Tufts
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American Ports & Infrastructure for Offshore Wind

Article from Civil Engineering Magazine • 2017

POWERFUL UPGRADE

The first port facility in North America expressly built to serve as a logistics hub for offshore wind farms, the New Bedford Marine Commerce Terminal, in New Bedford, Massachusetts, required a bulkhead capable of handling loads significantly greater than those imposed on other wharves in the United States. Designed to accommodate large crawler cranes that will lift turbine components weighing hundreds of metric tons, the bulkhead features a system of cellular sheet-pile cofferdams capable of providing the support and flexibility required. By combining port construction with significant efforts to remediate existing contamination in New Bedford Harbor, the project boosts local economic prospects while helping to foster the nascent U.S. offshore wind industry.

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Designed to facilitate the use of mobile cranes, the 21-acre facility forming the main storage area for the New Bedford Marine Commerce Terminal will be able to sustain uniform loads of 4,100 psf and concentrated loads nearly five times that amount.

APEX COMPANIES, LLC

RECOGNIZING THE BENEFITS that offshore wind energy could bring to New England, the Commonwealth of Massachusetts has been preparing for this industry for many years. Among these preparations has been the development of the New Bedford Marine Commerce Terminal, in New Bedford, Massachusetts. An ambitious, challenging effort, the terminal project entailed the creation of the first purpose-built marine terminal in North America having the capacity to stage and deploy offshore wind projects. Completed in 2016, the $113-million facility marks a significant milestone in the development of the infrastructure necessary to support the country's nascent offshore wind industry.

On August 8, 2016, Massachusetts's governor, Charlie Baker (R), signed into law an energy bill that would require the state's utilities to draw on at least 1,600 MW of offshore wind capacity in the coming years, enough to power a third of the homes in Massachusetts. One month later, on September 6, the governor announced the future use of the New Bedford Marine Commerce Terminal by three offshore wind developers that were to compete to construct wind projects in federal wind energy areas beginning 14 mi south of Martha's Vineyard. This industry, once it reaches maturity, is expected to deliver reliable, competitive, and clean power to metropolitan areas along U.S. coastlines, provide a measure of energy independence and security to regions that currently import most of their energy, and create hundreds of thousands of U.S. jobs in engineering, manufacturing, and construction.

Massachusetts has worked for more than 20 years to facilitate the development of renewable energy sources, including offshore wind. In 1997 it passed the Electric Industry Restructuring Act to divide energy generation and energy distribution into separate markets, aiming to make both markets more competitive. Around that same time, it created the Renewable Energy Trust Fund and implemented a surcharge of $0.0005 per kilowatt-hour on the retail sale of electricity to fund it. In 2008 legislation known as the Green Communities Act established the Massachusetts Clean Energy Center (MassCEC), the steward of the Renewable Energy Trust Fund. In 2011, before developing the New Bedford Marine Commerce Terminal, MassCEC completed work on the Wind Technology Testing Center, a massive facility in Charlestown for testing wind turbines (see "Testing Tomorrow's Turbines," *Civil Engineering,* July 2011, pages 64–71).

The Massachusetts Renewable Portfolio Standard, which took effect in 2003, mandates that utilities procure a certain percentage of electricity each year from such approved renewable energy sources as wind, the sun, and small-scale hydropower facilities. For 2016 utilities were required to procure 11 percent of their electricity from renewable sources. This requirement will increase by 1 percentage point per year until it reaches 15 percent by 2020. As of the end of 2015, the total installed capacity from renewable sources in Massachusetts exceeded legislative mandates by a factor of 2, surpassing 1,000 MW.

Recognizing the direct relationship between greenhouse gases and global warming, as well as the threat that rising sea levels pose to the commonwealth's coastlines, the Massachusetts legislature passed the Global Warming Solutions Act in 2008. The law commits the commonwealth to a 25 percent reduction of greenhouse gases from 1990 levels by 2020 and an 80 percent reduction by 2050. Meanwhile, a 2016 law entitled An Act Relative to Energy Diversity will further increase the amount of electricity that utilities must purchase from offshore wind and hydroelectric sources. ISO New England, Inc., the entity that operates the regional power system, has announced the possible retirement over the next several years of nuclear and fossil-fueled power plants having a combined capacity of more than 8,000 MW. Against this backdrop, the development of the offshore wind industry along U.S. shores could not be more timely.

Offshore wind represents a significant source of potential energy, one from which New England is well positioned to capitalize. According to the U.S. Department of Energy's National Offshore Wind Strategy, released last September, U.S. offshore wind resources have a gross recoverable power

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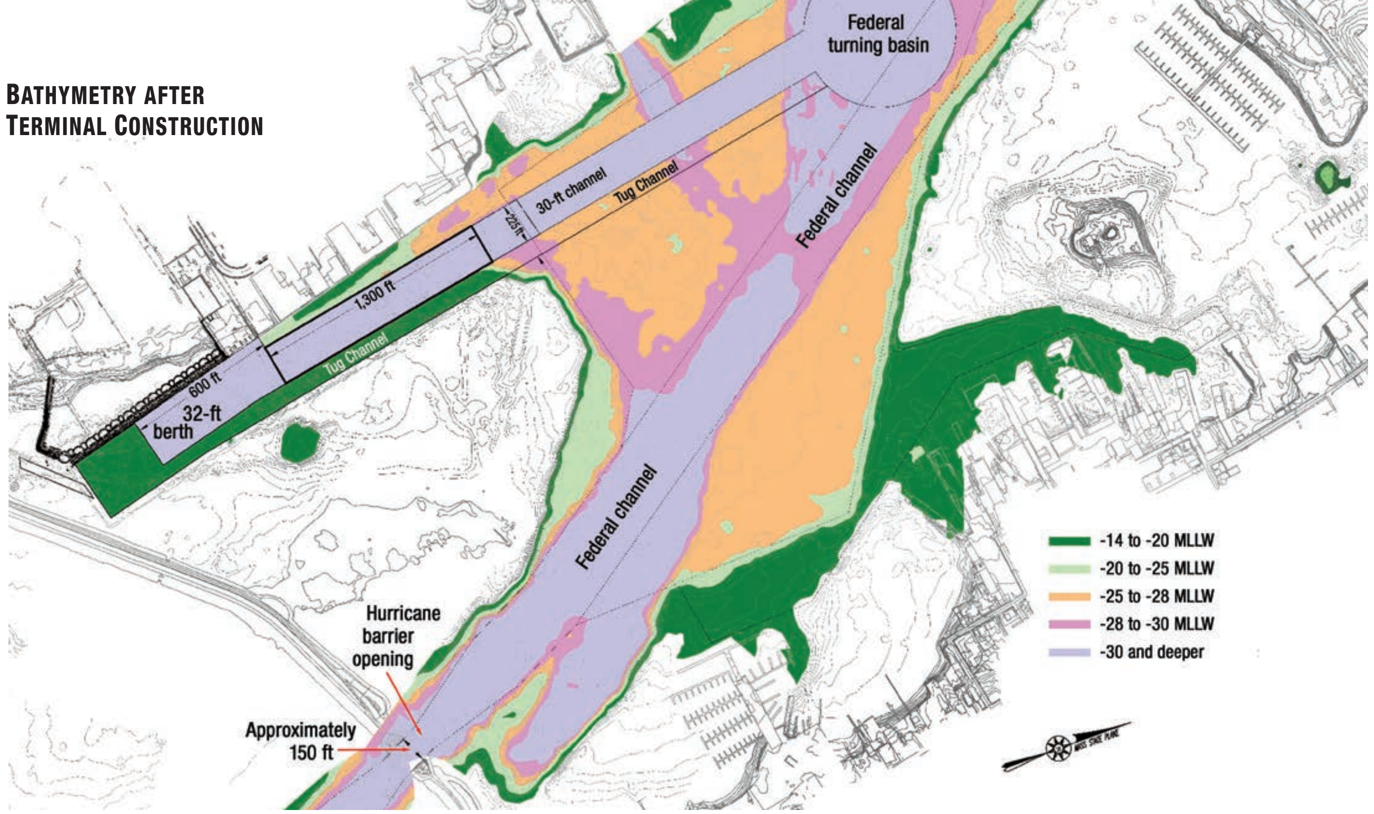


Bathymetry after Terminal Construction

potential of 10,800 GW, more than twice the current electrical generating capacity of the entire world. With respect to the portion of this resource that could be harnessed by means of current technology, the strategy concludes that the United States has a "technical potential capacity" of 2,058 GW from offshore wind, nearly twice the electrical generating capacity of the entire country. In 2013 the six states served by ISO New England had a net capacity of 34.4 GW and a net generation of 115,436 GWh. In 2010 the National Renewable Energy Laboratory, an arm of the U.S. Department of Energy, estimated that these states have an offshore wind generation potential of 391 GW. The laboratory estimated that 79 percent of this offshore wind potential comes from average wind velocities higher than 9 m/s, which is approximately 1.4 to 2.1 times higher than 87 percent of the offshore wind resources estimated for the rest of the country. In view of the fact that retail electricity prices in New England in 2013 were 14.11 cents per kilowatt-hour, 33 percent higher than the national average, commercial-scale offshore wind presents a viable and attractive option for electric power generation in New England. Assuming continued reductions in the cost of the technologies used to harness wind energy, New England could realistically generate a significant portion of its electricity from offshore wind.

Offshore wind energy in New England has progressed from the theoretical to the actual. In January 2015 the U.S. Bureau of Ocean Energy Management auctioned leases in the federal wind energy area south of Martha's Vineyard mentioned above. In 2016 Deepwater Wind, of Providence, completed the construction and commissioning of its 30 MW Block Island Wind Farm in waters off the coast of Rhode Island. The five turbines for the wind farm were imported from Europe, and the jacket foundations were constructed in Louisiana and floated by barge to the Block Island site.

Future commercial-scale projects will involve wind turbines, towers, and foundation components weighing hundreds of metric tons. In the near future many of these items will be imported from Europe because at present no U.S. manufacturing facilities have the ability to build the large primary components required by offshore wind farms operating on a commercial scale. Thus, for now, these primary offshore components will have to be transported by international cargo vessels. The assembly of wind turbines at sea requires specialized, highly mobile installation vessels that can create a stable platform in the open ocean and provide the heavy crane capacity needed to lift the large components into place. Offshore wind farms must be assembled and erected on an exacting seasonal schedule under restricted weather conditions. The very weather conditions that make the northern portion of the Atlantic Ocean ideal for offshore wind also confine the construction season to nonwinter periods. To prevent interruptions in the construction schedule, a sufficient backlog of components must be staged near the construction site in a secure location and transported on a regular basis to the construction site either by the installation vessels or by barge.

For these reasons, it was of paramount importance for the northeastern part of the country to develop industrial marine infrastructure capable of meeting the logistical demands associated with receiving, storing, and preparing these components before they are shipped to an offshore construction site. Complicating matters, the Merchant Marine Act of 1920, also known as the Jones Act, controls coastwise trade, or cabotage, in the United States and prohibits foreign-flag vessels from conducting trade between domestic points. For the offshore wind industry, this restriction means that foreign installation vessels equipped with heavy waterside cranes can assemble wind farms off the coast of the United States but cannot transport components from a U.S. port to a U.S. wind farm. Therefore, in its nascent form, the U.S. offshore wind industry can receive components imported on foreign-flag cargo vessels; arrange these components at a logistics port, for example, the New Bedford Marine Commerce Terminal; use land-side cranes to load the components on U.S.-flag barges; and transport these barges, which are not equipped with heavy cranes, to the construction site. These circumstances, combined with the need for maximum flexibility in transporting heavy components around the terminal site, made land-side heavy-lift capacity a prominent element in the design of the New Bedford Marine Commerce Terminal.

A 2010 STUDY COMMISSIONED by MassCEC listed Boston's Dry Dock 4 and New Bedford Harbor's South Terminal as the top candidates for terminals for supporting offshore wind energy development. The two sites were selected because of their locations in protected harbors, their shipping channel depths, the absence of physical restrictions on overhead clearance, the potential berth lengths they offered, and the available upland areas. Ultimately, the study recommended New Bedford over Boston for the following reasons:

• New Bedford is closer to the federal wind energy areas south of Martha's Vineyard.

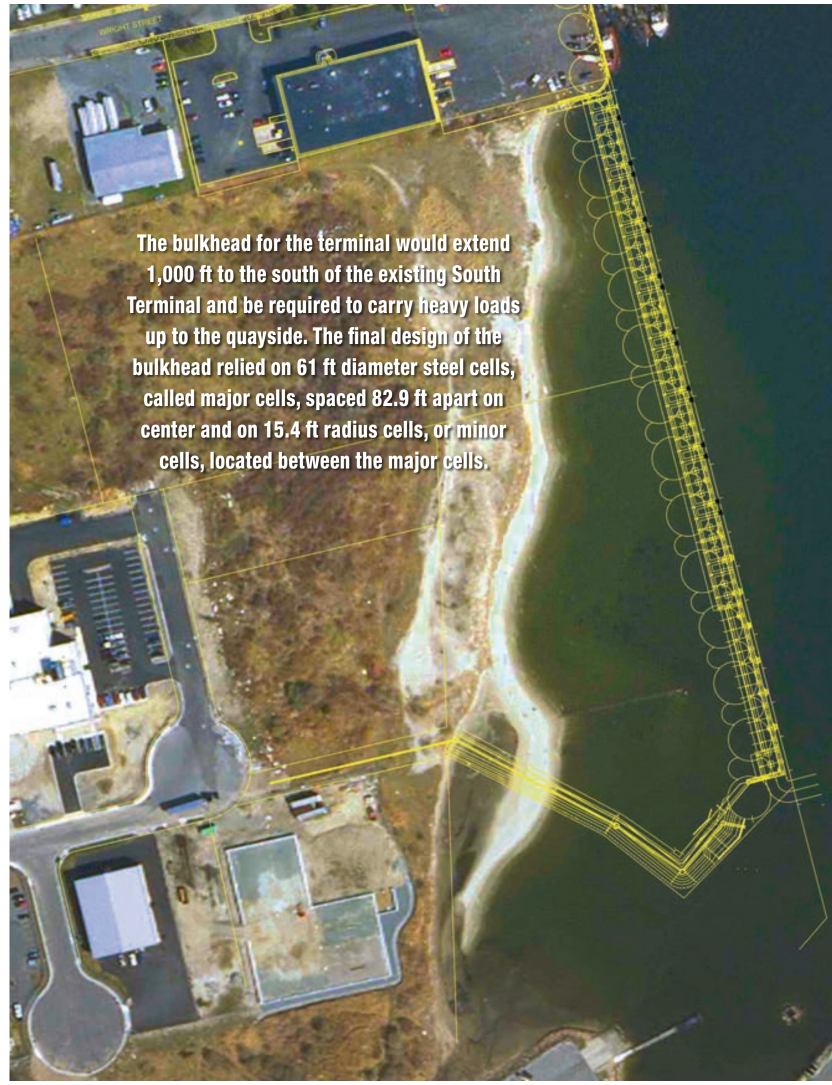
• The City of New Bedford viewed the proposed terminal and the offshore wind industry as keys to its economic future and had adopted formal measures to support the growth of this industry.

• As a designated Superfund site with a clearly defined plan for navigational dredging, New Bedford Harbor offered a more straightforward permitting process than would have been the case in Boston, where multiple state and federal agencies would have had jurisdiction. And given the Boston site's proximity to Boston Logan International Airport, the Federal Aviation Administration would have had authority over matters pertaining to overhead clearance.

In 2010 MassCEC hired its design team for the New Bedford Marine Commerce Terminal. Participants included Apex Companies, LLC, of Rockville, Maryland, which would provide civil and environmental engineering services; CLE Engineering, Inc., of Marion, Massachusetts, which would serve as the structural engineer; and GZA GeoEnvironmental, Inc., of Norwood, Massachusetts, which would provide geotechnical engineering services. In 2011 LeMessurier Consultants, Inc., of Boston, was brought on board as the owner's adviser. Cashman-Weeks NB, a joint venture comprising Cashman Dredging, Inc., of Quincy, Massachusetts, and Weeks Marine, Inc., of Cranford, New Jersey, served as the contractor.

To understand the challenges associated with the design and construction of the New Bedford Marine Commerce Terminal, one must consider the project's three governing conditions: heavy land-side lift capacity, glacial geology over shallow bedrock, and a contaminated harbor. The terminal's heavy-lift capacity would be needed to receive, prepare, and stockpile components weighing several hundred metric tons in a manner that would make it possible to deploy them to construction sites under favorable weather conditions. The complex logistical challenges associated with moving heavy components on a commercial scale required that the entire terminal's quayside and upland areas be engineered to support heavy crawler cranes without the use of load-spreading apparatus, or "dunnage." Such an approach was required to maximize operational flexibility.

Geologically, New Bedford Harbor is underlain by relatively shallow bedrock. More than 20,000 years ago, the Laurentide ice sheet scoured the bedrock there, fracturing it and entraining large pieces of rock within dense deposits of glacial lodgment till. Above these glacial till deposits, glacial outwash and marine deposits were laid down during the glacier's retreat. Situated above these outwash and marine deposits is a layer of silty, organic marine sediment that became heavily contaminated with polychlorinated biphenyls (PCBs) after World War II. In 1983 the U.S. Environmental Protection Agency (EPA) designated New Bedford Harbor as a Superfund site under the Comprehensive



The bulkhead for the terminal would extend 1,000 ft to the south of the existing South Terminal and be required to carry heavy loads up to the quayside. The final design of the bulkhead relied on 61 ft diameter steel cells, called major cells, spaced 82.9 ft apart on center and on 15.4 ft radius cells, or minor cells, located between the major cells.

APEX COMPANIES, LLC, BOTH

Environmental Response, Compensation, and Liability Act.

The presence of this contamination, which is still found in nearly the entire harbor environment, provided opportunities as well as challenges during the development of the New Bedford Marine Commerce Terminal. The commonwealth and the design team for the terminal project recognized that constructing an entirely new port facility along the coast would prove challenging from a regulatory perspective. However, building the new terminal in New Bedford Harbor meant that development could proceed in a manner that addressed the environmental contamination. For this reason, once New Bedford Harbor had been selected as the home for the Massachusetts offshore wind port, the commonwealth and the design team entered into discussions with environmental regulatory officials to begin developing a process that would be responsive to the project's circumstances. New Bedford Harbor's designation as a Superfund site meant that the EPA would serve as the primary permitting authority for the terminal project. The EPA's regional office in Boston and the National Marine Fisheries Service (known today as NOAA Fisheries, the acronym denoting "National Oceanic and Atmospheric Administration") held the project to high standards and worked closely with MassCEC and the design team to implement these standards.

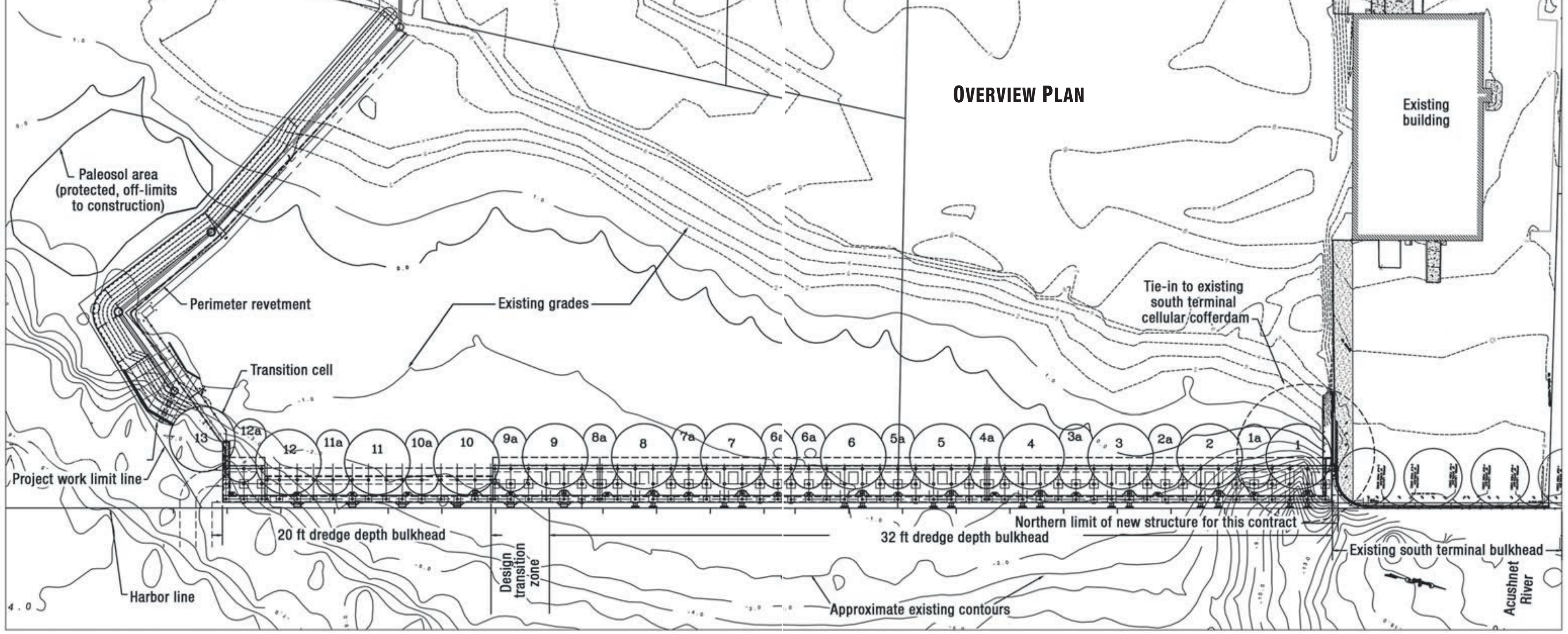
Since World War II, New Bedford's relationship with the water has been complicated by its attempts to diversify its economic base through electronics manufacturing in its former mill buildings. In particular, two manufacturers of electronic components discharged wastewater containing PCBs directly and indirectly into New Bedford Harbor. In 1983 the EPA declared more than 18,000 acres of New Bedford Harbor and Buzzards Bay a Superfund site containing more than 1 million cu yd of sediment significantly contaminated with PCBs and heavy metals. In 1998 the agency issued a record of decision that demarcated 450,000 cu yd of contaminated sediment to be removed from the harbor and placed in shoreline-confined disposal facilities.

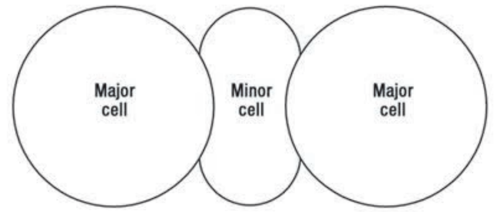
As part of this record of decision, the Commonwealth of Massachusetts requested an enhancement to the Superfund remedy that would allow the commonwealth to continue remediation work in the harbor within a special regulatory environment that would parallel the Superfund process. This so-called state-enhanced remedy provision was incorporated into the record of decision to allow special handling and disposal of dredge sediments from the navigation channel that contained contamination at a level below a certain threshold. Approximately 2.5 million cu yd of the sediment would not be suitable for disposal in the open water, would not be covered by the Superfund project, and would require dredging in order to maintain the shipping channels at the Superfund site at their federally mandated depths. Using the state-enhanced remedy provision as a guide, the commonwealth and the design team worked in tandem with the appropriate federal and state agencies to develop the regulatory process for the terminal project.

Ships entering New Bedford Harbor must pass through the hurricane protection barrier constructed by the U.S. Army Corps of Engineers in the 1960s. The 3.5 mi long barrier includes a 150 ft wide gate within the 29 ft deep, 350 ft wide federal navigation channel. To enable deep-draft vessels to reach the New Bedford Marine Commerce Terminal, the project included the dredging of an 825 ft diameter turning basin and a 300 ft wide channel leading to the terminal. In this way ships entering the harbor through the hurricane barrier would have to pass to the north of the terminal, change direction by means of the turning basin, and then approach the terminal to the south.

The design team's assessment of the project site to the south of the existing South Terminal included the following:

- Gathering information from land-side and waterside borings;
- Engaging land-side and waterside remote sensing programs;
- Analyzing side-scan sonar, vibracores, peat cores, and bottom material obtained by grab samplers within the dredge footprint;
- Gathering historical information on dredging at the South Terminal;





CLE ENGINEERING, *BOTH*

Constructed to accommodate the large cranes that will be capable of moving the heavy components associated with offshore wind energy projects, the New Bedford Marine Commerce Terminal, *right,* included the use of cellular sheet-pile cofferdams for the bulkhead because they were seen as an attractive means of handling the heavy loads and negotiating the anticipated rugged subsurface terrain. The front third of each cell's sheet piles were driven to refusal, *opposite,* and the remainder were gradually stepped as they progressed inshore. The sheet piles for the front half of the cells were epoxy coated, but uncoated sheet piles were used for the back half of the cells, which would not have direct exposure to seawater.

APEX COMPANIES, LLC

• Sampling contaminated sediment from underwater and contaminated soil and sampling groundwater from the upland area.

With this information, the design team began to conceptualize the channel and bulkhead designs, together with their complex interrelations, from environmental, structural, and geotechnical perspectives.

THE CHANNEL leading from the turning basin to the terminal would be dredged to –30 ft with respect to mean lower low water (MLLW) and end in a deep-draft (32 ft) berth on the north side of the bulkhead for incoming cargo ships and a shallow-draft (14 ft) berth on the south side of the bulkhead for outgoing barges. Dredging of the channel leading to the new terminal was complicated by the presence of contamination in the sediment to be dredged. The regulatory regime for the cleanup of New Bedford Harbor permitted the use of confined aquatic disposal cells for disposing of contaminated dredge sediment from the harbor. The terminal project created such a cell in the harbor for the permanent disposal of the contaminated harbor sediment excavated in constructing the new terminal and the channel leading to it.

The bulkhead would extend 1,000 ft to the south of the South Terminal and would be required to carry heavy loads up to the quayside. Key collaborators from the offshore wind industry provided early design criteria indicating that the bulkhead's superimposed load should be at least 4,100 psf, much higher than the 500 to 1,000 psf seen in many U.S. bulkhead structures. As its members considered a range of options for the bulkhead, the design team realized that this significant capacity, combined with the harbor's shallow bedrock and glacial geology, would be quite challenging. Ultimately, the team opted to use cellular sheet-pile cofferdams for the construction because they were seen as offering an attractive means of handling the heavy loads and negotiating the anticipated rugged subsurface terrain. However, before selecting this approach, the project participants evaluated in significant detail the basic loading criteria that had been provided by industry partners.

For several months during the spring and summer of 2011, MassCEC conducted a stakeholder engagement process that included multiple offshore wind developers, and it also studied European offshore wind ports. Studies of ports at such locations in Germany as Bremerhaven and Cuxhaven revealed that many of the ports currently in use for offshore wind projects had been repurposed and possessed loading capacities ranging from 1,000 to 20,000 psf, the high end of which was located at specific heavy-load platforms. Most of the ports had not been designed for the construction staging associated with offshore wind projects, which complicated the effort to establish standard design criteria for a new U.S. port of this type. Several European ports were able to function with lower loading capacities because European-flag installation vessels, which, as noted above, cannot be used in the United States, can lift the heaviest objects from the waterside. Components can thus be moved about the upland areas through a combination of smaller cranes on dunnage and self-propelled modular transporters.

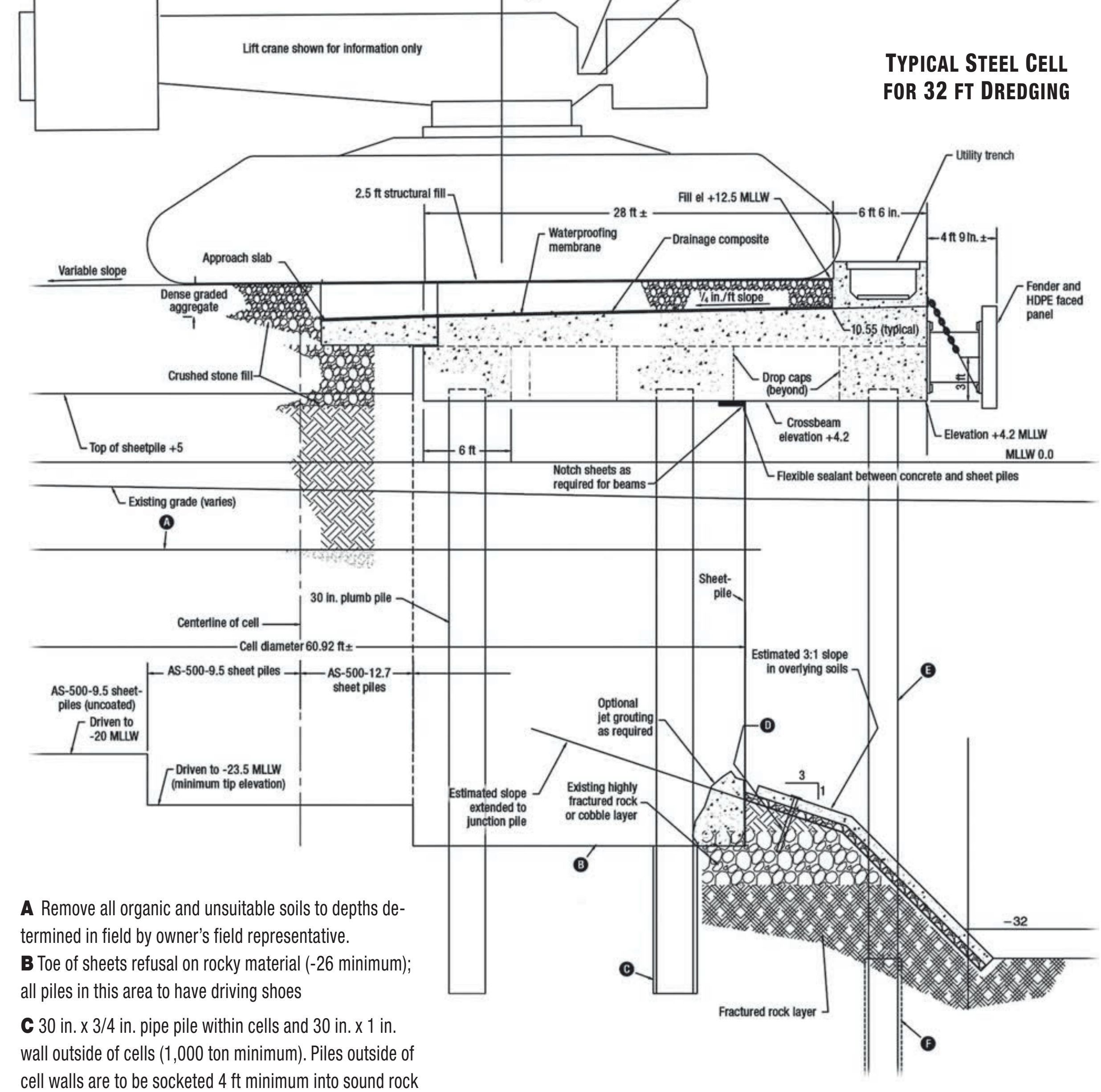
Although the procedures at existing European terminals can work well, European colleagues impressed upon MassCEC and the design team that these measures limited the flexibility of land-side logistics and would not be favored in the case of a new, purpose-built European terminal. A new U.S. terminal could be designed more efficiently, but it would also have to contend with the prohibition on European-flag installation vessels. Limiting the transfers to land-side cranes increases the radius of the "picks," driving up the size of the crane and counterweight necessary for such picks and subsequently increasing the peak loads under the tracks of the crane on the seaward side of the bulkhead. These considerations led MassCEC and the design team to consider loading criteria in more detail, going beyond the basic 4,100 psf originally suggested by the offshore wind industry.

The cost of designing for heavy loads also led MassCEC to investigate options for concentrated heavy-lift platforms that would involve stationary cranes at various locations along the bulkhead. However, these options were complicated by the presence of the so-called jack-up barges (also known as spud barges) that would be parked at the quayside during loading operations. Used to deliver the turbine components from the terminal to the wind farm, the barges employ multiple "legs" that are lowered to the ocean floor to jack up, or elevate, the barge above the water's surface and create a stable platform for construction. These legs, however, are raised in the air when the barges are in shallow water, so the presence of the barges at the quayside would restrict the movements of the stationary cranes. This observation helped clarify that the quayside ought to support crawler cranes, which could maneuver around obstructions. The required pick radius of these crawler cranes was determined on the basis of a survey of the vessels that were expected to service the terminal.

Discussions with offshore wind component manufacturers provided guidance on the size and weight of future components that may need to be loaded or unloaded. The stakeholder engagement process also revealed that existing offshore wind developers had various methods for using a staging port, that the logistics of offshore wind installation and the logistics of staging ports are continually evolving, and that the primary criterion that garnered consensus among stakeholders was maximum flexibility at the site.

Out of this process, MassCEC and the design team concluded that, because the heavy loads would require the use of crawler cranes throughout the site, it was important to directly study the loads that would be induced by large crawler cranes on the cofferdams, the relieving platform, and the compacted upland soils. This clear characterization of the design loads would make it possible to investigate the marginal cost of increasing the loading capacity. MassCEC had encountered similar circumstances during the design of the Wind Technology Testing Center. For that project, the design loads for the reaction structure and the dimensions of the building were directly related to the size of the blades that were expected to be tested. However, the blades contemplated for the design were larger and stronger than anything ever manufactured to that point. Based on its experience with the Wind Technology Testing Center and the results of the stakeholder engagement process, MassCEC instructed the design team to incorporate a crawler crane with a capacity of 1,350 metric tons and a maximum pick moment of 15,000 metric ton–meters. This selection implied picks of 500 metric tons at 30 m, 333 metric tons at 45 m, and 250 metric tons at 60 m.

Typical Steel Cell for 32 ft Dredging



A Remove all organic and unsuitable soils to depths determined in field by owner's field representative.

B Toe of sheets refusal on rocky material (-26 minimum); all piles in this area to have driving shoes

C 30 in. x 3/4 in. pipe pile within cells and 30 in. x 1 in. wall outside of cells (1,000 ton minimum). Piles outside of cell walls are to be socketed 4 ft minimum into sound rock as determined by engineer. Piles to be filled with 4,000 psi concrete as indicated.

D 3 in. diameter extraheavy steel pipe pins 4 ft long

E 24 in. x 5/8 in. wall pipe pile 450 ton rock socket 4 ft into sound rock and grouted piles to be filled with 4,000 psi concrete

F Rock sockets for piles to be minimum 6 in. larger than outer diameter of pile. Predrill rock sockets through loose and soft rocklike materials to sound rock as determined by engineer in field. Socket to penetrate 4 ft minimum into sound rock layer. Fill void to top with 4,000 psi grout or concrete

CLE ENGINEERING

A detailed study of the bulkhead and uplands under these crane conditions revealed that while the pile-supported relieving platform was sensitive to the size of the crane, the cofferdam structure was not as sensitive. In response, the design team minimized the size of the relieving platform to the width required to create a straight quayside and protect the scalloped waterside edges of the cellular cofferdams. Furthermore, the study's findings gave MassCEC confidence that the cellular cofferdam structure, which offered advantages with regard to constructability, would be able to accommodate future loading patterns, even if heavier. Through this process, 4,100 psf became the "uniform load" and governed the cofferdam design with regard to hoop tension, shearing, and sliding. Meanwhile, the maximum pressure under the crane tracks in a loaded condition, or "point load," governed the design of the pile-supported structure and the soil bearing capacity.

For high bearing capacities in the upland areas, the design team specified 3 ft of dense, graded aggregate over at least 7 ft of heavily compacted fill. This dense, graded aggregate cap made it possible to leave in place sediment contaminated with less than 50 ppm of PCBs. The cap also strengthened the bearing capacity of the sediment so that the cranes would be able to move freely at the site without dunnage.

THE FINAL DESIGN of the bulkhead relied on 61 ft diameter steel cells, called major cells, spaced 82.9 ft apart on center and on 15.4 ft radius cells, called minor cells, located between the major cells. Sheet piles for the minor cells were designed for both the waterside and the upland side so that pile-driving and other equipment could operate on top of the cells during construction. The front third of a cell's sheet piles were driven to refusal, the remainder being gradually stepped as they progressed toward shore.

The sheet piles for the front half of the cells were AS-500-12.7 sheets made of epoxy-coated, corrosion-resistant steel with a strength of 50 ksi. To reduce costs, lighter AS-500-9.5 uncoated sheet piles were used for the back half of the cells, which would not have direct exposure to seawater. (See the figure on pages 72 and 73.) The cells were topped with a shallow, hybrid relieving platform and marginal wharf expressly designed to withstand the crane loads discussed earlier. The design provided a pile-supported overhang with a maximum width of approximately 13 ft from the seaward face of the cells, and the fender system provided an additional standoff distance of 4 ft 9 in. The overhang and fender system was configured to provide enough room for the construction of a shaped slope of rock and soil extending from the toe of the sheet piles down to the berth dredge template. The finished slope was then protected from scour by the installation of a 16 in. precast-concrete mattress.

MassCEC and the design team selected the cellular sheet-pile cofferdam design for its ability to withstand heavy crane loads and accommodate reasonable differences in constructed sheet tip elevations without compromising structural integrity. Because the cofferdam structure would draw its lateral and vertical strength from the hoop tension capacity and the weight of the cells themselves, the cofferdam sheet piles were not required to develop a significant embedment at the sheet tip. Furthermore, the restraining effects of the subsurface boundary conditions on the constructed sheet tips would move the critical sheet junction point upward to where the sheet connections were regular. This robust structural behavior of the circular, cellular cofferdam would enable it to tolerate, within reason, adjacent sheet tips being driven to different depths.

Although the cofferdam cells were well suited to handle slight variations in driven sheet tip elevations, there were concerns about whether a contractor could drive flat sheets into very dense material that included obstructions. This led the design team to consider a variety of measures to reduce risk as part of the specification. If an obstruction were to block a sheet during the driving process, the resulting remedy would prove costly and affect the schedule's critical path. Although driving an H-pile probe in the sheet location might be able to displace smaller obstructions, larger obstructions would require excavation. Such excavation would probably necessitate the temporary removal of other sheets, as well as the cofferdam cell template. So the design team concluded that obstructions larger than 2 ft in diameter would have to be located and excavated before the template was set. To accomplish this, the specification included a requirement that the contractor conduct jet probing along all cell perimeters at 2 ft intervals. During construction, the design team approved the contractor's request to replace jet probes with pile probes.

The design team also had to consider the dredging of the new channel and turning basin from environmental, geotechnical, and logistical points of view and to coordinate the dredging with the land-side and waterside operations. This requirement resulted in the development of three dredge prisms based on prospective use or disposal scenarios for the dredged material. The three prisms were referred to as top of dredge, intermediate dredge, and bottom of dredge.

Material in the top of dredge prism was considered to be environmentally and geotechnically unsuitable for reuse as capping material or upland fill. Material in the intermediate dredge prism was considered to be environmentally suitable for reuse as capping material but geotechnically unsuitable for reuse as upland fill. Material in the bottom of dredge prism was considered to be environmentally and geotechnically suitable for reuse as upland fill, provided it was processed and graded accordingly.

A substantial portion of the top of dredge prism included volumes of silty material inside the turning basin and existing federal channel, which most recently (around 1952) had been dredged to –30 ft MLLW, and inside the existing channel at the South Terminal, which most recently (1968) had been dredged to –20 ft MLLW. To provide tolerance for the dredging operation and to help ensure that the contaminated material would be adequately removed, the top of dredge prism itself was designed to extend into the harder material directly below it.

It was determined that some of the rock in the bottom of dredge prism would have to be blasted, triggering intensive engagement with the EPA and the National Marine Fisheries Service. Measures were needed to protect the endangered Atlantic sturgeon, the sensitive winter flounder, and other marine life-forms sensitive to impulses propagated through the water by blasts. Blasting activities also had to be coordinated with the Corps of Engineers because the hurricane barrier mentioned above that it had built was within 1,000 ft of the project blast zone and with the Massachusetts Historical Commission, which expressed concerns regarding the effects of blast vibrations on the nearby Palmer Island lighthouse, which dates to 1849.

The resulting project modified 1,000 ft of existing harbor shoreline. Through discussions with the EPA, the design team developed a series of mitigation measures designed to compensate for the displaced aquatic resource:

- Removal and proper disposal of more than 280,000 cu yd of PCB-contaminated sediment into a confined aquatic disposal cell;
- Reuse of dredge spoils where possible;
- Creation of new spawning habitat for the winter flounder and an associated monitoring program to assess the success of the new habitat;
- Establishment of a shellfish seeding program;
- Creation of a program to monitor the presence of endangered terns in New Bedford Harbor;
- Construction of 1 acre of salt marsh habitat in the harbor north of the terminal;
- Creation of subtidal and intertidal habitat to compensate for that filled by the project.

MASSCEC AND THE DESIGN team consulted with the Northeast Marine Pilots Association, of Newport, Rhode Island, and the EPA regarding the appropriate width of the entrance channel. The marine pilots have sole jurisdiction over the size of vessels that can be brought into New Bedford Harbor and over restrictions on these vessels. The organization's enabling legislation charges it with ensuring navigational safety in the federal approach channel, through the hurricane barrier, and within the harbor. Potential channel designs were developed for discussion and critique by the association and the EPA, which evaluated them with an eye to minimizing untoward effects on the environment. Like the crane study that informed the bulkhead design, these channel designs were based on particular vessels, each of which has a unique combination of length, beam, draft, mass, propeller rotation, vessel rotation caused by currents, on-deck and below-deck cargo capacity and cargo weight, exposed "sail" area—that is, the area of the vessel exposed to wind forces—and bow or stern thruster capacity. Beyond maintaining safe channel widths, the measures to ensure navigation safety could include restrictions on vessel operations under certain wind speeds and tidal and daylight conditions and requirements regarding the number and configuration of tugboats.

The process of evaluating even one or two particular vessels in the proposed channel required MassCEC to commission the Maritime Simulation Institute—a division of the United States Maritime Resource Center, of Middletown, Rhode Island—to build a model of New Bedford Harbor and the new navigational channels constructed for the new terminal. The model enabled the marine pilots to conduct more than 100 simulations. Moreover, MassCEC organized a special meeting to introduce the district pilot commissioner for the Commonwealth of Massachusetts and a U.S. Coast Guard representative to the regulatory team at the EPA regional office in Boston. This introduction led to fruitful discussions covering multiple points of view on the channel and its construction.

These efforts resulted in a 300 ft wide channel design with 1:3 side slopes. This would mean a 400 ft wide channel at high tide accommodating tugboats of shallower draft on either side of the primary vessel, which would travel along the center of the channel. MassCEC and the design team also worked closely with the marine pilots to design navigational aids that would make the channel safer. Finally, the pilots set initial restrictions on vessel dimensions, wind speed, time of day, and other parameters, and they planned to review and modify these over time as they gained actual experience with the new channel.

The New Bedford Marine Commerce Terminal is the first major element of marine infrastructure completed in the United States to service the offshore wind industry. As such, it has afforded insights into the future of a new marine sector that has the potential to generate thousands of jobs and attract billions of dollars in investment over the next decade. The nature of this project required MassCEC and the design team to take a highly interdisciplinary approach with regard to design, permitting, and construction. The fundamental principle of this approach involved defining and understanding challenges so that team members could discuss them thoroughly and expeditiously from multiple points of view before making decisions.

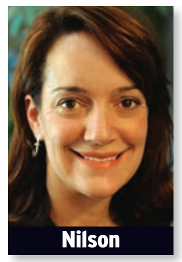
For the Commonwealth of Massachusetts and the City of New Bedford, the design and construction of the New Bedford Marine Commerce Terminal offered an opportunity to accelerate the cleanup of New Bedford Harbor and to plant the seeds of a 21st-century economy in New Bedford. Boasting the highest revenue of any fishing port in the country, New Bedford hosts fishing vessels from every major East Coast port and maintains a strong connection to an industrial maritime culture that values working on the water. Expanding the harbor's industrial capacity to meet the needs that will arise as offshore power generation comes into its own is widely viewed locally as both viable and attractive and is supported by a broad cross section of the public, including labor, business, the public sector, and environmentalists.

In the 19th century New Bedford's preeminence in the whaling industry was such that it was referred to as the city that lit the world. With the completion of the New Bedford Marine Commerce Terminal, the city has embraced its roots as a working harbor and, once again, could light the world with the modern energy source of the 21st century: offshore wind. **CE**


Hines


Borkland


Myers


Nilson


DeRugeris

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PROJECT CREDITS **Owner:** Massachusetts Clean Energy Center, Boston **Owner's adviser:** LeMessurier Consultants, Inc., Boston **Prime contractor and civil and environmental engineer:** Apex Companies, LLC, Rockville, Maryland **Structural engineer:** CLE Engineering, Inc., Marion, Massachusetts **Geotechnical engineer:** GZA GeoEnvironmental, Inc., Norwood, Massachusetts **Contractor:** Cashman-Weeks NB, a joint venture of Cashman Dredging, Inc., Quincy, Massachusetts, and Weeks Marine, Inc., Cranford, New Jersey

September 29, 2014

July 17, 2014

May 14, 2014

March 17, 2014

January 17, 2014

October 29, 2013

OSPRE OffShore Power Research & Education Collaborative

POWER-US Partnership for Offshore Wind Energy Research MASSACHUSETTS