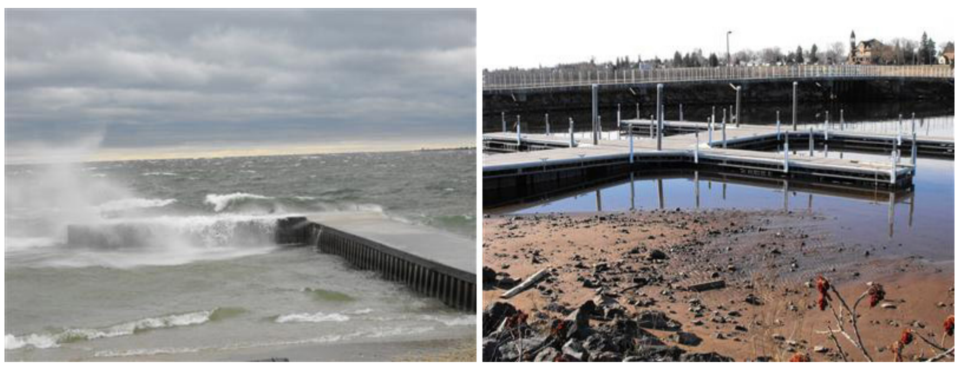
INFRASTRUCTURE BEST PRACTICES

Great Lakes marinas and harbors face a variety of changing conditions. More severe and frequent storms, shoreline erosion and fluctuating water levels will likely increase wear and tear on your facility's infrastructure, much of which may have been designed and built to withstand a different set of environmental challenges than those we're experiencing now and what we expect to see in the future.

This section provides an overview of potential risks and adaptations for stormwater management, buildings, wood infrastructure, floating docks, shoreline protection and pilings.

BEST MANAGEMENT PRACTICES

- Evaluate risks to infrastructure and grounds
- Invest in long-term adaptations



During high water conditions and/or periods of greater storm intensities, structures may become completely unusable. Without dredging, low water conditions may make docks unusable. (Source: Gene Clark, Wisconsin Sea Grant)

EVALUATE RISKS TO INFRASTRUCTURE AND GROUNDS

Much of our infrastructure was built to accommodate past conditions and is now showing its age. The changing nature of our environment, paired with the deterioration of our infrastructure, is now a limitation. The degree of vulnerability is different for each marina and its specific circumstances. However, harsher weather events like more frequent heat waves, floods and rapidly changing water levels may accelerate the effects of aging and expose infrastructure to damage or failure at any marina.

Evaluating the potential risks and weak points of infrastructure and grounds is a best practice and a first step in being prepared for and building resilience against uncertainty. For information on possible effects of fluctuating water levels, increased storms and precipitation and temperature changes, see: *Clean Marina Classroom: Increasing Resilience* — www.cleanmarinaclassroom.org

SHORE RECESSION AND EROSION

Storm surge and storm waves can dramatically increase the amount of property damage and shoreline erosion during periods of high water. Conversely, low lake levels lead to irreversible down-cutting (erosion) of the nearshore lakebed — allowing more storm waves to reach further inland when water levels later rise (Wisconsin Initiative on Climate Change Impacts, 2011).

Recommendations:

- Monitor signs of lakebed erosion. See: *Lakebed Erosion* (Wisconsin Sea Grant) — seagrant.wisc.edu/Home/Topics/CoastalEngineering/Details.aspx?PostID=635
- Assess effect on shore protection structure. If lakebed at foundation of a structure has eroded, a return of high lake levels and storms might overwhelm such a structure and cause it to fail.

SENSITIVE AREAS

As you evaluate your infrastructure, also consider the marina grounds. If your facility is near a dune or wetland, shifting climate conditions may affect aesthetic and ecosystem function (e.g., sport fisheries recruitment, shoreline stabilization).

In addition to regulated setbacks, also establish your own protections near these sensitive areas to provide space for the system to adapt naturally. Protecting ecosystems improves the quality of natural resources, increases ecosystem resilience and often provides patrons a pleasant experience. For more information on maintaining natural habitat at your marina or harbor, see: Clean Marina Classroom: Marina Facilities and Habitat — www.cleanmarinaclassroom.org

If your property includes coastal bluffs, it is especially important to carefully control increased volumes of stormwater. Increased precipitation and groundwater retention, more freeze-thaw cycles and high water levels all accelerate the rate of slope erosion. Periods of dryness can also cause problems, particularly when followed by an influx of stormwater. For example, prolonged dry periods cause cracks in slopes that, when filled with water, may cause major slope failures (Wisconsin Initiative on Climate Change Impacts, 2011).

Recommendations:

- Explore options for bluff stabilization, which is often paired with shore protection to reduce wave erosion at the base of the bluff (but which may have negative consequences for sediment transport for adjacent properties). For more information, see: *Stabilizing Coastal Slopes on the Great Lakes* (Minnesota Sea Grant) — www.seagrant.umn.edu/downloads/ch003.pdf
- In drastic cases, you could consider relocating facilities away from slope edges.

INVEST IN LONG-TERM ADAPTATIONS

When many structures in the Great Lakes region were built, design was based on historic conditions, which in some cases, may not account for changes now and in the future. The design life for most marina and harbor infrastructure is approximately 40-50 years. Much coastal protection infrastructure was built as long ago as the early 1900s and has long passed its design lifespan. As these structures face needed repairs or replacement, there is an opportunity to adapt to fluctuating environmental conditions.

To learn more about the current status of and threats to coastal infrastructure, see: *Great Lakes Coastal Infrastructure Brochure* (U.S. Army Corps of Engineers, 2012) — www.lre.usace.army.mil/Portals/69/docs/Navigation/Risk%20Com%20-%20GLCI-CPR_Brochure_%20Jan_2012.pdf

The brochure focuses on the vital role coastal infrastructure plays in protecting urban waterfronts from storm surges, waves and ice — plus offers a discussion of federal budgeting priorities related to the infrastructure.

When planning for adaptations to increase your facility's resilience, one rule of thumb is to plan around 100-year average conditions (e.g., historic range of water levels, amount of precipitation from 100-year storm events). For example, over the past 100 years, water levels have had a range of variation from 3.9 feet (1.2 meters) in Lake Superior to 6.6 feet (2.0 meters) in Lake Ontario. Though there is no guarantee future conditions will remain within this range, planning in the context of such parameters can inform infrastructure design and building, increasing the likelihood your facility will be well equipped to handle the uncertain conditions that we experience year to year, as well as in the future. For more information for planning for adaptation, see: *Clean Marina Classroom: Increasing Resilience* — www.cleanmarinaclassroom.org

STORMWATER MANAGEMENT SYSTEM

Increased precipitation will increase the burden on your facility's stormwater management system. As storms become more frequent and intense, operators may be well served by a careful assessment of stormwater management capacity (culverts, drains, permeable areas, etc.).

For information on how to control and treat stormwater, from traditional culverts to grassed swales, see: *Clean Marina Classroom: Stormwater Management* — www.cleanmarinaclassroom.org

BUILDINGS

Buildings will be subjected to more wear and tear through increased storm intensities. Energy requirements will also vary. For example, summer temperatures are expected to rise, so you may see increased cooling costs.

- Evaluate how the maintenance and operations of your buildings perform under extreme conditions (e.g., high temperatures, heavy downpours).
- Make changes to help prevent future problems. For example, make sure your equipment and buildings are structurally sound in order to confirm efficient energy use while keeping the inside environment comfortable for staff and customers. For example, explore ways to improve ventilation in your buildings and repair small leaks before they become big leaks.

Timber structure rot; timber crib settlement failure. Timber cribs may fail as rock escapes through gaps in the crib framework or by settlement. Poorly designed timber crib foundations have also caused structure failure. Wave action at the base erodes, or scours, the foundation material away, causing the timber crib to settle. Scour action is intensified by low water conditions. (Source: Gene Clark, Wisconsin Sea Grant)

WOOD INFRASTRUCTURE

Wood infrastructure is especially vulnerable to low water levels, which expose timber to oxygen that hastens deterioration. Traditional pile-supported or timber crib docks and retaining walls are susceptible to premature decay as water levels rise and fall. Timbers continually submerged in water can last 50 years or longer without treatment, but when exposed to air, they begin to deteriorate.

Failing timber cribs have been observed at many older ports and harbors as the timber core sections begin to decay and slump, compromising nearby structures (boat houses, etc.). Such timber structures are already vulnerable, and greater wave heights — as seen with increased storm surges — may further damage infrastructure.

A repaired section of dockage using vertical beams. (Source: Larry Ryan, W.F. Baird & Associates)

DOCKS

REPAIRS FOR EXISTING DOCKAGE

Repairs to timber crib docks depend on the location and extent of damage. If damaged wood is near the water surface, it is possible to remove failed timber and attach new structure to remaining crib (new timber crib or steel H-beams). If there is only slight deterioration, adding vertical reinforcing to an existing timber crib may help reinforce the structure.

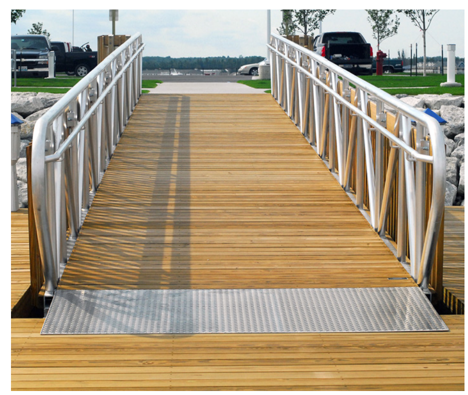
Where it is impractical to install a new dock, consider these changes:

- Modify slip layout to position shallower draft boats in the shallow areas and restrict large craft to deeper portions of the marina basin.
- Strengthen existing dockage by evaluating and strengthening connection points between dock sections — this is typically the weakest point in a dock's design.

Fixed adjustable docks. (Source: City of Boyne City)

FIXED ADJUSTABLE DOCKS

As an option to retain pilings and allow for increased flexibility to variable water levels, consider fixed adjustable docks. A base piling is set and a smaller piling nested within, using a pin system to set the dock at multiple levels. A crane is required to hold the dock while the pins are reset.



Floating dock and gangway at Straits State Harbor in Mackinaw City, Mich. (Source: Michigan Sea Grant). Right: Low water can create safety issues when the distance from a fixed dock to the water increases. (Source: Gene Clark, Wisconsin Sea Grant)

FLOATING DOCKS

Floating docks easily adjust for fluctuating lake levels. This type of infrastructure, which is common on the ocean coasts where tides create regular shifts in water level, is used on the Great Lakes to reduce the costs of adapting to lake level fluctuations.

Floating docks are commercially available and provide uniform freeboard regardless of water level. While pier and slip fingers migrate up and down with water levels,

Walstrom Marine Harbor Springs, Mich. A 58-foot aluminum truss-frame gangway is used to access these new floating docks. Left: The Harborage, Boyne City, Mich. Trex decking was used for this recently replaced dock system. (Source: Flotation Docking)

floating docks require a solid shoreline approach and a secure anchoring system. Floating docks use flotation and anchorage points and eliminate stationary pilings, which provide a significant advantage when dealing with water level changes.

Commercial providers offer floating docks made from many types of materials. Wood and metal are the most common materials, although docks made of plastics, fiberglass and composites are also available. Most floating structures are made up of three parts:

1. Deck: The deck is the upper portion of the structure that actually supports the user.
2. Frame: The frame provides the structural support for the deck.
3. Floats: The floats provide buoyancy and replace the pilings, crib or other structural foundation.

CONSIDERATIONS FOR FLOATING DOCKS

Floating docks are typically more expensive than traditionally constructed docks, however when this cost is measured against potential lost revenues from reduced access, the cost may be justified.

It is important to consult with a qualified engineer to develop a floating dock design suitable for your location. Considerations include:

- Water levels (high and low), water depth, wave heights and current direction and velocity.
- Navigational and recreational hazards.
- Prevailing wind direction and strength.
- Anchorage points.
- Protection from winter ice (e.g., bubbler system).

When installing a floating dock:

- Consult a qualified engineer to develop a design specific to your location.
- Use an experienced dock builder for installation.
- Depending on type of floatation used, take measures to avoid punctures from floats contacting the lake bottom.
- Encapsulate foam floats with plastic, fiberglass, concrete, wood or galvanized steel. Many lake management agencies, including the U.S. Army Corps of Engineers, have policies promoting encapsulation for new foam or polystyrene structures.

Resources:

- For additional information on dock design, see: *Clean Marina Classroom: Siting Considerations and Marina Design* — www.cleanmarinaclassroom.org
- Refer to state agency design guidelines and standards. For example, see: *Marina & Harbor Design Guidelines and Standards* (Michigan Department of Natural Resources) — www.michigan.gov/dnr/0,4570,7-153-58225_37985-124962--,00.html#design

Steel jacket on steel pipe, fiberglass shell on a steel H-pile, and high density polyethylene jacket on steel pile. (Source: Gene Clark, Wisconsin Sea Grant)

PILINGS

Repair or replace deteriorating wood or steel pilings. Pilings that have not rotted too severely could be encapsulated with jackets using the following materials:

1. Steel pipe halves bolted together around the damaged sections.

For more information on repairing wood infrastructure, see: *Failing Wood Infrastructure in the Great Lakes* (PDF; Gene Clark, Wisconsin Sea Grant) — www.seagrant.wisc.edu/home/Portals/0/Files/Ports%20Harbors%20and%20Marinas/SGfact_WoodInfrastructures7_2.pdf

SHORELINE PROTECTION – BREAKWATERS, WALLS AND SOFT SHORELINES

Where coastal erosion threatens property or buildings, the longstanding practice is to install shore-hardening structures such as riprap, sea walls, revetments, jetties, groins and others. However, these structural measures often adversely affect the lakebed and nearshore waters. Impacts include: lakebed erosion, which may undermine the structure and require frequent repair; reduced slope stability; reduced sand supply to replenish beaches; increased erosion at down drift properties; and restricted access for recreation or aquatic habitat. In some circumstances, structural protection for shoreline areas is necessary to protect against wave action and storm surges. Even then it should be used sparingly.

However, there are many viable alternatives to hard engineering along the shore. Natural shorelines or those featuring "soft engineering" reduce erosion and achieve the stabilization and safety of shorelines, while enhancing habitat, improving aesthetics and saving money.

Protect your shoreline with minimal impacts:

- Where possible, use soft engineering or natural shorelines. Shorelines that feature limited use of rock (riprap), incorporate vegetation and feature other soft methods provide a more flexible interaction between land and water, allowing for adaptation to changing conditions while also providing many benefits to the surrounding ecosystem. For more information, see: *Clean Marina Classroom: Siting Considerations and Marina Design* — www.cleanmarinaclassroom.org

Typical USACE breakwater section, with underwater timber crib base filled with rock and a cap of concrete. (Source: Gene Clark, Wisconsin Sea Grant)

Left: Increasing the height and strength of the breakwater structure. (Source: Bill Brose, Smith Group JJR) Right: Wind-generated waves breach the harbor structure in Canal Park in Duluth, Minn. (Source: Gene Clark, Wisconsin Sea Grant)

Take advantage of low water levels to perform an assessment of your structures:

- Inspect wood structures frequently for signs of increased deterioration, especially where wood was previously underwater.
- Examine rock foundations, as increased exposure to freeze-thaw cycles may cause the rock to crack, breakdown and become less protective (smaller stone size).
- If low water levels persist and there is a structural feature in place, explore restoration of beach and dunes using natural shorelines methods.

If high water levels are persistent and hard engineering is needed:

- Enlarge rock breakwaters to increase protection from higher water levels and increased storm intensities if needed. The original structure may not have been built to withstand greater wave energy, so you may need to consult with an engineer to evaluate overall structural integrity.
- Reinforce walls with precast concrete panels placed between vertical beams if needed. The facing could also be constructed of steel sheet pile with a fill of stone between the old and new structure.
- If needed, improve scour protection at base of dock infrastructure and walls.

To learn more about coastal protection structures, see: *Types of Shore Structures* (Ohio Dept. of Natural Resources) — coastal.ohiodnr.gov/shorestructures

Left: New wall constructed on top of failed timber wall. (Source: Chad Scott, AMI Consulting Engineers) Right: Timber wall, sometimes called soldier pile wall. Timbers stacked between grooves in steel "H" beams. (Source: Gene Clark, Wisconsin Sea Grant)

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Sources: 2014 National Climate Assessment, Great Lakes Integrated Sciences and Assessments Center, International Upper Great Lakes Study, NOAA Great Lakes Environmental Research Laboratory, University of Wisconsin Sea Grant Institute, Michigan Clean Marina Program, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, National Working Waterfronts Network, The Nature Conservancy and others.