Cost-Efficient Use of 1W72 Polyester Rope in Deep Water

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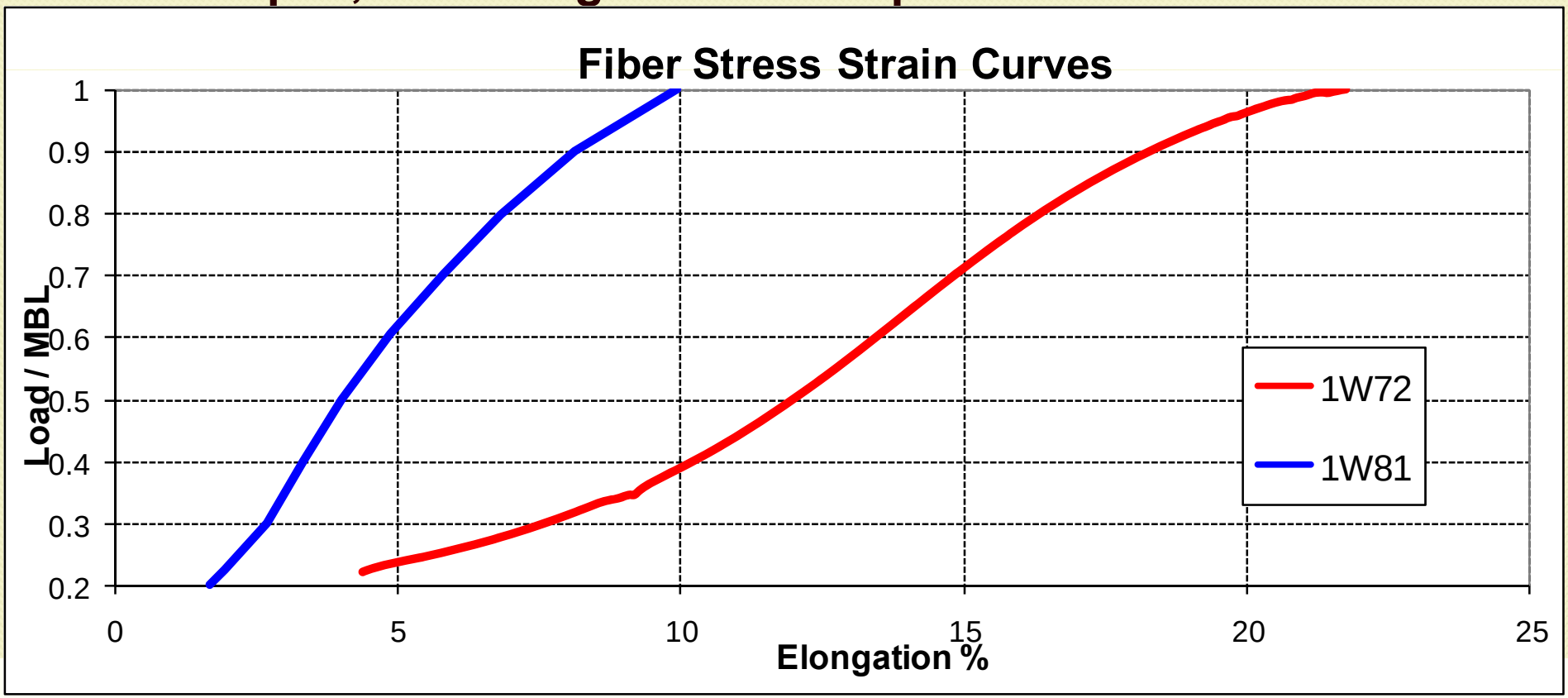
Presentation Outline

- Background on 1w72 Fibers
- Mooring Analysis Overview (ANSYS – AQWA)
- Mooring Analysis Matrix
- Mooring Cost Analysis
- Conclusion

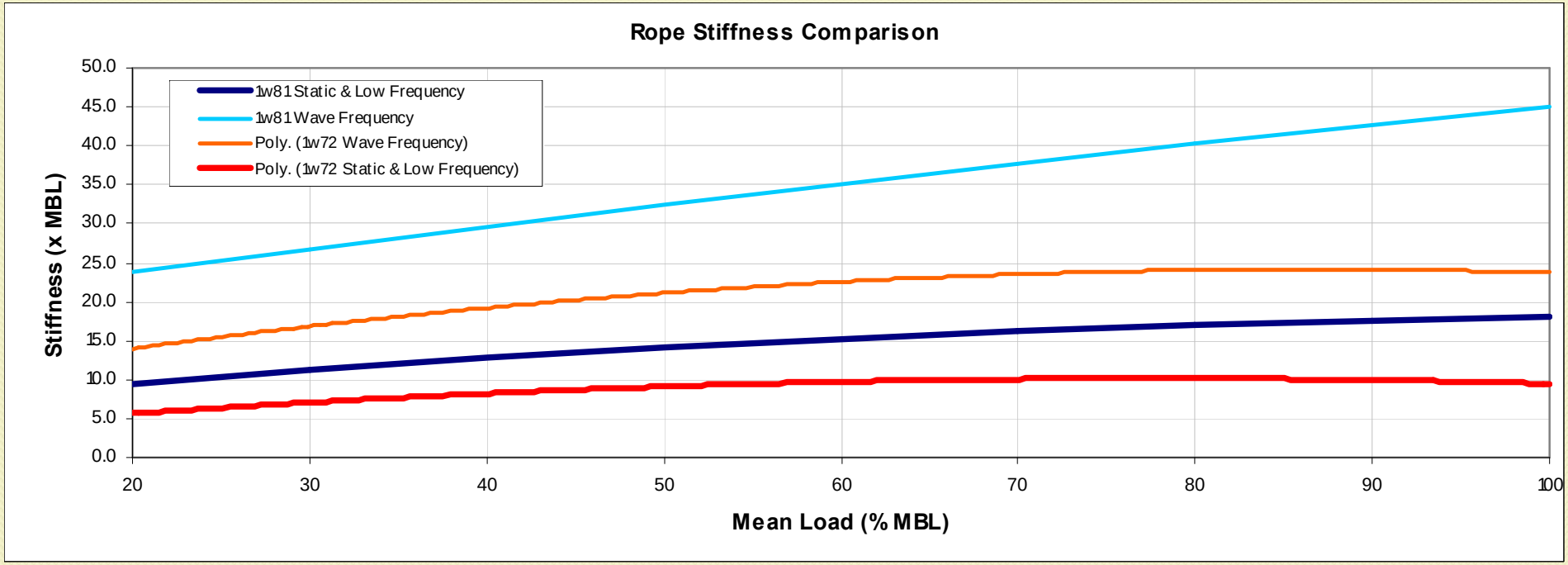
1w72 Background

- The following data shows stress-strain curve behavior for rope base fibers, which was assumed to carry over to the full ropes, assuming the same rope construction.



1w72 Background

- **For analysis purposes, only a change in rope stiffness was examined (ie. wet & dry weights, rope diameters, and MBL's were held constant).**

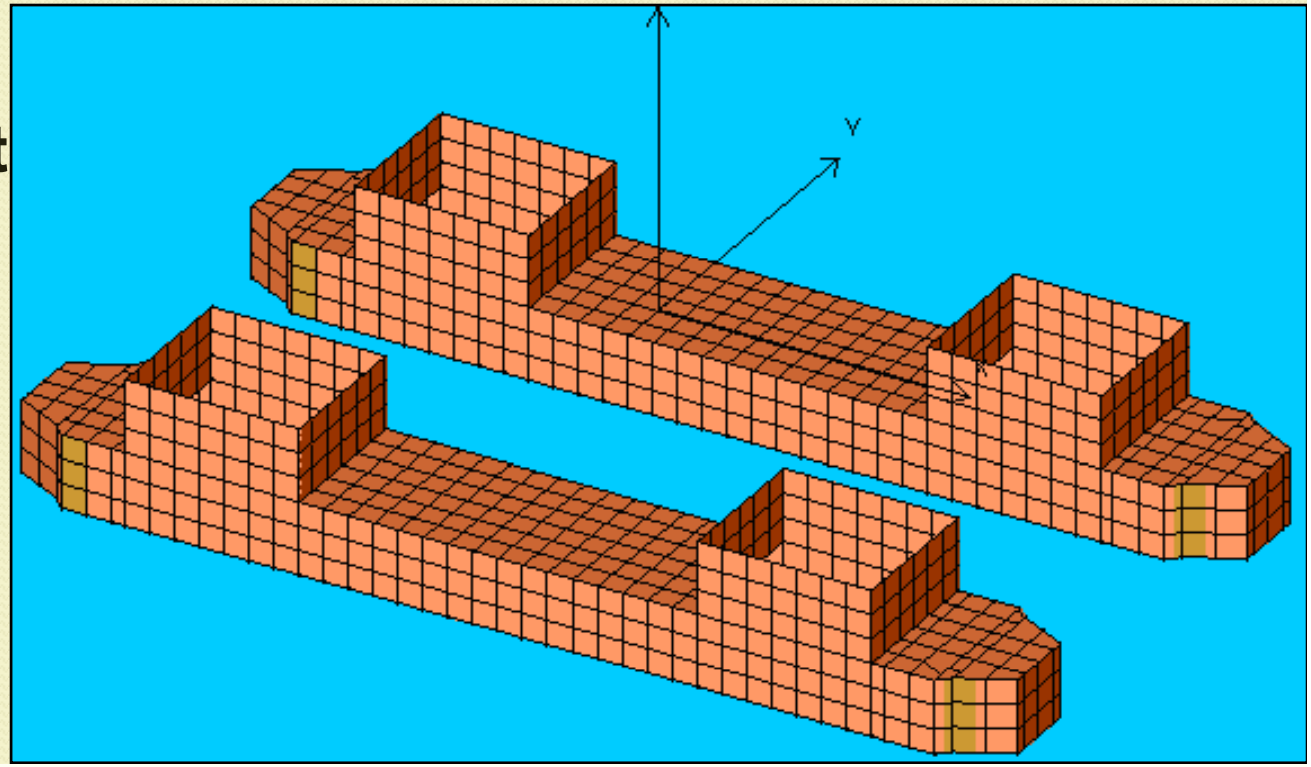


Mooring Analysis Overview

- **ANSYS AQWA:**
  - **Integrated suite of analysis programs that can be used to perform hydrodynamic and mooring analyses.**
  - **AQWA Utilization for this Presentation:**
    - **Diffraction & Radiation (AQWA Line)**
    - **Static and dynamic initial stability (AQWA Librium)**
    - **Frequency domain dynamic analysis (AQWA Fer)**

Mooring Analysis Overview

- **ANSYS AQWA:**
  - **Step 1: “Large Rig” Model Generation, symmetric about x-axis.**
  - **LOA ~400-ft**
  - **Breadth ~220-ft**



Mooring Analysis Overview

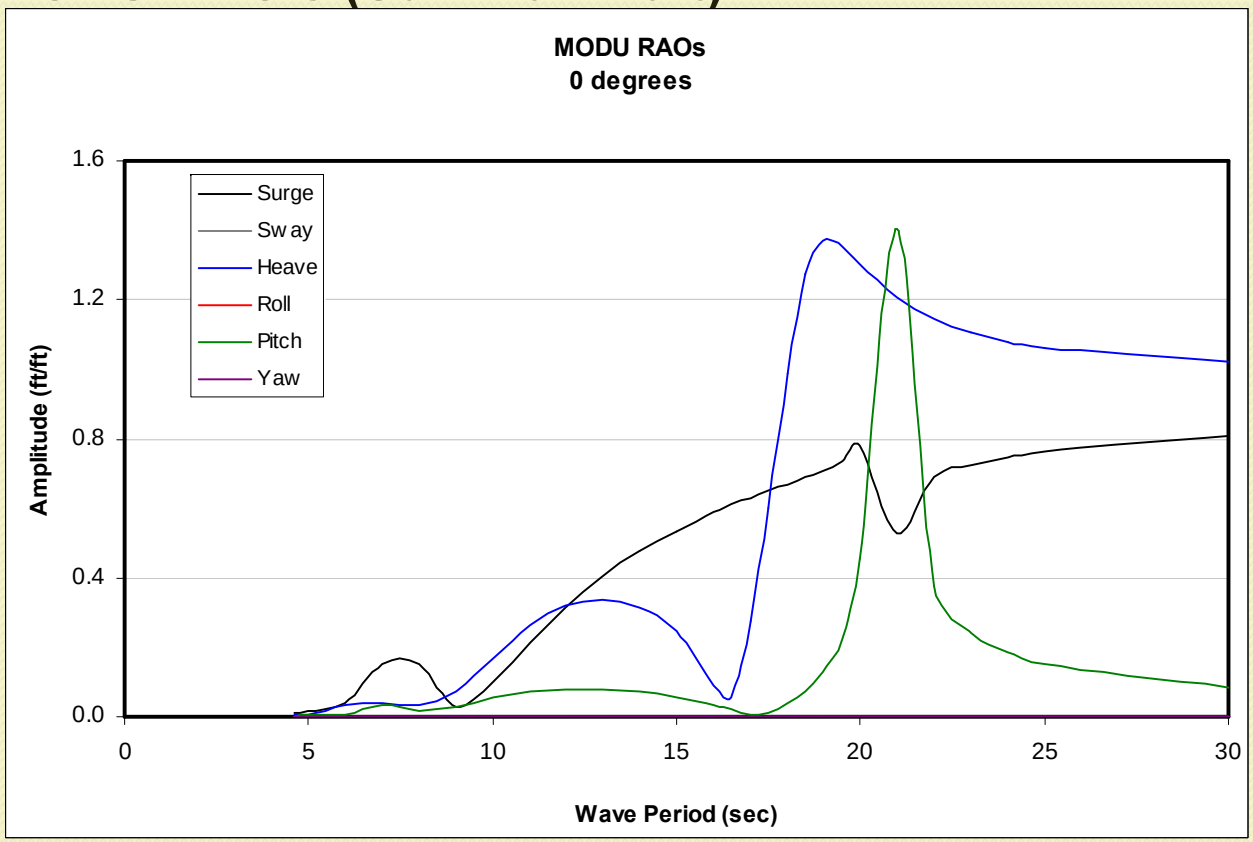
- **ANSYS AQWA:**
  - **AQWA Line is run to perform radiation and diffraction analyses of the generated model to obtain:**
    - **Hydrostatic properties**
    - **Vessel RAO's,**
    - **Wave drift force coefficients**

Mooring Analysis Overview

- **ANSYS AQWA:**
  - **Model Hydrostatic Properties (Survival Draft of 60-ft)**
    - **Total Displacement of ~141,000-kips**
    - **Transverse Metacentric Height (GMT) of ~65-ft**
    - **Longitudinal Metacentric Height (GML) of 11.6-ft**
    - **Vertical Center of Buoyancy (KB) from water line of ~ -49-ft**
    - **Vertical Center of Gravity (VCG) from water line -9.0-ft**
    - **Waterplane Area of ~16,800-ft^2**
    - **Pitch Gyradius: 110-ft**
    - **Roll Gyradius: 100-ft**
    - **Yaw Gyradius: 120-ft**

Mooring Analysis Overview

- **ANSYS AQWA:**
  - **MODU RAO's (Survival Draft)**



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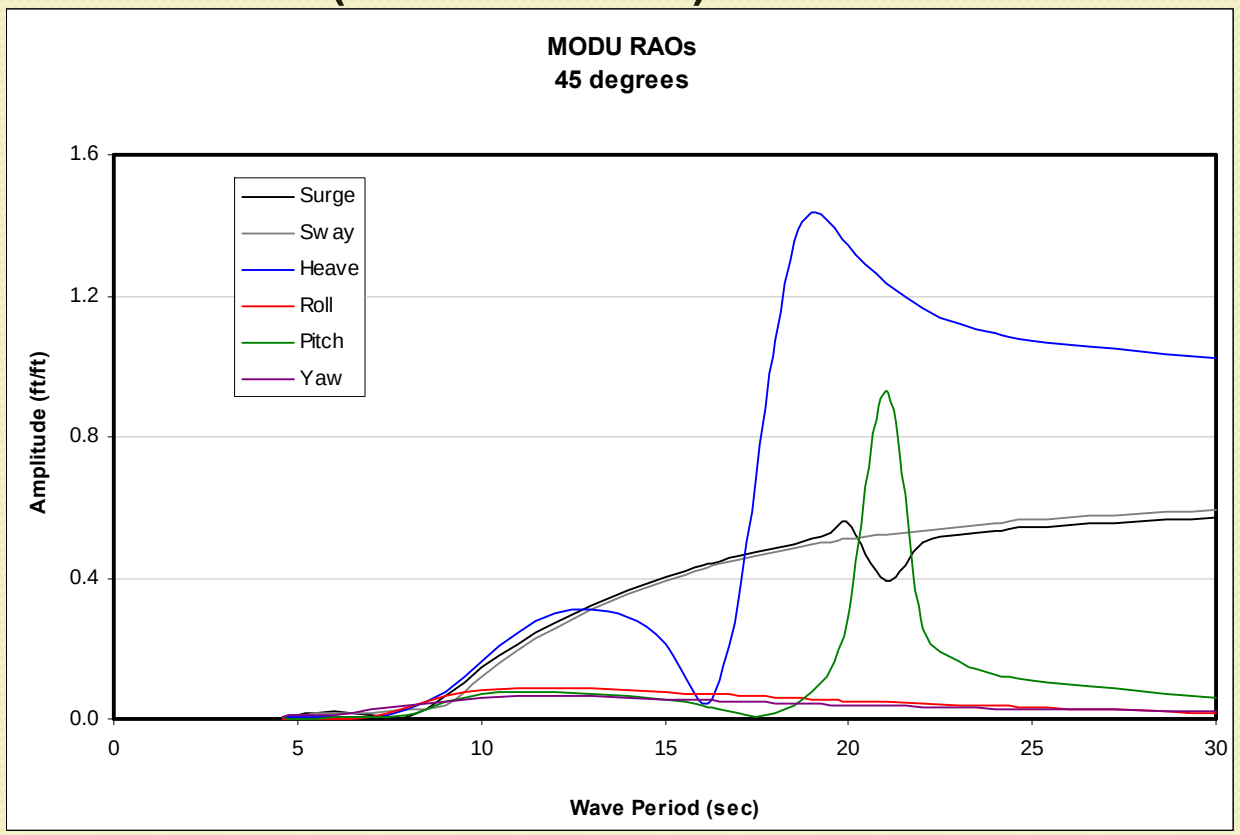

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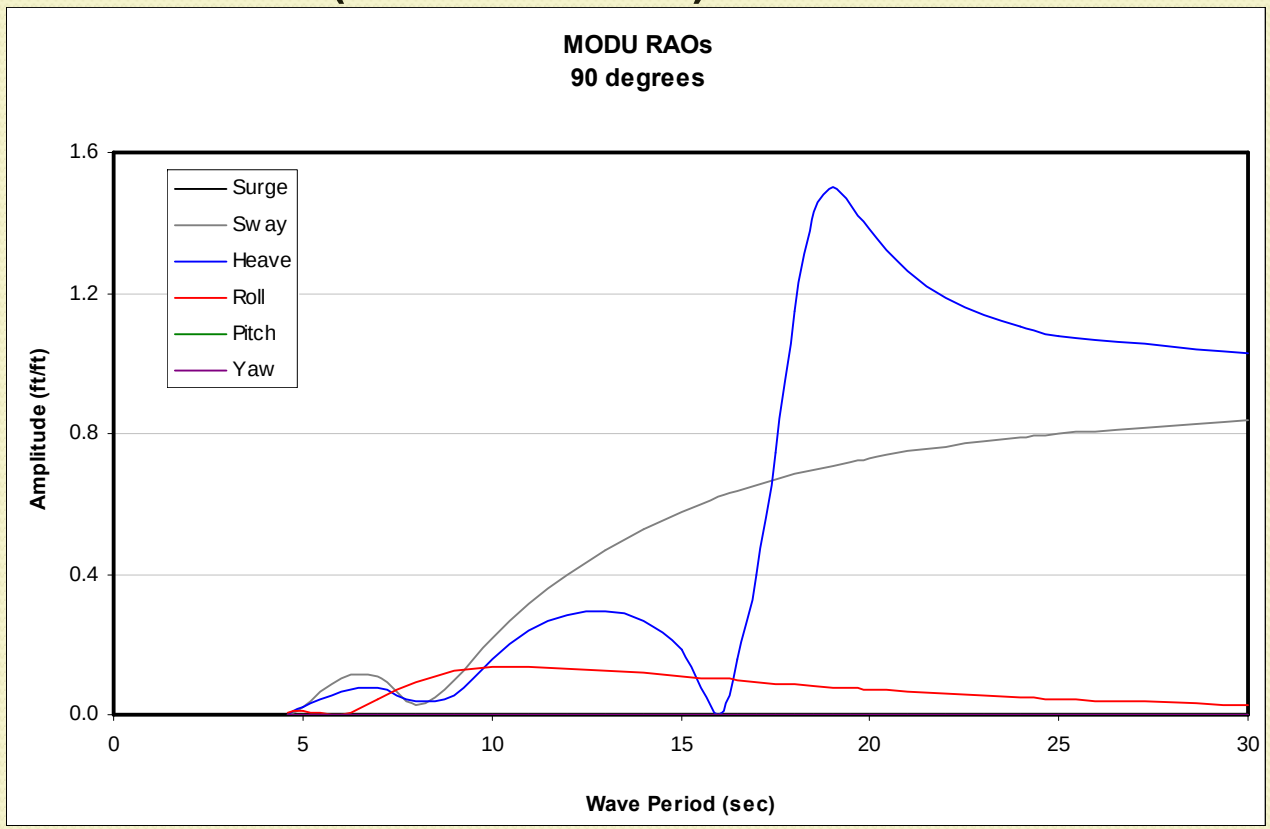
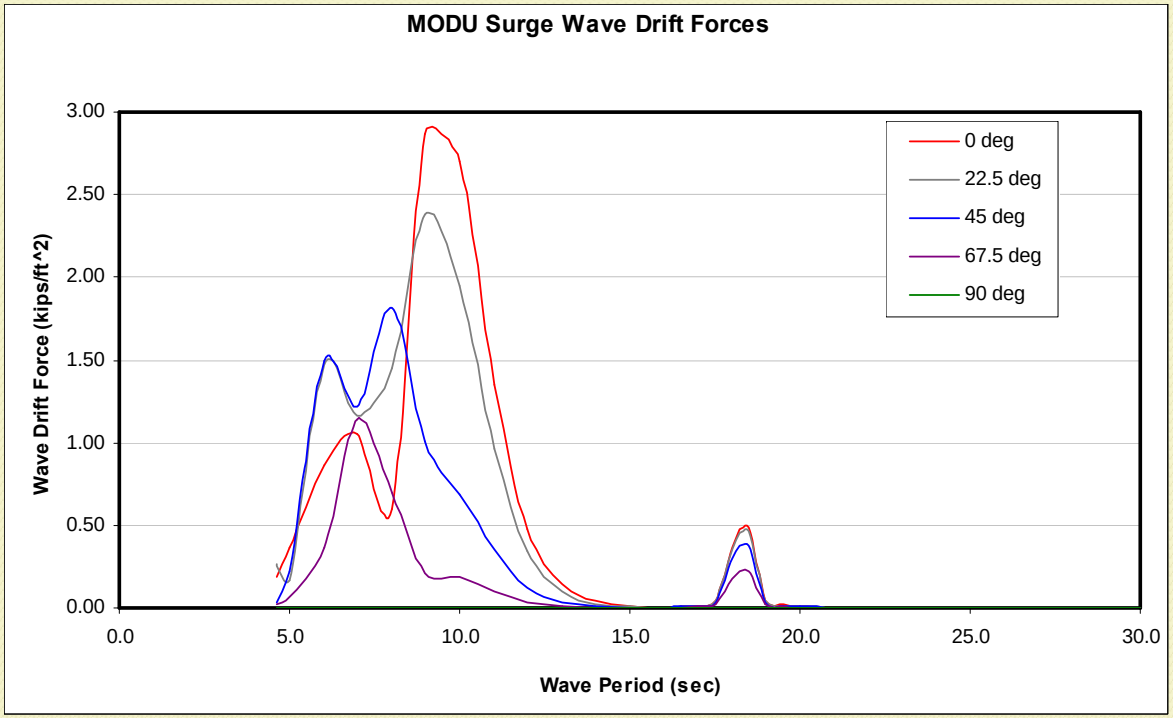


Mooring Analysis Overview

- **ANSYS AQWA:**
  - **Wave Drift Force Coefficients (Survival Draft)**



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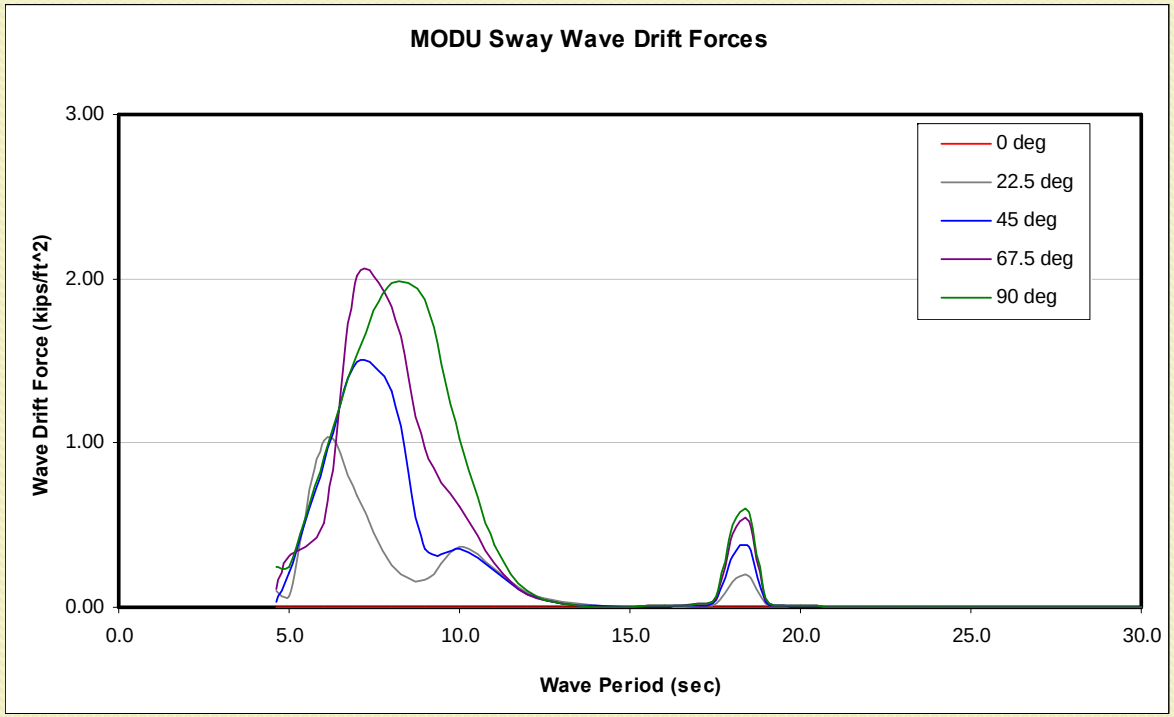

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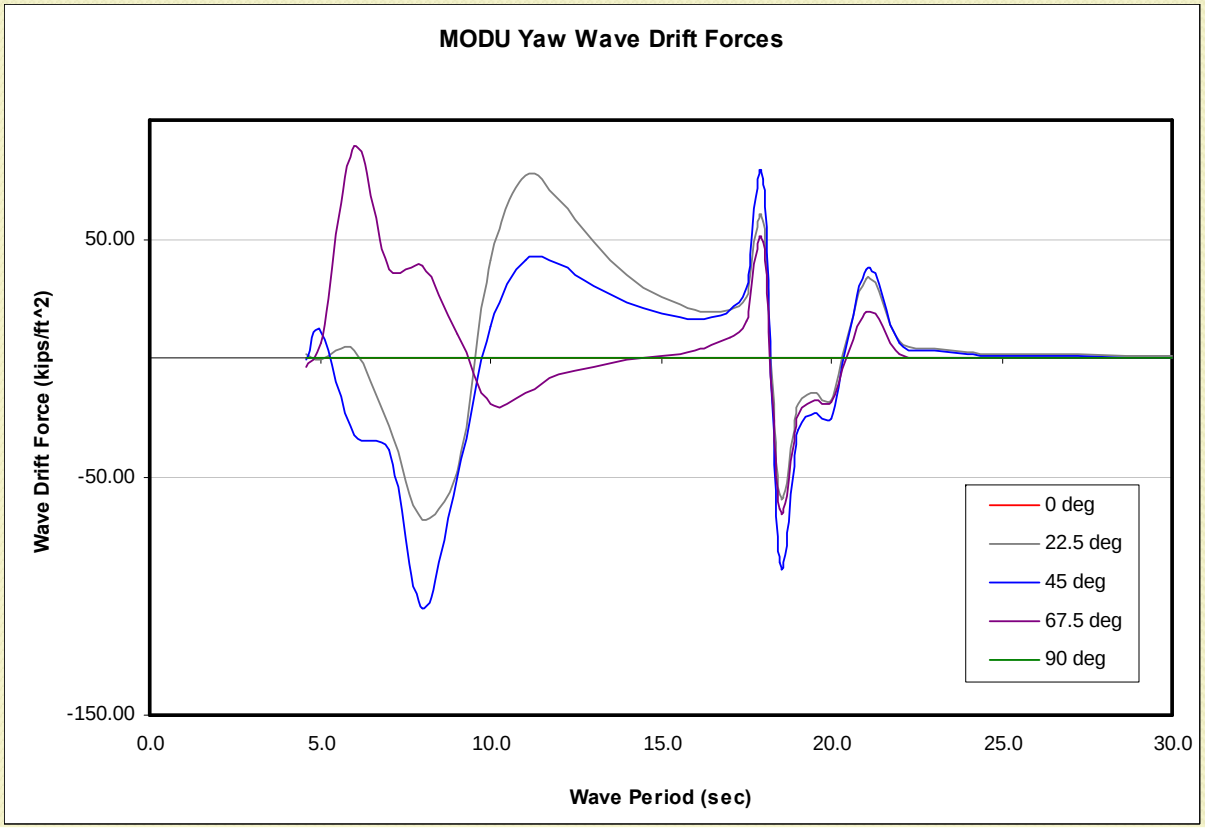
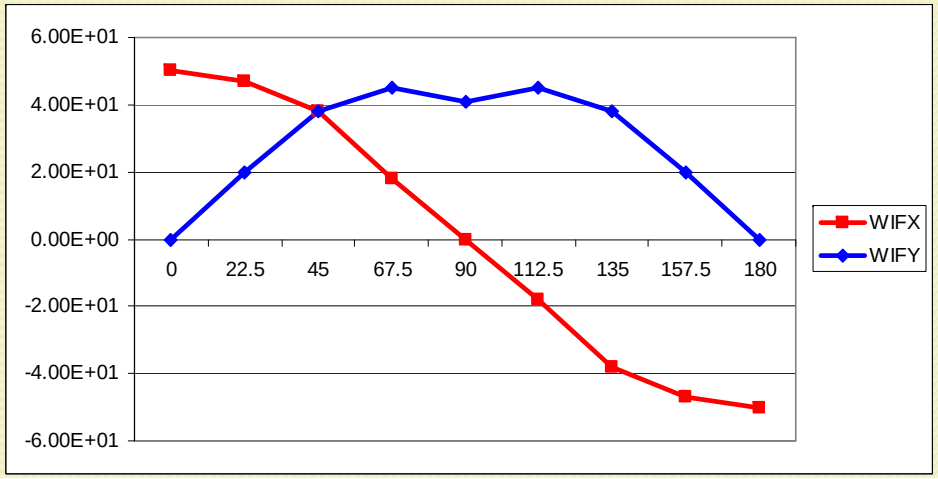
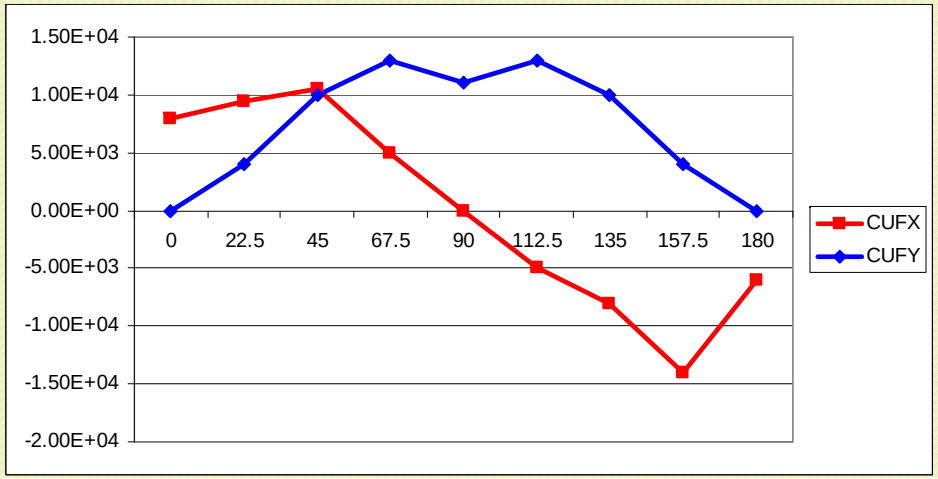


Mooring Analysis Overview

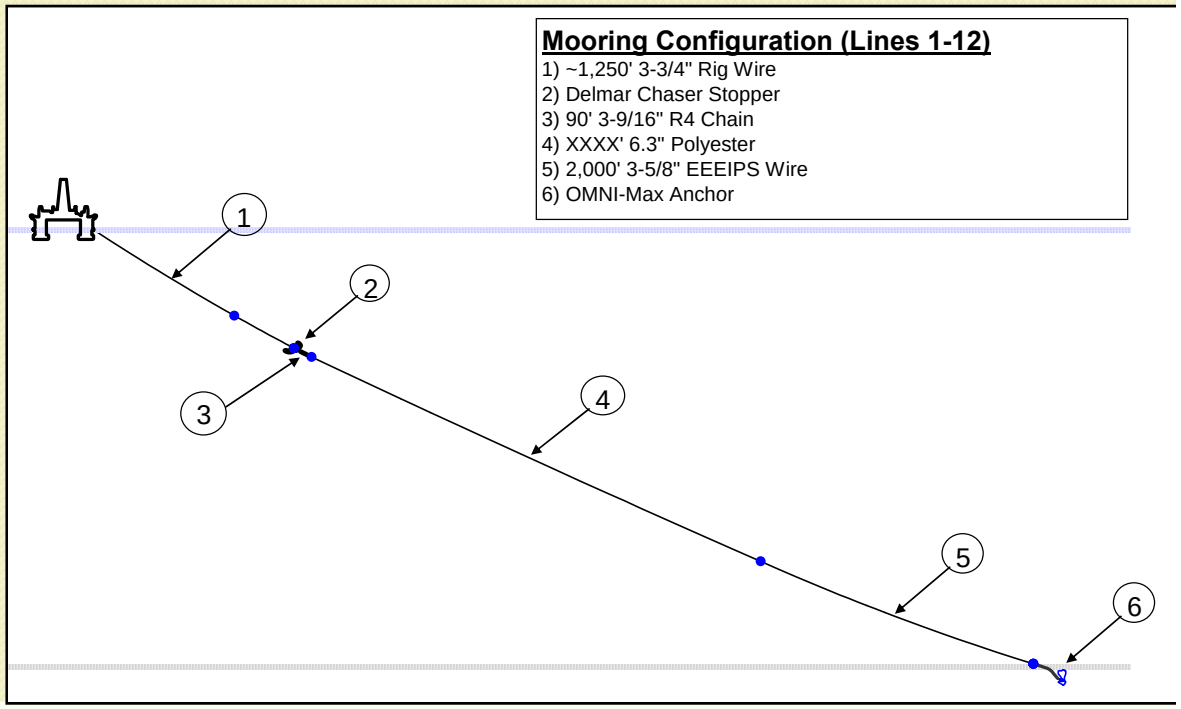
- **ANSYS AQWA:**
  - **Wind and Current force coefficients are obtained from wind tunnel test data and input into AQWA for static and dynamic analyses.**





Mooring Analysis Overview

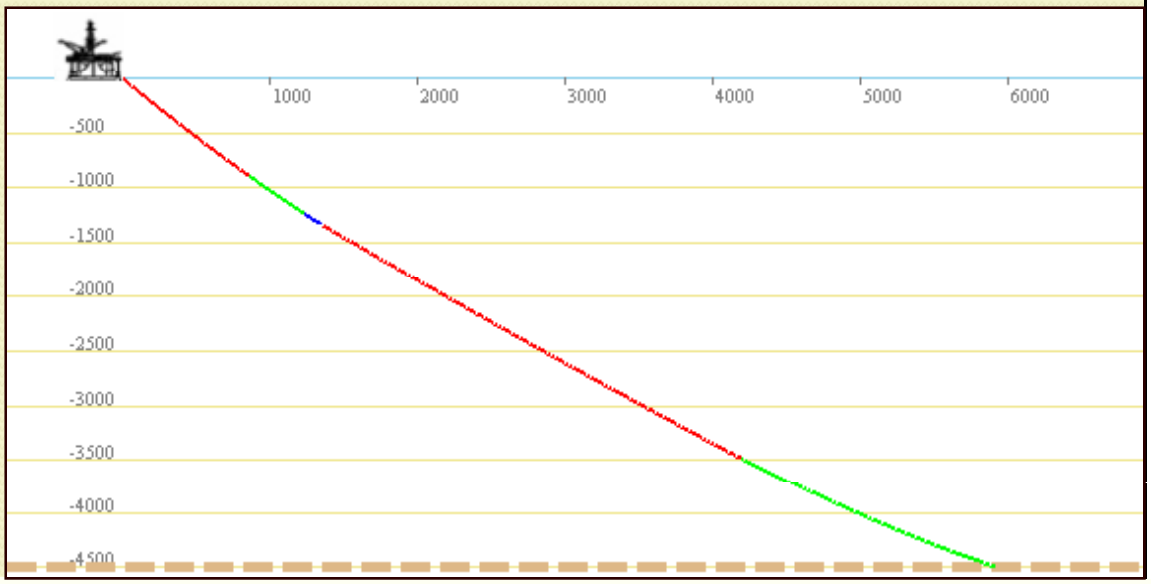
- **ANSYS AQWA:**
  - **Mooring component lengths and fairlead tensions were chosen for each water depth, polyester type and length.**
  - **Fairlead tensions of ~205 to 295-kips (to maintain ~160-kips of horizontal tension for each case)**

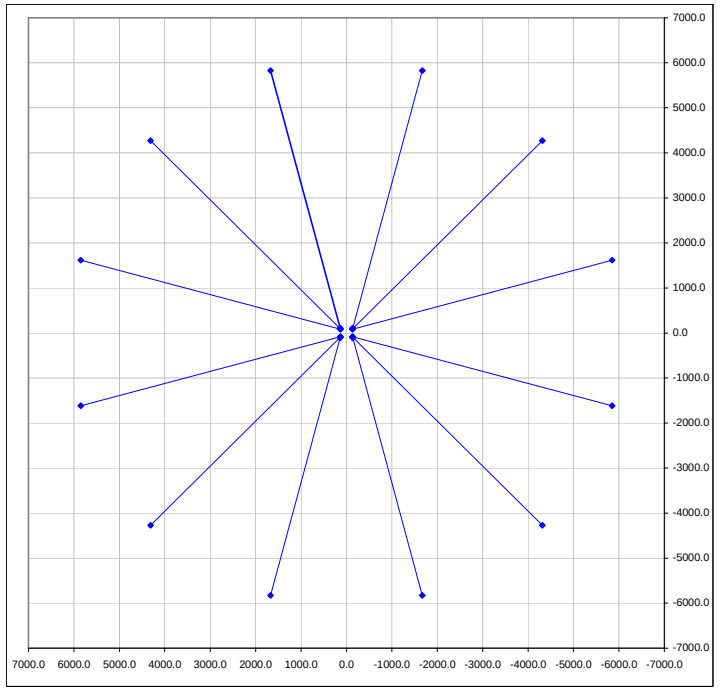


Mooring Analysis Overview

- **ANSYS AQWA:**
  - **Static catenary analyses were performed for each system by Delmar proprietary software to obtain mooring scopes.**

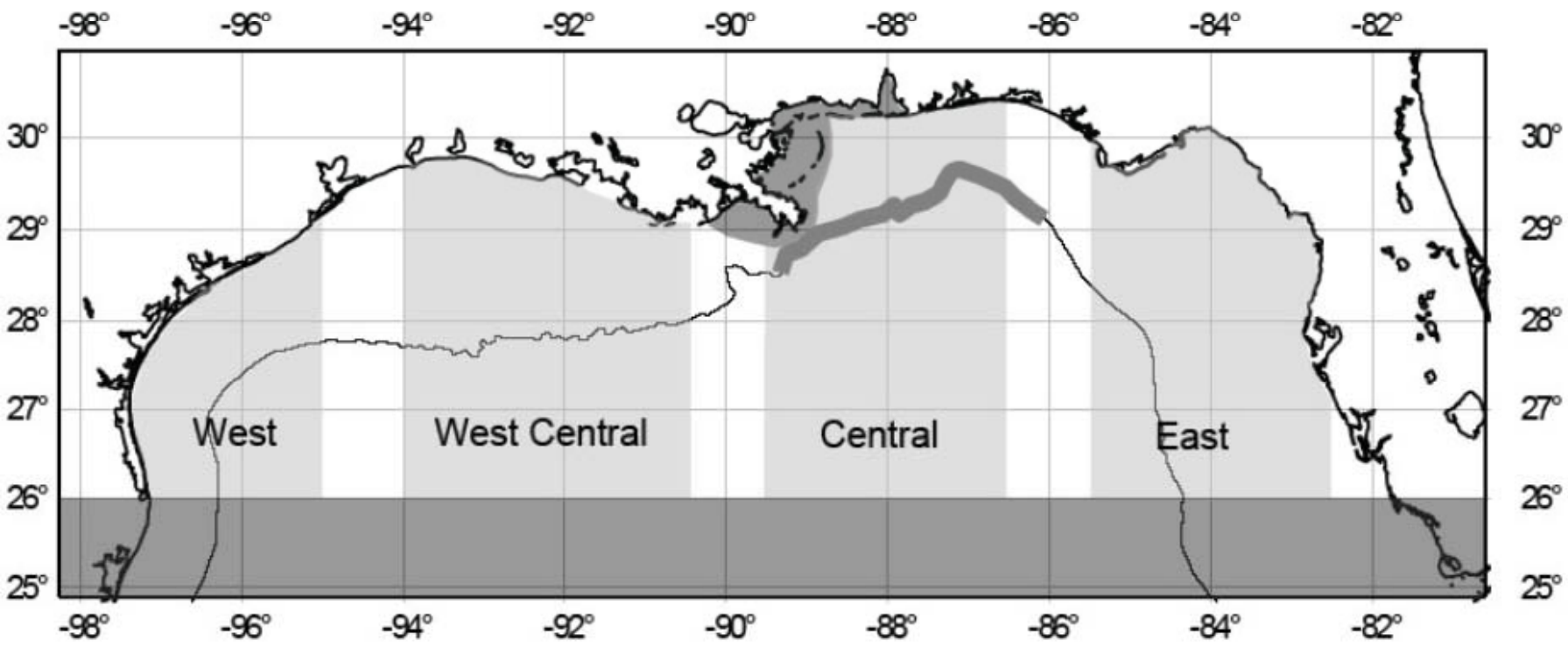
fairleads (#)	x (feet)	y (feet)	angle (deg.)	radius (feet)	x (feet)	y (feet)
1	110.4	-137.3	15	5916	**5825**	**-1668**
2	87.8	-131.1	45	5916	**4271**	**-4314**
3	86.4	-137.3	75	5916	**1618**	**-5852**
4	-86.4	-137.3	105	5916	**-1618**	**-5852**
5	-87.8	-131.1	135	5916	**-4271**	**-4314**
6	-110.4	-137.3	165	5916	**-5825**	**-1668**
7	-110.4	137.3	195	5916	**-5825**	**1668**
8	-87.8	131.1	225	5916	**-4271**	**4314**
9	-86.4	137.3	255	5916	**-1618**	**5852**
10	86.4	137.3	285	5916	**1618**	**5852**
11	87.8	131.1	315	5916	**4271**	**4314**
12	110.4	137.3	345	5916	**5825**	**1668**





Mooring Analysis Overview

- **ANSYS AQWA:**
  - **API 2-MET Peak Metocean for the Central Region USGOM was input collinearly into ANSYS-AQWA for each mooring analysis.**



Mooring Analysis Overview

- **ANSYS AQWA:**
  - **The JONSWAP Wave Spectrum (γ=2.4) and the NPD Wind Spectrum were utilized with the following metocean.**

Peak Wind Case (Wind -15 deg, Current +15 deg from Wave)								
(Based on API Metocean Data - Not for use in site-specific design)								
Return Periods	**10**	**25**	**50**	**100**	**200**	**1000**	**2000**	**10000**
Wind (@ 32.8 ft)								
1-hr (kts)	64.1	77.9	86.3	93.3	99.1	116.6	121.3	130.6
1-min (kts)	79.7	99.3	111.6	122.1	131.0	158.6	166.4	181.7
Waves, WD>=3281 ft								
Hs (ft)	32.8	41.5	46.1	49.2	51.4	61.7	63.9	68.9
Tp (s)	13.0	14.4	15.0	15.4	15.7	17.2	17.5	18.2
Current								
surface speed (kts)	2.6	3.1	3.2	3.5	3.7	4.4	4.5	4.9
mid-depth (kts)	1.9	2.3	2.4	2.6	2.8	3.3	3.4	3.7
0-speed depth (ft)	181.9	221.0	229.3	248.0	263.5	310.0	322.3	347.2

Mooring Analysis Overview

- **ANSYS AQWA:**
  - **All of the previous information was input into ANSYS-AQWA to run 6-Degree of Freedom frequency domain coupled motion mooring analyses at every 15° from 0° to 180°.**
  - **These analyses account for vessel motions, mooring line dynamics, and their interactions.**

Mooring Analysis Overview

- **ANSYS AQWA:**
  - **An analysis for synthetic moorings was performed (AQWA-Librium) to iteratively obtain nonlinear stiffness "EA" values within 5% of the input equation at the resulting line tensions.**
    - **Initial mean EA values are solved for iteratively using mean tensions.**
    - **Corresponding mean tension is used to determine Low Frequency and Wave Frequency stiffness (EA).**

Mooring Analysis Matrix

- **For each polyester type, the following analysis matrix was analyzed:**

Water Depth [ft]					
4500		6000		7500	
Polyester Length [ft]	Fairlead Tension [kips]	Polyester Length [ft]	Fairlead Tension [kips]	Polyester Length [ft]	Fairlead Tension [kips]
3500	245	5000	265	6000	295
4500	230	6000	245	7500	260
6000	215	8000	230	10000	235
7500	210	10000	220	12500	225
9000	205	12000	215	15000	220

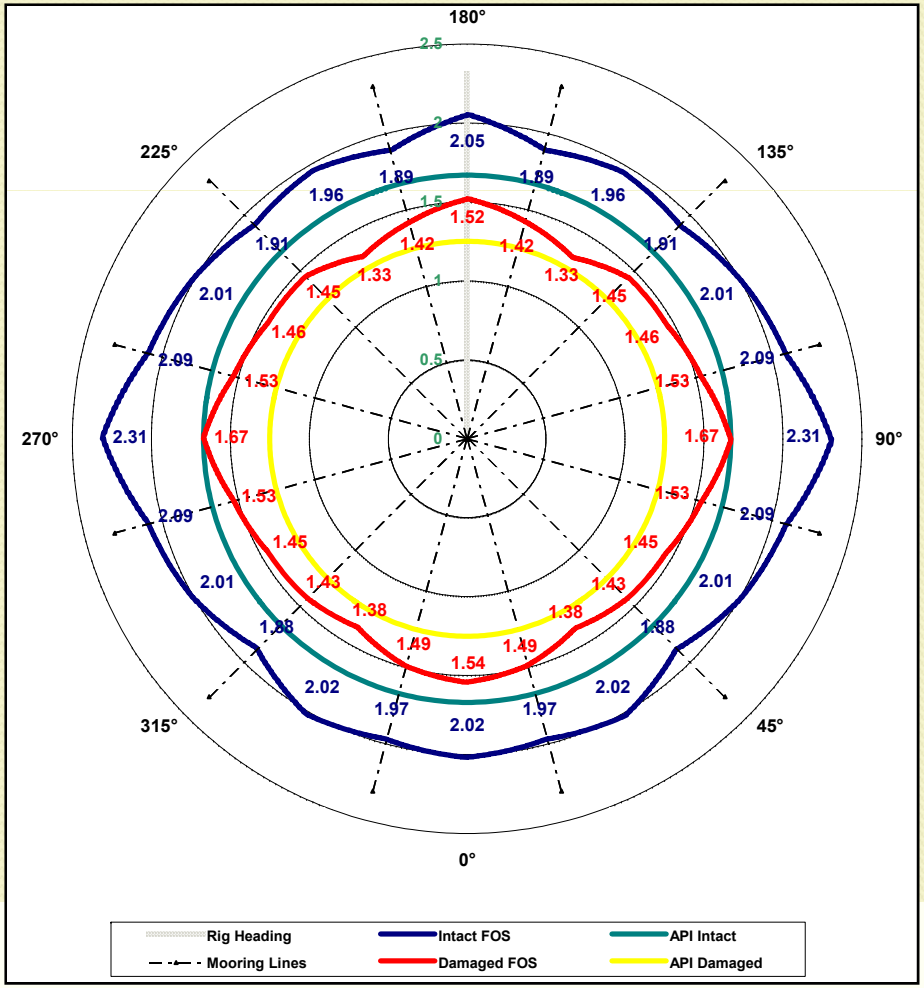
- **This analysis matrix has 30 intact sets and 60 damaged sets of mooring analyses, plus limit states, with each set examining 13 colinear metocean directions… that comes out to ~1,500 directional mooring analyses examined!**

Mooring Analysis Matrix

- For all mooring analysis results, the 500’ section of connecting wire was assumed to be the weak link, with an MBL of 1,498-kips.
- All of the data obtained from the ANSYS-AQWA analyses was post-processed and put into charts and plots for this presentation.

Mooring Analysis Matrix Results

- Each water depth & polyester length combination produced the following sample information:



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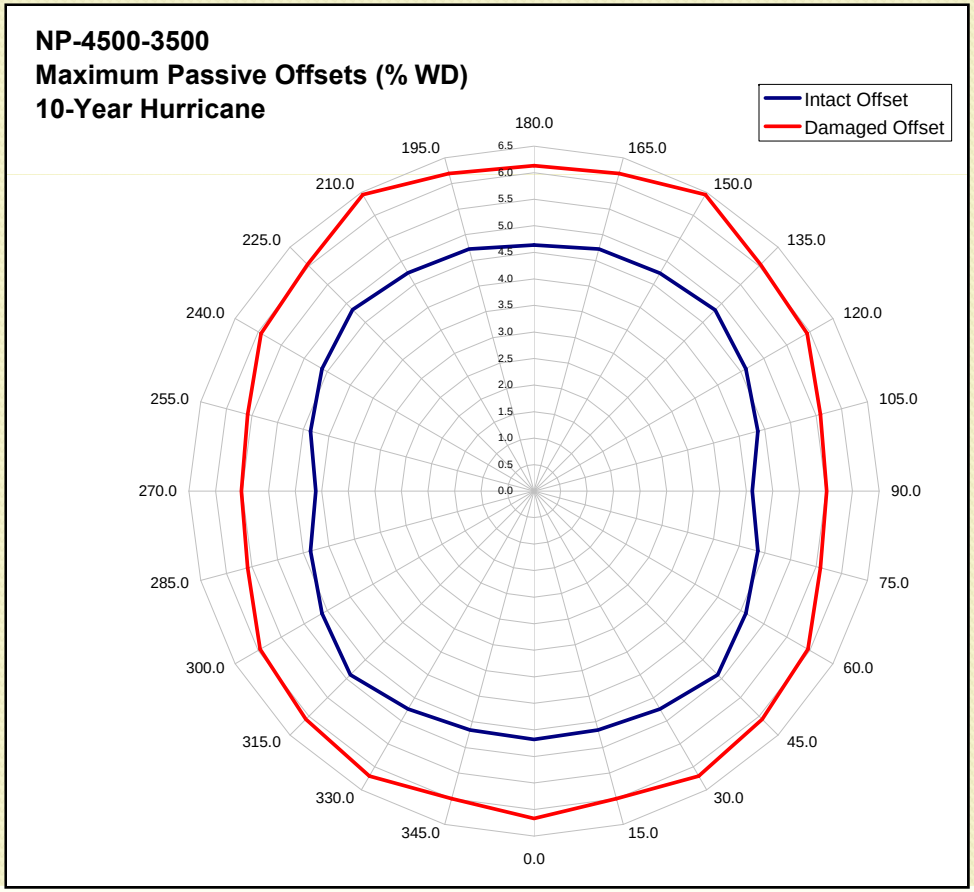

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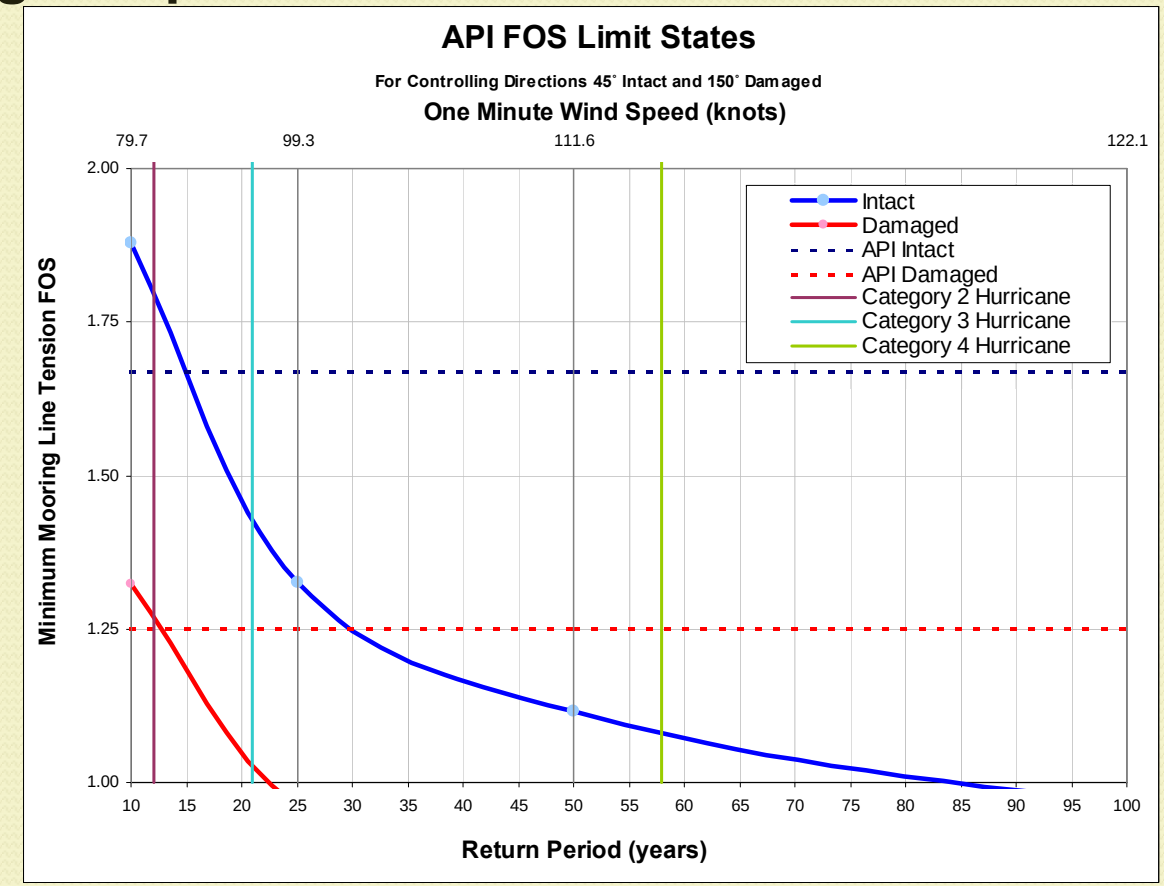
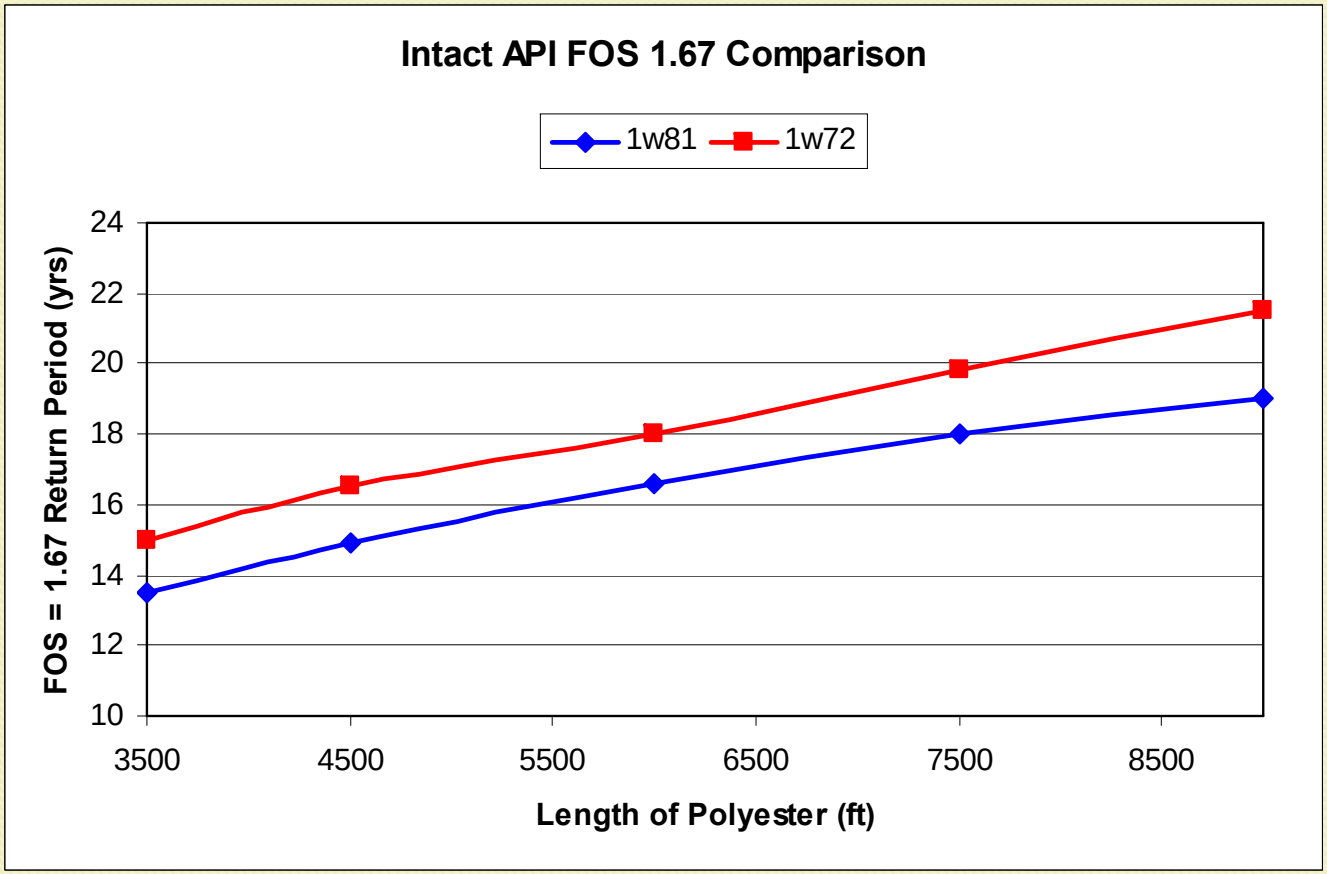


Mooring Analysis Matrix Results

- For the shallowest water depth (4,500'), the following comparison plots were created for the two polyesters:



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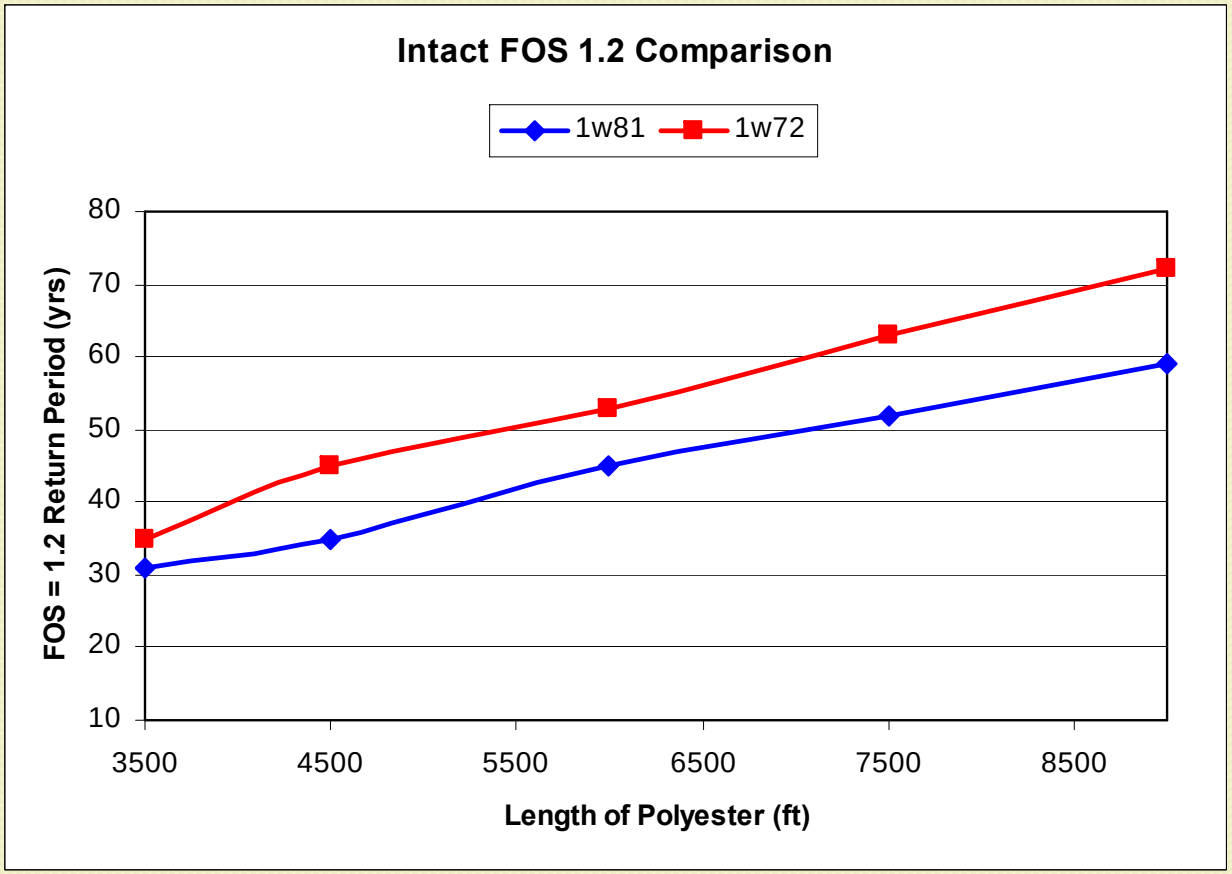

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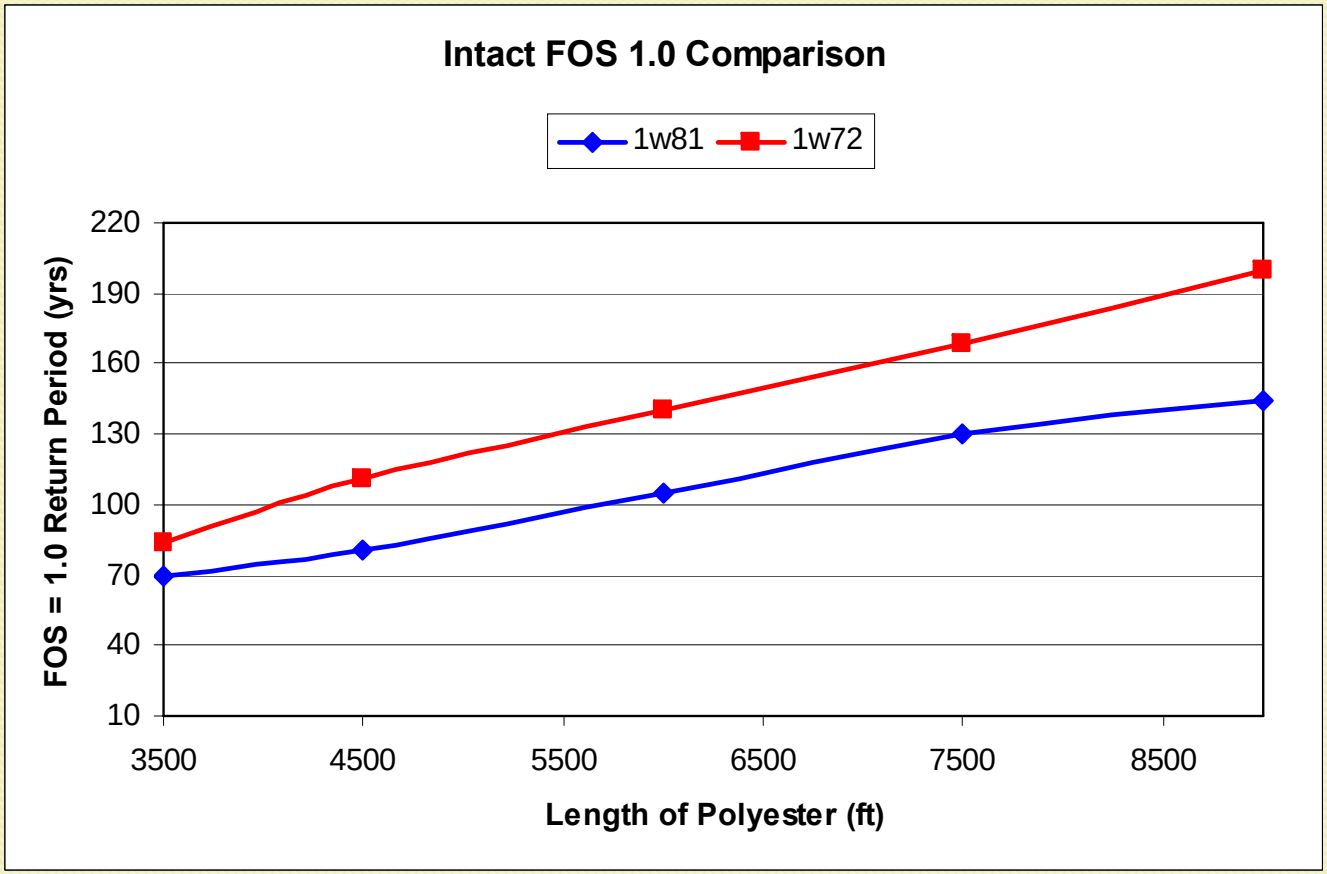
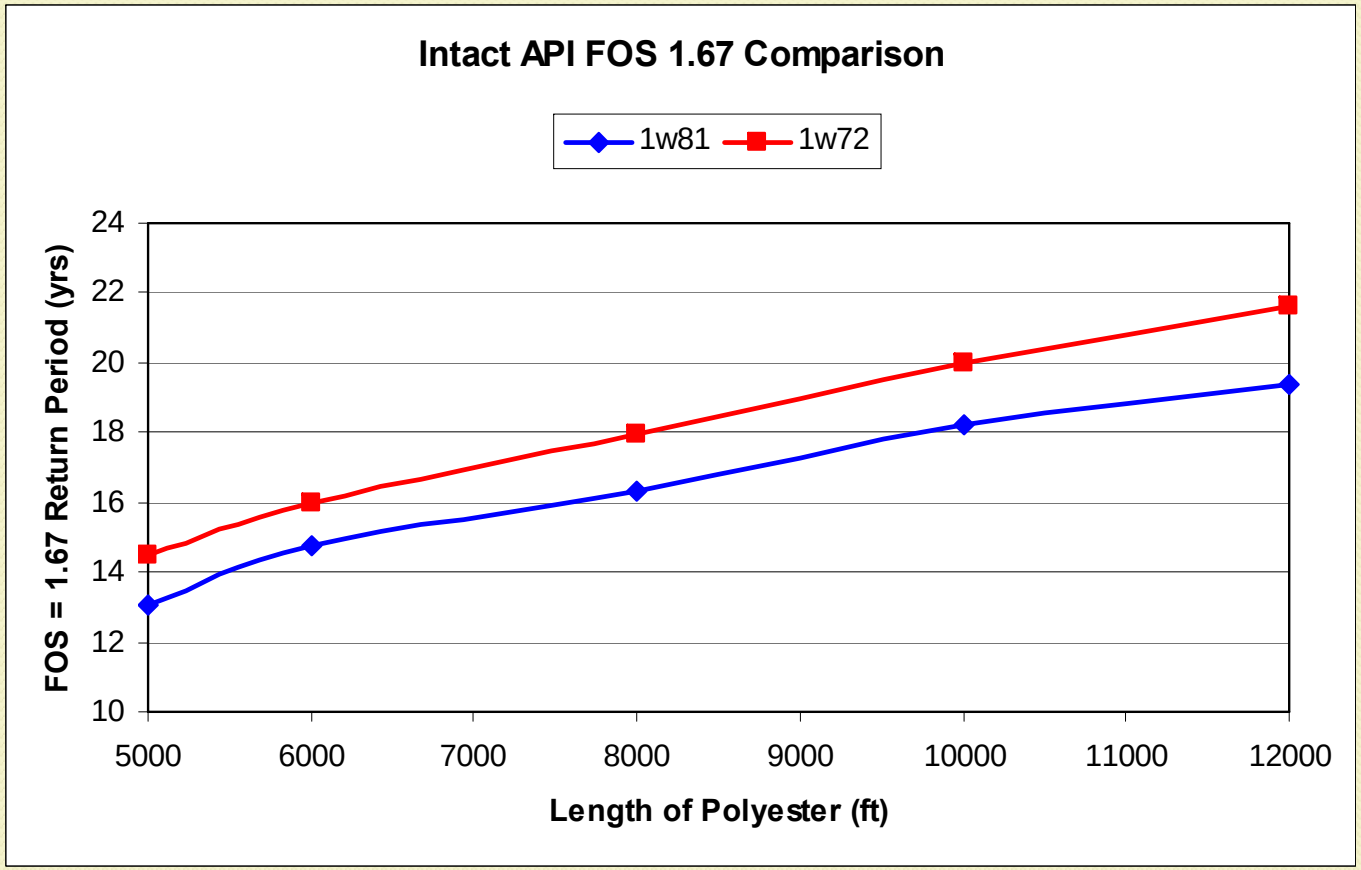


Mooring Analysis Matrix Results

- For the 6,000’ water depth, the following comparison plots were created for the two polyesters:



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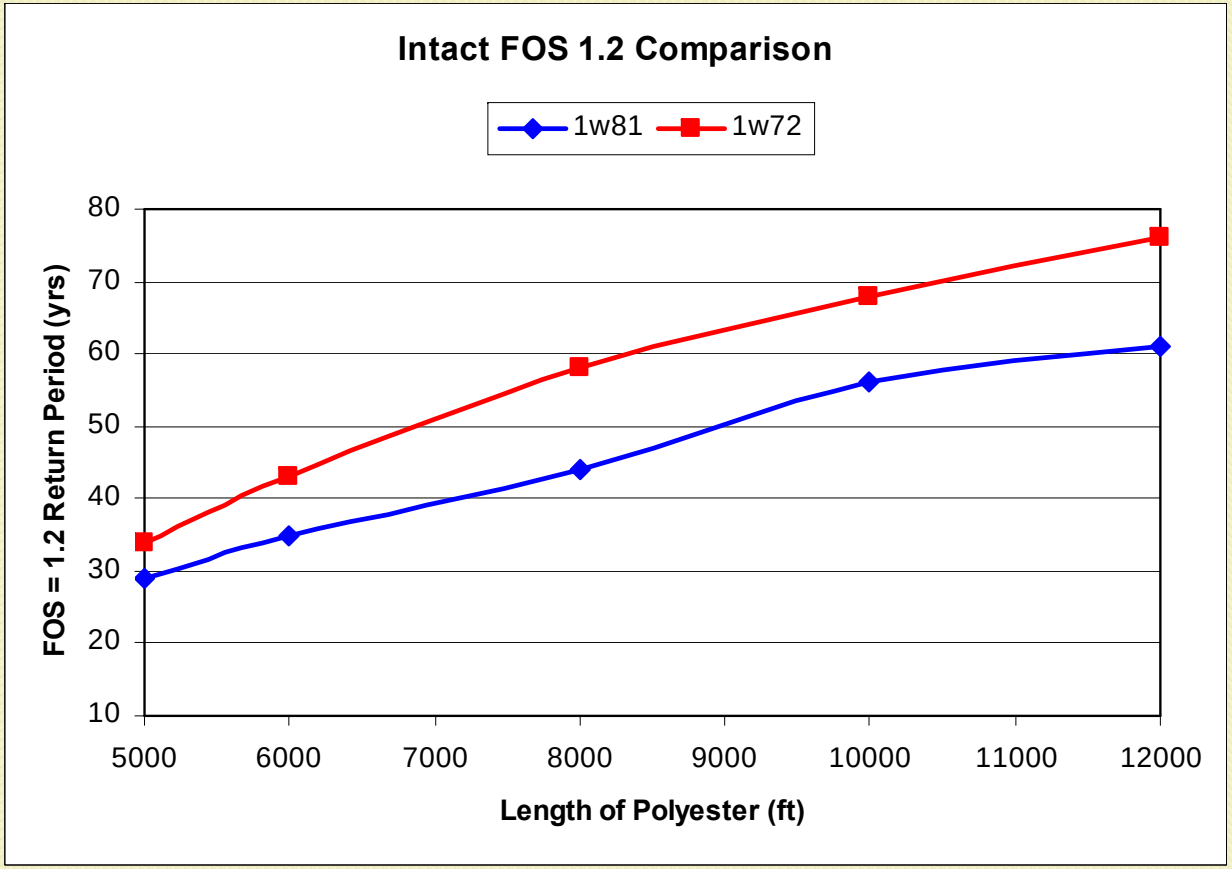

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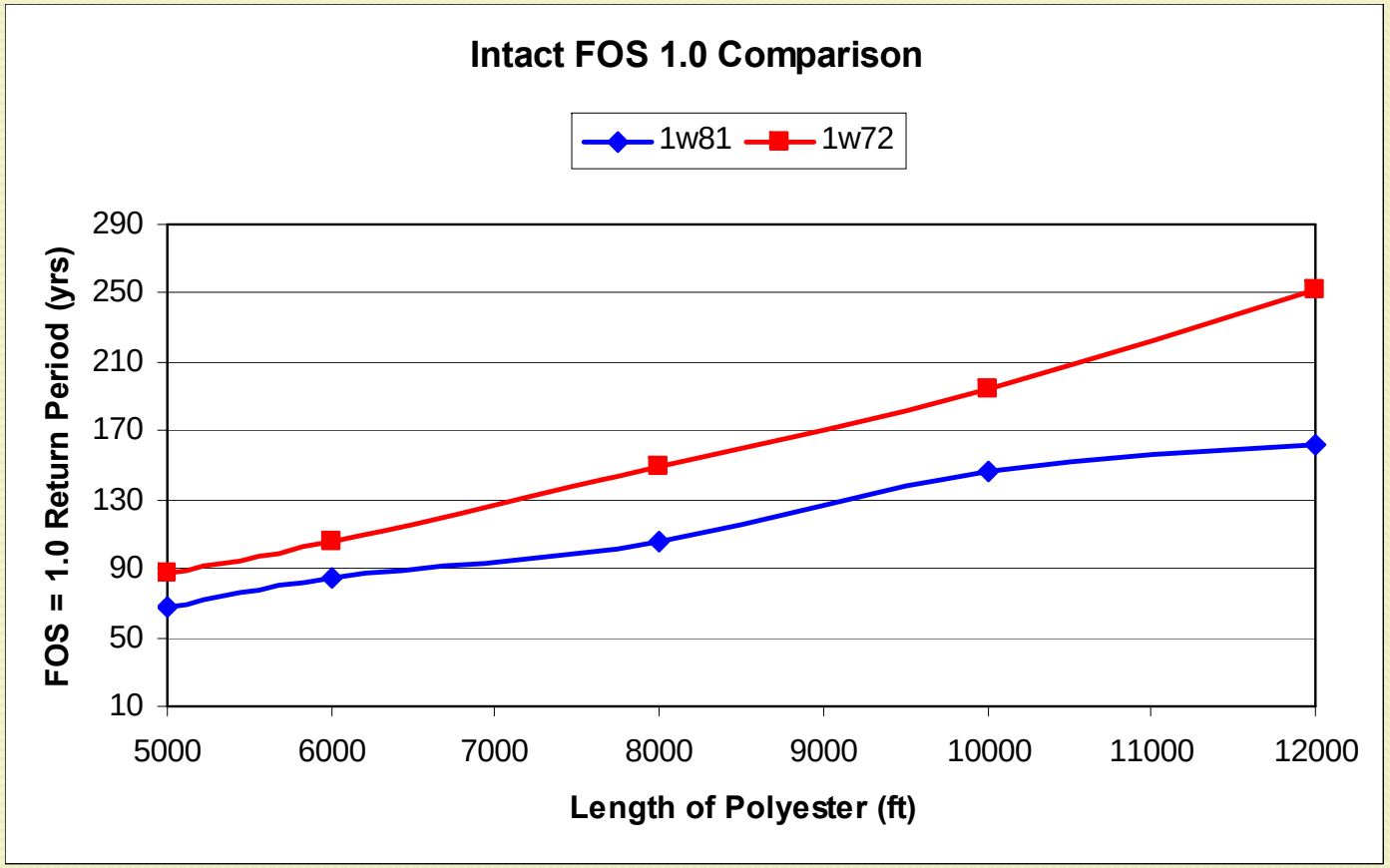

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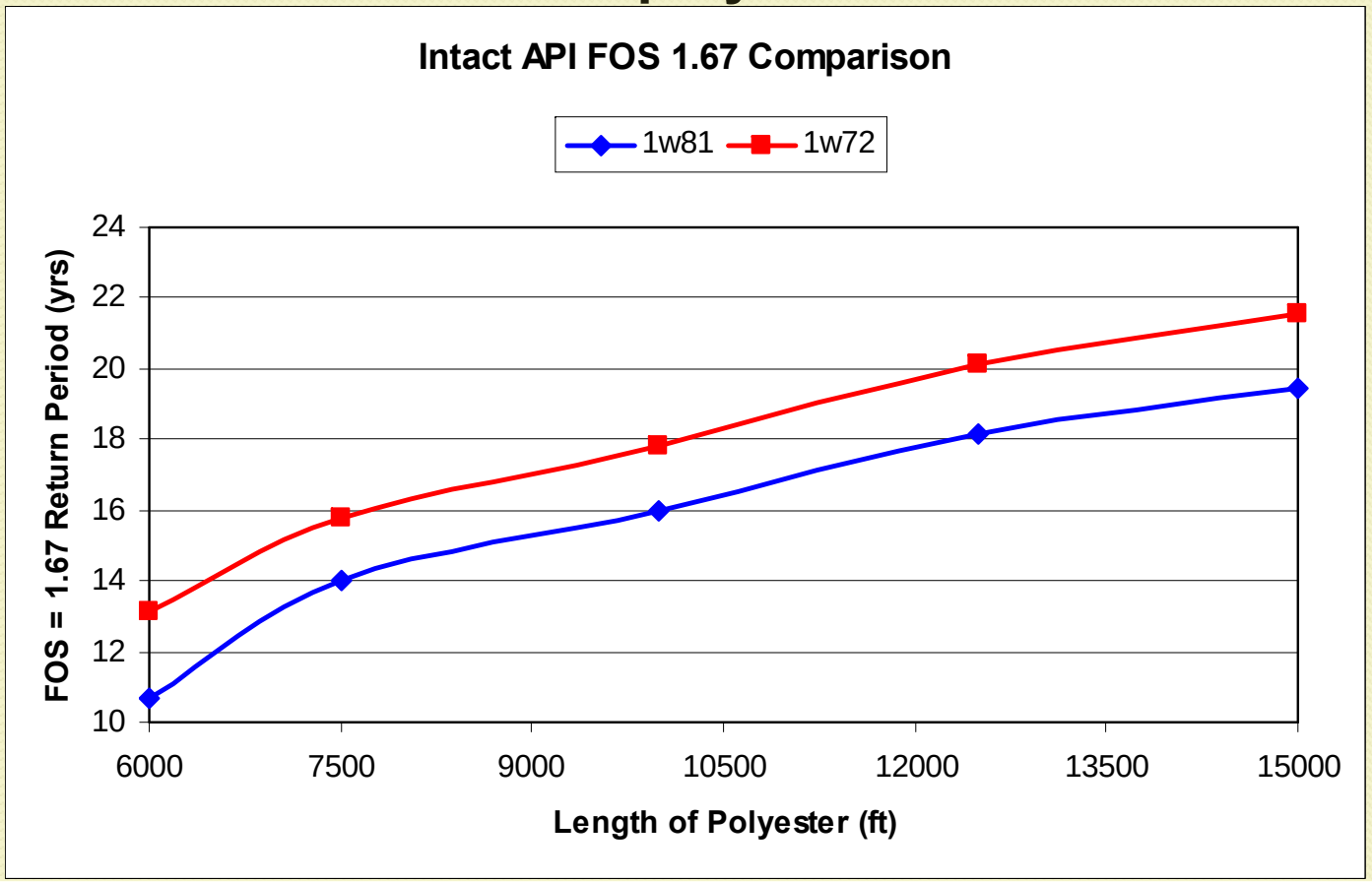
- For the deepest water depth (7,500'), the following comparison plots were created for the two polyesters:



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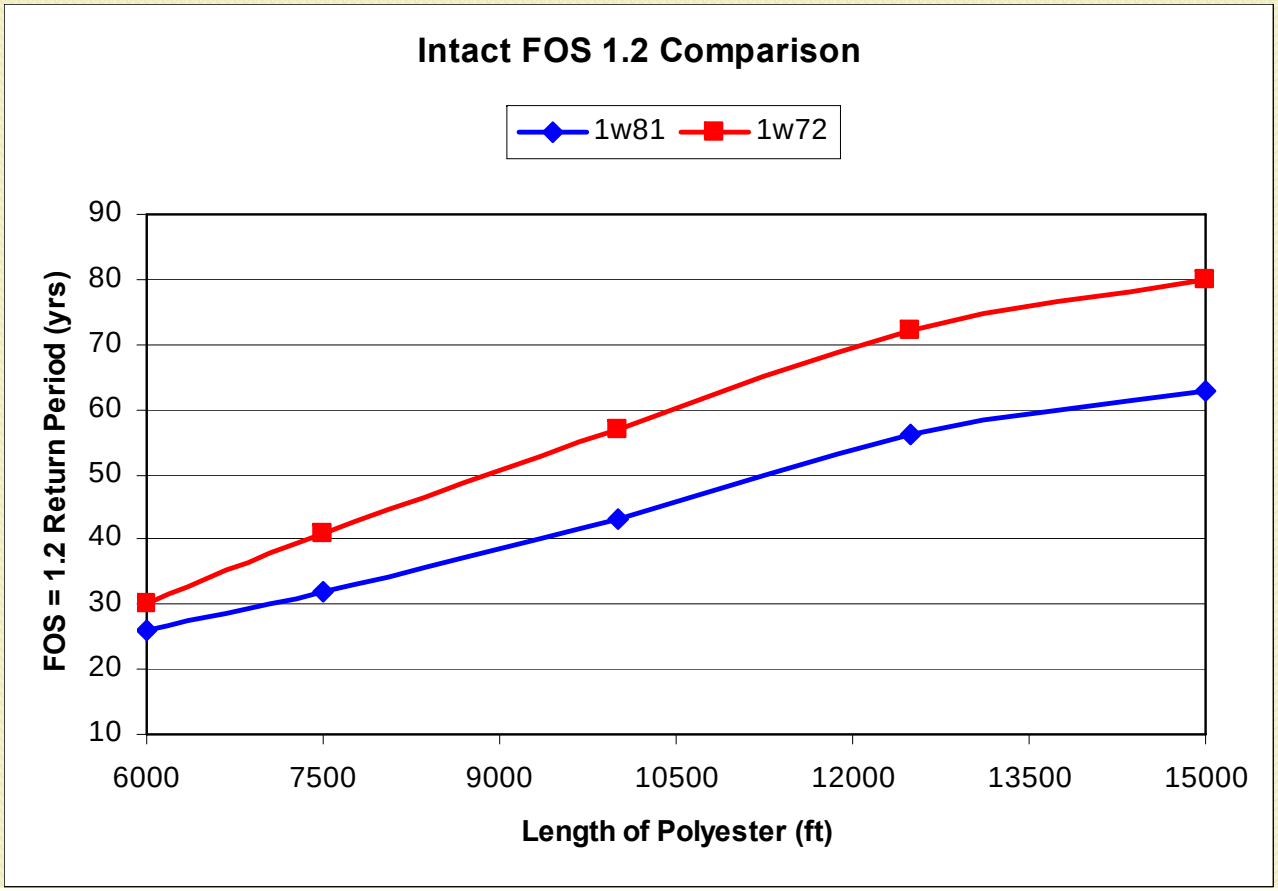

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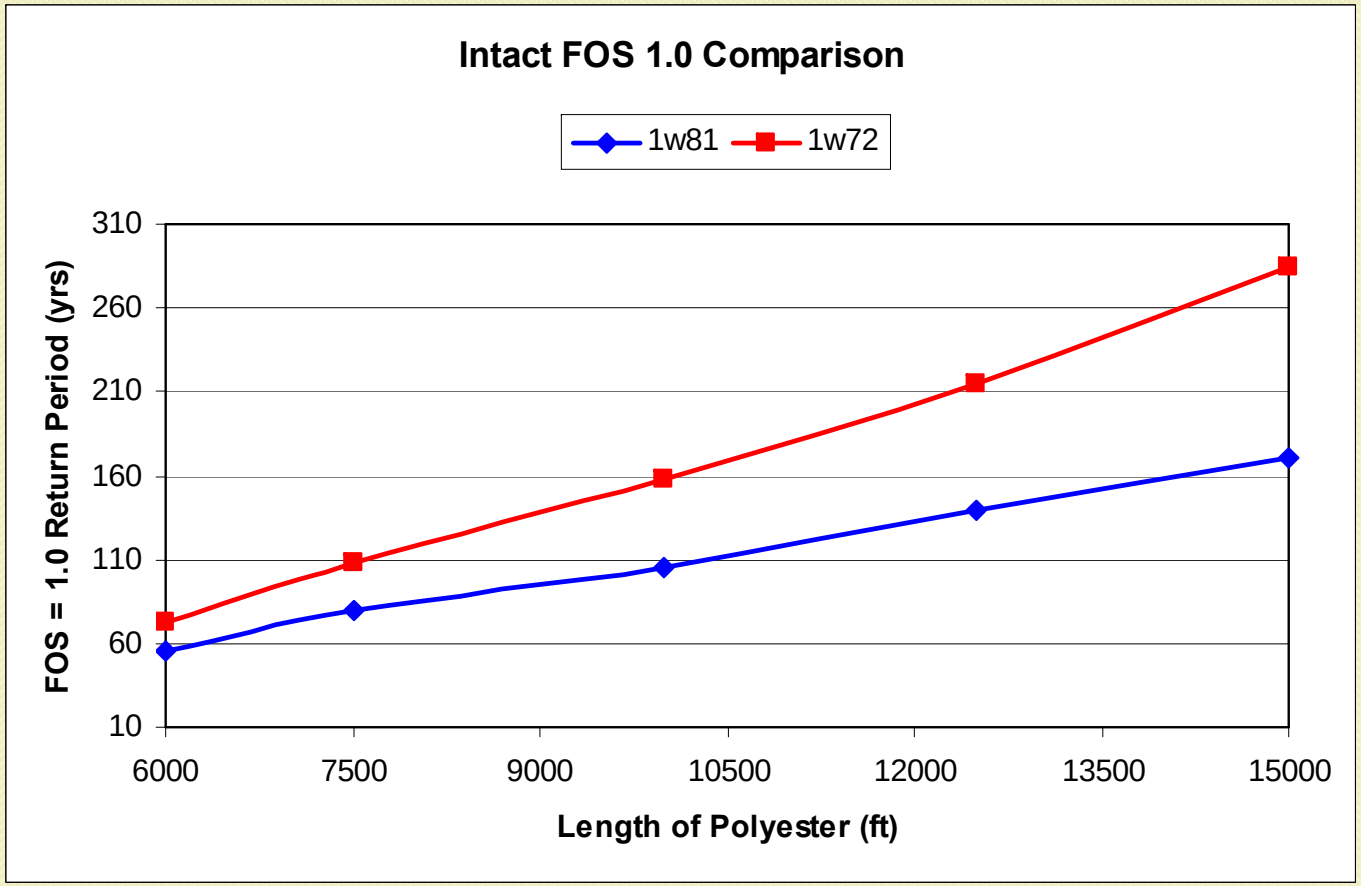
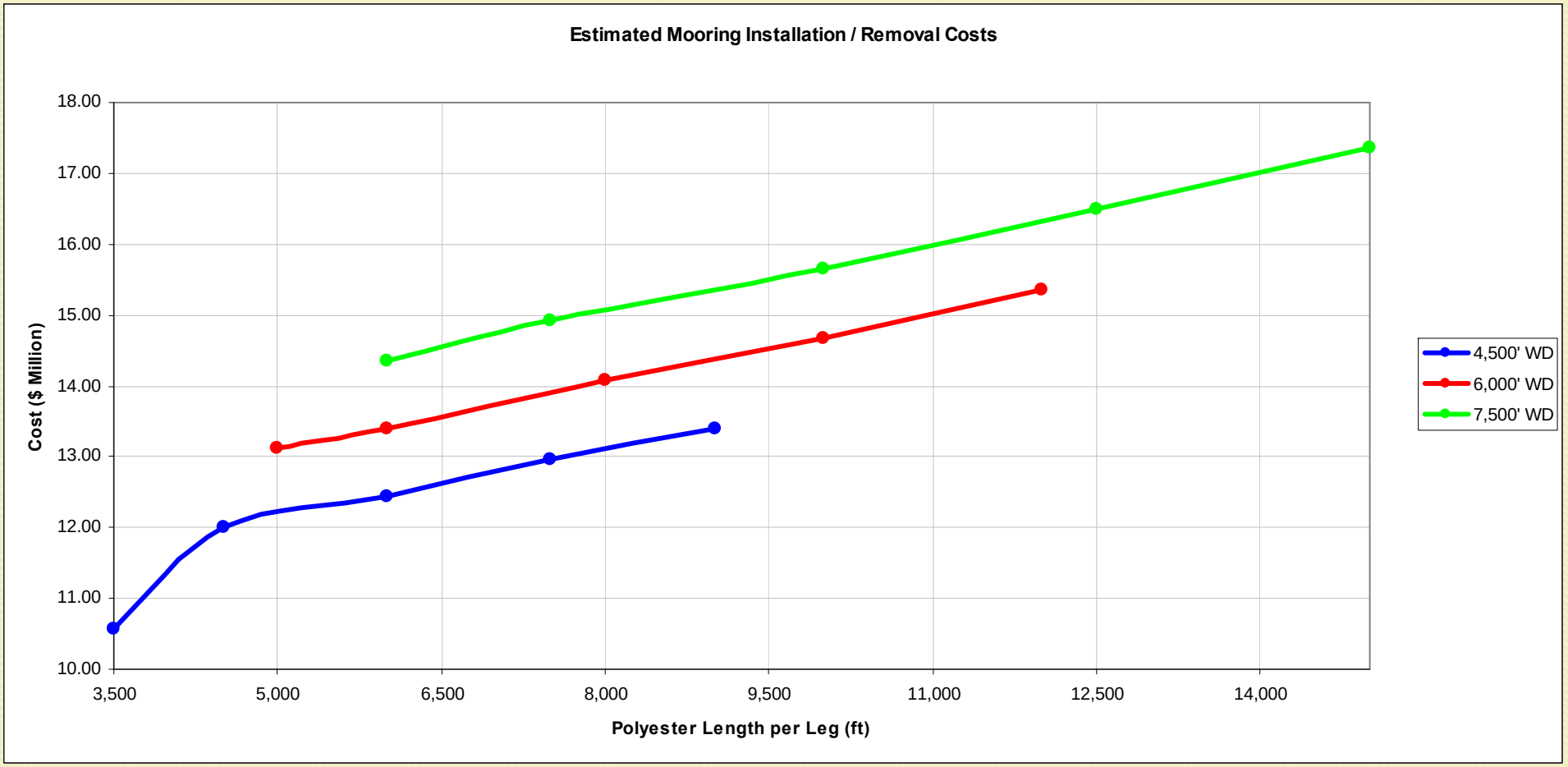


Mooring Cost Analysis

- Cost Assumptions:
  - Rig Rate of $500,000 per day
  - 1 large Tug at rate $192,000 per day
  - 1 large AHV at term rate of $80,000 per day
    - Can hold ~24,000’ of polyester + wires and anchors.
  - 1 Reel Boat Rate of $70,000 per day (when required)
    - Can hold ~36,000’ of polyester
  - Anchor handling crews with tools at $20,000 per day
  - 12 mooring lines
  - 60-day well

Mooring Cost Analysis

- Costs associated with moving the rig on and off location.

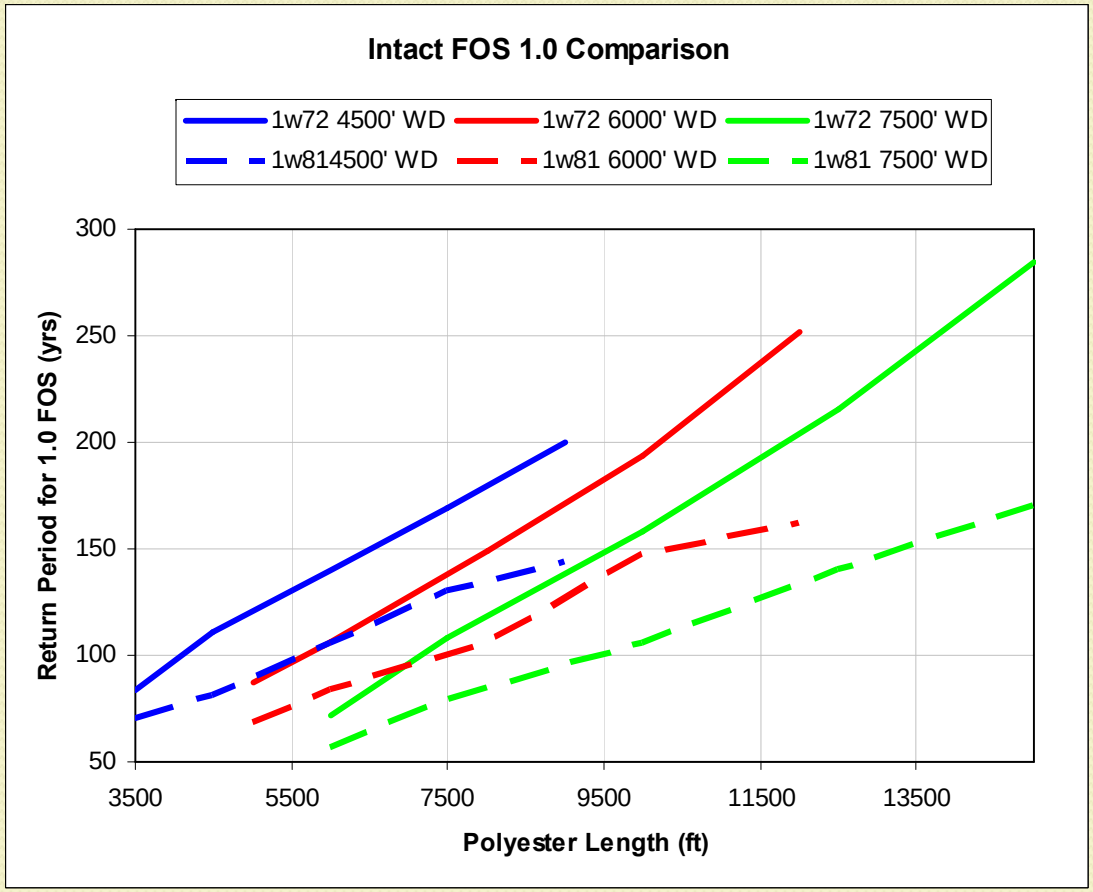


Mooring Cost Analysis

- Costs for moving the rig and rental while on location.

Conclusion

- **For the examined range, as water depths increase the benefit from more 1w72 polyester in the system also increases.**



Conclusion

- Assuming no rental savings from using less 1w72 with comparable return period vs. 1w81 (ie. 1w72 rope may be more expensive than 1w81 rope), there are still substantial potential savings:
  - Minimum estimated savings: $290,000 per well
  - Maximum estimated savings: $1,420,000 per well
  - Average estimated savings: $670,000 per well

Questions?