Evaluating buoyancy pod/tension leg platforms for tidal energy development

March 31, 2016

ORPC
OCEAN RENEWABLE POWER COMPANY

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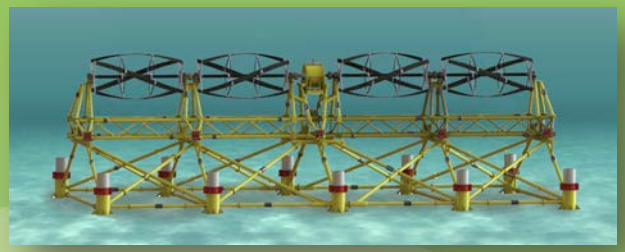
About ORPC

- Founded in 2004 to develop new technology and projects that generate emission-free electricity from rivers and oceans while creating substantial local economic benefits
- Modular, effective and proven core technology component (turbine generator unit, or TGU) with low vertical profile that has been adapted for tidal, river and deep water ocean current applications
- An industry leader in development of hydrokinetic energy projects, including community, agency and other stakeholder outreach, environmental protocols, monitoring and licensing, supply chain development, and maximizing community economic opportunities
- ORPC Solutions launched in 2013 to provide development, regulatory and strategic assistance to colleague companies in the offshore wind, ocean and river hydrokinetic industry internationally.
- Headquartered in Portland, ME; operations center in Eastport, Maine; and project development office in Anchorage, Alaska. Subsidiaries in Nova Scotia (ORPC Nova Scotia Ltd.) and Québec (EMARQ) and Ireland (ORPC Ireland, Ltd.). Currently 19 employees.

ORPC Power Systems



TidGen® Power System

RivGen® Power System

TidGen® TGU

ORPC's patented turbine generator unit (TGU) uses proprietary advanced design cross flow (ADCF) turbines to drive an underwater permanent magnet generator.

TidGen® - for tidal and deep river sites
RivGen® - for river sites, particularly those serving isolated communities

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TidGen® Deployment

- Deployed in 2013
- Rated for 150 kW
- First Grid-connected MHK device in the United States
- Mounted on Pile mounted Bottom Support Frame

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Industry barriers to development

- Cost and effort associated with marine hydrokinetic device installation and retrieval

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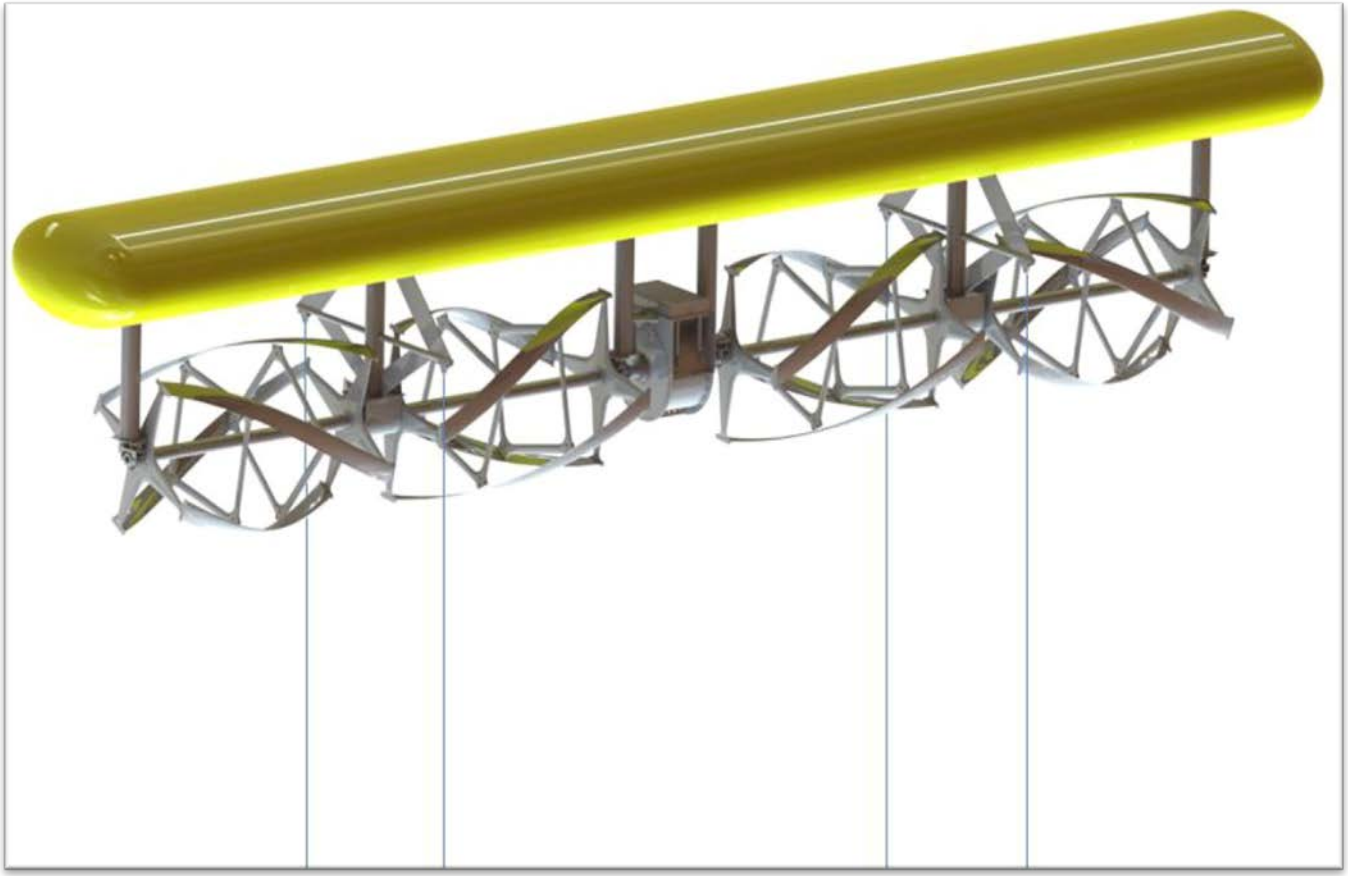
Moored Systems



- ORPC examined the benefits of moored systems.
- Effort partially funded by the U.S. Dept. of Energy

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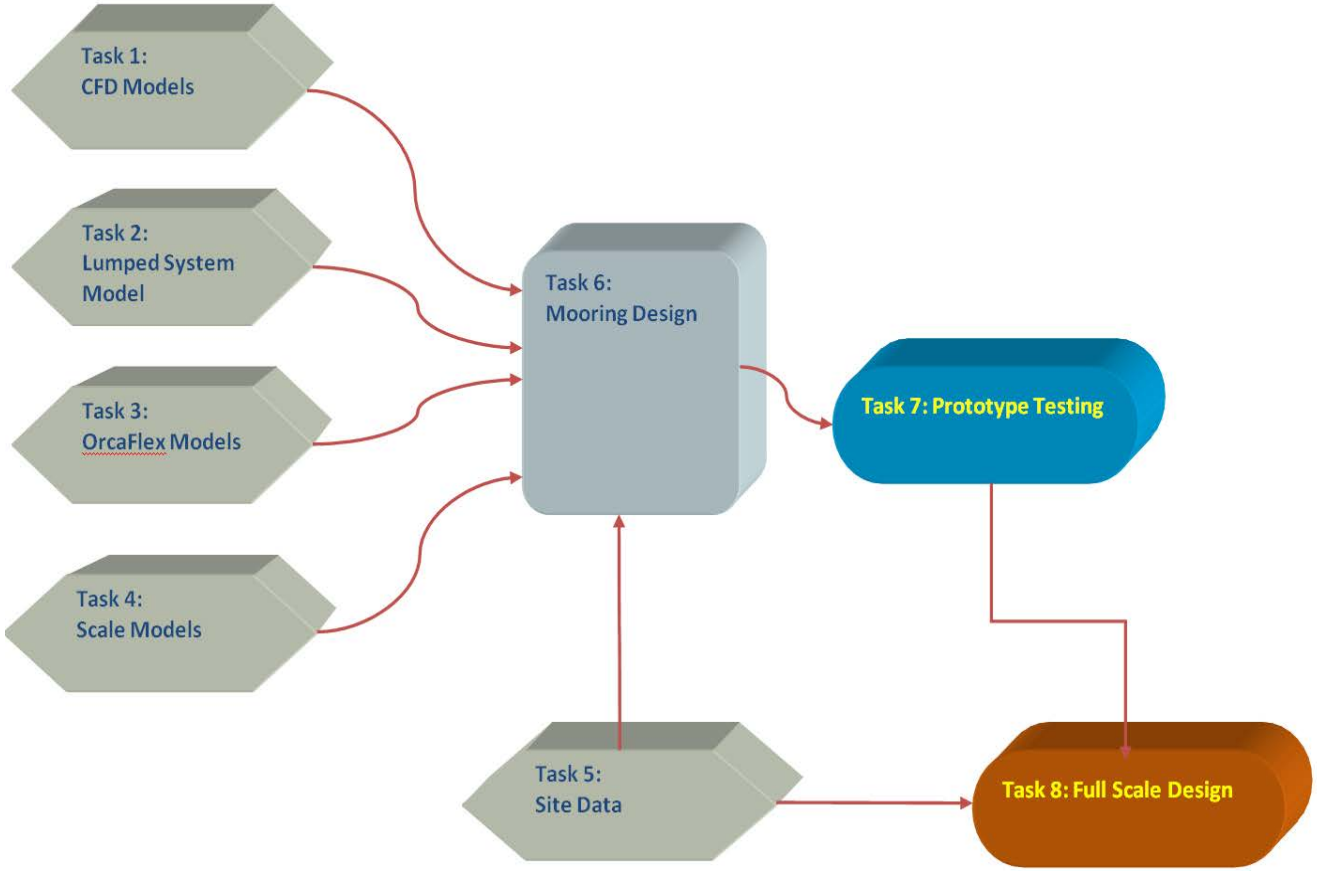
System Design



- Buoyancy Pod above turbines
- Cross-flow turbines
- Centrally mounted generator
- Mooring Lines attached to structure

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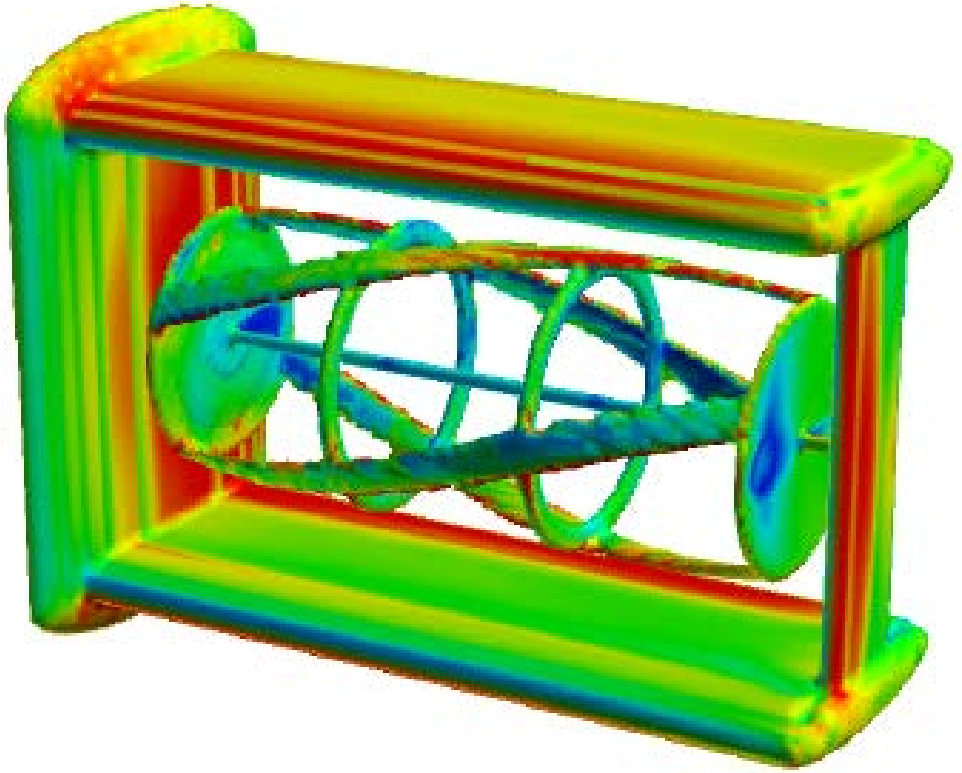
OCGen® Design: Computational Fluid Dynamics (CFD)

- Analytical Tools
  - Concept is to validate design tools by
    - Design
    - Build & Test
    - Collect Data
    - Validate design tools

CFD – FAVOR Technique

(Fractional Area Volume Obstacle Representation)



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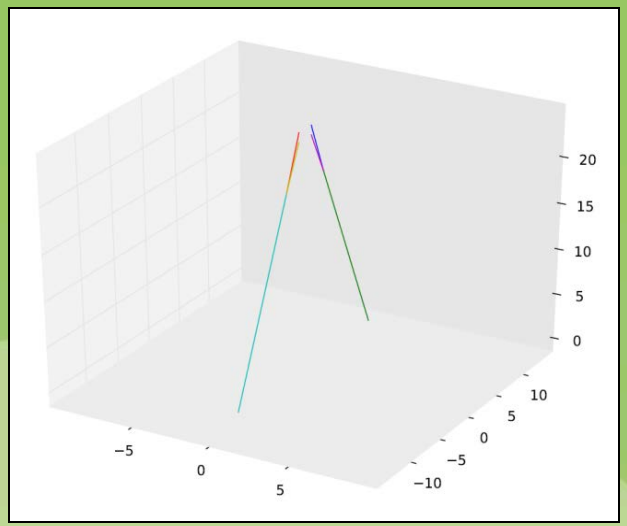
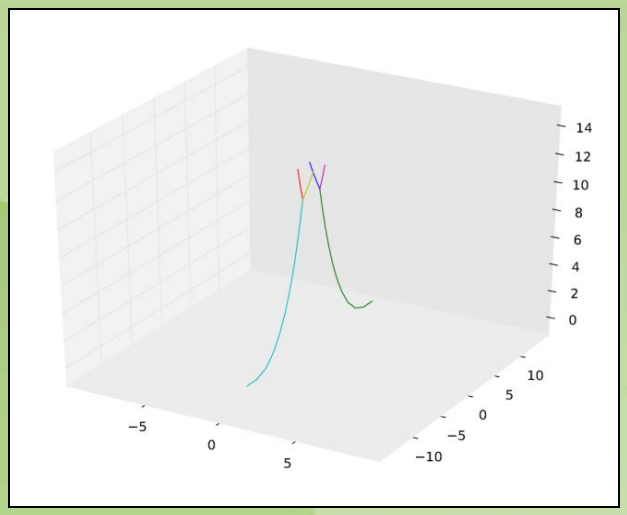
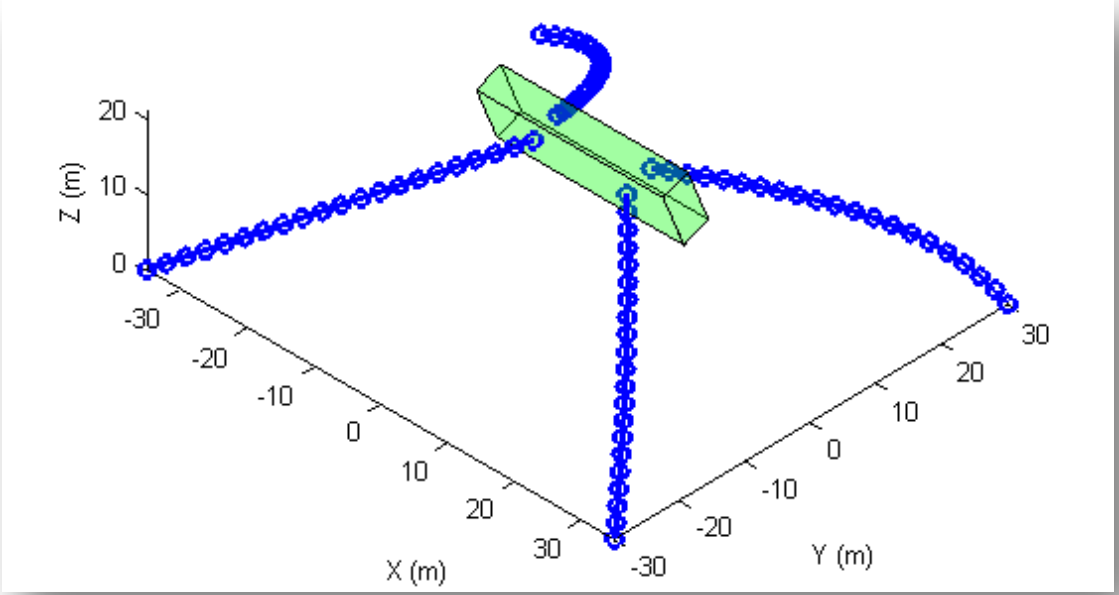




OCGen® Design: Lumped Sum Analysis

ORPC developed modeling tools

- Work performed by the Northwest National Marine Renewable Energy Center, University of Washington
- Based on space tether systems



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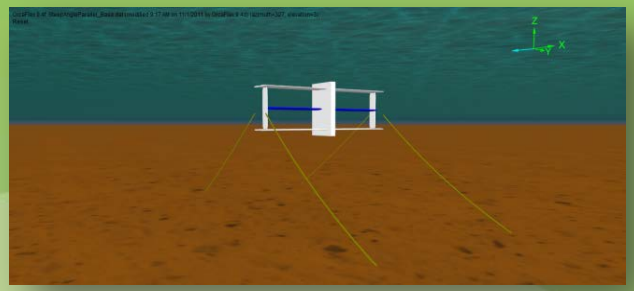
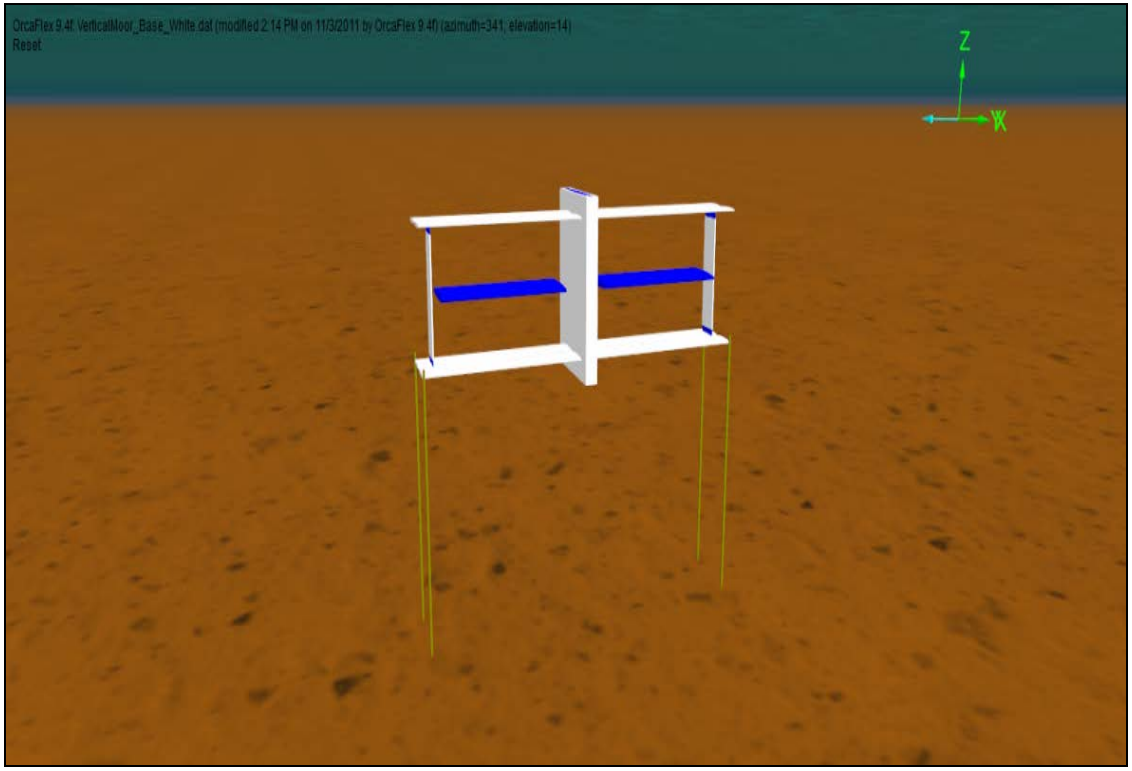


OCGen® Design: Commercial Codes

OrcaFlex®

•Modeling of mooring systems



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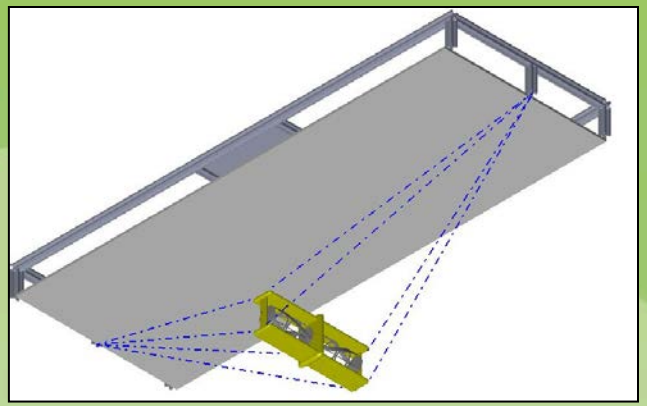
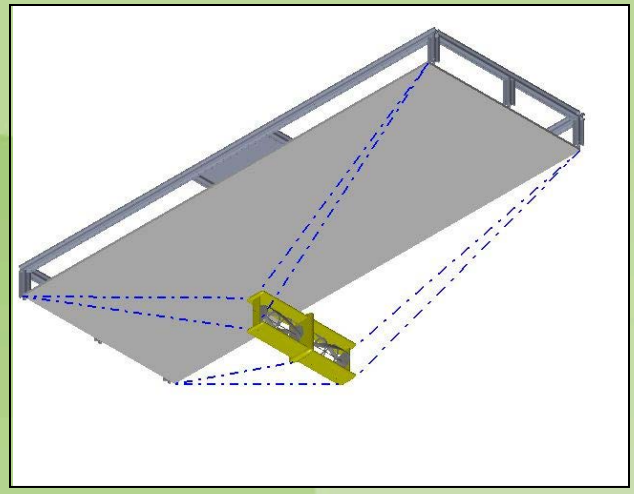
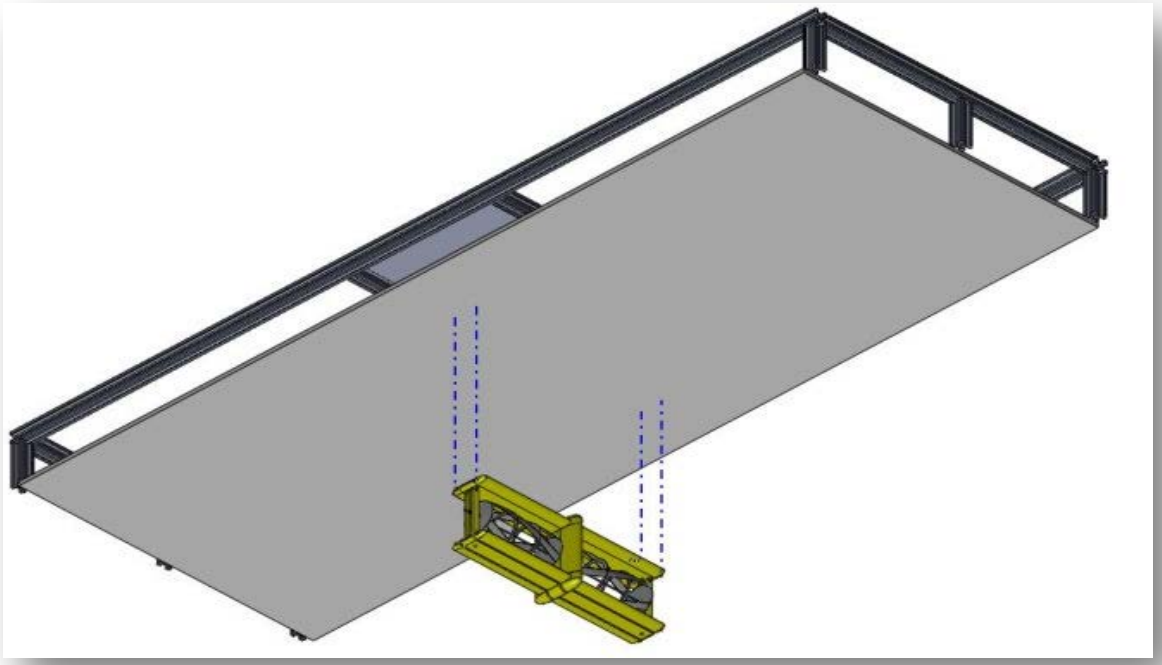
OCGen® Design
Scale Model Testing





University of Maine Tow Tank

- Flipped the model upside down
- Weight ≡ Buoyancy



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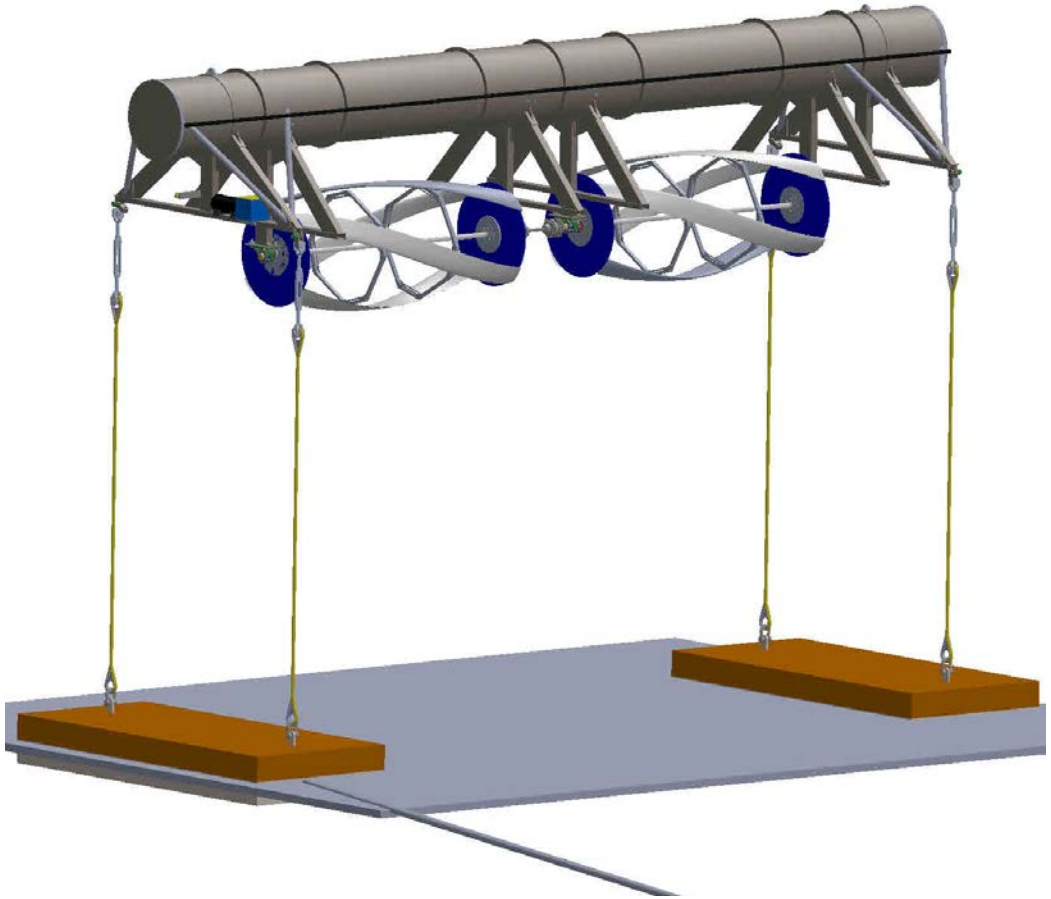
Final Test Arrangement



- Buoyancy pod Above TGU
- Cross flow turbines
- Central generator
- Mooring lines attached to structure

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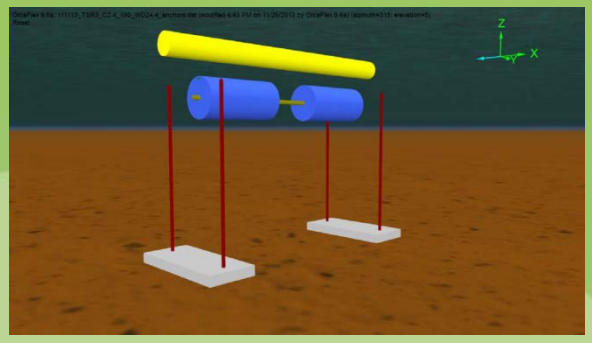
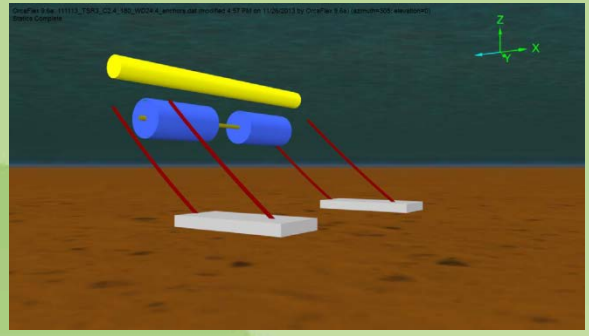
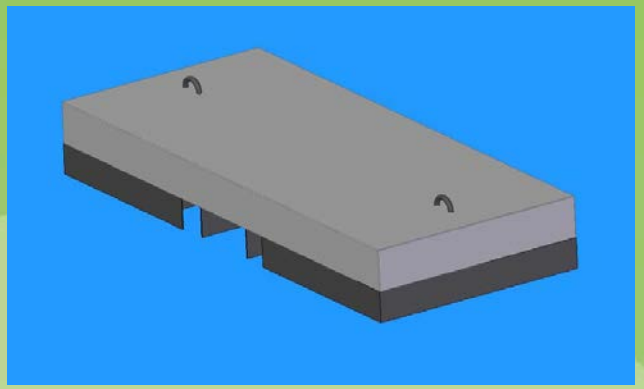


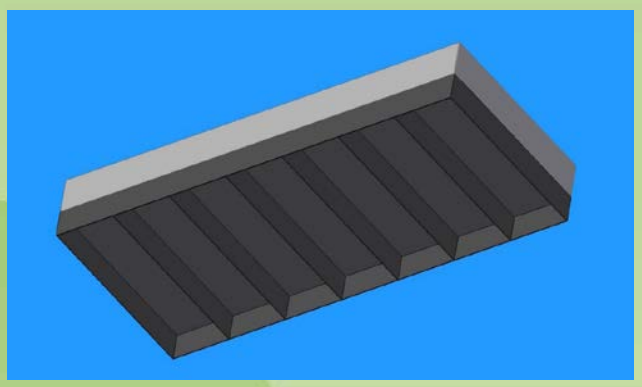


Tension Leg Mooring Arrangement

- Relatively high turbine displacements
- Best load sharing between Mooring Lines
- Allowed use of Gravity Anchors

OCGen® Anchors





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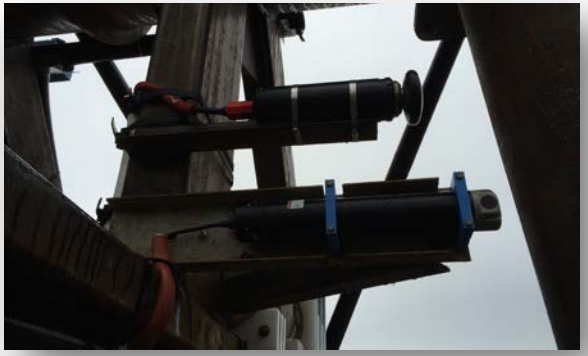
Mooring Line

- 1” Oceanographer’s Brait supplied by Yale Cordage.
  - Better load balancing than chain or high tensile synthetic lines
  - 1” Oceanographer’s Brait (Yale Cordage)
  - Four lap, single loop
  - Common lift sling arrangement
  - All 4 lines 23’4” at proof load of 7,500 lbf
  - Sheathed in polyester cover

Prototype Instrumentation



Environmental

- Flow speed
- Flow direction
- Water depth

OCGen® Module

- Flow speed
- Depth of TGU
- Attitude
- Heading
- Turbine RPM

Mooring System

- Mooring loads
- Mooring movement

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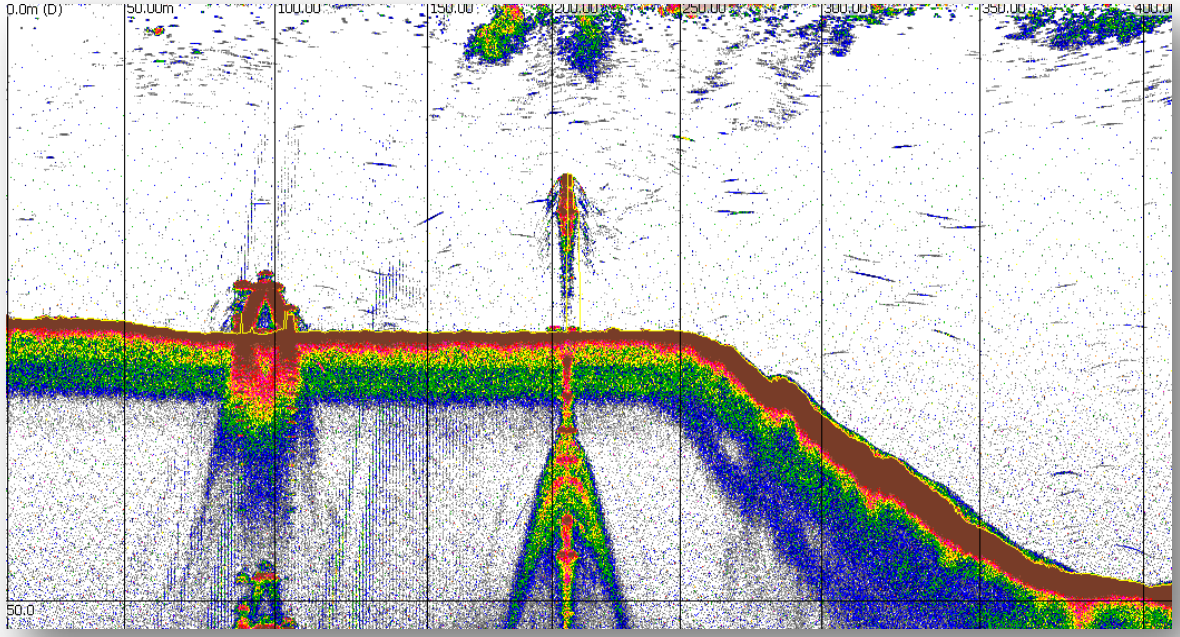
Prototype Deployment



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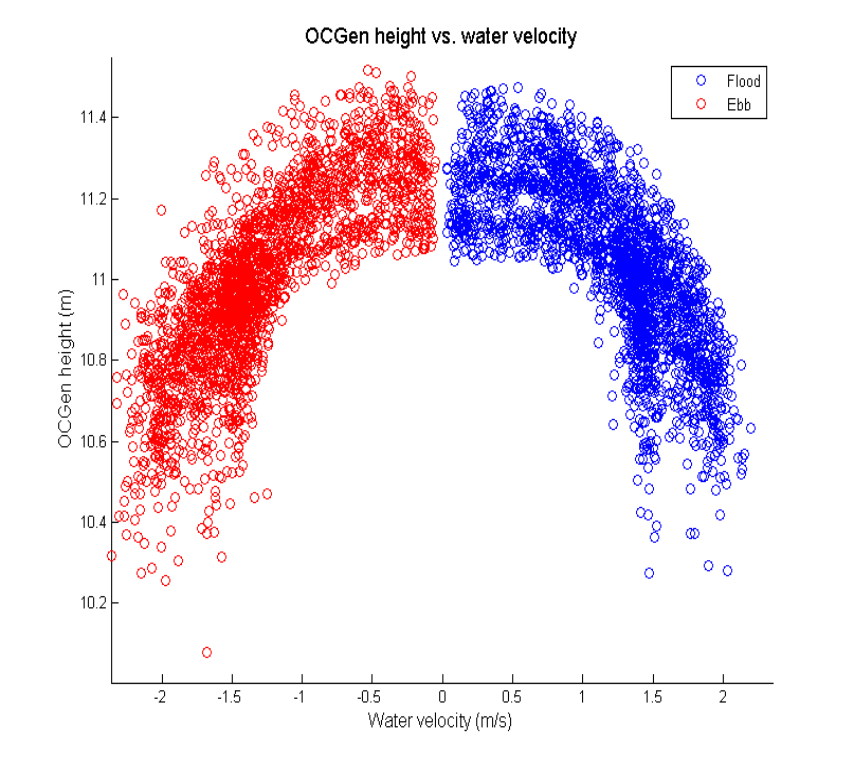
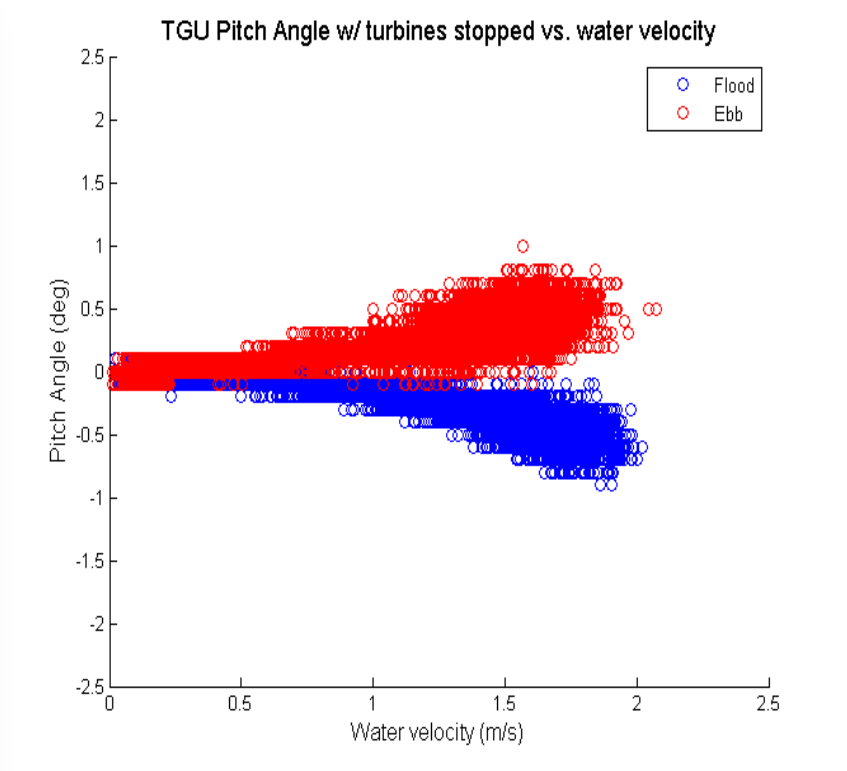
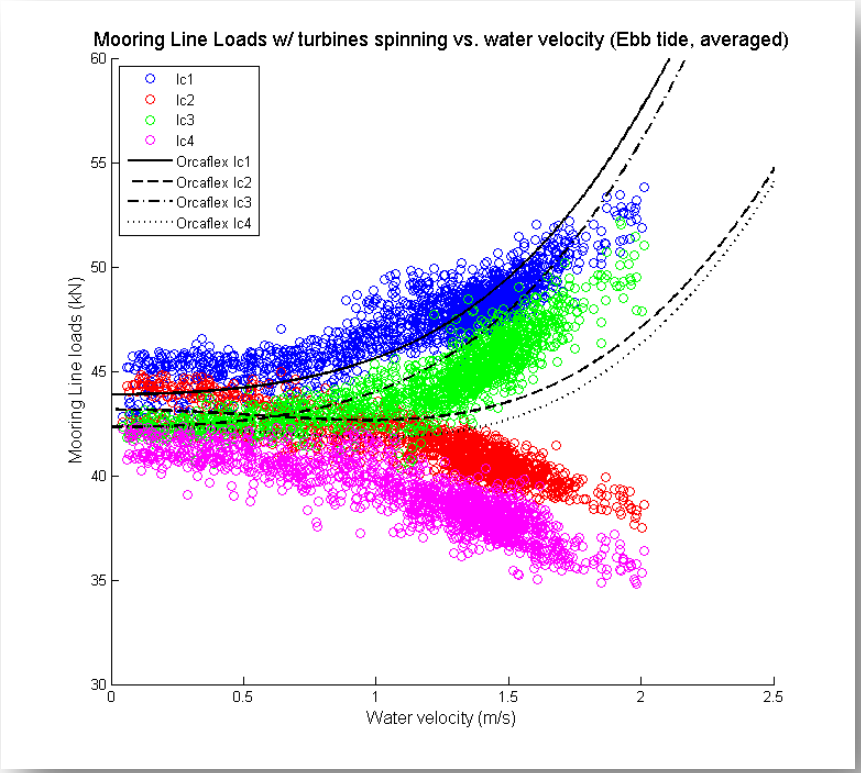
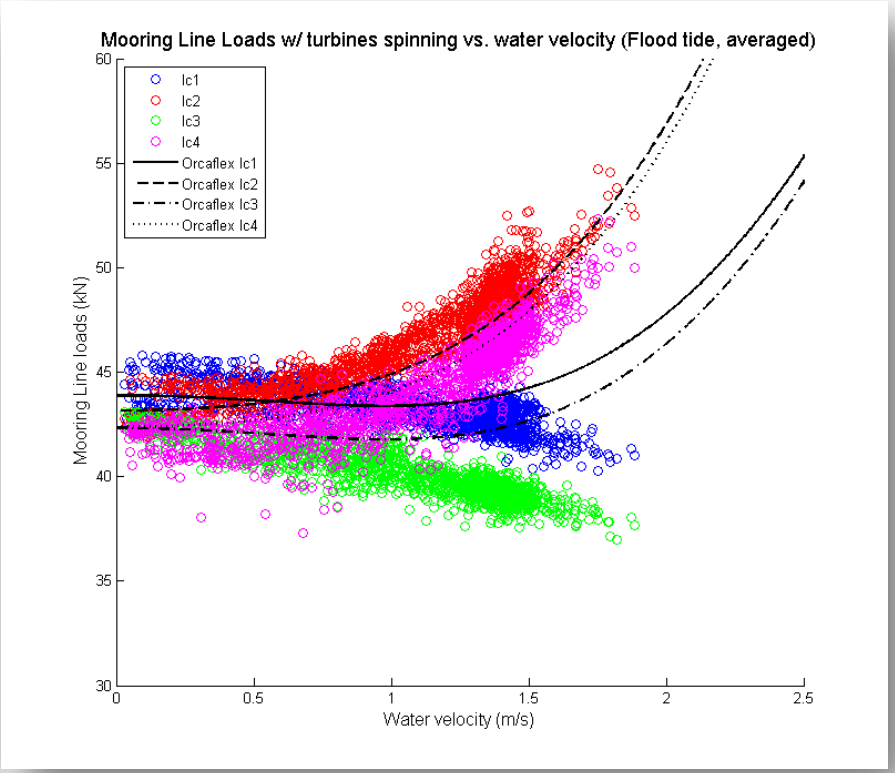
Monitoring Turbine Position





OCGen® Monitoring: Mooring Loads





Mooring System Corrosion

After 83 days submerged with minimal corrosion protection, the device was retrieved…

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Metal Corrosion

The nuts securing carbon steel bolts on the turbine end-disks showed severe corrosion.

No coating or cathodic protection was provided for these bolts

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Abrasion on Mooring Lines

Abrasion on Mooring Line cover at the anchor end shackles. Likely due to sliding of the mooring line on the Shackles.

Unexplained abrasion and some tearing of the mooring line cover. Evident on all 4 mooring lines at different locations.

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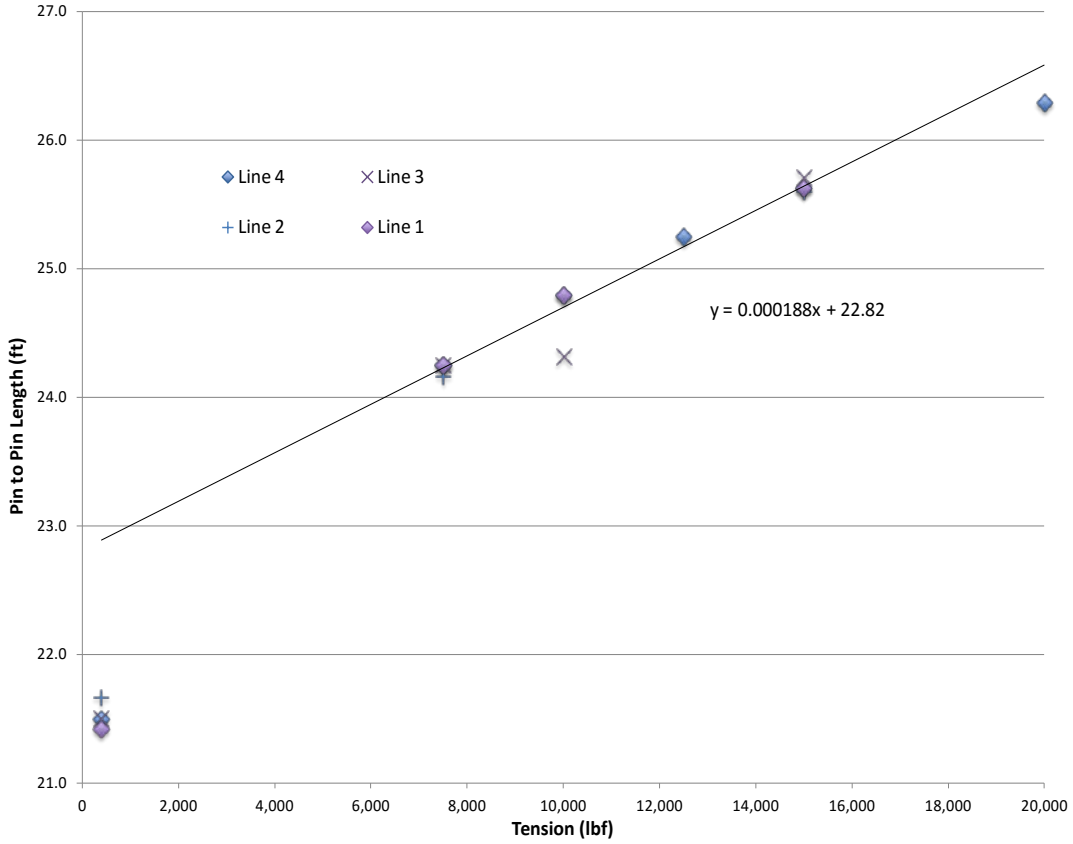
Post Deployment Mooring Line Testing



All four mooring lines showed similar stiffness characteristics and lengths post deployment. Properties did not change as a result of the deployment.

Lines were saturated when tested.

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Comparing the Mooring System to a Bottom Support Frame

- *Capital Costs:*
  - *Buoyant Tension Leg Mooring System: $540,000*
  - *Bottom Support Frame: $1,100,000*

- *Operational Commitments:*
  - *1 week (1 month first time) minimum for installing BSF*
  - *1 tidal cycle required for Mooring System*

- *Environmental Concerns:*
  - *Driving Piles requires Environmental monitoring due to potential negative impact*
  - *Anchoring system does not require.*

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Thank You!

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