are anchored against wave and flood loads and have internal secondary containment.
- Use “flex” structures for waste oil storage, washdown water treatment, etc., that can be physically moved with forklifts and cranes as part of severe weather preparation.

In Conclusion

Ultimately, the benefits of a Resilient Marina will depend on proactive risk identification, operational preparedness, capital investments in resilient structures and infrastructure, resulting in and reduced losses, prevented operational disruption and affordable insurance. By integrating these design and risk management strategies, resilient marina developments can sustain property value, long-term market advantage and financial stability, while facing more frequent and intense storms, rising marina insurance premiums and challenging environmental regulations. ⚓

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