AECOM

Interim Sheen Containment System

North Water Street Former Manufactured Gas Plant
Poughkeepsie, NY

Central Hudson Gas & Electric Corp.

Project reference: NYSDEC Site C314070
Project number: 60543645

August 27, 2026

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Quality information

Prepared by	Checked by	Verified by	Approved by
Derrick Tang	Kira Ambery	James Greco	Robert Forstner

Revision History

Revision	Revision date	Details	Authorized	Name	Position

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Prepared for:

Central Hudson Gas & Electric Corp.
2001 Ulster Avenue
Lake Katrine, NY 12449

Prepared by:

AECOM
605 Third Avenue
New York, NY 10158
aecom.com

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1. Introduction

AECOM has been retained by Central Hudson Gas & Electric Corp. (Central Hudson) to develop plans for and install an absorbent boom system to provide additional site controls at the North Water Street Former Manufactured Gas Plant (MGP) site (Site) on an interim basis while plans for a permanent remedy are developed. The project team was tasked with developing a deployment and anchorage strategy for an 18-inch oil containment boom, absorbent boom, and anchorage system to collect potential sheen in the Hudson River. The Site is located at 2 Dutchess Avenue in Poughkeepsie, NY, under the Walkway Over the Hudson pedestrian bridge. A plan view of this area and the proposed boom locations are shown in Figure 1 below. The objective of this installation is to evaluate the performance of a boom system in controlling sheens that occur as a result of ebullition processes from an area of concentrated non-aqueous phase liquid (NAPL) in Hudson River sediments directly in front of the Site.

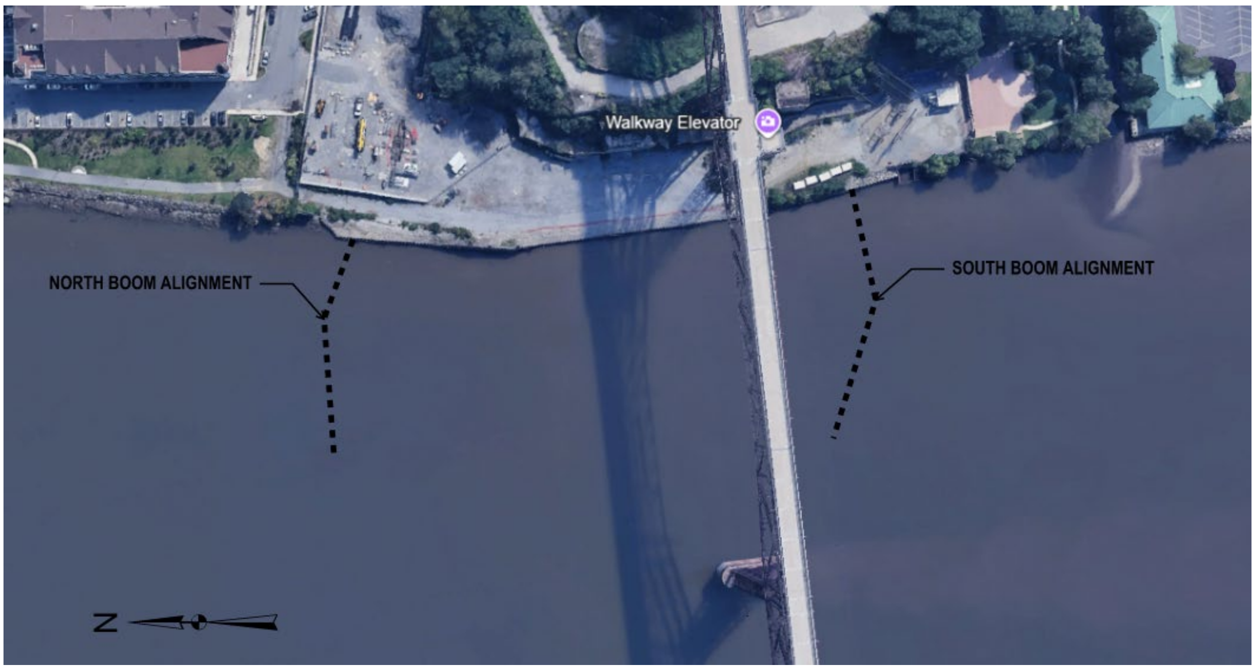


Figure 1. General Boom Layout

A dual-direction anchor configuration will be required for each anchor point due to changing current directions. The proposed boom system will also be connected to the existing sheet pile bulkhead wall along the eastern riverbank, inclusive of a tidal compensator appurtenance to allow the anchorage of the boom to rise and fall with the tidal fluctuations.

2. Design Criteria

The sheen containment boom was selected based on experience from a previous phase of this project to consist of the Elastec PermaFence containment boom (images below). The containment boom will be 18-inches in overall height (estimated 8-inch freeboard and 10-inch draft), provided in 50-foot or 100-foot lengths, and flexible to accommodate river current reversal, with integral floats for buoyancy. The containment boom will be paired with an absorbent boom (not shown below) that will need to be replaced as necessary based on the amount of ebullition-generated sheen collected.

The containment boom will be anchored in place via a combination of:

- New pyramid anchors spaced at approximately 100 feet on either side of each boom alignment
- Connection to the eastern shoreline of the Hudson River at the existing steel sheet pile wall via a welded guide beam and tidal compensator
- Indicator buoys are provided at the anchorage locations and along the length of the containment boom

The current task is developed to evaluate the efficacy of the system and is designed to work under normal fair-weather river conditions. Storms, extreme wave conditions, and river ice are not incorporated into the design or performance of the system. It is understood that the containment boom and absorbent boom will be removed from the river in the fall, in advance of winter ice conditions. During installation, embedment of the pyramid anchors will be tested and results of that evaluation will inform the final approach to winterization (e.g., whether the anchors can be left in place and easily recovered for use in the next season, or removed and reinstalled).

Figure 2: PermaFence - Image courtesy of Elastec

The anchor system was designed for an assumed drag force resulting from a current speed of 2.0 knots acting on the containment boom. This current speed is estimated based on peak average flow events along the Hudson River in this area.

The anchor system connection to existing sheet pile wall will account for tidal changes. Tidal elevations were obtained from the tidal gauge 5.5 miles north of Poughkeepsie and are listed in Table 1 below.

Elevations on

Station: 8518951, Hyde Park, NY
Status: Accepted (Nov 24 2014)
Units: Feet
Control Station: 8518750 The Battery, NY
T.M.: 75
Epoch: 1983-2001
Datum:

Datum	Value	Description
MHHW	2.32	Mean Higher-High Water
MHW	1.93	Mean High Water
MTL	0.18	Mean Tide Level
MSL	0.23	Mean Sea Level
DTL	0.27	Mean Diurnal Tide Level
MLW	-1.58	Mean Low Water
MLLW	-1.78	Mean Lower-Low Water
NAVD88	0.00	North American Vertical Datum of 1988
STND	-29.04	Station Datum
GT	4.10	Great Diurnal Range
MN	3.51	Mean Range of Tide
DHQ	0.39	Mean Diurnal High Water Inequality
DLQ	0.20	Mean Diurnal Low Water Inequality
HWI	-23.45	Greenwich High Water Interval (in hours)
LWI	-16.85	Greenwich Low Water Interval (in hours)
Max Tide		Highest Observed Tide
Max Tide Date & Time		Highest Observed Tide Date & Time
Min Tide		Lowest Observed Tide
Min Tide Date & Time		Lowest Observed Tide Date & Time
HAT	3.36	Highest Astronomical Tide
HAT Date & Time	11/24/2003 17:48	HAT Date and Time
LAT	-2.39	Lowest Astronomical Tide
LAT Date & Time	02/13/2032 01:06	LAT Date and Time

Table 1: Hyde Park, NY Tidal Elevations in NAVD88

Preliminary geotechnical subsurface borings were obtained in 2015 along the north and south alignment. The soil classification ranges from soft to very soft silts with slight traces of sand and clay.

3. Anchor Design

Based on the current speed, boom system sizing and properties, the current drag forces were calculated acting on the boom curtains as a lateral force. The ~450-ft long northern boom alignment was determined to require 9 total pyramid anchors spaced at 100-ft on-center along the containment boom. The ~490-ft long southern boom alignment anchoring system was determined to need 10 total pyramid anchors spaced at 100-ft on-center along the containment boom.

Details for the pyramid anchors are shown in Section 3.1. See Appendix A for the proposed boom and anchor layout.

The boom system will be connected to existing sheet pile wall through a tidal compensator. See Section 3.2 for further details.

3.1 Pyramid Anchors

The anchoring system has been designed using pyramid anchors due to existing site conditions and holding capacity. Pyramid anchors rely on their weight to sink straight down into the river bottom and provide resistance via friction/embedment in the riverbed sediment when pulled by currents. Pyramid anchors do not rely on dragging horizontally along the river bottom unlike Danforth anchors. Thus, the pyramid anchors will remain in the installed location and will avoid damaging the existing adjacent underwater utilities along the river bottom. A pyramid anchor example is shown below in Figure 3. The previous phase of this project, which also included an extensive turbidity curtain system, utilized large custom concrete blocks which are highly labor intensive to locate and connect to the boom, requiring divers in 55 to 60-foot-deep turbid water. Therefore, the pyramid anchor system has been developed in coordination with the anchor manufacturer as an equivalent alternative solution for positioning the containment boom.

Figure 3. Dor-mor Pyramid Anchors

The pyramid anchors would have adequate chain and cable length to achieve desired holding capacity. Per our coordination with the pyramid anchor manufacturer (Dor-Mor), the total chain and cable length shall be three times the river depth to achieve the appropriate geometry for the anchor to achieve its maximum holding capacity of 10 times the anchor dry weight. See below for a general section view of the anchoring system. See Appendix A for detailed section and elevation view. While this results in an efficient system with respect to the weight of each anchor required to secure the booms, it does require significant lengths of line/chain to allow the boom to drift with the current before engaging the lines and anchors for positioning. A simplified sketch of this requirement is shown in Figure 4 below.

The installation of the anchors and booms will require a spudded barge-mounted crane due to the weight of these elements. Similar to activities conducted during the Pre-Design Investigation completed in 2025, it is anticipated that the spudding activities would generate sheens. A sheen patrol boat will be utilized during all barge operations to collect these sheens via absorbent materials. As has been successfully accomplished on past field work programs for this Site, AECOM will provide an observer on the Walkway Over the Hudson to direct the sheen patrol boat captain in the collection of the sheens.

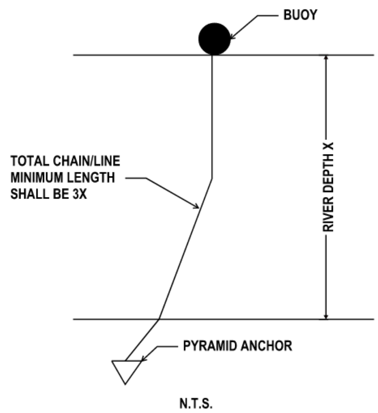


Figure 4. General Anchor and Cable Geometry

3.2 Tidal Compensator

A stainless-steel tidal compensator will be utilized for the anchorage of the containment boom at the eastern shore of the Hudson River. The compensator will allow free vertical travel of the boom up and down with water level fluctuations, while securing the boom from horizontal translation either parallel or perpendicular to the river flow. The compensator will connect to the containment boom and will be attached to the existing steel sheet pile wall along the shoreline via a vertical stainless steel W6x16 beam. After coordination with the Contractor regarding their preferred means and methods, a mechanical bolted connection has been abandoned, and the connection will be via field welding of the guide beam to the existing sheet pile including surface preparation of the sheet pile surface in advance of welding. The elevation and length of the vertical beam were determined to satisfy the lowest and highest astronomical tides as seen in Table 1. See Figure 5 below for a representation of the tidal compensator. See Appendix A for detailed tidal compensator connection to existing sheet pile.

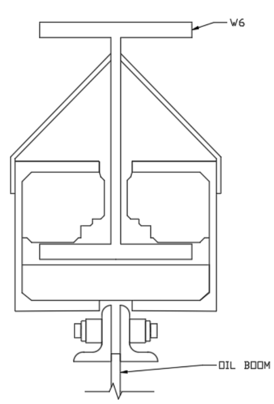


Figure 5. General Tidal Compensator Detail

4. Routine Operation and Maintenance

The containment boom system would operate in a passive manner. There is no active or powered equipment proposed as part of this system, and the only consumable components are the absorbent booms to be placed on the inboard (closest to the concentrated NAPL area) sides of the two booms. Maintenance requirements will be driven by the rate of ebullition (affecting the frequency at which absorbent booms will require replacement), potential impacts to the boom due to debris occurring in the river (which may require removal or release of accumulated debris and/or refastening of boom sections), and/or other external factors that may require complete or partial removal of the system (e.g., should it become a hazard to navigation or unreasonably obstruct recreational use of the river).

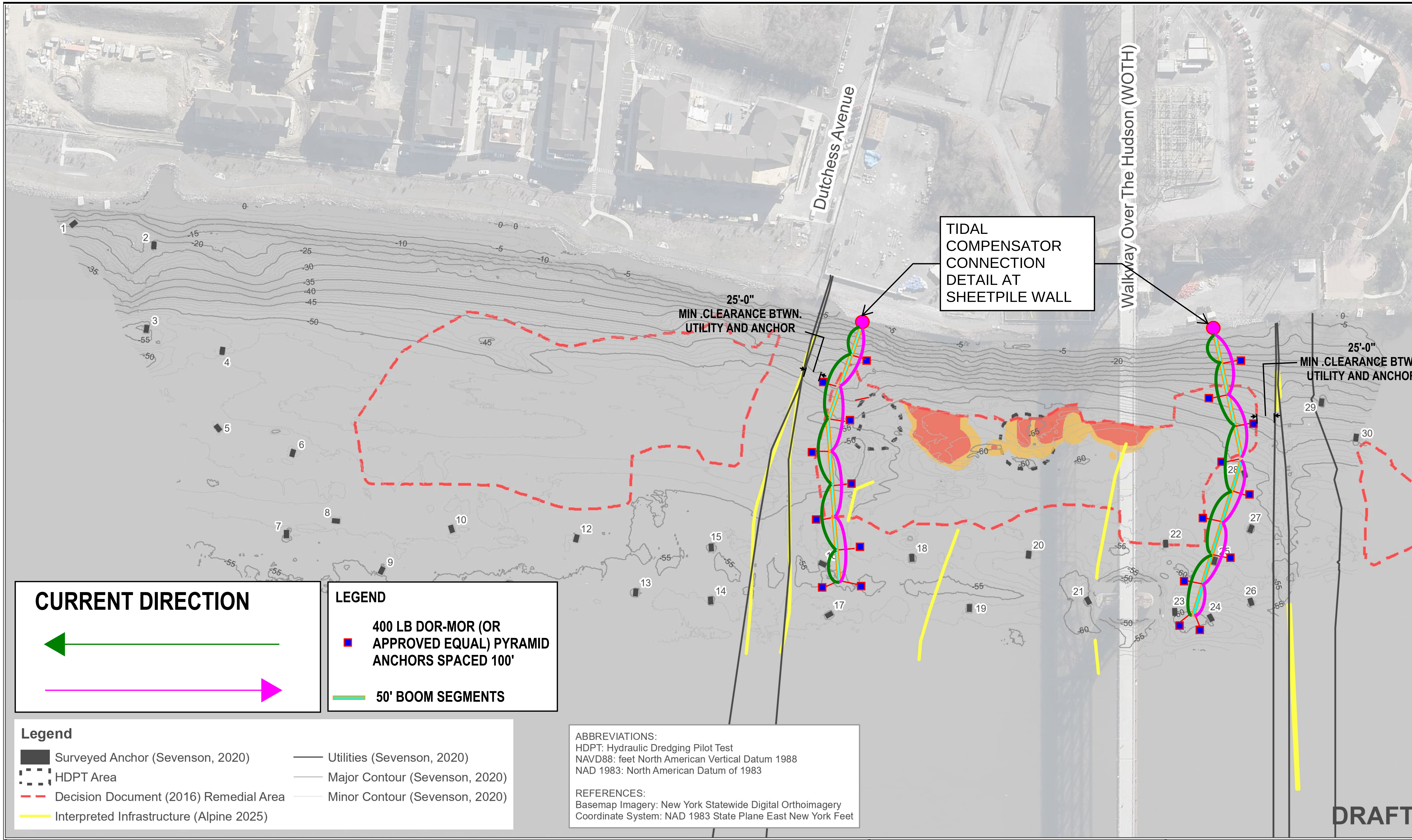
Routine inspection of the system will be performed by Central Hudson or authorized alternate personnel through observations from the upland portion of the Site and/or from the Walkway Over the Hudson. The frequency of inspections will be established based on observations of system performance immediately after installation. At this time, daily (not including weekends) inspections for the first week following installation and then weekly inspections thereafter are anticipated. Maintenance of the system will likely be performed by others under direct contract to Central Hudson, at a frequency to be determined based on post-installation observations. Central Hudson will provide periodic updates to NYSDEC staff, including information as to system performance, operation and maintenance requirements, and removal of the system from the River.

5. Conclusion

To support ongoing remedial efforts at the Central Hudson North Water Street MGP Site, AECOM developed the anchorage and boom system detailed in this memorandum. The proposed system consists of an 18-inch oil containment boom paired with an absorbent boom, with the absorbent component intended to be maintained and replaced as needed to sustain collection effectiveness. The anchorage approach consists of 19 new pyramid anchors spaced at approximately 100 feet along the boom alignments, and a shoreline termination at the eastern bank of each boom alignment using a tidal compensator assembly attached to the existing steel sheet pile bulkhead. This combined strategy provides restraint under reversing river currents while minimizing the risk of anchor drag and potential interaction with underwater utilities by utilizing pyramid anchors. The reuse of existing submerged concrete blocks was considered but not recommended due to the desire to minimize diving work. The proposed layout and connection details are provided in Appendix A sketches.

The installation of the system will require a spudded barge; similar to activities conducted during the 2025 Pre-Design Investigation, it is anticipated that the spudding activities would generate sheens. An observer on the Walkway Over the Hudson bridge and a sheen patrol boat will be utilized during all barge operations to observe and collect these sheens via absorbent materials.

Appendix A Boom Anchor & Layout Sketches



AECOM

N

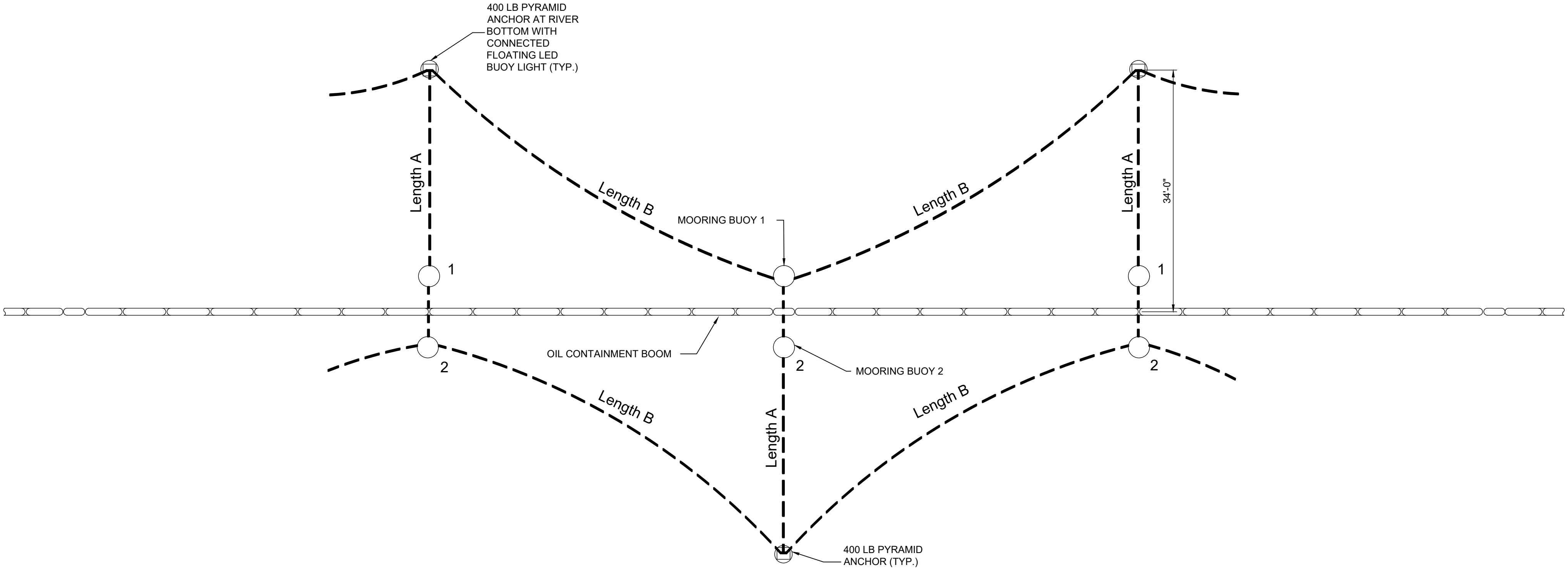
0 37.5 75 150 Feet

FORMER NORTH WATER STREET MGP SITE
CENTRAL HUDSON GAS & ELECTRIC CORPORATION
POUGHKEEPSIE, NY

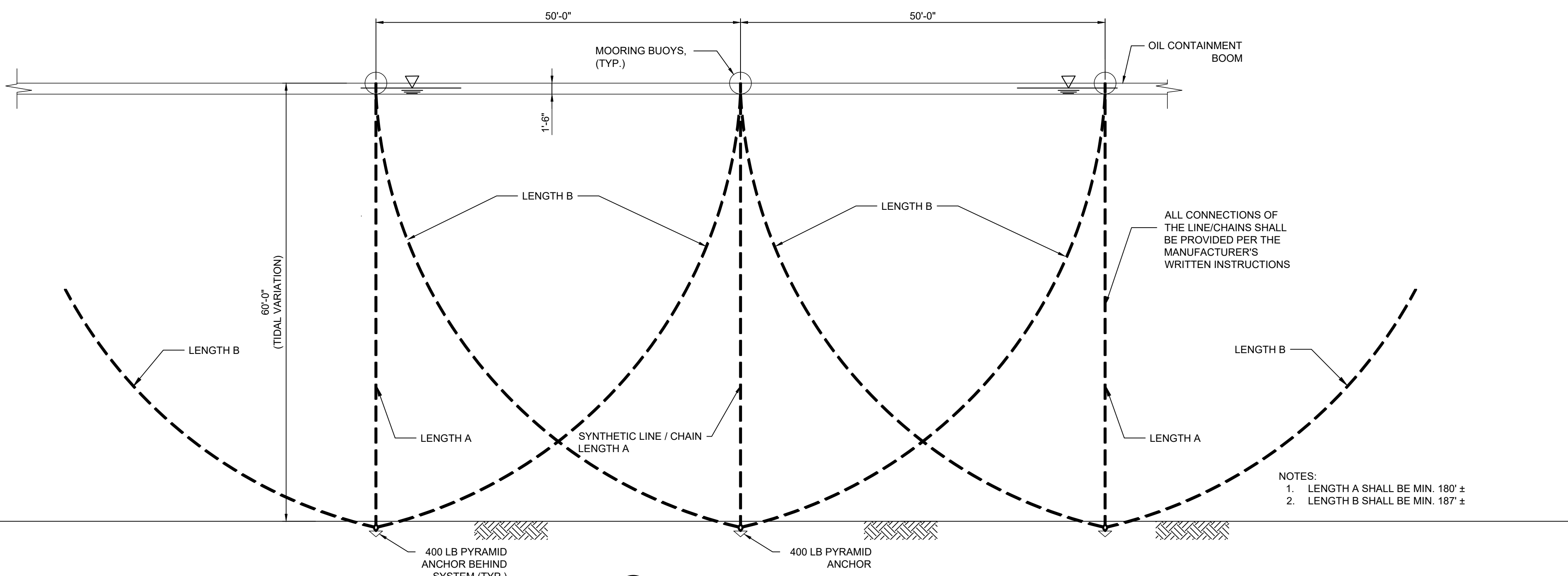
DATE: 8/14/2026 | DRWN: DT

Anchor Locations

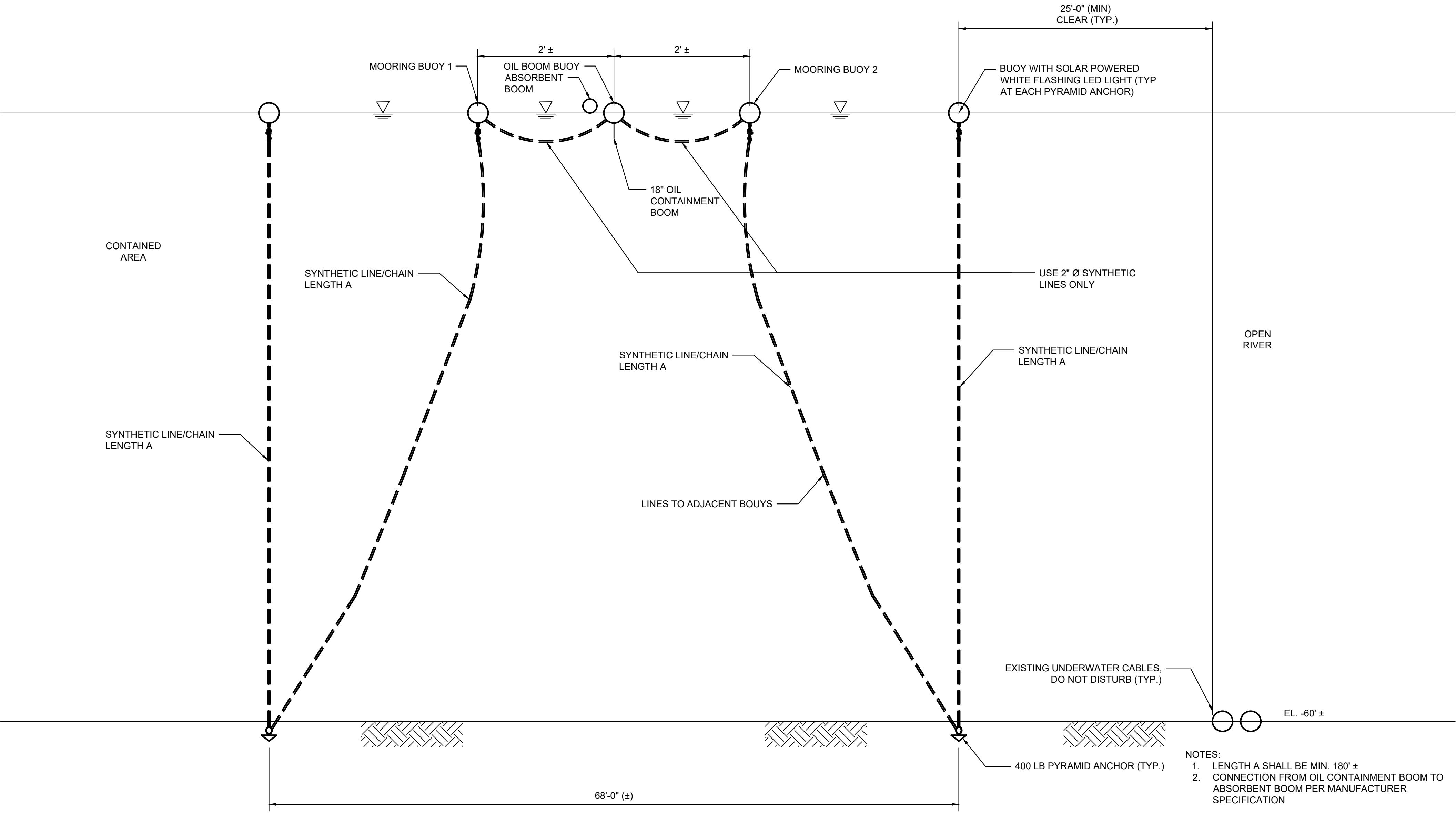
FIGURE 1



1 OIL BOOM/ANCHOR PLAN

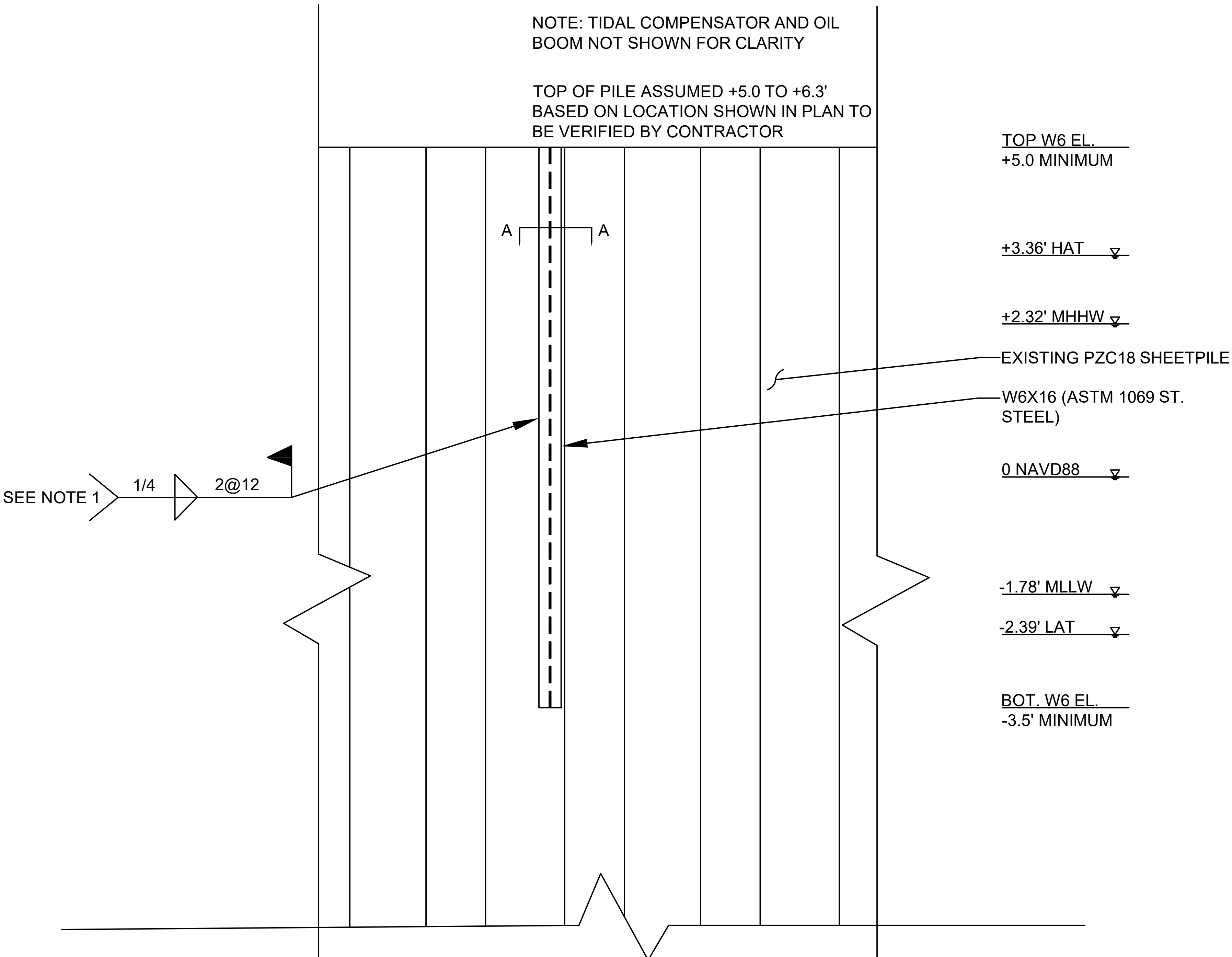


2 OIL BOOM/ANCHOR ELEVATION

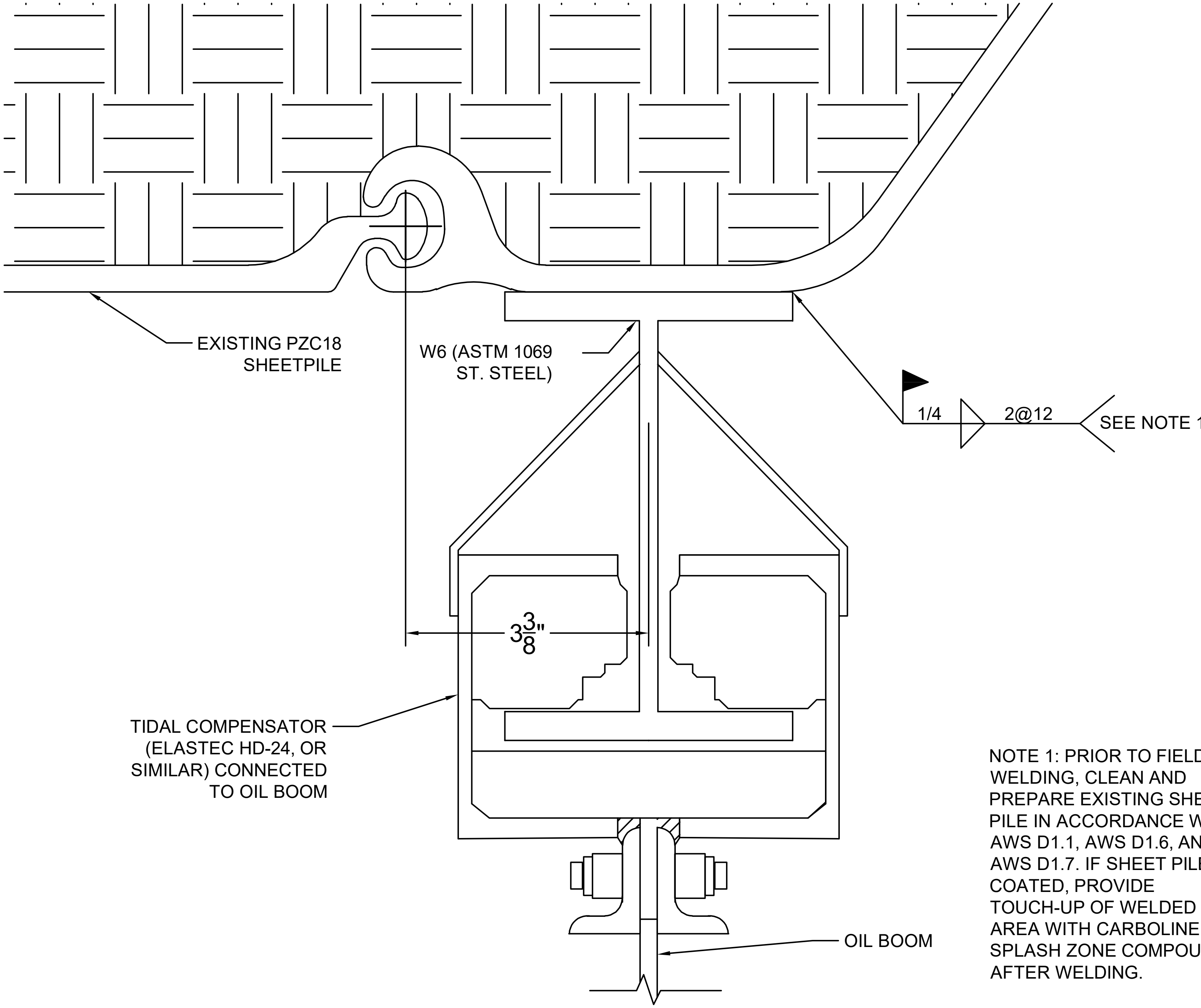


NOTES:
1. LENGTH A SHALL BE MIN. 180' ±
2. CONNECTION FROM OIL CONTAINMENT BOOM TO ABSORBENT BOOM PER MANUFACTURER SPECIFICATION

A OIL BOOM/ANCHOR SECTION VIEW
SCALE: 3/16"=1'-0"



1 TIDAL COMPENSATOR CONNECTION ELEVATION VIEW



NOTE 1: PRIOR TO FIELD WELDING, CLEAN AND PREPARE EXISTING SHEET PILE IN ACCORDANCE WITH AWS D1.1, AWS D1.6, AND AWS D1.7. IF SHEET PILE IS COATED, PROVIDE TOUCH-UP OF WELDED AREA WITH CARBOLINE A788 SPLASH ZONE COMPOUND AFTER WELDING.

A TIDAL COMPENSATOR CONNECTION SECTION VIEW

Anchor System Design

Drag force on booms with differing spaces (50', 100') were analyzed to design anchoring system.

Drag Force Calculation

Performance review prepared by Robert Schulze assumed drag coefficient to be 1.5 for an oil containment boom. Research prepared by SL Ross found rigid barriers to have drag coefficient of 1.9 while a constant value could not be determined for flexible barriers. Thus, drag coefficient of 1.9 was conservatively used in this calculation.

Drag Force - 50' Spacing

Drag Coefficient $C_D := 1.9$

Spacing $L_{50} := 50\ ft$

Draft $draft := 18\ in$

Reference Area $A_{50} := L_{50} \cdot draft = 10800\ in^2$

Fluid Density $\rho_w := \frac{(62.4\ pcf)}{g}$

Flow Velocity $V := 2.0\ knot = 3.376\ \frac{ft}{s}$

Drag Force $F_{D.50} := C_D \cdot A_{50} \cdot \frac{\rho_w \cdot V^2}{2} = 1.575\ kip$

Drag Force per Foot $F_{D.50.lf} := \frac{F_{D.50}}{L_{50}} = 31.492\ plf$

Drag Force - 100' Spacing

Spacing $L_{100} := 100\ ft$

Reference Area $A_{100} := L_{100} \cdot draft = 21600\ in^2$

Drag Force $F_{D.100} := C_D \cdot A_{100} \cdot \frac{\rho_w \cdot V^2}{2} = 3.149\ kip$

Drag Force per Foot $F_{D.100.lf} := \frac{F_{D.100}}{L_{100}} = 31.492\ plf$

Pyramid Anchor Design

Pyramid anchors achieve a holding capacity of 10 times the anchor dry weight given that the total chain and cable length is three times the river height according to the manufacturer Dor-mor.

Pyramid anchors shall be designed for 100' spacing to remain conservative in reactions and align with proposed boom system spacing.

Required Anchor Weight $W_{pyramid} := \frac{F_{D.100}}{10} = 314.92\ lbf$

Final Anchor Weight $W_{pyramid.fin} := 400\ lbf$

Factor of Safety $FOS_{pyramid} := \frac{W_{pyramid.fin}}{W_{pyramid}} = 1.27$

Concrete Anchor Design

Concrete block anchor design is provided below solely to demonstrate that the blocks are a viable backup anchoring option. Pyramid anchors shall remain as the primary option.

Assume friction coefficient to be 0.35 for concrete bottom friction along roughened bottom. Roughened bottom will be achieved by waffle-pattern on the concrete underside. It is necessary to not rely on passive resistance from embedment in soil since it is not predictable.

The waffle-pattern will reduce the weight slightly, but the FOS will still be greater than 1. Actual FOS is greater since the block will have some embedment and passive resistance.

50' Spacing

Concrete Density $\gamma_{conc} := 150\ pcf$

Assumed Concrete Size $V_{conc} := 6\ ft \cdot 5\ ft \cdot 2\ ft = 60\ ft^3$

Concrete Weight $F_g := V_{conc} \cdot \gamma_{conc} = 9\ kip$

Buoyancy Force $F_{buoy} := 62.4\ pcf \cdot V_{conc} = 3.744\ kip$

Friction Coefficient $\mu := 0.35$

Allowable Lateral Resistance $F_{ult.50} := \mu \cdot \left(F_g - F_{buoy}\right) = 1.84\ kip$

Factor of Safety $FOS_{50} := \frac{F_{ult.50}}{F_{D.50}} = 1.168$

100' Spacing

Assumed Concrete Size $V_{conc.100} := 6\ ft \cdot 6\ ft \cdot 3\ ft = 108\ ft^3$

Concrete Weight $F_{g.100} := V_{conc.100} \cdot \gamma_{conc} = 16.2\ kip$

Buoyancy Force $F_{buoy.100} := 62.4\ pcf \cdot V_{conc.100} = 6.739\ kip$

Allowable Lateral Resistance $F_{ult.100} := \mu \cdot \left(F_{g.100} - F_{buoy.100}\right) = 3.311\ kip$

Factor of Safety $FOS_{100} := \dfrac{F_{ult.100}}{F_{D.100}} = 1.051$

References

Oil Spill Response Performance Review of Booms, Robert Schulze

1.4 Discussion of Existing and New Empirical Equations

The ITOPF equation for computing forces on booms is perhaps the best known and is shown below (2).

$$F_w = 26\ A_w\ (V_w/40)^2$$
$$F_c = 26\ A_c\ V_c^2$$

where:
F_w = force on a boom due to wind, kg
A_w = freeboard area, m^2
V_w = wind velocity, knots
F_c = force on a boom due to waves and current, kg
A_c = submerged area, m^2
V_c = current/tow velocity, knots

Although not specified in some references, the submerged area is clearly what is generally called the "projected area," which is either the boom draft times the towing gap or the boom length times the draft times the gap ratio.

Comparison of the results using the ITOPF formula and other computations is difficult because of the units of force. Further, the force computed here is the total force, not tension (one half of total force) used in the MMS equations. Other computations used here have the result in pounds of force. Converting the ITOPF equation to tension and pounds of force, the constant multiplier becomes approximately 2.64 instead of 26. It turns out that this is just a special case in the equations developed in the MMS study. This relationship is discussed later along with the MMS equations.

The World Catalog/Exxon equations have been published in editions of the Catalog since 1986 and most recently in 1999 (3,4). These formulas are shown by the following:

$$T_a = 0.5\ L\ \tau\ C_d\ \rho_a\ f\ V_a^2$$
$$T_w = 0.5\ L\ \tau\ C_d\ \rho_w\ d\ (V_w + 0.5\sqrt{H_s})^2$$
$$D = 2\ (T_a + T_w)$$

where:
D = total drag force, in pounds force
T_a = tension due to wind, in pounds force
T_w = tension due to waves, in pounds force
V_a = wind speed in ft/sec
V_w = current/tow speed, ft/sec
ρ_a = density of air (0.00238 slugs/ft^3)
ρ_w = density of water (1.98 slugs/ft^3)
L = length of the boom, ft
τ = tension parameter, dimensionless
C_d = drag coefficient (assumed to be 1.5), dimension less
f = boom freeboard, ft
d = boom draft, ft
H_s = significant wave height, ft

Research and Development of Oil Containment Boom Designs, SL Ross

consequently failure initiated at a lower velocity. Flexible barriers were more sensitive to the variations of wave characteristics. Applying appropriate time and length scales, a critical wave period of 6 s and wave height of 0.5 m were proposed for the prototype. Accurate measurements of velocity profiles and flow patterns in the vicinity of barriers with different conditions by means of Ultrasonic Velocimetry Profiling (UVP) and Large-Scale Particle Image Velocimetry (LSPIV) methods provided a reasonable understanding of the hydrodynamics in the vicinity of the barrier. The characteristics of the headwave at the upstream end of the oil slick were deliberately compared with those of a gravity current. It was concluded that despite geometrical similarities, these two phenomena are quite diverse. Furthermore, the oil-water interface was traced by detecting the maximum ultrasonic echo intensity, and velocity profiles in water and oil phases were independently obtained. To enhance the understanding of the mechanisms associated with oil containment failure, numerical simulations of multiphase flow were carried out using FLUENT code, applying the finite volume method (FVM). Comparisons between the obtained flow pattern and velocity field derived from numerical simulations and precise experimental measurements confirmed the capability of the numerical model to simulate the multiphase flow. The turbulence wake downstream of rigid and flexible barriers was simulated with and without the presence of oil phase. The simulations revealed the effect of contained oil on flow pattern and consequently the drag force acting on the barrier. Simulations of a full-scale barrier proposed a drag coefficient, Cd, of 1.90 for rigid barriers. Contrarily a constant value for the drag coefficient cannot be attributed to flexible barriers, since its deformations do not allow it to form similar shapes at different velocities. Last but not least, comparing the drag force on a rigid barrier with that of a flexible barrier towed by the same velocity demonstrated the fact that the forces acting on the skirt could be appreciably reduced by allowing flexibility.

REFERENCES APPENDIX

TBC Texas Boom Company

REQUEST A QUOTE

PYRAMID MOORING ANCHOR

The patented Dor-Mor Pyramid Mooring Anchor rapidly penetrates the bottom due to the high point loading of its compact size and shape. Our product achieves approximately 10 times its dry weight in holding power at a 3:1 scope once it has penetrated the bottom and is completely covered with bottom material. The large surface area of the pyramid shape has a high suction effect which increases the deeper it sets.

- Pyramid shape digs into the bottom
- One piece cast iron mooring anchor
- Short shank prevents chain wrap-up
- Large diameter eye eliminates rust out and accommodates appropriate shackle
- Made in USA

Product Number	Weight (lbs)	Shackle Size (in)
TXB-15-DOR	15	3/8

TXB-35-DOR	35	3/8
TXB-70-DOR	70	1/2
TXB-135-DOR	135	5/8
TXB-200-DOR	200	3/4
TXB-300-DOR	300	7/8
TXB-400-DOR	400	7/8
TXB-500-DOR	500	1 1/4
TXB-700-DOR	700	1 1/4
TXB-1000-DOR	1000	1 1/2
TXB-2000-DOR	2000	2
TXB-4000-DOR	4000	2

Containment Booms | Fuel Bladders | Turbidity Curtains | ADA Help

Alliances

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a bare minimum. The heavier the better, as long as you don't have to move it. The suction that develops as a mushroom settles into a soft bottom over months and years is what gives a well-established mushroom mooring its holding power — a freshly placed mushroom has only its dead weight working for it, and may drag in a moderate storm before it has had time to settle and develop suction. For this reason, new mushroom moorings should be inspected particularly carefully in their first season before being trusted to hold in adverse conditions.

- **Pyramid Anchor:** The cast-iron Dor-Mor pyramid mooring anchor is a superior alternative to the mushroom. Its smaller size, concentrated weight and pyramid shape allows it to embed itself more rapidly, and its holding power (at a scope of 3:1) is up to about ten times its weight. Recommended by *Practical Sailor/Powerboat Reports* in 2009. The pyramid's geometry is what gives it its advantage over the mushroom: the shape resists horizontal drag by presenting angled faces to the direction of pull, and the concentrated weight in a small footprint allows it to penetrate and embed in a wider variety of bottom types including firm sand and mixed bottoms where a mushroom would simply sit on the surface. For a given holding requirement, a Dor-Mor pyramid is significantly lighter and easier to handle than an equivalent mushroom, which matters when setting or retrieving the mooring.
- **Helical Screw:** While the above types rely for holding power on sheer weight or a combination of weight and embedding themselves in the bottom, the helical anchor is screwed into the seabed, usually by a barge-mounted hydraulic device. Helical screws have long, high-tensile steel shafts (8' length is common) with large screw threads (10" to 14" diameter) on the bottom and an attachment eye at the top. These professionally-installed anchors, originating in the offshore oil industry, have gained popularity with recreational boaters since the 1990s, and have the most extreme holding power in relation to their weight. A properly installed helical screw in suitable substrate will hold loads that would drag any comparably sized dead weight or mushroom mooring. Their significant drawbacks are cost — professional installation by a barge and hydraulic equipment is not inexpensive — and the need for suitable substrate, as helical screws cannot be installed in rock or very shallow soft substrate where the shaft cannot achieve adequate depth. In permitted mooring fields where the harbormaster controls what type of mooring anchor may be used, helical screws are increasingly the required standard in many jurisdictions because of their superior holding power and smaller footprint on the seabed.

Mooring Chain

Chapman's recommends two sections of galvanized chain: a heavier, primary chain and a lighter, secondary chain. The primary (ground) chain lies on the bottom. Its length should be 1 1/2 times maximum water depth. The secondary (riding) chain, is connected to the ground chain with a galvanized shackle or swivel. It's usually half the diameter of the ground chain and equal in length to maximum water depth. The heavier chain is not used for the entire run so that the mooring buoy does not have to support an excessive amount of weight. The chain should be as large as practical; make the riding chain at least double the size of the chain on your anchor rode.

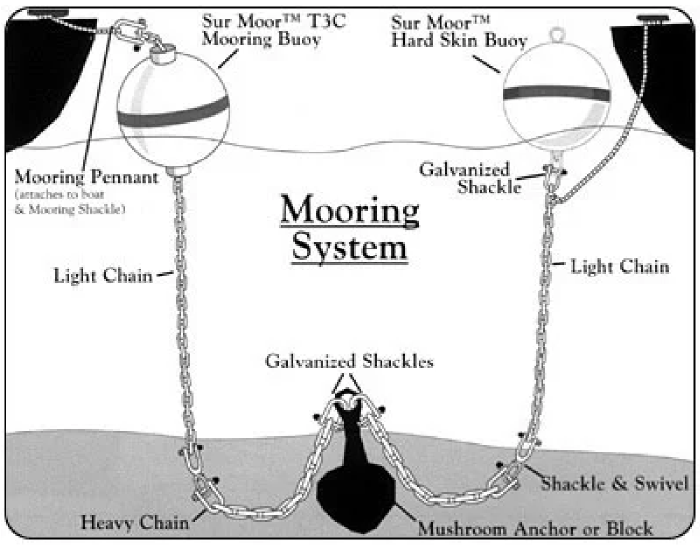
Chain inspection and replacement is the most critical and most frequently neglected aspect of mooring maintenance. Galvanized chain in saltwater service degrades continuously through galvanic corrosion, and the rate of degradation accelerates dramatically once the galvanizing is worn through and bare steel is exposed to seawater. A chain that looks adequate above the surface may have significant section loss at or below the mud line, where oxygen depletion and bacterial activity create a particularly aggressive corrosion environment. The ground chain — which lies on the seabed and is perpetually in contact with abrasive bottom material — typically degrades faster than the riding chain and should be the primary focus of any chain inspection.

Best practice for mooring chain management:

- **Inspect chain annually, ideally by hauling the entire system for inspection on deck.** Visual inspection while the chain is in the water is inadequate for detecting section loss at the mud line or at shackle pins. Haul the mooring at least every two to three years for full out-of-water inspection, and replace any chain showing visible corrosion pitting, link elongation, or section reduction of more than 10 to 15 percent of original diameter.
- **Mouse all shackle pins with seizing wire.** A shackle pin that works loose over months of constant motion in a mooring system will eventually unscrew and allow the chain to separate. Mouse every shackle pin with stainless steel seizing wire passed through the hole in the pin and twisted tight around the shackle body. This takes two minutes per shackle and is the simplest and most effective insurance against shackle failure.
- **Use a swivel between the ground chain and riding chain.** A swivel prevents the riding chain from transmitting rotational load to the ground chain as the boat weathervanes around the mooring. Without a swivel, the constant twisting motion of the riding chain gradually works open shackle pins and stresses chain links at the connection point. Galvanized swivels sized appropriately for the chain diameter are inexpensive insurance.
- **Consider stainless steel chain for the riding section in high-wear applications.** Stainless steel chain costs significantly more than galvanized but degrades more slowly in saltwater, resists abrasion better, and is easier to inspect for section loss because it does not form the scale and rust that obscures galvanized chain damage. For a permanent mooring in a high-exposure location, stainless riding chain with galvanized ground chain is a reasonable long-term investment.

Mooring Buoy

Your mooring buoy supports the mooring chain and is an essential part of your mooring gear. The two preferred designs for mooring buoys are a traditional buoy with hardware or a buoy with a tube through the center. Both offer reliable flotation and will last for several seasons, depending upon the salinity of the water. Obviously,



Two styles of Taylor mooring buoys are shown on typical systems with primary and secondary chain.

freshwater applications will extend the useful life of any mooring system.

The buoy must have about twice as much flotation as the suspended chain has weight in order for it to ride high enough in the water to be visible. The Taylor Sur-Moor™ T3C™ Mooring Buoys allow you to pass the chain through the center of the buoy, and attach the pendant on top. Secure the mooring chain at the top using a 4" galvanized O-ring, and add the T3C™ Mooring Collar to protect the buoy from wear by the anchor chain and extend its lifespan.

Buoy condition is a frequently overlooked indicator of overall mooring system health. A buoy that is waterlogged, cracked, or riding low in the water is not simply an aesthetic problem — it is signaling that the chain load it is carrying exceeds its available flotation, which can mean the riding chain is longer than specified, the chain has been replaced with a heavier grade, or the buoy has absorbed water and lost buoyancy. A buoy riding low also reduces the catenary in the riding chain, which increases the angle of pull on the ground tackle and reduces the effective holding power of the mooring anchor. Replace buoys that show cracking, persistent low riding, or visible water absorption rather than continuing to use a marginal buoy in the interest of saving the replacement cost.

Mooring Pendant

This powerboat is moored through both bow chocks with two of New England Ropes' Cyclone Mooring Pendants. The bottom white section of the pendant is traditional three-strand nylon.

The pendant (pronounced "pennant") attaches the chain to the boat. Large-diameter three-strand nylon line is used because its inherent elasticity (stretching about 10 percent under a load equaling 20 percent of its tensile strength) allows it to act as a shock absorber. Polyester line, Dyneema line or stainless steel wire is preferred by some for better chafe resistance. Length should be about 2 1/2 times the boat's freeboard. Diameter should be as large as is practical—but it must be able to fit through bow chocks and around a bow cleat.

Effective chafe protection is recommended for the point where the pendant passes through a chock. This is critical, as failure caused by chafe at this location is one of the main reasons why boats end up on the beach. A light pick-up buoy at the boat end makes it easy to grab the pendant.

Chafe failure at the bow chock is not a rare or unusual event — it is one of the most consistently documented causes of boats coming off their moorings in storm conditions. The combination of sustained high load, constant motion, and the sharp edge of a chock creates exactly the conditions under which nylon rope fails fastest. A pendant that shows no visible chafe in calm conditions can fail within hours in a sustained blow once the load and motion increase enough to generate heat at the chock contact point. Chafe protection at the chock is not optional equipment on a properly rigged mooring pendant — it is a required component of the system. Leather, heavy-wall rubber hose, chafe tape, or a commercial chafe guard sleeve should be installed at every contact point and replaced at the first sign of wear.

Cyclone Mooring Pendants, made from Endura-12 Dyneema line, were developed by Nantucket Moorings in conjunction with MIT. Traditional pendants are made from three-strand nylon, to absorb shocks by their elastic nature. This stretch, while allowing your boat a comfortable, cushioned ride, allows the line to move across the bow chocks, creating friction and causing chafe.

Cyclone Pendants are attached (using a lunch pail hitch, also called a "cow hitch") to your standard nylon pendant with its floating pickup buoy, and allow use of a low-stretch upper section. Their high tensile strength allows smaller mooring lines to be used, so they fit more easily on boats with smaller cleats and chocks. Very low elongation results in a dramatic reduction in friction, heat and chafing. Also, because the top and bottom sections are just looped together through spliced eyes, you can replace a damaged section without replacing the entire pendant.

Using two pendants rather than one is a practice strongly recommended by experienced mooring professionals for boats left unattended for extended periods or in exposed locations. Two pendants passed through separate bow chocks and secured to separate cleats distributes the load across two contact points rather than one, halves the load on each pendant and its chafe protection, and ensures that even if one pendant fails completely, the boat remains secured by the second. The cost of a second pendant is trivial compared to the cost of recovering a boat that has come off its mooring.

Surviving a Storm

Hurricanes making landfall in locations along the Eastern Seaboard have wrecked hundreds of boats over the past twenty years, many of which were driven ashore with their complete and intact mooring systems still attached. Weather forecasters predict that we are now in a period where we can expect more storms of greater destructive force, storms like Harvey, Irma and Maria that caused tremendous damage in 2017. Just how large does a mooring system need to be if your boat is caught in extreme weather? The following chart gives an estimate of the wind loads (based on the windage of the vessel) and the required size of a pyramid anchor.

The wind load numbers in the table below illustrate why boats on seemingly adequate moorings come off in major storms. A 40-foot powerboat experiencing 100-knot winds generates 12,000 pounds of load on its mooring system. Every component in the system — the anchor, the ground chain, the riding chain, every shackle, the buoy, the pendant, and the chafe protection at the chock — must be capable of sustaining that load continuously for hours. A single undersized shackle pin, a pendant worn through at the chock, or a chain section with undetected corrosion damage is all it takes to lose the boat. Storm preparation for a moored boat means inspecting and upgrading every component of the mooring system to the standard required for the worst conditions the boat might realistically encounter — not the conditions it usually encounters.

If a major storm is forecast and your boat is on a mooring, the most reliable protection is to move the boat to a well-protected marina or hurricane hole if time permits. No mooring system is as reliable as a boat in a properly protected slip with adequate dock lines and fenders. If the boat cannot be moved, double all pendants, add chafe protection at every contact point, remove or furl all sails and covers that add windage, and ensure the mooring system has been recently inspected and is in good condition. A mooring system that has not been hauled and inspected in three or more years should not be trusted to hold in a major storm regardless of its original size and specification.

Minimum Dor-Mor Mooring Anchor Size Requirements

Boat Length	Beam Sail/Power	Wind Load 64 Knots	Dor-Mor Size	Wind Load 100 Knots	Dor-Mor Size
20'	8'/9'	1,600lb.	200lb.	3,600lb.	400lb.
25'	8'/9'	2,200lb.	300lb.	5,000lb.	500lb.
30'	9'/11'	3,200lb.	400lb.	7,000lb.	700lb.
40'	11'/14'	5,400lb.	700lb.	**12,000lb.**	2,000lb.
50'	13'/16'	7,300lb.	1,000lb.	16,000lb.	2,000lb.
60'	15'/18'	9,100lb.	1,000lb.	20,000lb.	2,000lb.
80'	19'/22'	13,000lb.	2,000lb.	31,000lb.	4,000lb.

Based on wind loading data at min. 3:1 scope, with suitable bottom conditions for anchor to embed. Wind loads based on data from ABYC.

Mooring System Maintenance Schedule

A mooring system that is never inspected is a mooring system that will eventually fail. The following maintenance schedule reflects best practices for recreational boat moorings in saltwater environments. Freshwater moorings can extend these intervals modestly, as the corrosion environment is significantly less aggressive without salt.

- **Every season:** Inspect the pendant for chafe at all contact points. Replace chafe protection at bow chocks. Check that all shackle pins are moused with seizing wire. Confirm the buoy is riding at the correct height and showing no signs of waterlogging or cracking. Inspect the visible portion of the riding chain for corrosion and section loss.
- **Every two to three years:** Haul the complete mooring system for out-of-water inspection. Measure chain link diameter at multiple points along both ground and riding chain and compare to original diameter. Replace any chain showing section loss greater than 10 to 15 percent. Inspect the mooring anchor for condition and confirm it is still properly embedded. Replace the mooring buoy if it shows cracking, water absorption, or loss of buoyancy.
- **Before any major storm forecast:** Double the mooring pendants. Add fresh chafe protection at all contact points. Remove all windage-adding equipment from the boat. Confirm all shackle pins are

moused. If the mooring has not been inspected in the past two years, consider moving the boat to a protected marina rather than trusting an uninspected system in extreme conditions.

Glossary of Mooring Terms

Beam: The maximum width of a boat at its widest point, used along with boat length to estimate windage and wind load for mooring sizing purposes.

Catenary: The natural sag or curve a chain forms under its own weight between two fixed points. A mooring chain with adequate catenary absorbs shock loading from waves and wind gusts by straightening slightly under load rather than transmitting the full force instantly to the anchor; a chain pulled taut with no catenary loses this shock-absorbing effect.

Chafe: The wearing away of line or chain caused by repeated friction against a hard surface, most commonly where a pendant passes through a bow chock. Chafe is one of the leading causes of mooring failure.

Fetch: The unobstructed distance over open water across which wind can blow, generating wave height and energy. A mooring location with long fetch in the prevailing storm wind direction requires a more robust system than a tightly protected anchorage with minimal fetch.

Ground Chain (Primary Chain): The heavier section of mooring chain that lies on the seabed, connecting the mooring anchor to the riding chain. It is sized larger than the riding chain and typically experiences the fastest corrosion due to constant bottom contact.

Ground Tackle: The complete underwater assembly of a mooring system, including the anchor, ground chain, riding chain, swivels, and shackles — everything below the buoy.

Holding Power: The maximum load a mooring anchor can resist before it begins to drag through or across the seabed. Holding power varies significantly by anchor type, weight, bottom composition, and scope.

Mousing: The practice of securing a shackle pin in place with seizing wire or a similar wrap, preventing it from working loose and unscrewing under the repeated motion of a mooring system.

Pendant: The line, also pronounced "pennant," that connects the mooring chain to the boat itself, typically passed through bow chocks and secured to a cleat. Pendants are usually made from three-strand nylon for shock absorption, or from low-stretch materials like Dyneema for reduced chafe.

Riding Chain (Secondary Chain): The lighter section of mooring chain that connects the ground chain to the mooring buoy and pendant. It is sized smaller than the ground chain to reduce the weight the buoy must support.

Scope: The ratio of the length of chain or line deployed to the depth of water at the mooring site. Holding power figures for mooring anchors are typically stated at a specific scope, commonly 3:1, and holding power decreases as scope is reduced.

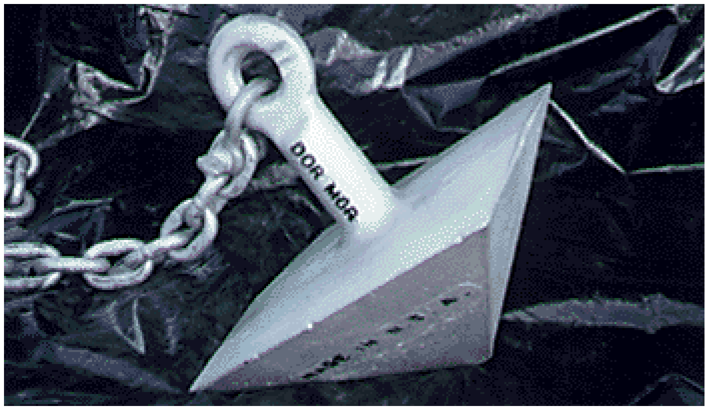
Swivel: A rotating connector installed between the ground chain and riding chain that allows the chain to rotate freely as the boat weathervanes around the mooring, preventing twisting forces from working open shackle pins or stressing chain links.

Weathervaning: The natural tendency of a moored boat to swing and align its bow into the prevailing wind or current, which causes the mooring chain to twist unless a swivel is installed to absorb the rotation.

Windage: The surface area of a boat exposed to wind, which determines how much load the wind generates on the mooring system. Windage is influenced by hull freeboard, cabin structure, masts, rigging, and any covers or canvas left in place.

DOR-MOR®, Inc.

Proven Performance Since 1988



Patented

Pyramid Mooring Anchor

Designed to penetrate the bottom and prevent dragging.

The Dor-Mor Pyramid Mooring Anchor rapidly penetrates the bottom due to the high point loading of its compact size and shape. Our product achieves approximately 10 times its dry weight in holding power once it has penetrated the bottom and is completely covered with bottom material. The large surface area of the pyramid shape has a high suction effect which increases the deeper it sets.

Independent test results are in!

Conventional Mooring Anchor Holding Power Test Data

Comparative holding power based on actual independent testing at Newport, Rhode Island, USA
Tests conducted during June, 1994 at 3:1 scope (3 times water depth in chain).

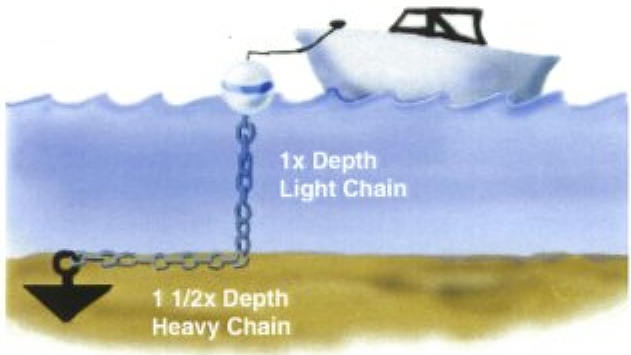
MOORING SIZE	Dor-Mor 650 lb.	Mushroom 500 lb.	Concrete 2,000 lb.	Concrete 8,000 lb.
HOLDING POWER	6,500 lb.*	1,200 lb.	800 lb.	4,000 lb.

The Tests revealed three important facts:

- Only the Dor-Mor Pyramid had completely imbedded itself in the bottom.
- The embedded Dor-Mor Pyramid achieves approximately 10 times its weight in holding power at 3:1 scope.

- The Dor-Mor Pyramid Mooring anchor was the only mooring anchor which dug again into the bottom and reset itself after the Tug broke it free.

* The pull test was conducted with the Dor-Mor Pyramid Anchor being attached with only 2.2 to 1 scope. At that ratio had holding power of 4,500 lb. All other devices being attached with 3: 1 scope or more. Calculations have been interpolated to extend the Dor-Mor anchor pull to the 3:1 scope data. All of these anchors had been put in the water and left for some period of time with no special installation procedure prior to the test.



Find The right Pyramid Anchor for your needs.

Minimum Mooring Anchor Size Requirements

Based on wind loading data at minimum of 3:1 scope with suitable bottom conditions for anchor to imbed.

Boat Length	Beam Sail/Power	Wind Load 64 Knots	Dor-Mor Size	Wind Load 100 Knots	Dor-Mor Size
20 Ft.	8/9 Ft.	1,600 Lb.	200 Lb.	3,600 Lb.	400 Lb.
25 Ft.	8/9 Ft.	2,200 Lb.	300 Lb.	5,000 Lb.	500 Lb.
30 Ft.	9/11 Ft.	3,200 Lb.	400 Lb.	7,000 Lb.	700 Lb.
40 Ft.	11/14 Ft.	5,400 Lb.	700 Lb.	12,000 Lb.	2,000 Lb.
50 Ft.	13/16 Ft.	7,300 Lb.	1,000 Lb.	16,000 Lb.	2,000 Lb.
60 Ft.	15/18 Ft.	9,100 Lb.	1,000 Lb.	20,000 Lb.	2,000 Lb.
80 Ft.	19/22 Ft.	13,000 Lb.	2,000 Lb.	31,000 Lb.	4,000 Lb.

Wind loads recited based on data from the American Boat & Yacht Council.

Let Dor-Mor give you a free quote for your mooring.

Anchor sizes for every purpose:
holding vessels
docks
navigation and regulatory buoys
oceanographic equipment
containment booms
nets
communication cables
aquaculture pens and more.

We can supply individual anchors or a complete, custom designed mooring system for your particular application.

- Pyramid shaped one-piece cast iron permanent mooring/anchor for fresh and salt water use.
- Mooring will rapidly set itself by presenting a digging edge to penetrate the bottom.
- Short shank allows mooring in more shallow water with less chain wrap-up and potential hull damage.
- Large diameter eye prevents rust-out and accommodates proper size shackle and chain for recommended mooring weights.
- Popular sizes available from 15 pounds up through 4,000 pounds.
- Larger sizes available on request

- **Made in the U.S.A.**

The holding power of a mooring weight is affected by the following factors: whether or not it is set (imbedded in the bottom); the proper amount of scope is used; the weight and shape of the boat; the condition of the chain, hardware and line used; the wind, wave, tide and current conditions at any given moment. DOR-MOR, Inc. has no control over these factors and, therefore, assumes no liability for loss or damage in the utilization of our products.

Information on how to set up a mooring is available on request.

Call, fax or e-mail for more information or a quote for a specific application.

DOR-MOR, Inc.
PO Box 461
Claremont, NH 03743
Phone/Fax: 603.542.7696
info@dor-mor.com

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