Anchors for Deepwater Mooring Planning & Installation

Expect Moor from a Leader.

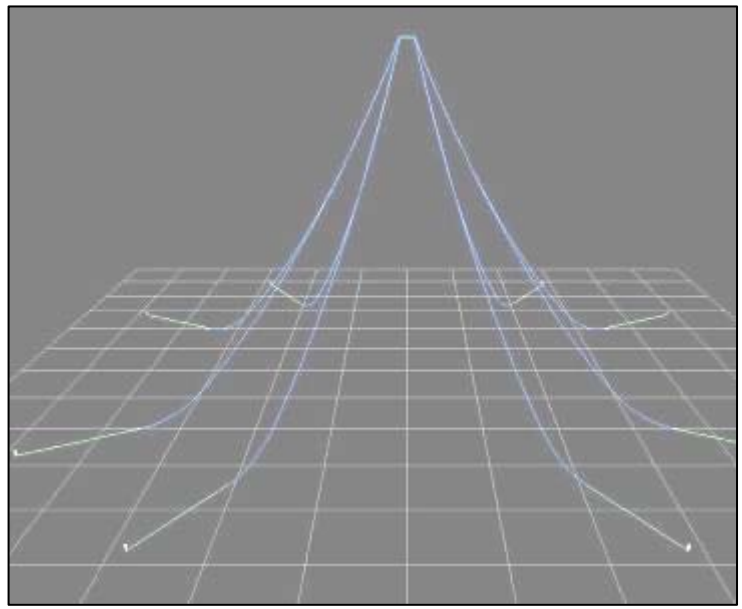
an ACTEON company

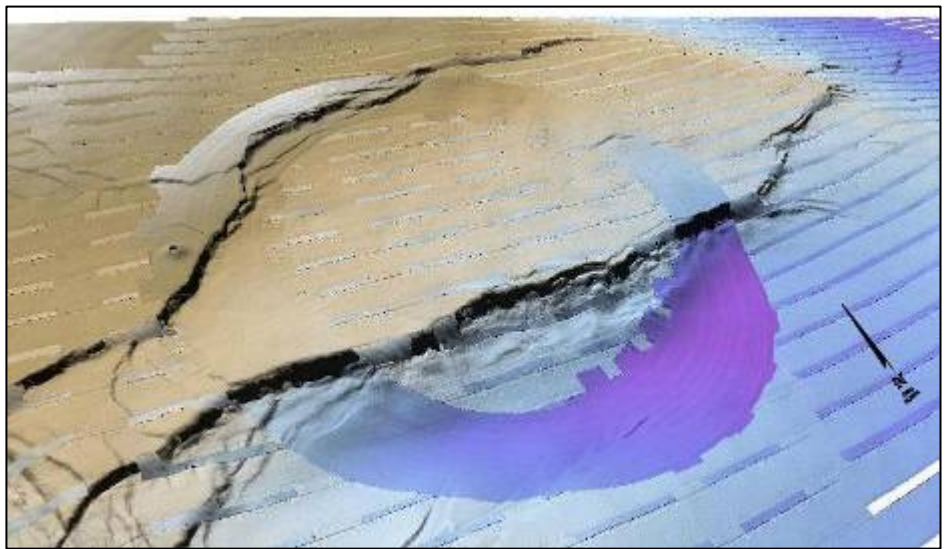
Presentation Overview

- **Jamie Armstrong:**
  - Planning deepwater mooring systems
  - Hazards & geophysical surveys
  - Design for GOM hurricane season
  - Installation calculations
  - Mooring system approval
  - Example field layout
- Bob Wilde:
  - Geotechnical investigation
  - Anchor types and associated seafloor footprint
  - Anchor installation simulations

Planning Deepwater Mooring Systems

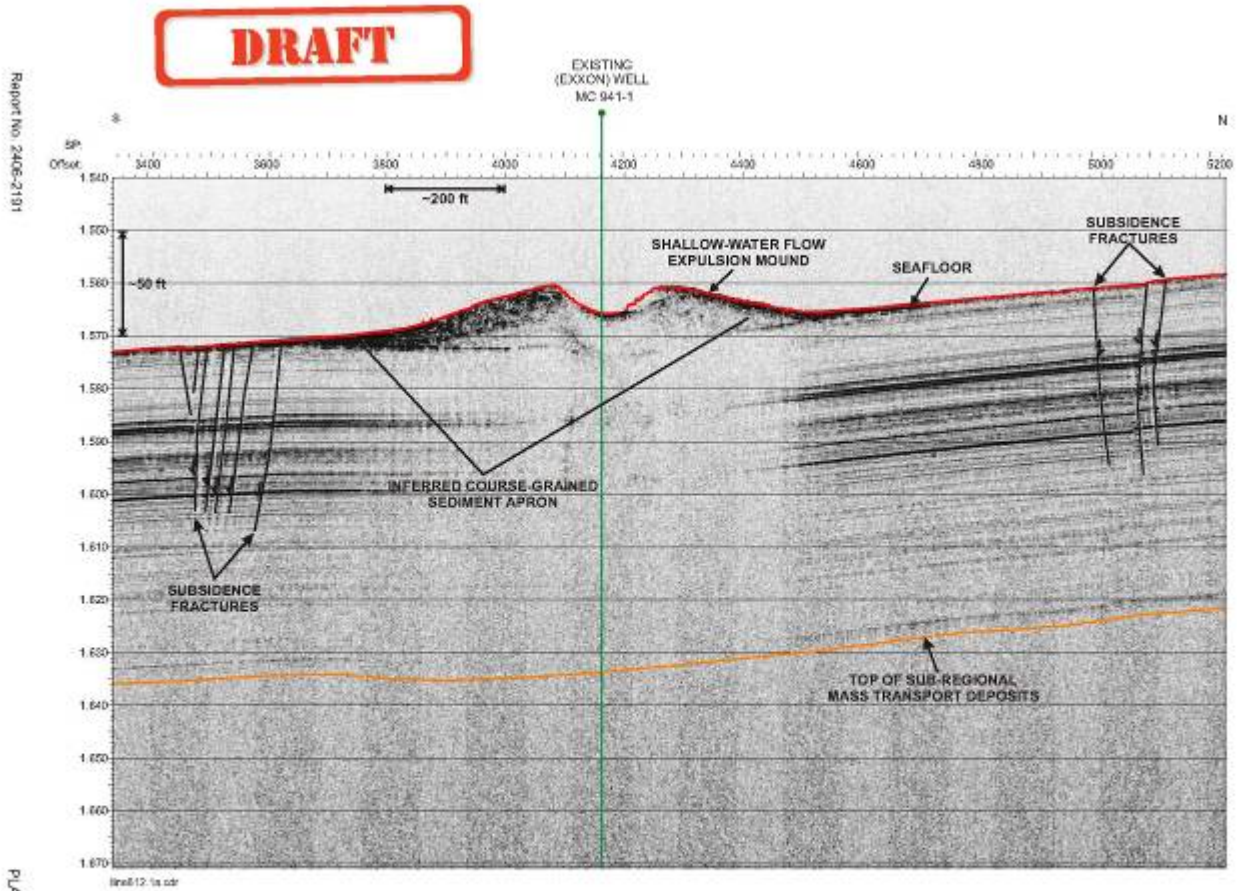
- Hazards & Geophysical Survey
  - Shallow Faults/Hazards
  - Gas Seeps/Shallow Gas
  - Slump Sediments
  - Shallow Water Flows
  - Hydrates
  - Soil Borings
  - Archeological Sites
  - Field Infrastructure





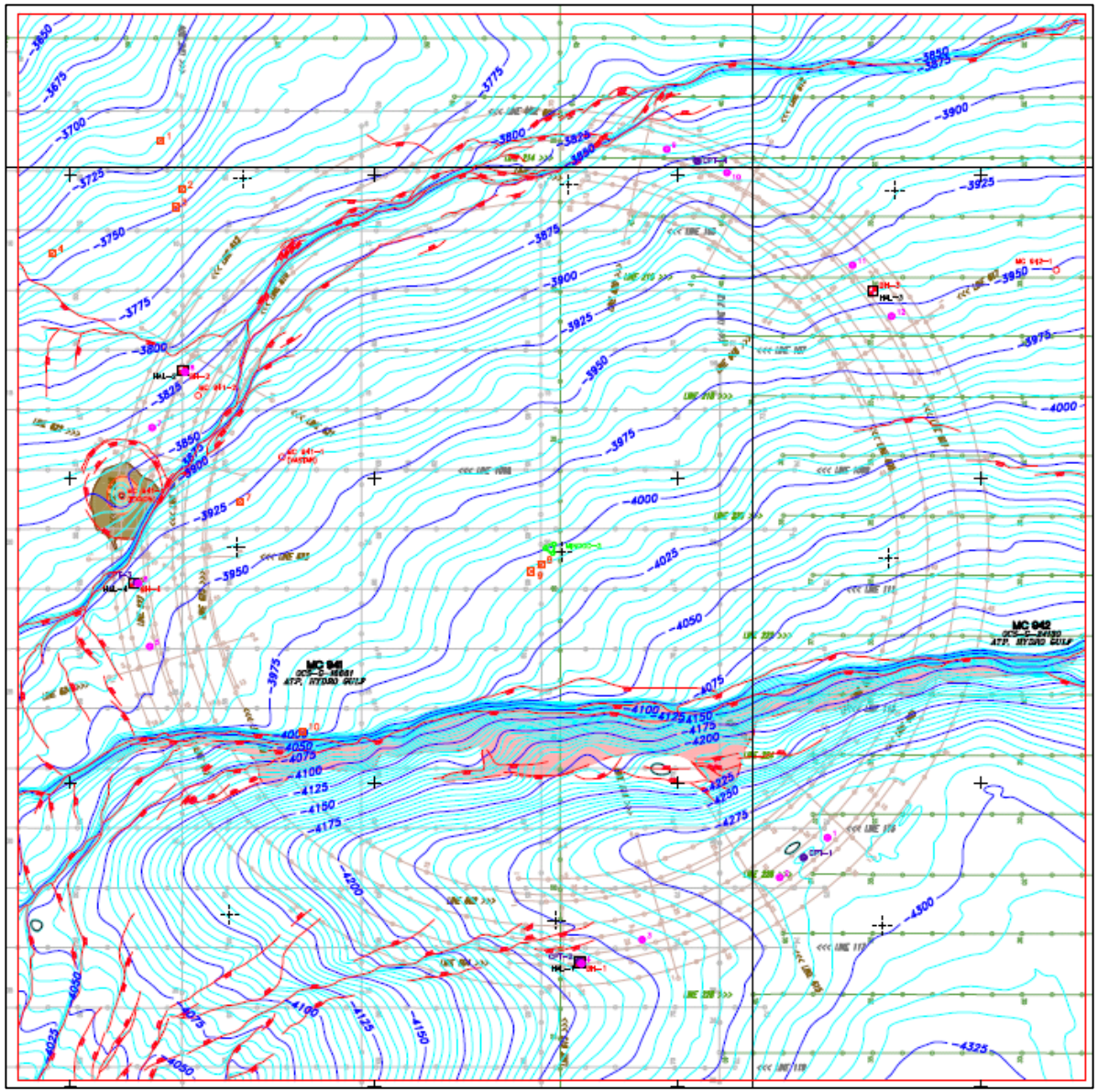
Geophysical Analysis

AUV Sub-bottom Profile



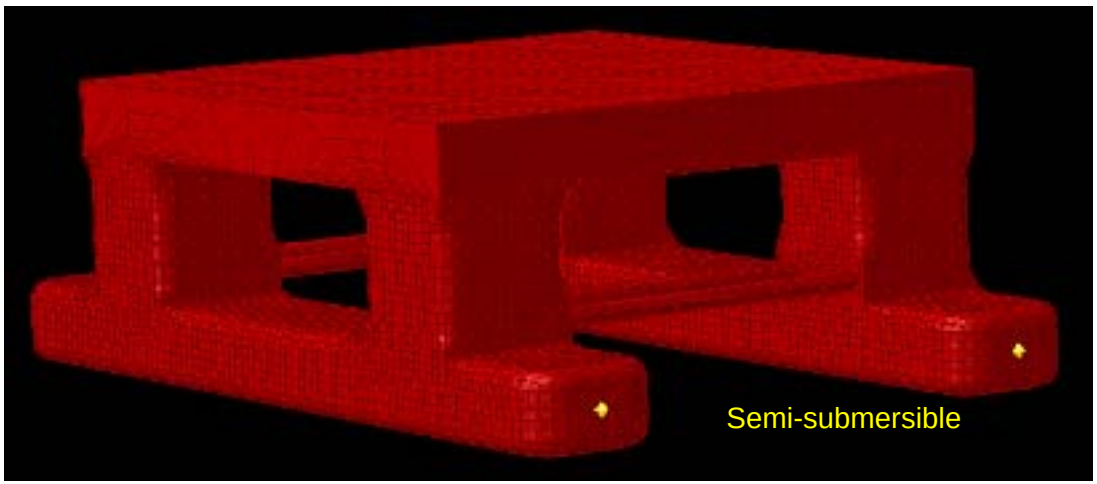
PORTION OF SUBBOTTOM PROFILE LINE 612.1 SHOWING SHALLOW-WATER FLOW MOUND
MIRAGE DEVELOPMENT, MISSISSIPPI CANYON BLOCK 941

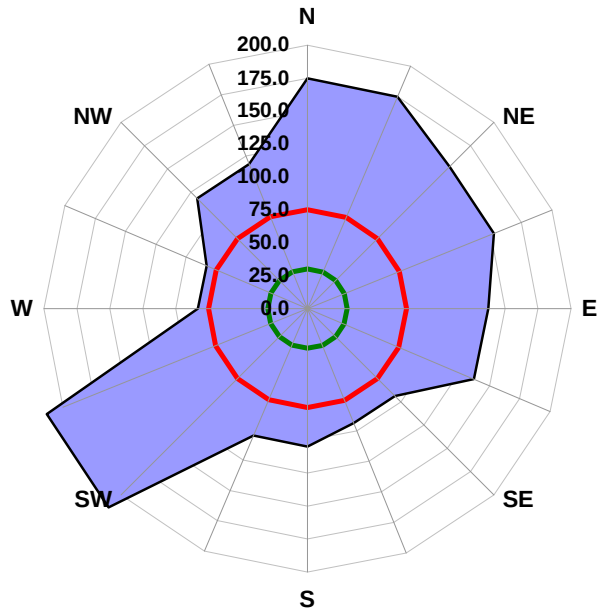
Planning Deepwater Mooring Systems



Design for GOM Hurricane Season

- **New Hurricane Mooring Environmental Criteria (API 2INT-MET & Site Specific)**
- **New API Guidance (API RP 2SK Hurricane Design Commentary – *Appendix K*)**
- **New MMS Approval Process Requires an Understanding of the *Risk***
- **Requirement for Mooring Analysis to Estimate *Probability of Failure***
- **Requirement for Consequence Analysis to Estimate *Consequence of Failure***

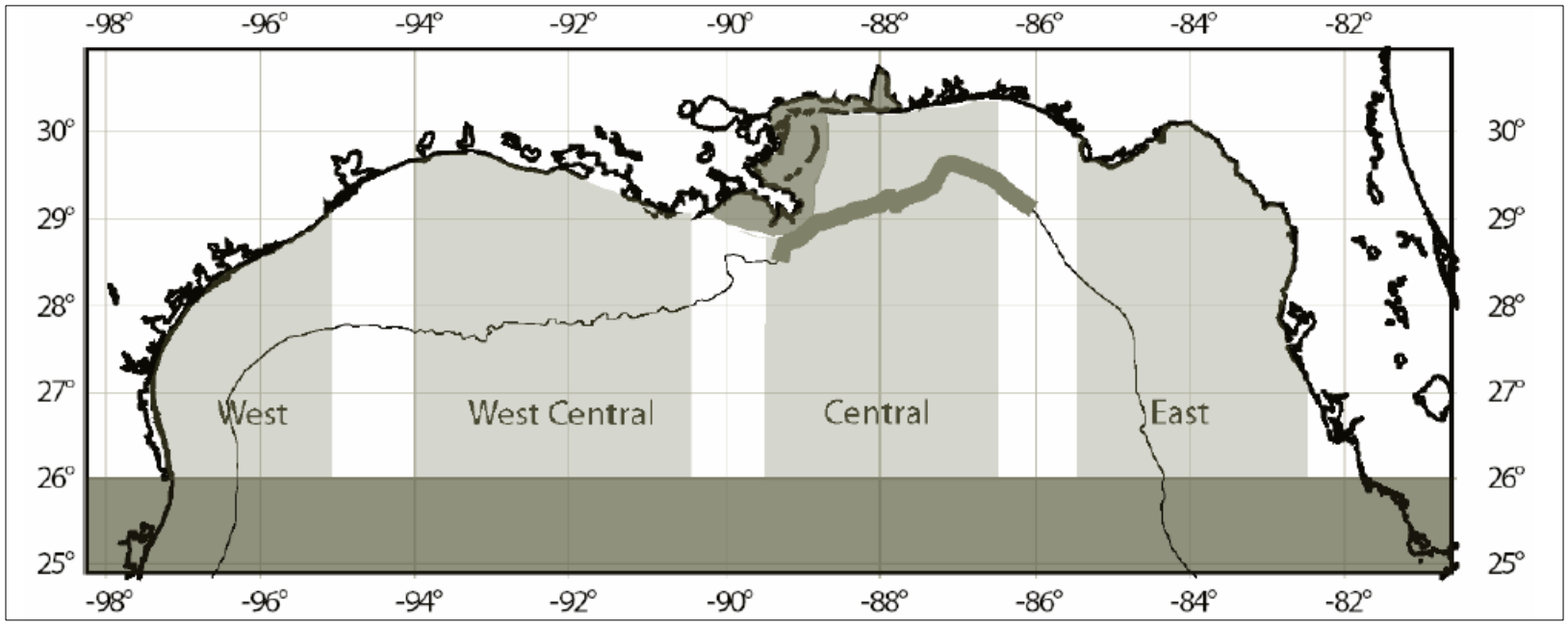




Design for GOM Hurricane Season

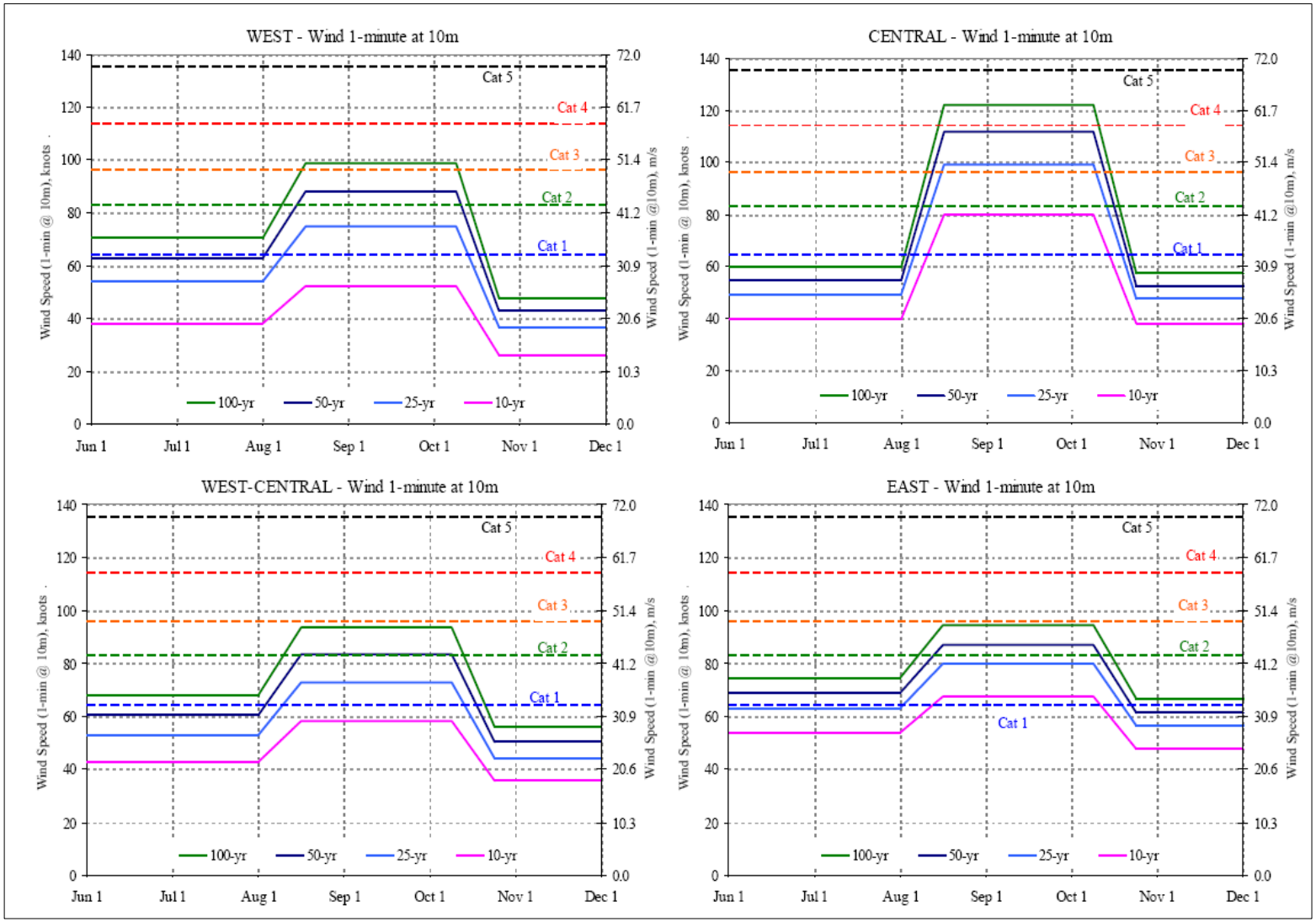
Regionally & Seasonally Varying Metocean Data

- West: 97.5°W to 95°W
- West-Central: 94°W to 90.5°W
- Central: 89.5°W to 86.5°W
- East: 85.5°W to 82.5°W



Design for GOM Hurricane Season

Regionally & Seasonally Varying Metocean Data



Design for GOM Hurricane Season

MODU Mooring Strength and Reliability Joint Industry Project
Location-Specific Consequence Assessment Worksheet (Based on API RP2SK Commentary)

Results

Assessment Results

Block Area	**Garden Banks**
Rig Name:	**Ocean Victory**
Operator:	**Callon Petroleum**
Location Name:	**Garden Banks 782-Well #2**
OCS Designation:	**0**
Water Depth at Wellsite	**4,523**
Rig Heading	**355**
Latitude:	**0**
Longitude:	**0**
UTM-N (Grid):	**9,881,098.00**
UTM-E (Grid):	**1,873,738.00**

Anchors: **Normal-loaded plate anchor (VLA)**
Sea Floor Component: **Wire at the Anchor**

Overall Summary of Results (Summed over all Octants)

Component	Value	
Near Surface	6.50	6.5 =Block Area Component
$Surface_{dist}$	62.59	
Near Subsea	0.64	0.6 =Block Area Component
$Pipelines_{dist}$	7.96	
$Wells_{dist}$	0.20	
Total Combined Likelihood Modified Consequence Factor	**77.89**	

Expected Ranges:
0 to 30 Low
30 to 75 Medium
Over 75 High

Are JIP Factor Values used throughout? **Yes**

Consequence Values corrected so that Worst Octant matches Combined Factor:

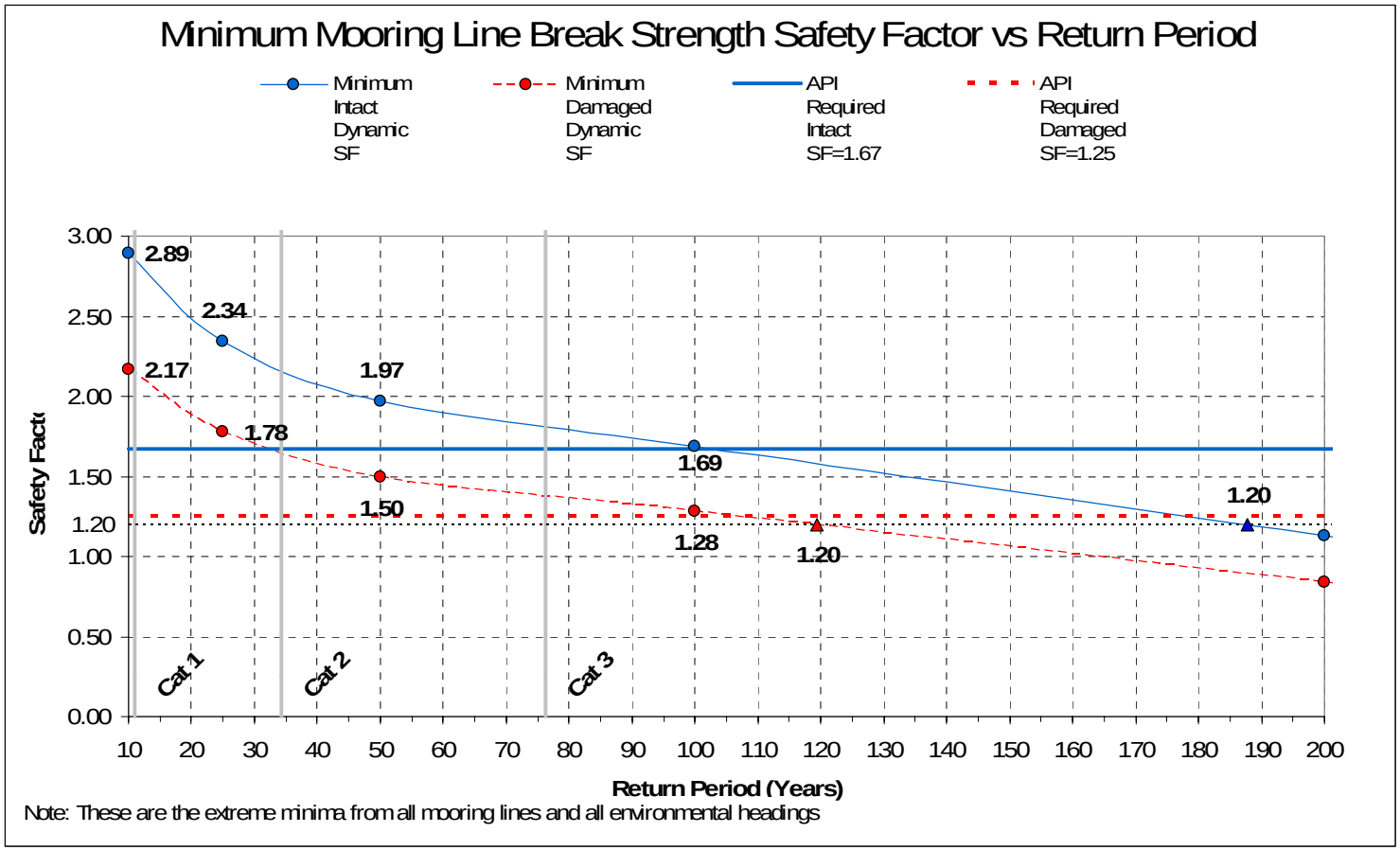
	N	NE	E	SE	S	SW	W	NW
Near Surface	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$Surface_{dist}$	0.0	0.0	75.0	0.0	0.0	0.0	0.0	0.0
Near Subsea	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$Pipelines_{dist}$	1.8	1.8	1.8	0.0	0.0	0.0	0.0	4.2
$Wells_{dist}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ΣSubsea	1.9	1.9	1.9	0.1	0.1	0.1	0.1	4.4
ΣSurface	1.0	1.0	76.0	1.0	1.0	1.0	1.0	1.0
Corrected Totals	**2.9**	**2.9**	**77.9**	**1.1**	**1.1**	**1.1**	**1.1**	**5.4**

Which produces worst results, Directional or Random Drift data? **Random**

The values in the table are corrected to represent the value for the relevant octant as if there was a 100% certainty that should the MODU break adrift it WILL drift in that relevant octant, but then factored so that the maximum value given as "Total Combined Likelihood Modified Consequence Factor" is aligned with the worst direction. Hence each octant is assigned the full near surface and subsurface values, plus the distant values for that octant multiplied by 8, but then reduced by a ratio to ensure the worst octant value is correct. It is for this reason that the numbers will not be the same as the obvious source of the data.

Design for GOM Hurricane Season

Estimate Probability of Failure for Mooring Lines



Installation Calculations

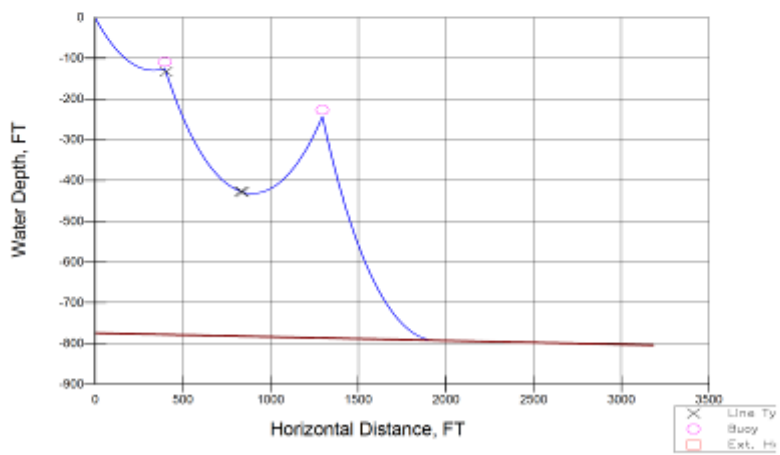
QMoor 95
Copyright 1996-2005, InterMoor Inc

09/14/05 14:46:10 Run Reference	POGO - Ocean Concord @ EW948 - Hurricane Leg Hookup - 195 ft Rig Offset - Line 11 - 23 deg Stern Angle

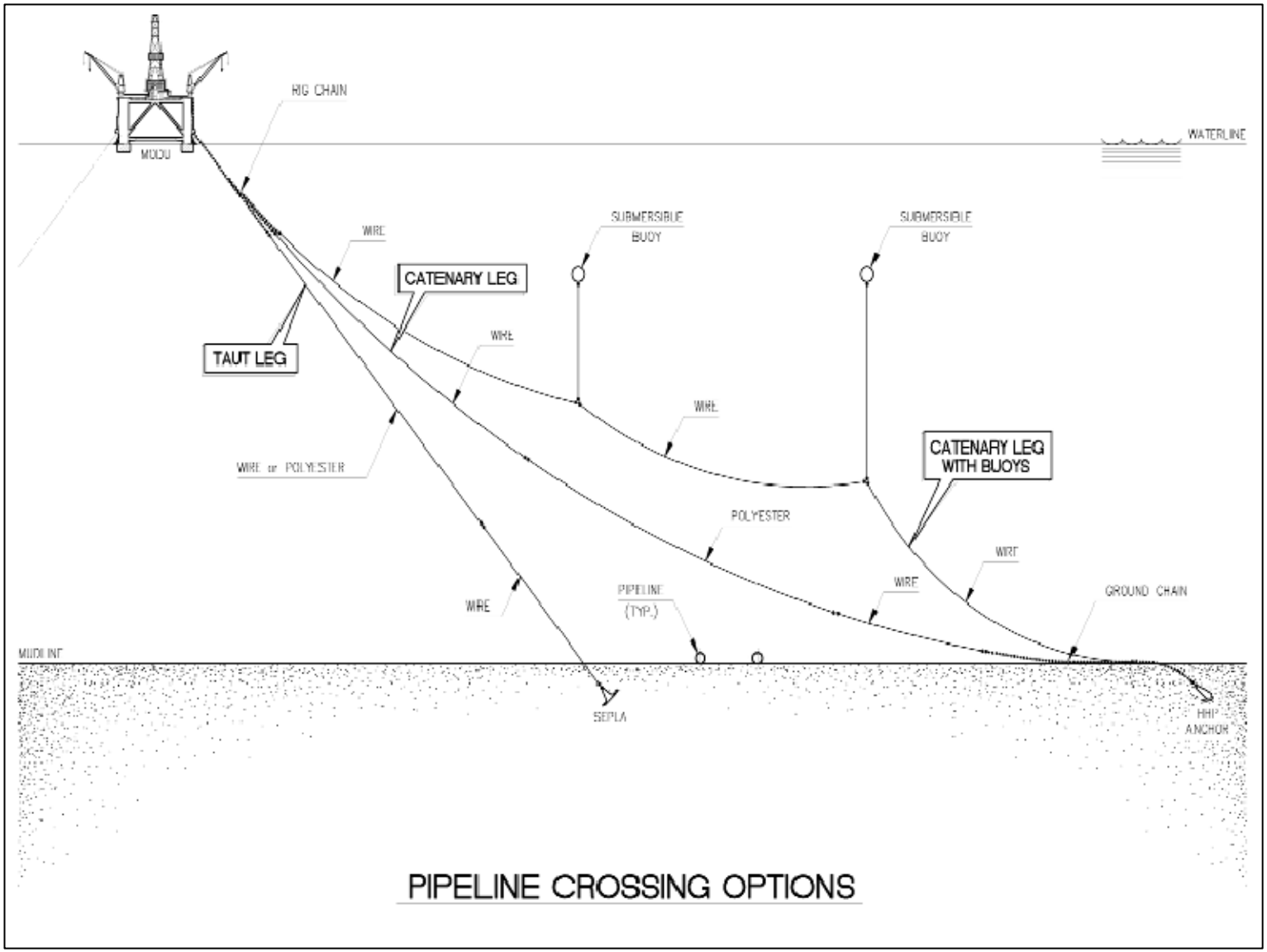
	Tension Kips	H Comp. Kips	V Comp. Kips	Horizontal Distance Total Ft.	Horizontal Distance to TD Ft.	Ground Length Ft.	Elastic Stretch Ft.	Err. at TD Ft.	Engineer: klongridge Project Number: 10372 Line Properties File: LineProp.Dat
Fairlead	42.80	33.37	26.80	3179.74	1939.74	1250.06	0.83	0.00	Bathymetry File: Local.Bty
Anchor	0	0	0	Anchor Ang = 0		Fairlead Angle = 38.77			Saved File: Pogo - Ocean Concord @ EW948 - Hu

Element Number	1	2	3	4	5	6	7	8	9	10
Line Type Name	K4Chain	K4Chain	EPS+20%	K4Chain						
Diameter, in	3	3	3.50	3						
Length, ft	430	540	1	2650						
# of Segments	43	54	1	265						
Segment Length, ft	10	10	1	10						
B.S., kips	1356.69	1356.69	1353.60	1356.69						
Tension at Top of Seg., kips	42.80	55.88	33.69	33.69						
Safety Factor	31.70	24.28	40.18	40.27						
Unit Weight, lbf/ft (dry)	85.50	85.50	22.70	85.50						
Unit Weight, lbf/ft (wet)	74.39	74.39	18.84	74.39						
E, ksi	18565	18565	9604	18565						
Friction	1	1	0.60	1						
Buoy Number	1	2	3	4	5	6	7	8	9	10
Position from Fairlead, ft	430	1491								
Buoy(+)/Clump(-) Size, kips	50	100								
Buoy Depth, ft	-125.34	-243.31								
Horizontal Load Number	1	2	3	4	5	6	7	8	9	10
Position from Fairlead, ft										
Hor. Force Toward (+)/Away(-), kips										

Fairlead Depth, ft	0	Water Depth at Fairlead, ft	-775	Anchor Depth, ft	-804.57
Fairlead Offset, ft	0	Water Depth at Touchdown, ft	-793.04	Water Depth at Anchor, ft	-804.39

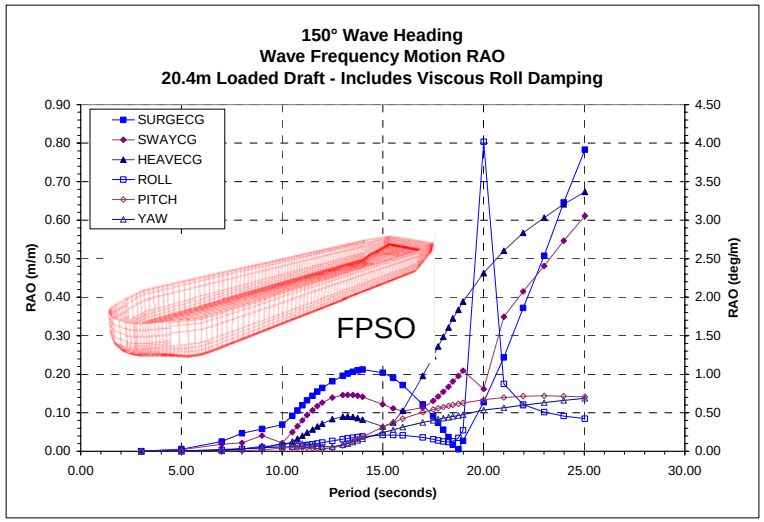


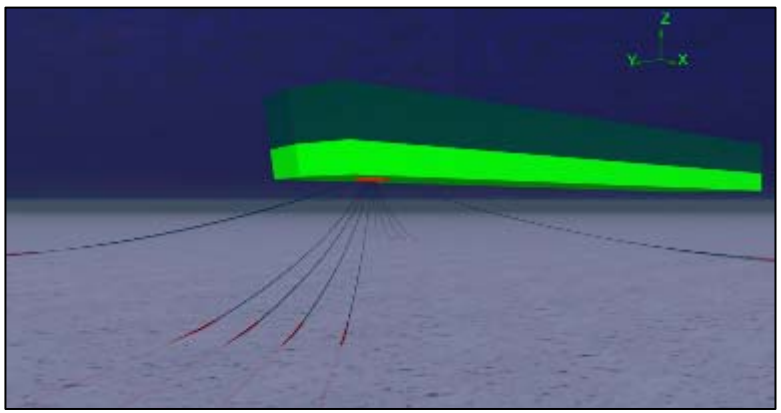
Potential Mooring Configurations

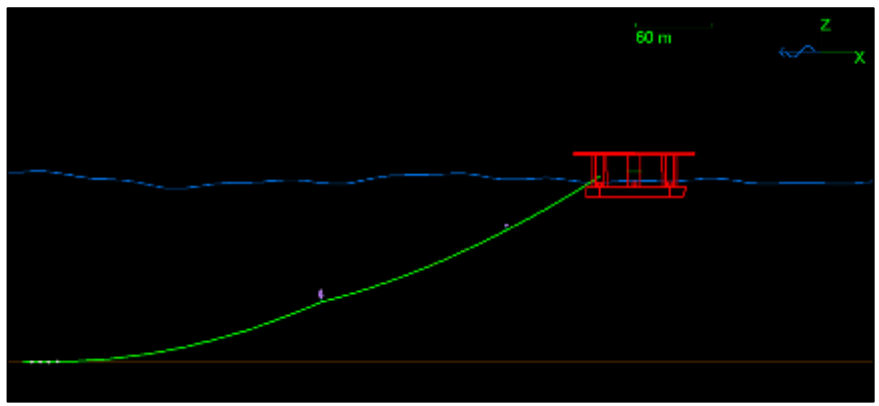


Mooring System Approval

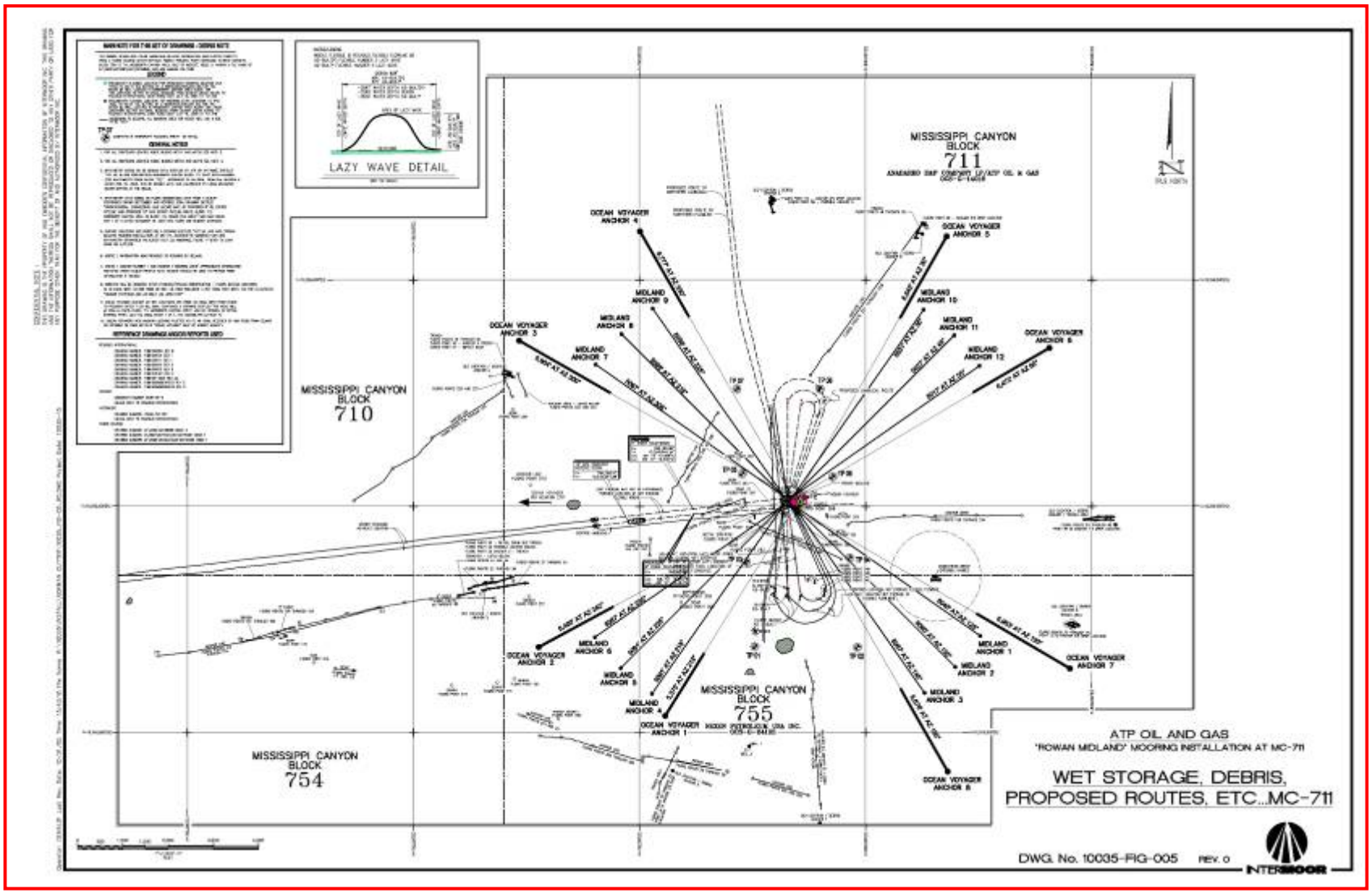
- **Requirement for Equipment Inspections to Validate their Capacity**
- **All above is rolled into InterMoor's MMS Submittal for Approval**
- **Requirement for "As-Built" Mooring Verification Analysis (*Proof that it works)***







Example Field Layout



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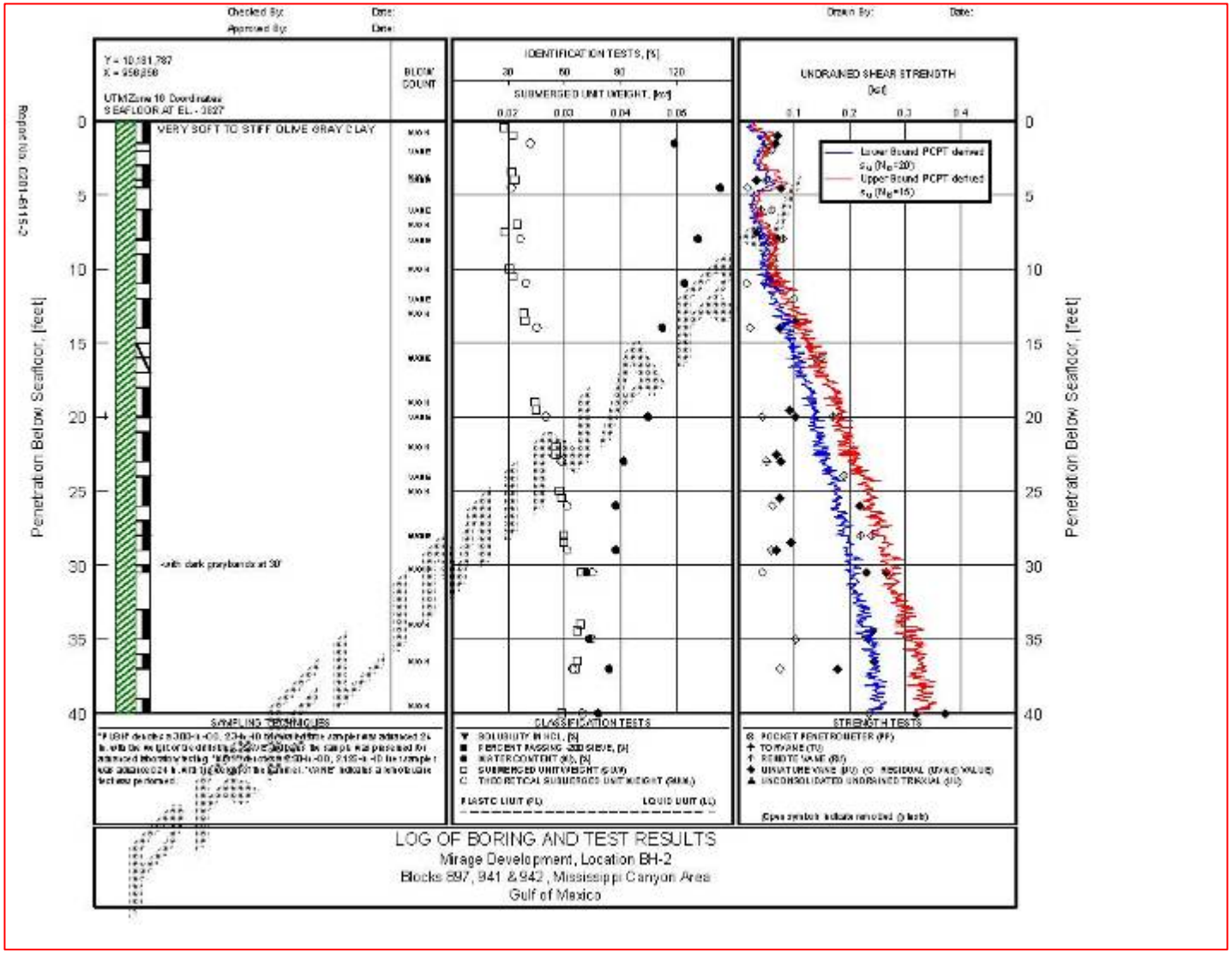
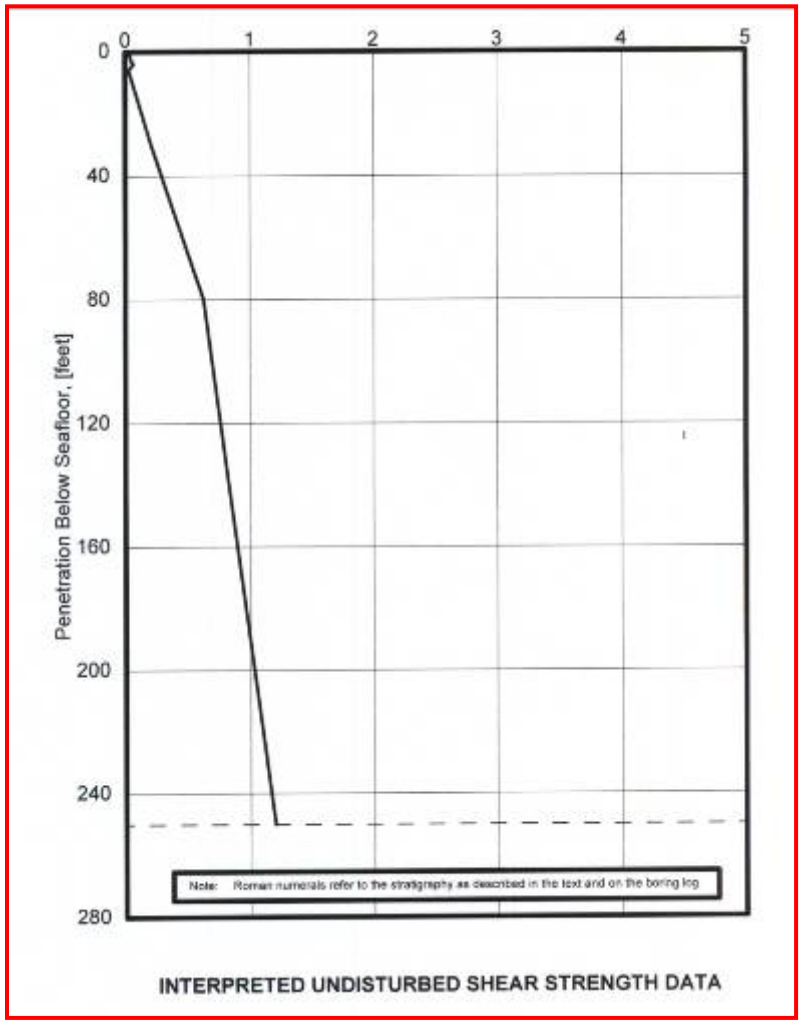
Geotechnical Analysis

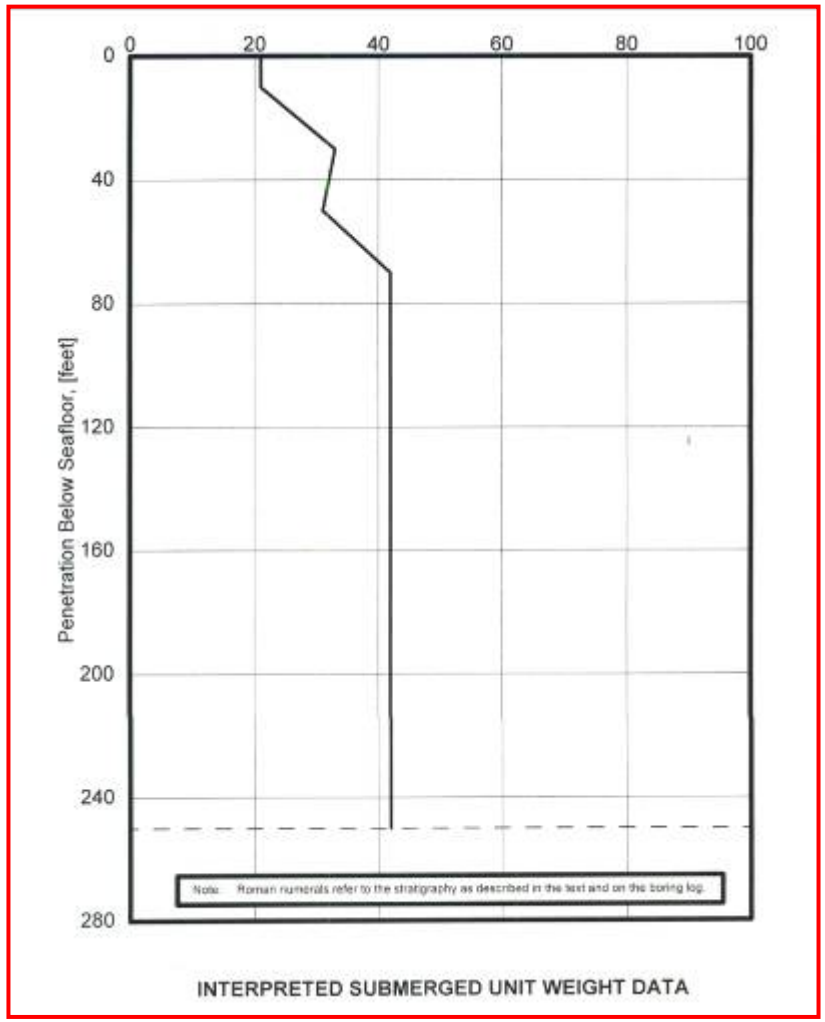
PCPT Test Data



Geotechnical Analysis



INTERPRETED UNDISTURBED SHEAR STRENGTH DATA



INTERPRETED SUBMERGED UNIT WEIGHT DATA

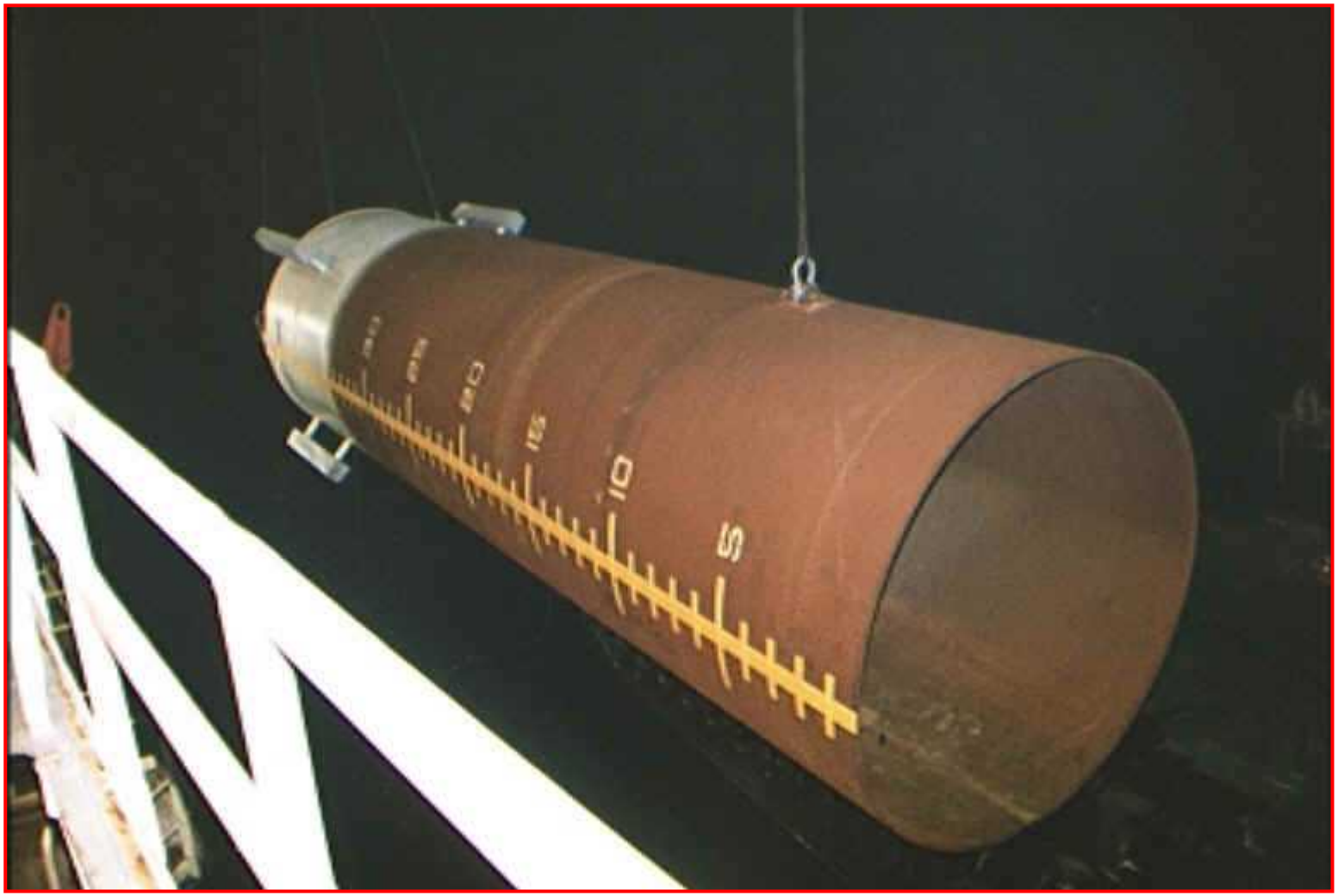
Suction Embedded Anchors

Red Hawk Suction Anchors

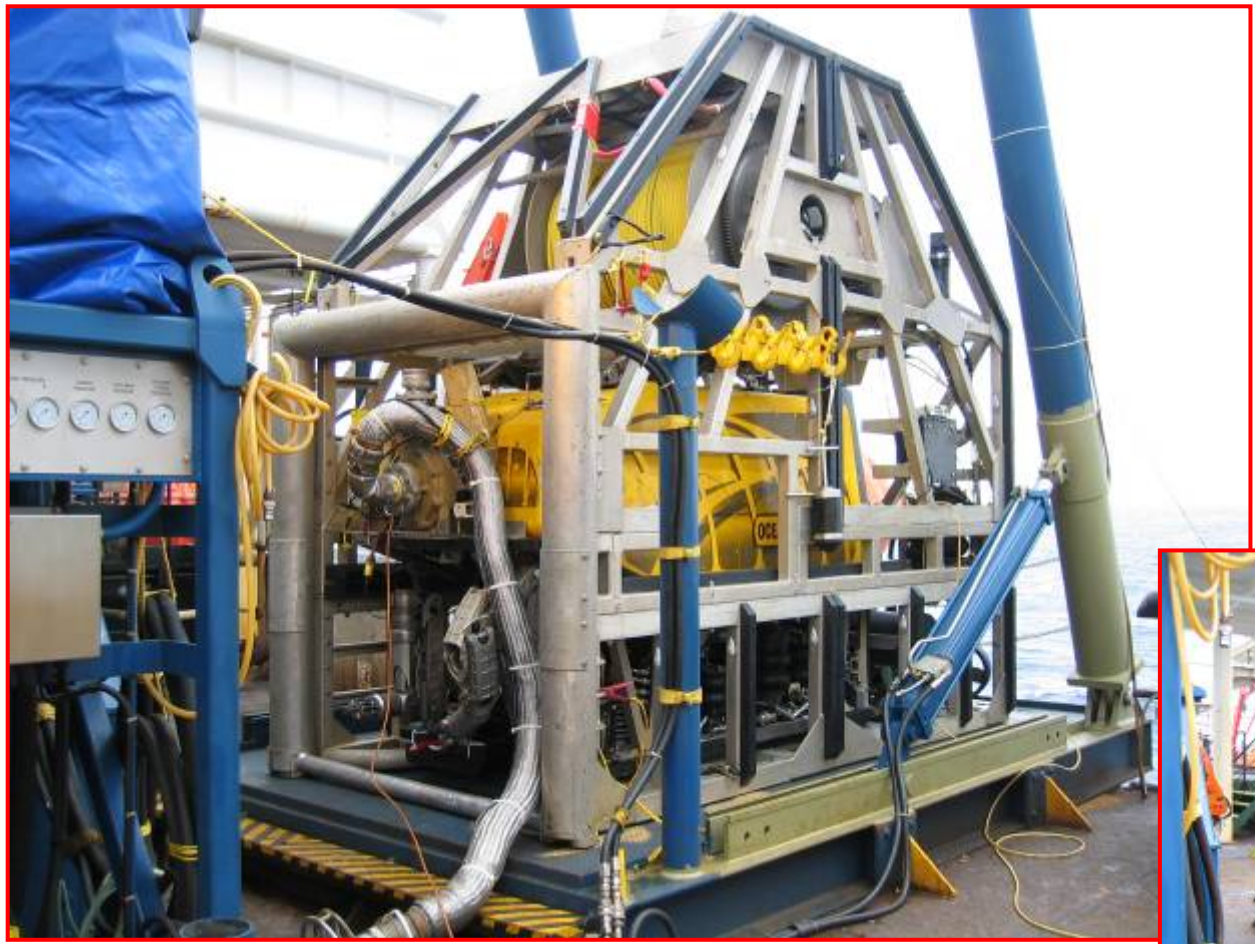
Thunder Horse PLET Anchors

Thunder Horse Manifold Piles

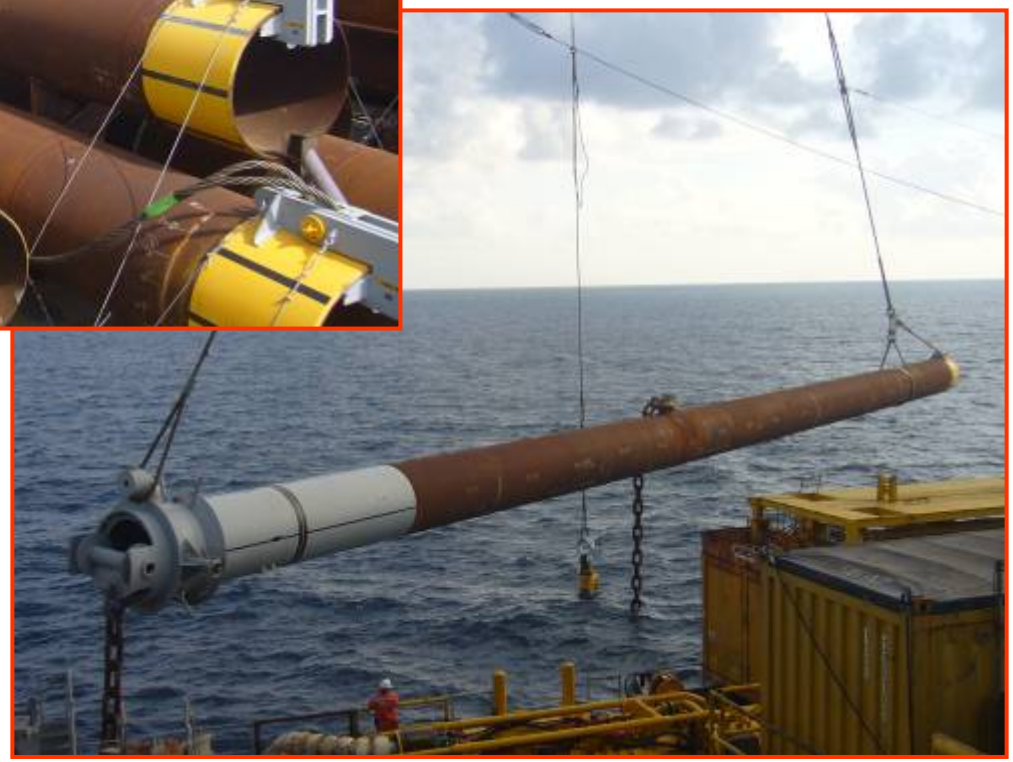
Pipeline Starter Anchors



ROV Interface



Driven Piles



Menck MHU-500C Hammer

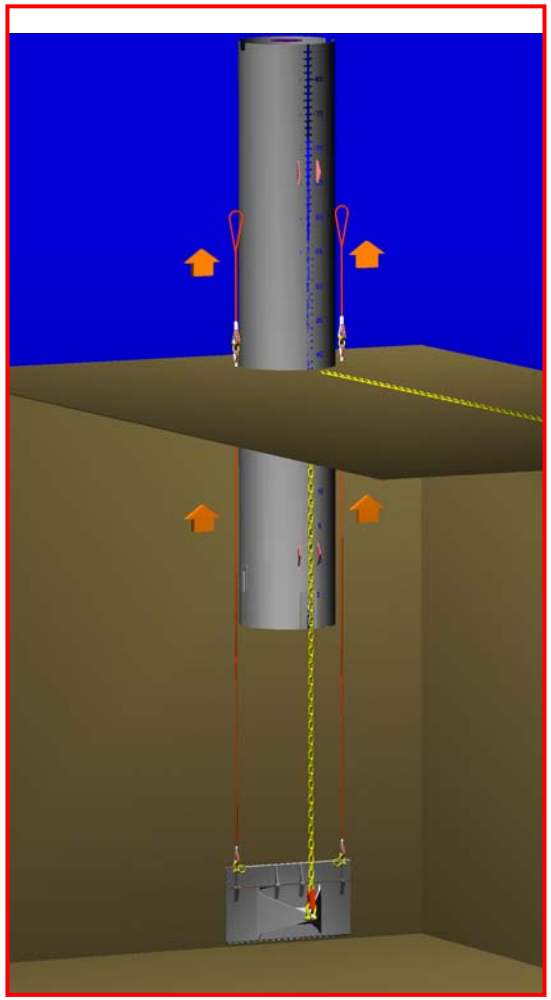
High Holding Power Drag Anchors

Drag Embedment

Plate Anchor Types

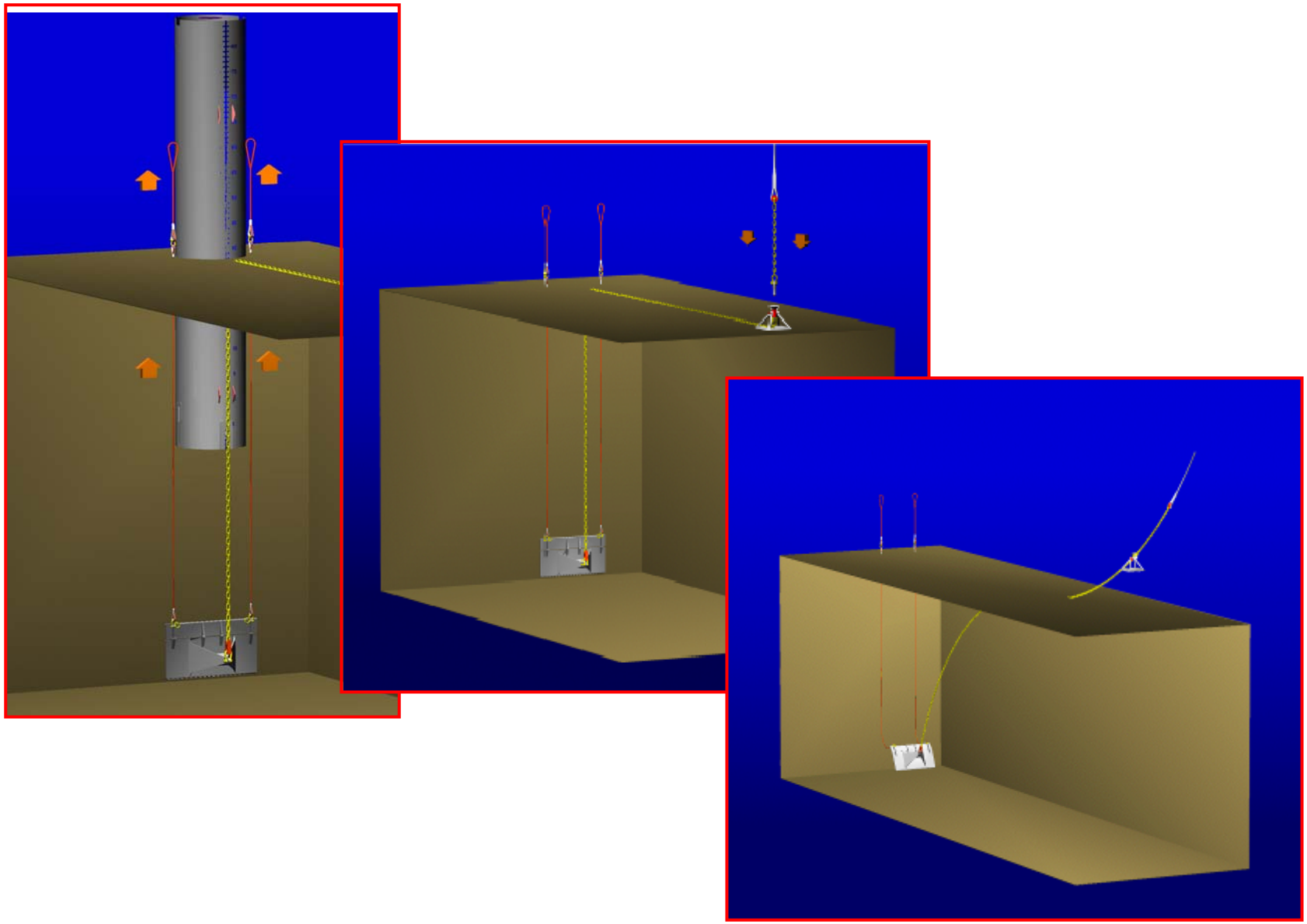
DRAG EMBEDMENT

DIRECT EMBEDMENT (SEPLA)

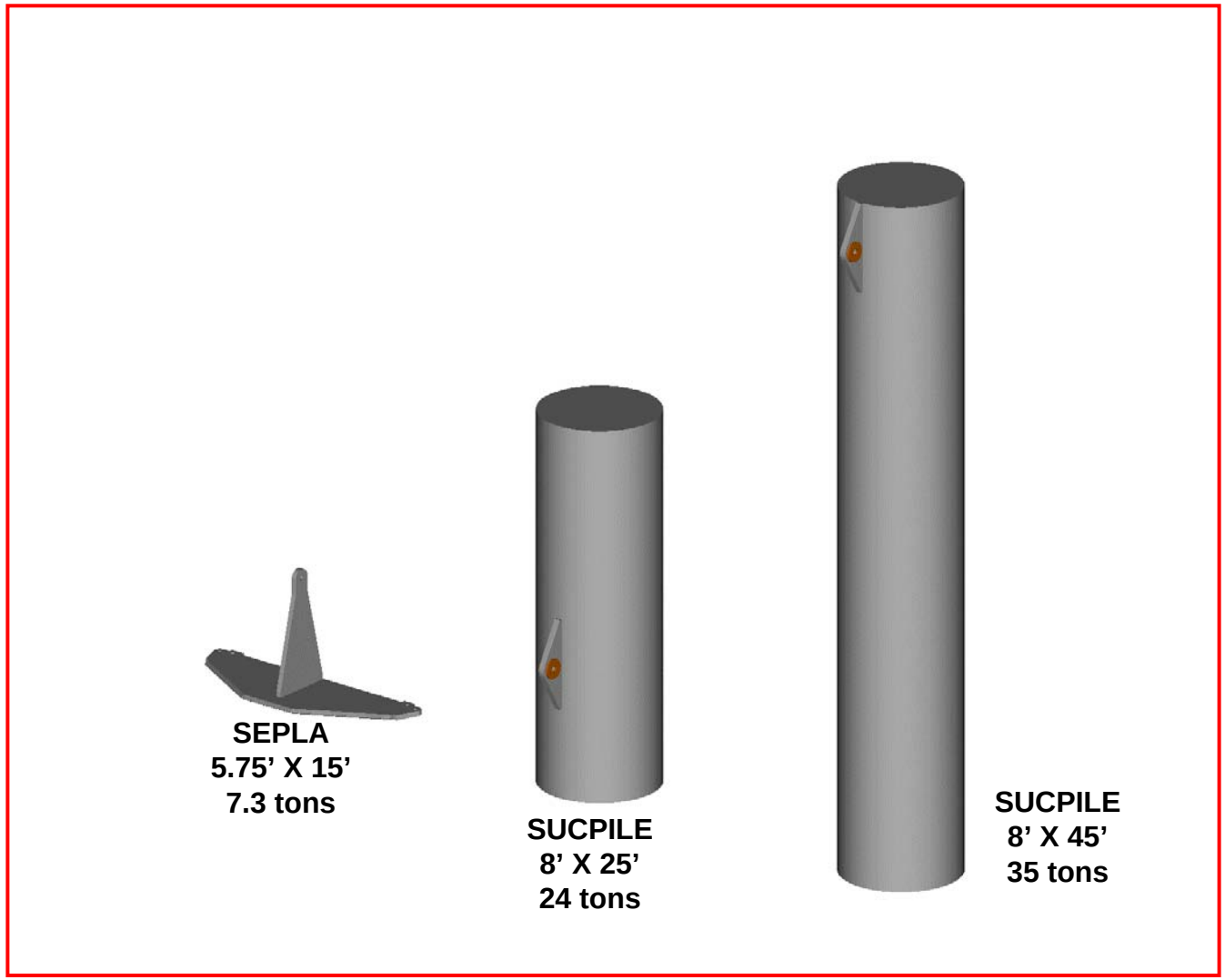


Follower + SEPLA Anchor

SEPLA Anchor

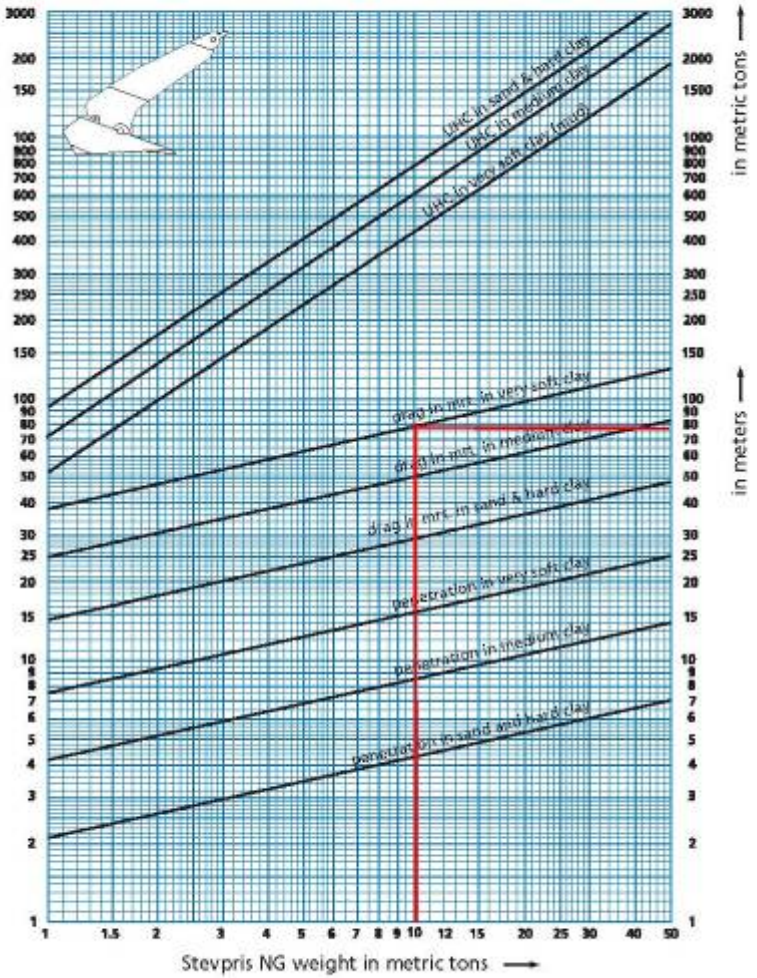


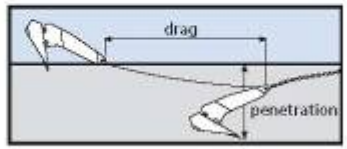
Suction Pile vs Plate Anchor



High Holding Power Drag Anchors

Stevpris New Generation UHC chart



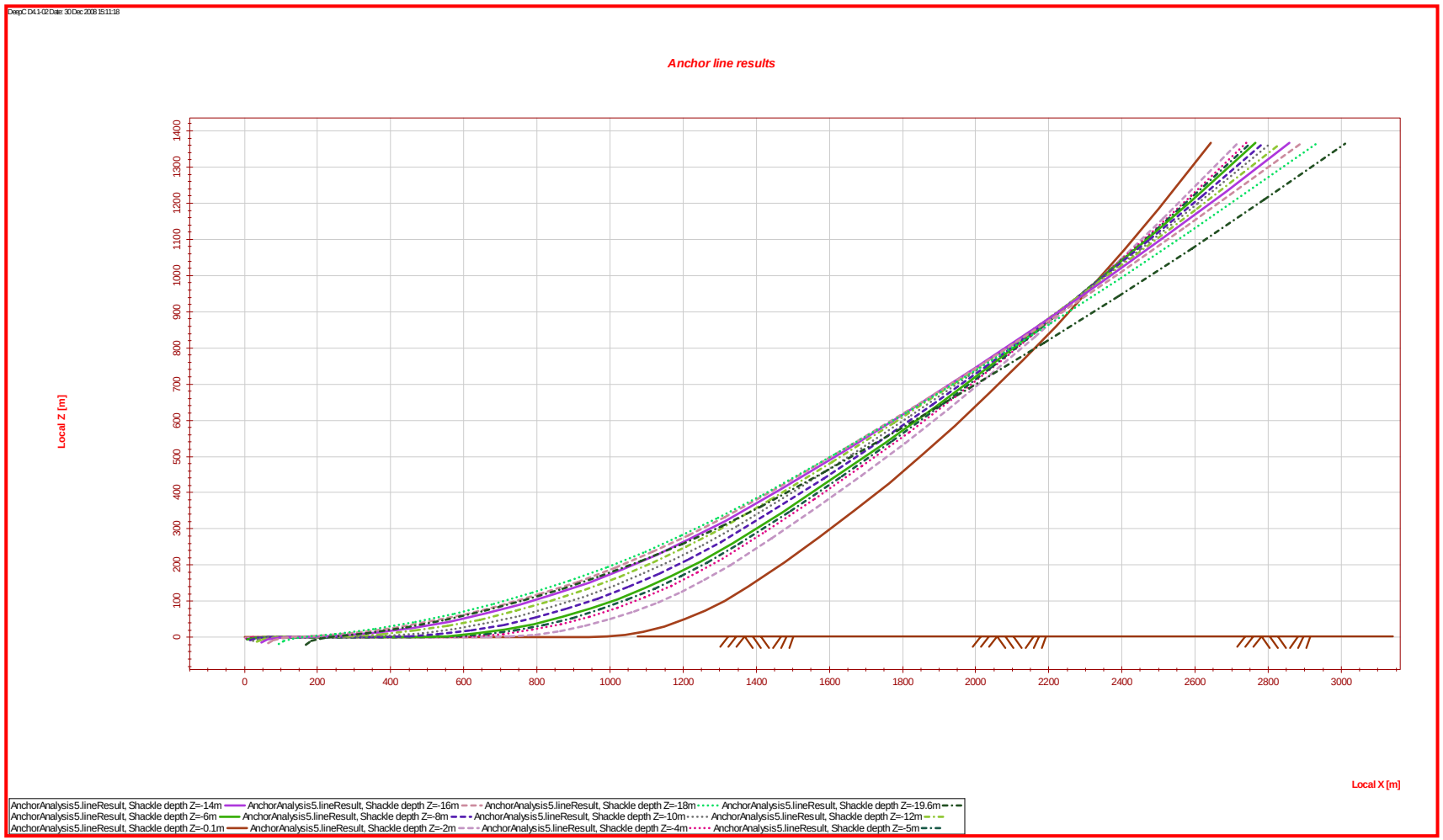


Example: loading 70% of ultimate holding capacity corresponds with 48% of maximum drag and 80% of maximum penetration at ultimate holding capacity.

anchor load as % of UHC	drag % max drag	penetration as % max penetration
70	48	80
60	37	68
50	27	55
40	18	42
30	9	23

Courtesy of Vryhof Anchors BV

High Holding Power Drag Anchors



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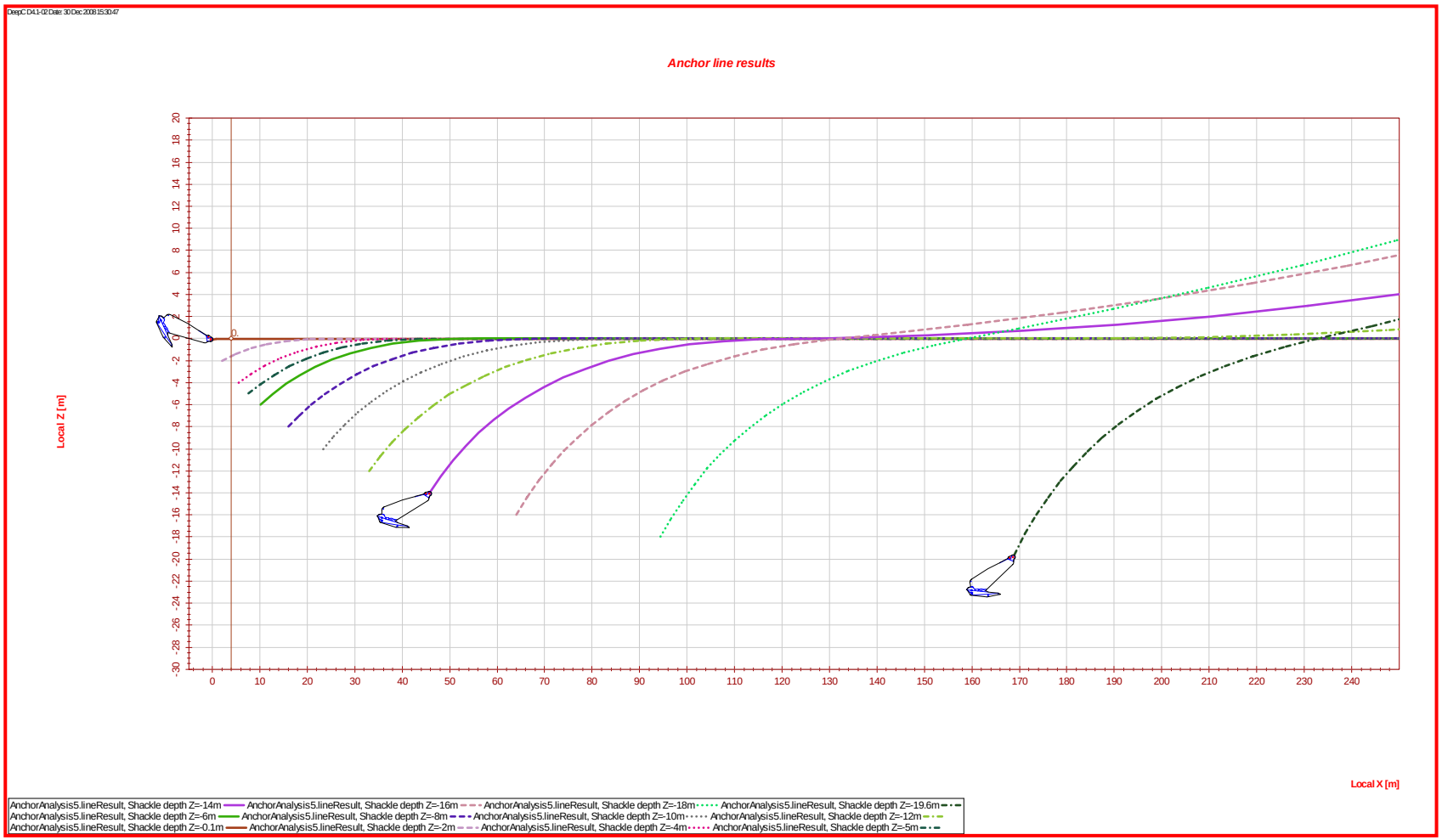
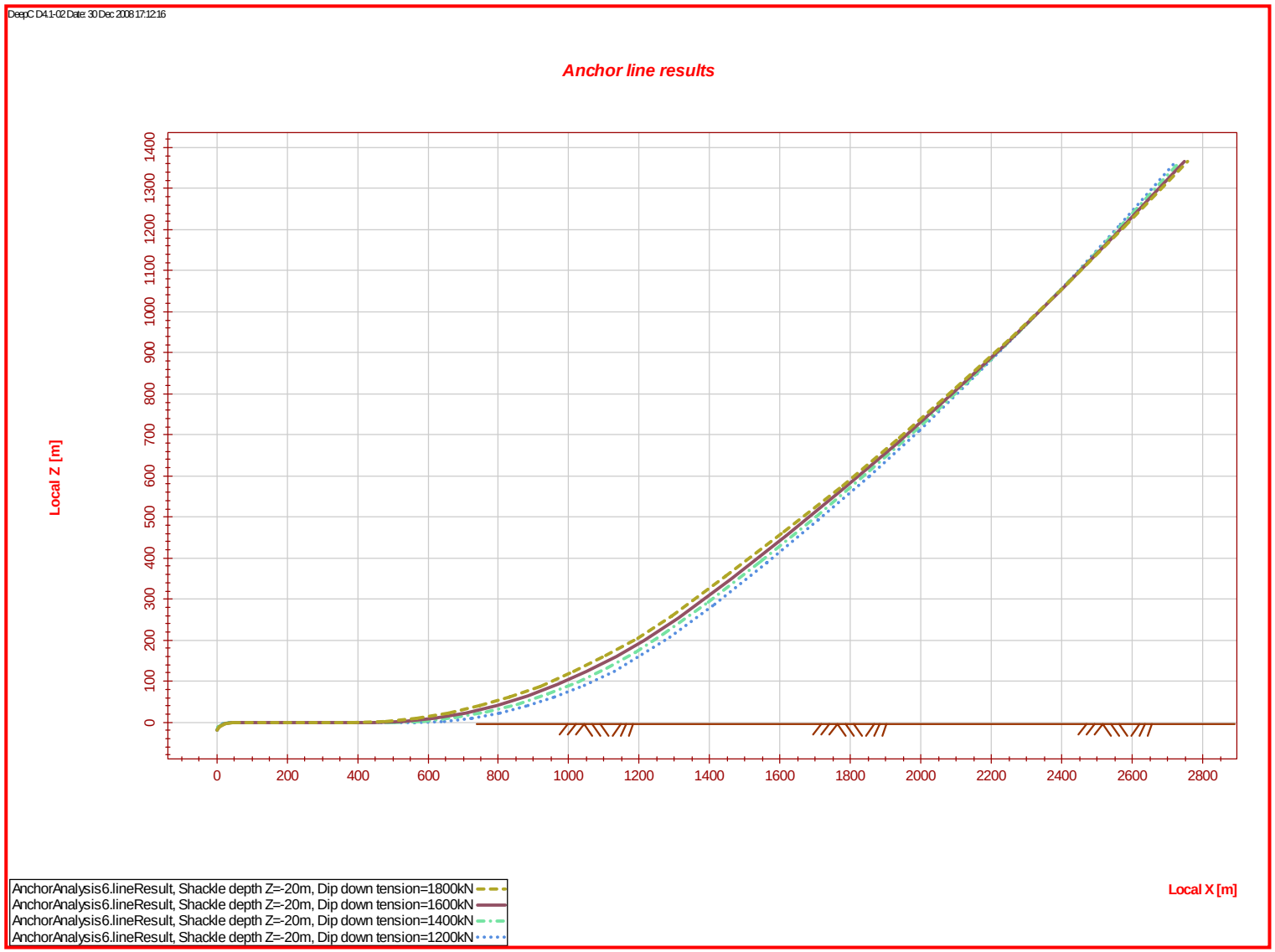
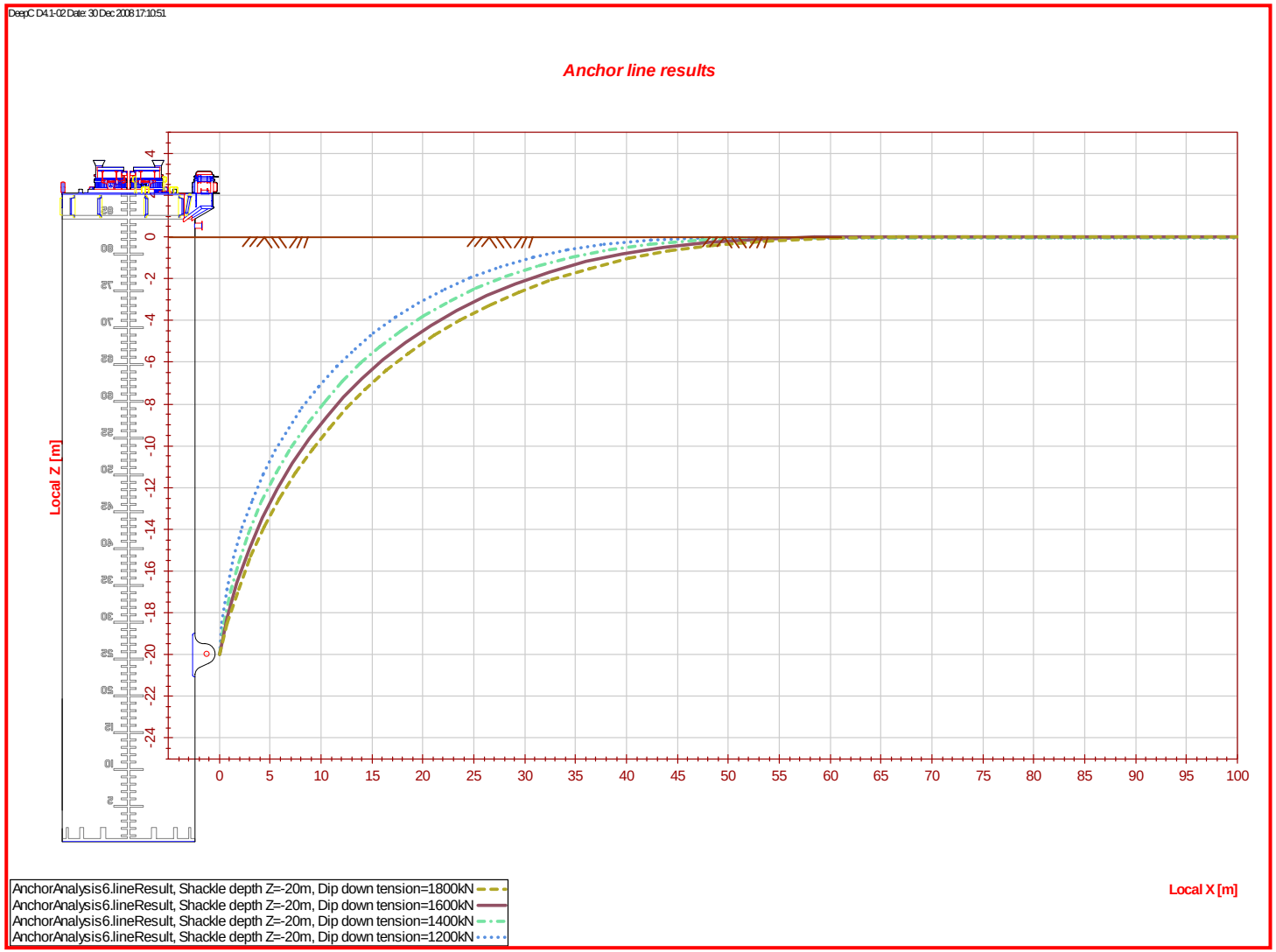


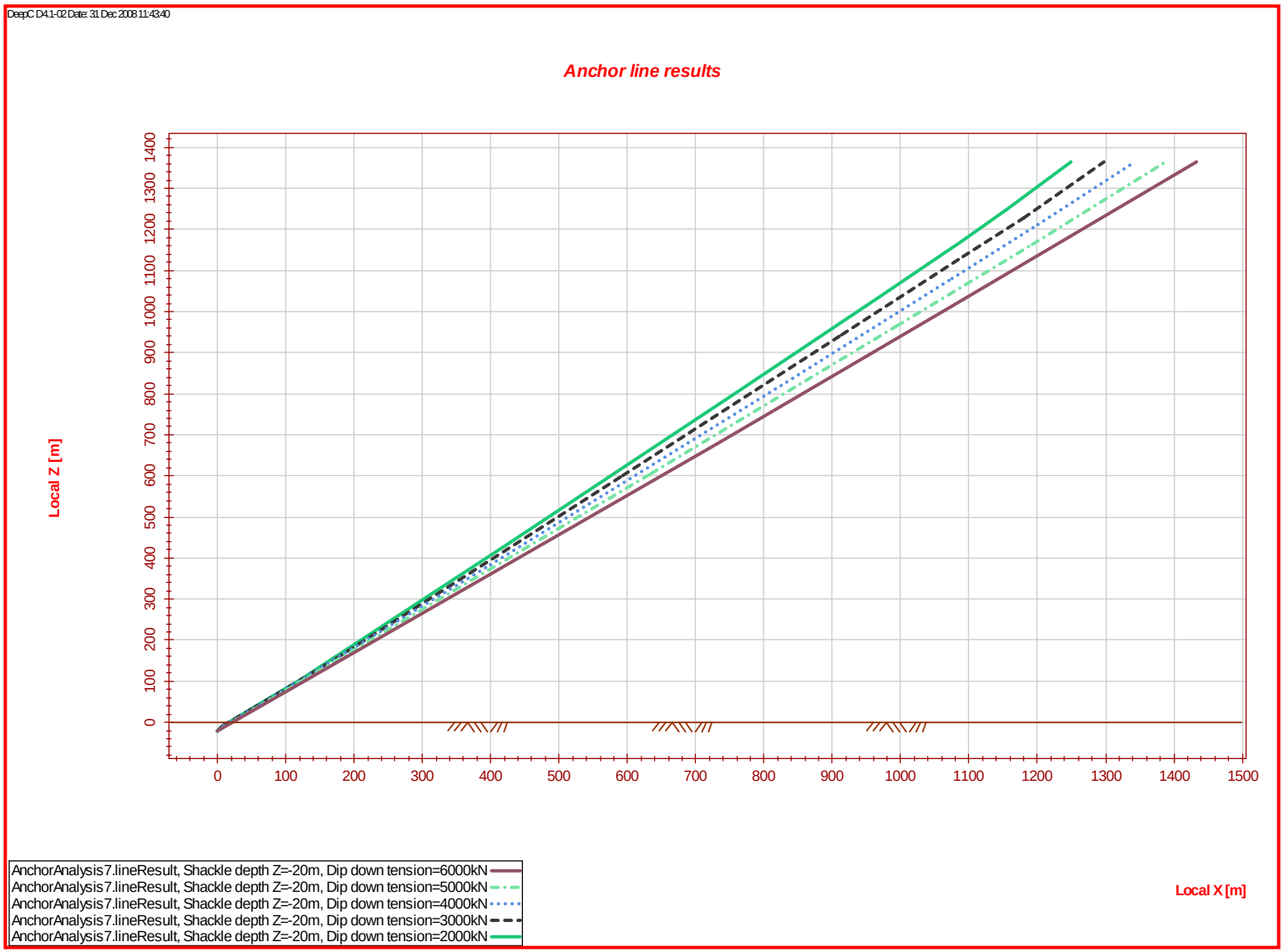
Pile Anchors



Pile Anchors



SEPLA Anchors with Taut Leg



SEPLA Anchors with Taut Leg