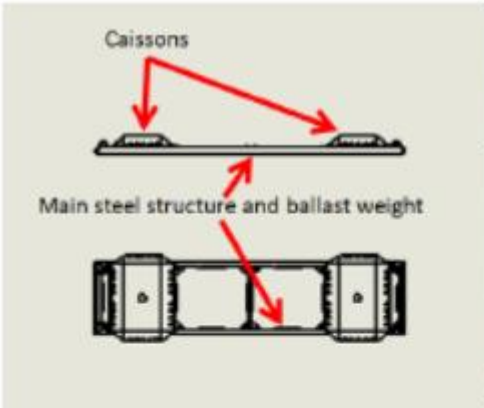
D4.4a Downselection Report
DE-EE-0007345
M3 Wave, LLC

Introduction

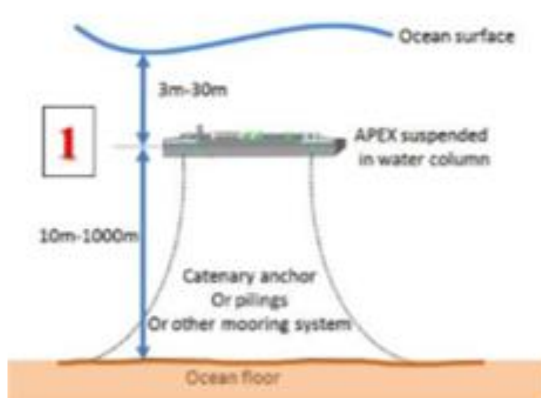
In 2014, open water testing revealed that sediment scour around and under the device was significant and likely interrupted operations. To explore methods to mitigate this phenomenon, M3 developed a number of alternate concepts as detailed in concept sketches.



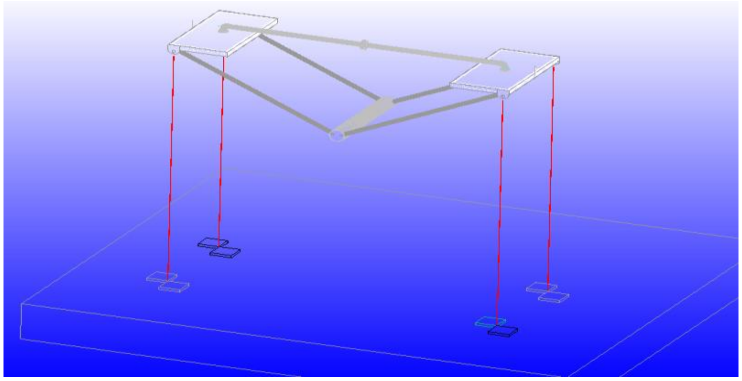
M3 engineers, in collaboration with deployment and fabrication partners, brainstormed a number of methods, configurations, and countermeasures for mitigating sediment transport.

The preliminary list of configurations contained the following methods:

1. Moored off the bottom. Mitigation method: operate away from sediment bed.
    a. Catenary

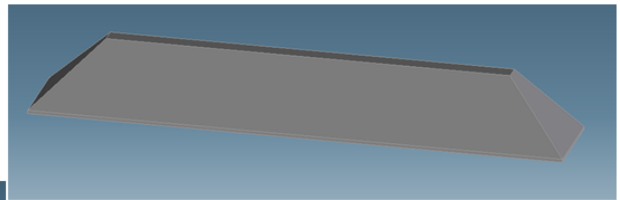


b. Tension Leg Platform

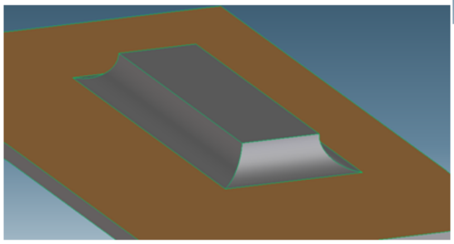


2. Continuous shell covering all of the intricate device geometry. Mitigation method: reduce localized flow accelerations.

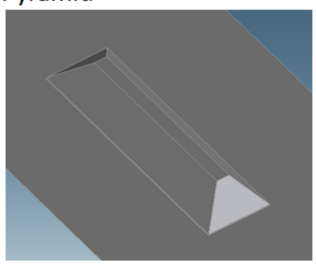
Contiguous Shell
Idea: reduce/eliminate localized regions of accelerated flow under or around device.



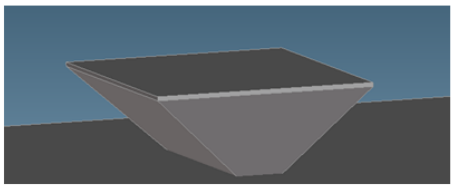
Beveled Contiguous shell
"Pyramid"



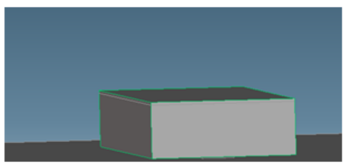
Blended edges



Beveled Contiguous shell
"Reverse Pyramid"

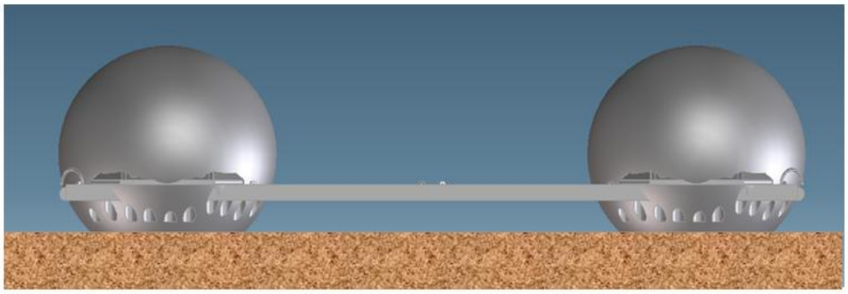


Solid Block



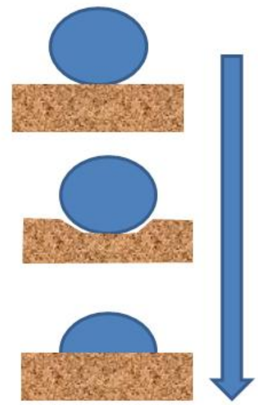
3. Spherical Caissons. Mitigation method: make caissons hydrodynamically neutral.

Symmetric Caisson- Spherical Concept



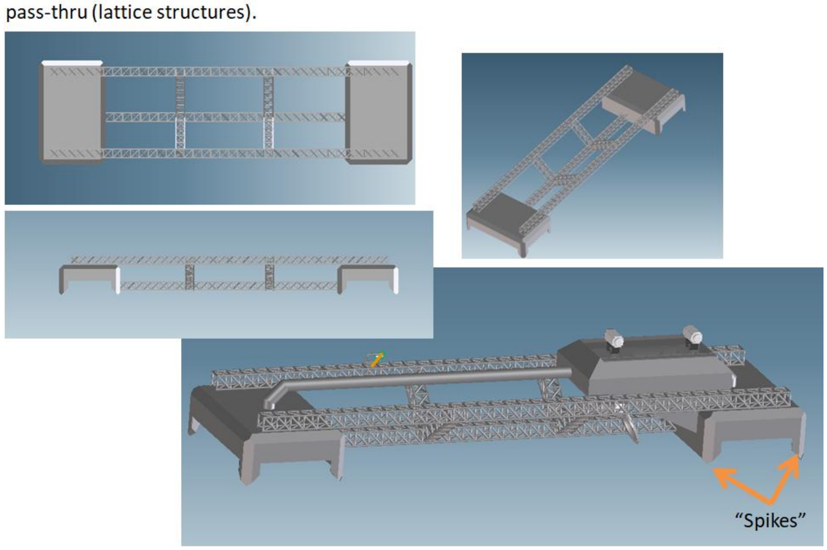
Idea: as sediment accretes or scours, system reaches a stable balance.
Cross structure TBD (design flexibility)

Issues:
Different scour on each end could lead to pitch
Manufacturability



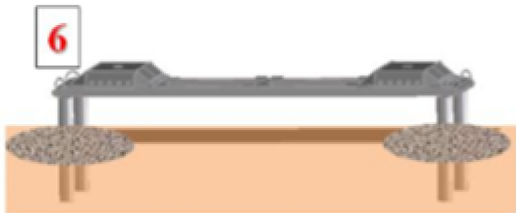
4. Integral embedment framework. Mitigation method: minimize contact points with sediment and reduce cross-section of main structure.

Integral Embedment Framework.
Idea: Caissons have corner “spike” structures that embed into sediment. Cross-structures between caissons are made from structural materials that allow particle pass-thru (lattice structures).

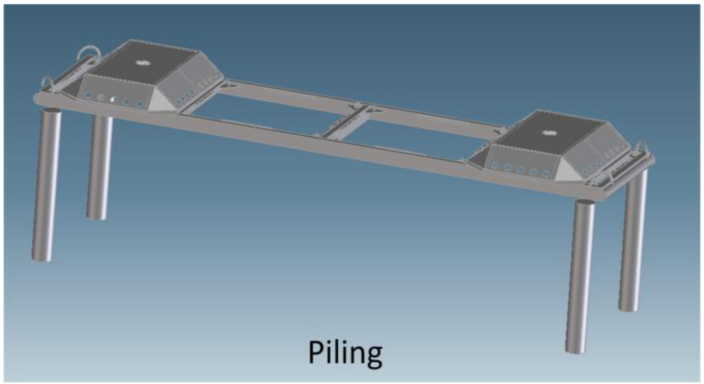


5. Symmetric caissons. Mitigation method: approximate hydrodynamic neutrality.

6. Rigidly mount structure off bottom. Mitigation method: operate away from sediment bed.
    a. Use rock or other reinforcement at base of mounting structure (pilings)

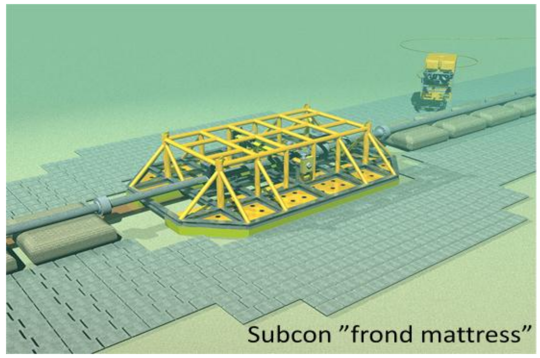


    b. Use jet embedment pilings



7. "Snow Fence" style defenses around the APEX device. Mitigation method: disrupt particle velocities approaching device.

8. Cobble skirt or sediment armor around based of standard APEX. Mitigation method: prevent localized sediment transport.
    a. Example: Subcon “frond mattress”



9. Separate caissons. Mitigation method: remove localized velocity accelerations due to cross-structure.

Preliminary downselect.

An initial review of literature, preliminary modeling results, and industry experts resulted in an initial consolidation of the list.

Moored (moving body) systems were ruled out due to the added cost and complexity of mooring as well as the challenges observed with a moored (TLP) system called NEXUS which was M3 Wave’s Wave Energy Prize Finalist candidate.

Defensive measures like armoring the sediment bed, installing snow fences, or deploying large quantities of cobble were ruled out due to deployment complexity and the conclusion that these might only afford temporary protection. Many of these systems become ineffective once covered completely by sand or undermined near their perimeter, resulting in higher maintenance costs.

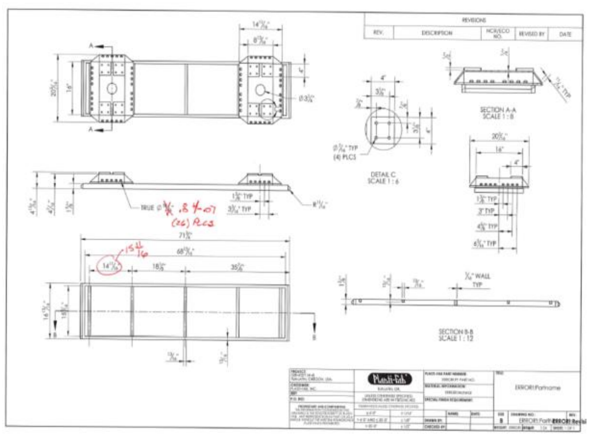
Initial modeling results showed that symmetric designs including the spherical caissons we not effective countermeasures when wave direction shifted and flow velocities were not in line with the device. This, coupled with the anticipated expense of larger, more complex structures led to these concepts being ruled out.

Final candidates

The final 3 candidates were selected for testing at 1:5 scale. Each of these was constructed by Ershigs out of Ridgefield, WA.

1. **Default APEX** (baseline).

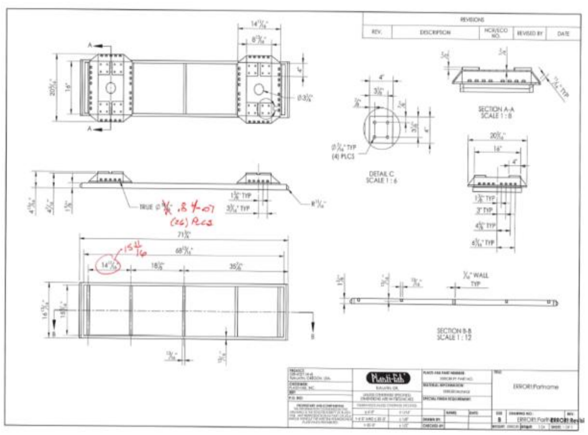
   a. The default geometry was a true 1:5 scale version of the 30m APEX tested in 2014.

      i. 

   b. The caissons were fabricated from FRP composite and the main frame was steel tube. The Oscillating Air Column (OAC) was conventional 2” PVC with a 1” dia ISO-5167 Orifice plate centrally located to capture velocity data when available.
   c. Theory of sediment mitigation: This design did not have any sediment mitigation aspects- it was intended to be the baseline device so we could recreate the scour patterns observed in the ocean.
   d. This model was tested at various heights off the bottom to simulate specific test points for the “rigidly mounted off the floor” design.
   e. Deployment: Initial runs were conducted free-flying where the WEC was lowered to the sea bed and allowed to gravity anchor. Subsequent off-the-bottom tests were done using a lift rig that rigidly suspended the WEC at precise elevations off the bottom.

2. **<u>Minimalist APEX, nicknamed “Skeleton</u>**.” This is a modified default APEX with much of the side structure of the caissons removed to allow flow through and around the caissons.

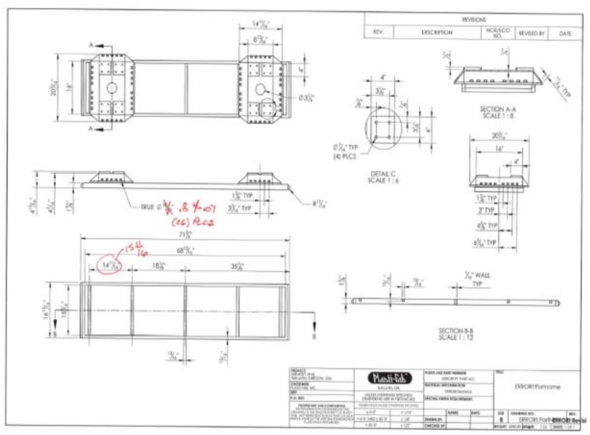
   a. The Skeleton geometry utilized the same default geometry as the control model except that the sides of the caissons had been cut out to allow flow through the caissons.

      i. 

   b. The caissons were fabricated from FRP composite and the main frame was steel tube. The Oscillating Air Column (OAC) was conventional 2” PVC with a 1” dia ISO-5167 Orifice plate centrally located to capture velocity data when available.
   c. Theory of sediment mitigation: The large openings on the sides of the caissons will allow particle flow through the device, reducing local areas of flow acceleration that can contribute to particle motion and scour.
   d. This model was tested at the sediment bed- both in free-flying mode and with lift structure attached (although elevated model was not tested- the rig was installed to allow comparison to similar test points with default geometry and to provide particle velocity data enabled by instrumentation on the lift rig.
   e. Deployment: Initial runs were conducted free-flying where the WEC was lowered to the sea bed and allowed to gravity anchor

3. APEX rigidly mounted off the floor. Aka APEX II

a. The APEX II geometry utilized the same default geometry as the control model except that the corners had vertical suction pile pipes 2” in diameter and 30cm long. These were connected to a vacuum manifold topside.



   i.

b. The caissons were fabricated from FRP composite and the main frame was steel tube. The Oscillating Air Column (OAC) was conventional 2” PVC with a 1” dia ISO-5167 Orifice plate centrally located to capture velocity data when available.
c. Theory of sediment mitigation: By standing off the bottom, sediment is allowed to ebb and flow below the device.   Specific target heights were determined from earlier experiments with the default geometry and the rigid lift rig.
d. This model was tested at specific heights off the sediment bed (ocean floor).
e. Deployment: The WEC was lowered until the suction piles contacted the sediment. Vacuum was then drawn to pull the piles into the sand bed.