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Technical Validation of Existing U.S. Flagged Barges as a Feeder Solution for the U.S. Offshore Wind Industry:

Barge, Cargo and WTIV Load Properties Technical Report

Milestone Number 1.3 (Rev 2)

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Abstract

This report provides a technical description of two cargo feeder vessel stow plans, each with two ballast options. The conditions are presented with stow plans, weight estimates, shear and bending moment values, radius of gyration values, maximum KG curves with load conditions and stability analysis. The load characteristics are prepared as input to the next steps of the "Technical Validation of Existing U.S. Flagged Barges as a "Feeder" Solution for the U.S. Offshore Wind Industry," including the Dynamic Motions Analysis and the Maneuvering Simulation.

Keywords

Feeder barge, wind turbine generator installation, wind installation vessel, stow plan

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Acronyms and Abbreviations

CES	Crowley Engineering Services
CFV	Cargo Feeder Vessel
CGS	Crowley Government Services
CMS	Crowley Marine Services
DNV GL	Det Norske Veritas / Germanischer Lloyd
ft	feet
IEA	International Energy Agency
kWh	kilowatt hours
m/s	meters per second
MW	megawatts
MWS	marine warranty survey
NOWRDC	The National Offshore Wind Research and Development Consortium
NREL	National Renewable Energy Laboratory
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
OCMI	Officer in Charge, Marine Inspection
OEM	Original Equipment Manufacturer
TBD	to be determined
W	watts
WDT	weather downtime
WTIV	Wind Turbine Installation Vessel
WTG	Wind Turbine Generator

Executive Summary

Wind Turbine Installation Vessels (WTIV) are high value, high day-rate equipment whose primary role is installing wind turbine generators on site. Using them to ferry equipment to the installation site is not cost effective since that operation can be conducted by a fleet of low-cost cargo feeder vessels (CFV). This frees up the WTIVs to remain on site and continually erect wind generators.

This report describes and evaluates two stow plans each with two ballast options for transporting one (1) NREL 15 MW Reference Wind Turbine Generator on Crowley 455 Series Barges:

- Base Case, Case 0-Lt – Barge with Fender Wall and other outfit transporting two (2) Tower sections (T1/2, T3), Nacelle and Blades – minimum ballast (Draft 27% hull depth)
    - Sensitivity 0-Hvy – ballast to draft 43% hull depth
- Sensitivity, Case 1-Lt – Barge with Fender Wall and other outfit transporting three (3) Tower sections (T3, T2, T1), Nacelle and Blades – minimum ballast (Draft 29% hull depth)
    - Sensitivity 1-Hvy – ballast to draft 45% hull depth

The load cases are developed to include:

- Stow plans,
- Weight estimates,
- Shear and bending moment values,
- Radius of gyration values,
- Ballast Plans for port-to-starboard and starboard-to-port cargo discharge,
- Maximum KG curves for each cargo transport and discharge step load condition, and
- Stability analysis.

These load cases will be used to study WTIV feeder system feasibility using a minimally modified deck cargo barge accompanied by the appropriate tugs. The analysis includes:

- Dynamic Motions Analysis – under tow and alongside the WTIV
- Maneuvering Simulation – bringing barge to standoff zone and to make “soft landing”
- WTIV/Feeder Weather Down Time (WDT) Simulation – based on motions and maneuvering

1 Introduction

Europe presently has a total installed offshore wind capacity of 25 GW. That corresponds to 5,402 grid-connected wind turbines across 12 countries.[1] There are two projects totaling 42 MW in operation in the United States.[2] The U.S. offshore wind industry is just transitioning from the pilot stage to utility-scale commercial development.

Fixed foundation offshore wind turbines are installed in water depths of up to about 160 ft (50 m). Wind Turbine Installation Vessels (WTIVs) are self-propelled with azimuthing thrusters, a ship-shaped hull, and a jack-up system to lift the hull out of the water providing a stable foundation for a very large crane. The first Jones Act-compliant vessel, the 472-ft *WTIV CHARYBDIS,* is currently under construction at a cost of a half billion dollars[3] with a day rate above a quarter of a million dollars. It is highly unlikely that there will be enough WTIVs available to meet the needs of all the projects in the pipeline due to the high cost of Jones Act-compliant WTIVs.

Foreign flag WTIVs may be used to install offshore wind turbines if they do not transport any cargo within the U.S. territorial sea (46 U.S. Code § 55102). Jones-Act qualified cargo vessels are available to transport cargo, and they have day rates several orders of magnitude less than WTIVs. In theory, a cargo feeder vessel (CFV) could improve the efficiency of a WTIV by eliminating the time spent traveling to and from port. The CFV would deliver cargo to the WTIV just-in-time for it to transload the cargo, install the WTG and move to the next installation site. CTVs may also be able to operate out of ports with restrictive bridge clearance or water depth limitations, thus offering more flexibility for marshalling site selection.

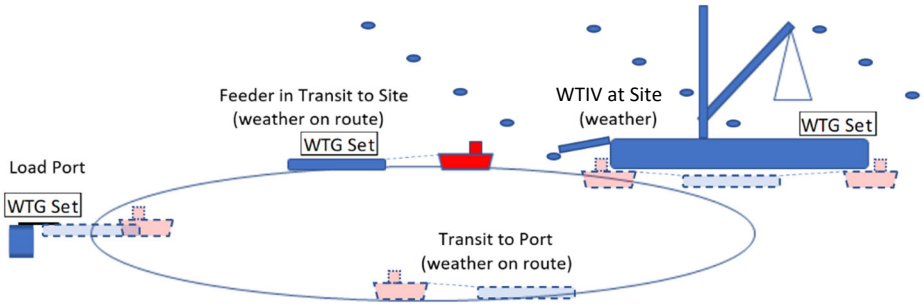

Figure 1 – WTIV with Feeder System

This study evaluates a minimally modified deck cargo barge accompanied by the appropriate tugs in three key facets of the operation:

- Dynamic Motions Analysis – under tow and alongside the WTIV
- Maneuvering Simulation – bringing barge to standoff zone and to make "soft landing"
- WTIV/Feeder Weather Down Time (WDT) Simulation – based on motions and maneuvering

2 Methods

2.1 Considerations for Stow Plan

Transporting the tower as a single unit minimizes the number of lifts the WTIV must make, however, it makes for a very tall deck load which limits the number of available ports, tends to reduce vessel stability, and amplifies top motions. Transporting the tower in three sections has the opposite effect.

For this study, a two (2) tower section base case and a three (3) tower section sensitivity case will be evaluated. The CFV stow plans were developed to:

- Maximize space between components,
- Be within the WTIV crane's lift range and capacity, and
- Minimize trim and heel.

2.2 Cases for Analysis:

When ballasting the vessel, the displacement (and draft) should be limited to provide adequate freeboard and stability, but large enough to reduce motions and slamming. Minimizing ballast reduces the overall displacement of the loaded barge, which should make the barge easier for the tugs to maneuver. It should also impart a smaller contact load on the WTIV than it would if the CFV were more heavily ballasted. Therefore, for transporting one (1) NREL 15 MW Reference Wind Turbine Generator on Crowley 455 Series Barges, light and heavy cases will be studied:

- Base Case, Case 0-0 – Barge with Fender Wall and other outfit transporting two (2) Tower sections (T1/2, T3), Nacelle and Blades – minimum ballast (Draft 27% hull depth)
  - Sensitivity 0-1 – ballast to draft 43% hull depth
- Sensitivity, Case 1-0 – Barge with Fender Wall and other outfit transporting three (3) Tower sections (T3, T2, T1), Nacelle and Blades – minimum ballast (Draft 29% hull depth)
  - Sensitivity 1-1 – ballast to draft 45% hull depth

2.3 Stow Plan – Base Case with Two Tower Sections

To prepare the barge to transport this cargo, several structures and systems were minimally developed for weight estimate, including:

- A fender wall design was developed for 10.8 ft x 32.8 ft (3.3 m x 10 m) fenders centered 20.6 ft (6.3 m) above the CFV deck with a maximum allowable reaction load of 200 LT (203 MT),
- A ballast system for tanks 2P/S and 7 P/S with four (4) Goulds 3171 vertical sump pumps and associated piping,
- Sea fastenings/grillages for the WTG components, and
- An electrical system, mooring fittings and other outfit.

Outboard Profile:

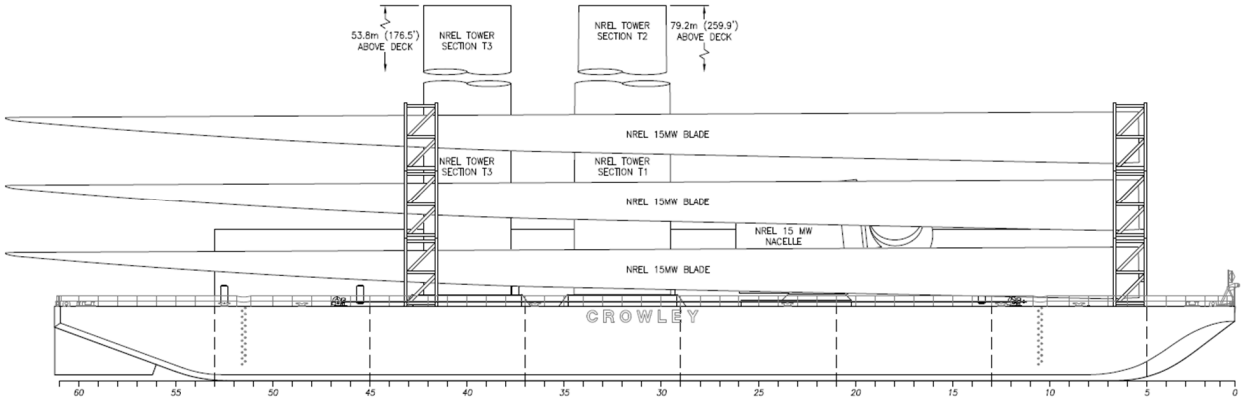

Figure 2 – Base Case, Elevation

Plan View:

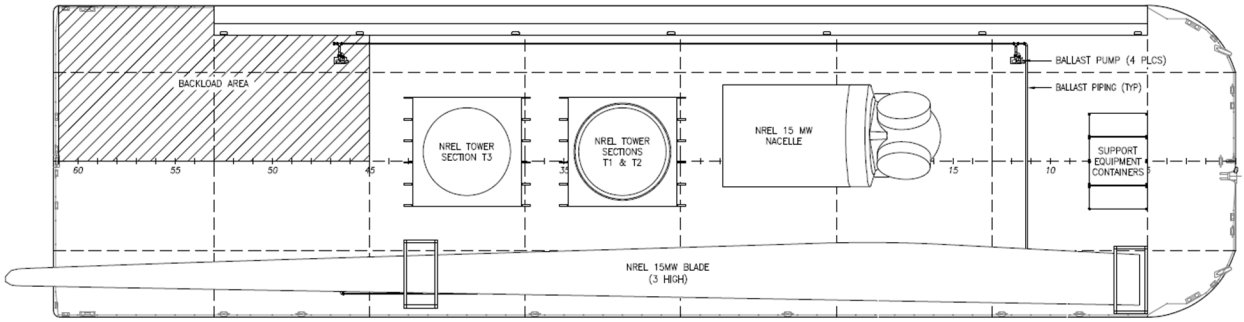

Figure 3 – Base Case, Deck Plan

2.4 Stow Plan – Sensitivity Case with Three Tower Sections

Outboard Profile:

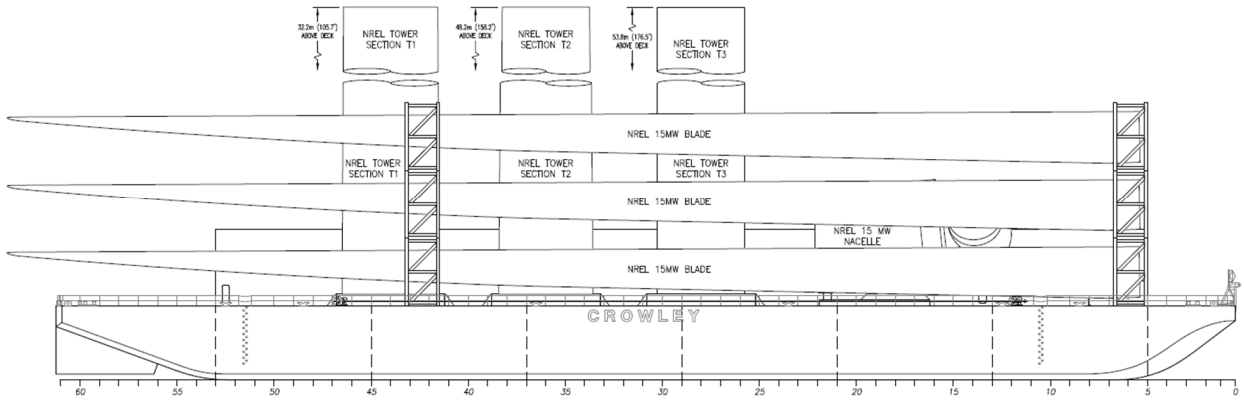

Figure 4 – Sensitivity Case, Elevation

Plan View:

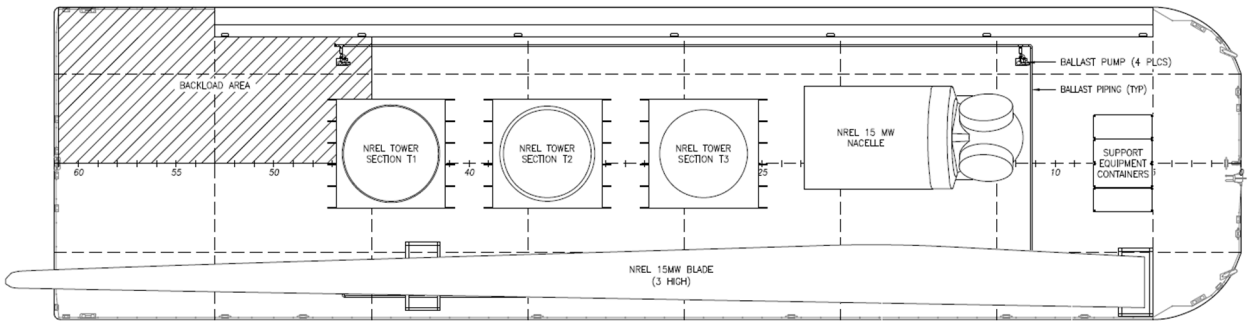

Figure 5 – Sensitivity Case, Deck Plan

2.5 Weight Estimate

A detailed weight estimates for both stow plans are provided in Appendix A. Load characteristics are:

			Base Case (T12-T3)		Sensitivity Case (T3-T2-T1)	
			0-0 Light	0-1 DNV Draft	1-0 Light	1-1 DNV Draft
Draft		[ft]	6.78	10.80	7.13	11.1
Mass		[LT]	6,767	11,094	7,140	11,467
VCG (from keel)		[ft]	35.7	25.0	29.9	21.7
VCG Corr for FSM		[ft]	36.6	26.6	30.6	23.2
Radius of Gyration	Kxx	[ft]	56.3	52.9	45.4	45.4
	Kyy	[ft]	114.0	97.6	113.6	97.6
	Kzz	[ft]	108.5	96.3	113.5	100.2
GMt*		[ft]	109	69.7	108	70.4

			Base Case (T12-T3)		Sensitivity Case (T3-T2-T1)	
			0-0 Light	0-1 DNV Draft	1-0 Light	1-1 DNV Draft
Draft		[m]	2.07	3.3	2.2	3.4
Mass		[MT]	6,875	11,272	7,254	11,652
VCG (from keel)		[m]	10.9	7.6	9.1	6.6
VCG Corr for FSM		[m]	11.1	8.1	9.3	7.1
Radius of Gyration	Kxx	[m]	17.1	16.1	13.8	13.8
	Kyy	[m]	34.7	29.7	34.6	29.7
	Kzz	[m]	33.1	29.4	34.6	30.5
GMt*		[m]	33.2	21.3	32.9	21.5

* GMt includes true free surface.

Table 1 – Load Condition Characteristics

2.6 Regulatory Requirements

For feeder vessels operating on wind farm installation projects in the U.S., strength, stability, and other operational requirements are established by:

- U.S. Coast Guard – regulations published in 46 CFR – Shipping,
- American Bureau of Shipping – Rules for Building and Classing Steel Barges, July 2021,
- DNV GL – Marine Operations and Marine Warranty, DNVGL-ST-N001, Sept 2018 (MWS)

For this study, the maximum shear and bending moments for each load condition were compared with the limits described on the 455 Series Barge Spec Sheet (reference 3.1.2).

Each load condition was evaluated with respect to the following intact stability criteria:

- 46 CFR 170.165 - International Code on Intact Stability
  - IMO Code on Intact Stability, Part B, Chapter 2.2 (Stability for Pontoons)
- 46 CFR 174.015 – Deck Cargo Barge Righting Energy
- DNV GL MWS 10.6.4/15.5.3 Minimum GM & Freeboard During Load Transfer (On or Off)
- DNV GL MWS 11.10.2 – GM and Range
- DNV GL MWS 11.10.3 Wind Overturning to 70 knot wind

A damage stability analysis is not required for cargo transport on flagged trading vessels sailing at the assigned ‘B’ freeboard or greater (per DNV GL MWS 11.10.7.5).

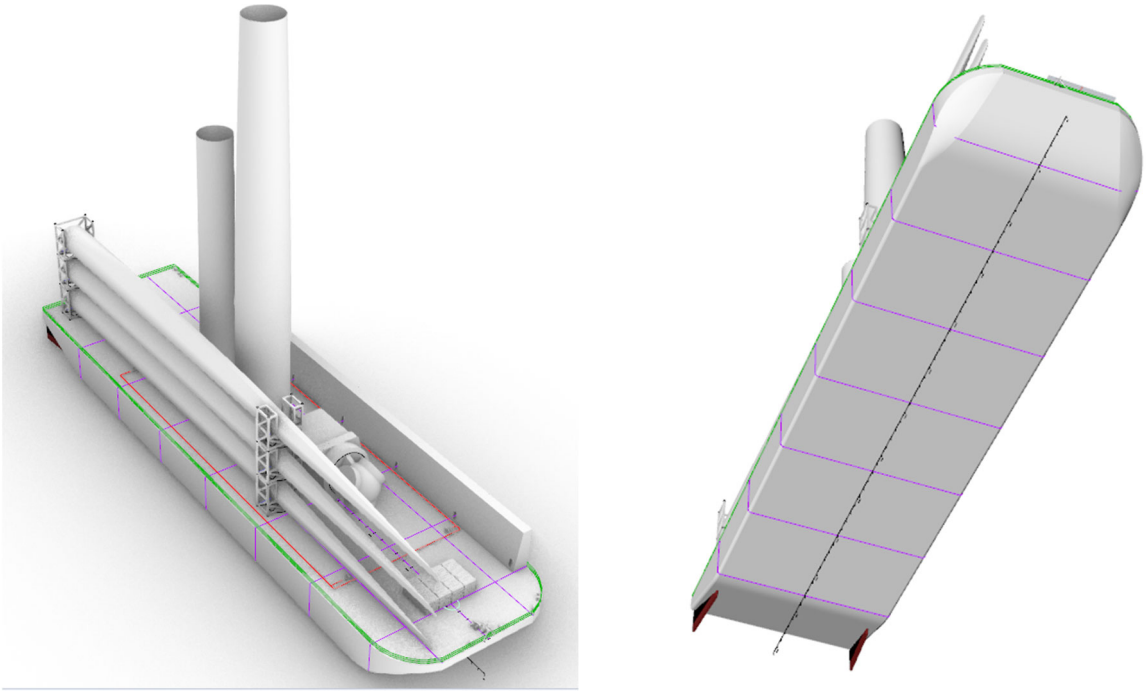

Figure 6 – 455 Series Barge with Base Case Load Configuration

3 References

3.1 Barge Info

1. 400’ x 105’ x 26’ Deck Cargo Barge, GENERAL ARRANGEMENT, Dwg 73-03, Rev B
2. Crowley Spec Sheet: 455 Series – 400’ x 105’ x 25’
   [applicable to Barges: 455-1 (Marty J), 455-3, 455-4, 455-5, 455-6, 455-7. 455-8, 455-9]
3. 213025-833-1, Weight Estimate
4. 213025-034-01, 15 MW NREL Reference Turbine Stow Plan, Base Case – Two Tower Sections
5. 213025-034-02, 15 MW NREL Reference Turbine Stow Plan, Sens. Case 1 – Three Tower Sections

3.2 Wind Turbine Generator Info

1. IEA Wind TCP Task 37, Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine Technical Report, March 2020

3.3 Endnotes

[1] https://windeurope.org/intelligence-platform/product/offshore-wind-in-europe-key-trends-and-statistics-2020/
[2] https://www.energy.gov/eere/wind/wind-market-reports-2021-edition#offshore
[3] https://news.dominionenergy.com/2021-06-01-Dominion-Energy,-rsted-and-Eversource-Reach-Deal-on-Contract-to-Charter-Offshore-Wind-Turbine-Installation-Vessel

Appendix A. Weight Estimate

A.1 Weight Estimate for Base Case with Two Tower Sections

Barge with Fender Wall and other outfit transporting two (2) Tower sections (T1/2, T3), Nacelle and Blades. Ballast is not included.

Weight Estimate

U.S. Customary Units

1) LCG Reference: Fr 0 (Bow)
2) TCG Reference: (+) Stbd, (-) Port
3) VCG Reference: Baseline

Item	Qty	Weight (LT)	LCG[1] (ft)	TCG[2] (ft)	VCG[3] (ft)
100 STRUCTURE		3,816.67	197.19	- 4.39	16.29
455 Barge Lightship	1	3,473.67	198.12	0.00	14.07
110 FENDER WALL	1	343.00	187.75	- 48.82	38.82
124 Breakwater	0	0.00	11.05	0.00	31.42
OUTFIT		171.00	122.23	0.00	34.12
300 Electrical system	1	50.00	200.00	0.00	31.00
529 BALLAST SYSTEM	1	6.00	191.82	0.00	17.48
582 Mooring system	1	25.00	187.75	0.00	51.00
Mooring Lines (8)	0	0.00	0.00	0.00	0.00
Yokohama Fenders (3)	0	0.00	187.75	- 48.82	47.72
600 Outfitting	1	10.00	187.75	0.00	51.00
Storage Containers (20')	4	80.00	39.75	0.00	29.93
TOWER		926.00	222.12	- 3.25	123.94
Tower Section T1	1	298.00	207.50	- 3.25	76.33
Tower Section T2	1	310.00	207.50	- 3.25	203.95
T1 & T2 Seafastening/Grillage	1	61.00	207.50	- 3.25	27.08
Tower Section T3	1	233.00	260.17	- 3.25	113.73
T3 Seafastening/Grillage	1	24.00	260.17	- 3.25	27.08
NACELLE		893.00	141.67	- 8.63	41.61
Nacelle w/ Transport Frame	1	858.00	141.67	- 8.63	42.21
Nacelle Seafastening/Grillage	1	35.00	141.67	- 8.63	27.08
BLADES		296.00	134.33	39.18	64.00
Blades	3	196.00	123.41	39.28	64.00
Blade Rack, fwd	3	50.00	35.49	40.00	64.00
Blade Rack, aft	3	50.00	275.98	38.00	64.00
Fixed Load Displacement		6,102.67	187.70	- 2.60	39.15

Table 2 – Base Case 0, Weight Estimate, Two Towers (U.S. Units)

Weight Estimate

Metric Units

1) LCG Reference: Fr 0 (Bow)
2) TCG Reference: (+) Stbd, (-) Port
3) VCG Reference: Baseline

Item	Qty	Weight (MT)	LCG[1] (m)	TCG[2] (m)	VCG[3] (m)	Lmom (MT-m)	Tmom (MT-m)	Vmom (MT-m)
100 STRUCTURE		3,877.92	60.10	- 1.34	4.97	233,074	- 5,186	19,260
455 Barge Lightship	1	3,529.41	60.39	0.00	4.29	213,130	0	15,136
110 FENDER WALL	1	348.50	57.23	- 14.88	11.83	19,944	- 5,186	4,124
124 Breakwater	0	0.00	3.37	0.00	9.58	0	0	0
OUTFIT		173.74	37.26	0.00	10.40	6,473	0	1,807
300 Electrical system	1	50.80	60.96	0.00	9.45	3,097	0	480
529 BALLAST SYSTEM	1	6.10	58.47	0.00	5.33	356	0	32
582 Mooring system	1	25.40	57.23	0.00	15.54	1,454	0	395
Mooring Lines (8)	0					0	0	0
Yokohama Fenders (3)	0		57.23	- 14.88	14.54	0	0	0
600 Outfitting	1	10.16	57.23	0.00	15.54	581	0	158
Storage Containers (20')	4	81.28	12.12	0.00	9.12	985	0	742
TOWER		940.86	67.70	- 0.99	37.78	63,697	- 932	35,544
Tower Section T1	1	302.78	63.25	- 0.99	23.26	19,150	- 300	7,044
Tower Section T2	1	314.97	63.25	- 0.99	62.16	19,921	- 312	19,580
T1 & T2 Seafastening/Grillage	1	61.98	63.25	- 0.99	8.26	3,920	- 61	512
Tower Section T3	1	236.74	79.30	- 0.99	34.66	18,773	- 235	8,206
T3 Seafastening/Grillage	1	24.39	79.30	- 0.99	8.26	1,934	- 24	201
NACELLE		907.33	43.18	- 2.63	12.68	39,179	- 2,388	11,509
Nacelle w/ Transport Frame	1	871.77	43.18	- 2.63	12.86	37,643	- 2,294	11,215
Nacelle Seafastening/Grillage	1	35.56	43.18	- 2.63	8.26	1,536	- 94	294
BLADES		300.75	40.94	11.94	19.51	12,314	3,592	5,867
Blades	3	199.15	37.61	11.97	19.51	7,491	2,384	3,885
Blade Rack, fwd	3	50.80	10.82	12.19	19.51	550	619	991
Blade Rack, aft	3	50.80	84.12	11.58	19.51	4,273	588	991
Fixed Load Displacement		6,200.60	57.21	- 0.79	11.93	354,737	- 4,913	73,986

Table 3 – Base Case 0, Weight Estimate, Two Towers (S.I. Units)

A.2 Weight Estimate for Sensitivity Case with Three Tower Sections

Barge with Fender Wall and other outfit transporting three (3) Tower sections (T3, T2, T1), Nacelle and Blades. Ballast is not included.

Weight Estimate

U.S. Customary Units

1) LCG Reference: Fr 0 (Bow)
2) TCG Reference: (+) Stbd, (-) Port
3) VCG Reference: Baseline

Item	Qty	Weight (LT)	LCG[1] (ft)	TCG[2] (ft)	VCG[3] (ft)
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455 Barge Lightship	1	3,473.67	198.12	0.00	14.07
110 FENDER WALL	1	343.00	187.75	- 48.82	38.82
124 Breakwater	0	0.00	11.05	0.00	31.42
OUTFIT		171.00	122.23	0.00	34.12
300 Electrical system	1	50.00	200.00	0.00	31.00
529 BALLAST SYSTEM	1	6.00	191.82	0.00	17.48
582 Mooring system	1	25.00	187.75	0.00	51.00
Mooring Lines (8)	0	0.00	0.00	0.00	0.00
Yokohama Fenders (3)	0	0.00	187.75	- 48.82	47.72
600 Outfitting	1	10.00	187.75	0.00	51.00
Storage Containers (20')	4	80.00	39.75	0.00	29.93
TOWER		926.00	237.87	- 3.25	89.90
Tower Section T3	1	233.00	181.17	- 3.25	113.73
T3 Seafastening/Grillage	1	24.00	181.17	- 3.25	27.08
Tower Section T2	1	310.00	233.83	- 3.25	102.25
T2 Seafastening/Grillage	1	31.00	233.83	- 3.25	27.08
Tower Section T1	1	298.00	286.50	- 3.25	76.33
T1 Seafastening/Grillage	1	30.00	286.50	- 3.25	27.08
NACELLE		893.00	115.33	- 8.63	41.61
Nacelle w/ Transport Frame	1	858.00	115.33	- 8.63	42.21
Nacelle Seafastening/Grillage	1	35.00	115.33	- 8.63	27.08
BLADES		296.00	134.33	39.18	64.00
Blades	3	196.00	123.41	39.28	64.00
Blade Rack, fwd	3	50.00	35.49	40.00	64.00
Blade Rack, aft	3	50.00	275.98	38.00	64.00
Fixed Load Displacement		6,102.67	186.23	- 2.60	33.98

Table 4 – Sensitivity 1, Weight Estimate, Three Towers (U.S. Units)

Weight Estimate

Metric Units

1) LCG Reference: Fr 0 (Bow)
2) TCG Reference: (+) Stbd, (-) Port
3) VCG Reference: Baseline

Item	Qty	Weight (MT)	LCG[1] (m)	TCG[2] (m)	VCG[3] (m)	Lmom (MT-m)	Tmom (MT-m)	Vmom (MT-m)
100 STRUCTURE		3,877.92	60.10	- 1.34	4.97	233,074	- 5,186	19,260
455 Barge Lightship	1	3,529.41	60.39	0.00	4.29	213,130	0	15,136
110 FENDER WALL	1	348.50	57.23	- 14.88	11.83	19,944	- 5,186	4,124
124 Breakwater	0	0.00	3.37	0.00	9.58	0	0	0
OUTFIT		173.74	37.26	0.00	10.40	6,473	0	1,807
300 Electrical system	1	50.80	60.96	0.00	9.45	3,097	0	480
529 BALLAST SYSTEM	1	6.10	58.47	0.00	5.33	356	0	32
582 Mooring system	1	25.40	57.23	0.00	15.54	1,454	0	395
Mooring Lines (8)	0					0	0	0
Yokohama Fenders (3)	0		57.23	- 14.88	14.54	0	0	0
600 Outfitting	1	10.16	57.23	0.00	15.54	581	0	158
Storage Containers (20')	4	81.28	12.12	0.00	9.12	985	0	742
TOWER		940.86	72.50	- 0.99	27.40	68,215	- 932	25,780
Tower Section T3	1	236.74	55.22	- 0.99	34.66	13,073	- 235	8,206
T3 Seafastening/Grillage	1	24.39	55.22	- 0.99	8.26	1,347	- 24	201
Tower Section T2	1	314.97	71.27	- 0.99	31.16	22,449	- 312	9,816
T2 Seafastening/Grillage	1	31.50	71.27	- 0.99	8.26	2,245	- 31	260
Tower Section T1	1	302.78	87.33	- 0.99	23.26	26,440	- 300	7,044
T1 Seafastening/Grillage	1	30.48	87.33	- 0.99	8.26	2,662	- 30	252
NACELLE		907.33	35.15	- 2.63	12.68	31,896	- 2,385	11,509
Nacelle w/ Transport Frame	1	871.77	35.15	- 2.63	12.86	30,646	- 2,292	11,215
Nacelle Seafastening/Grillage	1	35.56	35.15	- 2.63	8.26	1,250	- 93	294
BLADES		300.75	40.94	11.94	19.51	12,314	3,592	5,867
Blades	3	199.15	37.61	11.97	19.51	7,491	2,384	3,885
Blade Rack, fwd	3	50.80	10.82	12.19	19.51	550	619	991
Blade Rack, aft	3	50.80	84.12	11.58	19.51	4,273	588	991
Fixed Load Displacement		6,200.60	56.76	- 0.79	10.36	351,972	- 4,911	64,222

Table 5 – Sensitivity 1, Weight Estimate, Three Towers (S.I. Units)

Appendix B. Ballast Plan

B.1 Ballast Plan for Base Case with Two Tower Sections – Base Case 0-0

Barge with Fender Wall and other outfit transporting two (2) Tower sections (T1/2, T3), Nacelle and Blades. (Deepest draft = 27% hull depth.)

Ballasted to minimum ballast required to offload cargo in any order with ballast sequence as follows:

		UNLOADING PORT TO STARBOARD										BALLAST TANKS % OF LOADING					
LCF Draft (ft)	Trim per 400 ft	SEQUENCE	CONDITION	Origin Depth (ft)	DISPLACEMENT (LT)	TRIM (deg, +aft)	HEEL (deg, +stbd)	MAX SHEAR (LT)	MAX BENDING (LT-ft)	RANGE OF POSITIVE RA (deg)	GM (ft)	2.C	2.P	2.S	7.C	7.P	7.S
6.778	1.487	0	FULL LOAD - 1 TO 2 FT AFT TRIM (MIN DRAFT)	6.052	6,768.21	0.21	0.20	- 386	15,919	1	109.0	0%	0%	5%	0%	13%	62%
6.778	0.098	0	FULL LOAD - NO TRIM	6.732	6,766.63	0.01	0.19	- 376	16,567	1	109.1	0%	0%	22%	0%	13%	45%
5.960	1.843	0	BALLAST (STILL FOR FULL LOAD-NO TRIM) REMOVE NACELLE (MIN DRAFT)	5.058	5,908.82	0.26	0.74	- 464	34,047	1	129.5	0%	0%	22%	0%	13%	45%
5.958	0.000	1	BALLAST (P2S1) REMOVE NACELLE (MIN DRAFT)	5.957	5,907.26	0.00	0.19	- 452	36,422	1	129.0	0%	19%	25%	0%	5%	31%
5.735	- 0.600	1	BALLAST (P2S1) REMOVED: NACELLE AND TOWER SECTION T3 (MIN DRAFT)	6.025	5,674.26	- 0.09	0.23	- 451	36,999	1	137.2	0%	19%	25%	0%	5%	31%
5.735	0.168	2	BALLAST (P2S2) REMOVED: NACELLE AND TOWER SECTION T3 (MIN DRAFT)	5.653	5,674.81	0.02	0.18	- 455	36,122	1	138.4	0%	10%	25%	0%	15%	30%
5.145	- 0.168	2	BALLAST (P2S2) REMOVED: ALL TOWER SECTIONS AND NACELLE (MIN DRAFT)	5.226	5,066.83	- 0.02	0.29	- 486	49,541	1	169.1	0%	10%	25%	0%	15%	30%
5.146	0.098	3	BALLAST (P2S3) REMOVED: ALL TOWER SECTIONS AND NACELLE (MIN DRAFT)	5.100	5,067.10	0.01	0.16	- 481	49,361	1	168.9	0%	20%	12%	0%	8%	40%
4.857	0.796	3	BALLAST (P2S3) REMOVE ALL (MIN DRAFT)	4.470	4,771.07	0.11	- 0.59	- 400	42,687	1	182.4	0%	20%	12%	0%	8%	40%
4.859	0.112	4	BALLAST (P2S4) REMOVE ALL (MIN DRAFT)	4.805	4,770.43	0.02	- 0.01	- 423	43,211	1	182.5	0%	15%	25%	0%	0%	40%
4.863	1.417	5	LOAD DISCHARGED - 1 TO 2 FT AFT TRIM (MIN DRAFT)	4.171	4,771.71	0.20	- 0.01	391	42,587	1	183.4	0%	5%	20%	0%	10%	45%

		UNLOADING STARBOARD TO PORT										BALLAST TANKS % OF LOADING					
LCF Draft (ft)	Trim per 400 ft	SEQUENCE	CONDITION	Origin Depth (ft)	DISPLACEMENT (LT)	TRIM (deg, +aft)	HEEL (deg, +stbd)	MAX SHEAR (LT)	MAX BENDING (LT-ft)	RANGE OF POSITIVE RA (deg)	GM (ft)	2.C	2.P	2.S	7.C	7.P	7.S
6.778	1.487	0	FULL LOAD - 1 TO 2 FT AFT TRIM (MIN DRAFT)	6.052	6,768.21	0.21	0.20	- 386	15,919	1	109.0	0%	0%	5%	0%	13%	62%
6.778	0.098	0	FULL LOAD - NO TRIM	6.732	6,766.63	0.01	0.19	- 376	16,567	1	109.1	0%	0%	22%	0%	13%	45%
6.494	0.768	0	BALLAST (STILL FOR FULL LOAD-NO TRIM) REMOVE BLADES & RACKS (MIN DRAFT)	6.120	6,470.82	0.11	- 0.68	- 341	16,886	1	116.8	0%	0%	22%	0%	13%	45%
6.497	0.119	1	BALLAST (S2P1) REMOVE BLADES & RACKS (MIN DRAFT)	6.441	6,470.13	0.02	- 0.01	334	17,306	1	116.3	0%	0%	30%	0%	0%	50%
5.915	- 0.195	1	BALLAST (S2P1) REMOVE BLADES & RACKS AND TOWER SECTIONS T1 & T2 (MIN DRAFT)	6.008	5,862.12	- 0.03	0.12	- 395	29,861	1	141.7	0%	0%	30%	0%	0%	50%
5.914	- 0.021	2	BALLAST (S2P2) REMOVE BLADES & RACKS AND TOWER SECTIONS T1 & T2 (MIN DRAFT)	5.925	5,862.33	0.00	- 0.01	- 397	29,821	1	141.5	0%	3%	25%	0%	0%	52%
5.693	- 0.621	2	BALLAST (S2P2) REMOVE BLADES & RACKS NACELLE AND ALL TOWER SECTIONS (MIN DF	5.992	5,629.28	- 0.09	0.03	- 426	34,960	1	150.3	0%	3%	25%	0%	0%	52%
5.691	0.056	3	BALLAST (S2P3) REMOVE BLADES & RACKS NACELLE AND ALL TOWER SECTIONS (MIN DF	5.664	5,629.45	0.01	- 0.01	- 433	34,962	1	151.4	0%	0%	20%	0%	4%	56%
4.864	1.850	3	BALLAST (S2P3) REMOVE ALL (MIN DRAFT)	3.960	4,772.10	0.27	0.47	400	42,404	1	182.8	0%	0%	20%	0%	4%	56%
4.859	0.112	4	BALLAST (S2P4) REMOVE ALL (MIN DRAFT)	4.805	4,770.42	0.02	- 0.01	- 423	43,213	1	182.5	0%	15%	25%	0%	0%	40%
4.863	1.417	5	LOAD DISCHARGED - 1 TO 2 FT AFT TRIM (MIN DRAFT)	4.171	4,771.71	0.20	- 0.01	391	42,587	1	183.4	0%	5%	20%	0%	10%	45%

Table 6 – Base Case 0-0, Ballast Plan, Two Tower Sections

B.2 Ballast Plan for Base Case with Two Tower Sections – Sensitivity 0-1

Barge with Fender Wall and other outfit transporting two (2) Tower sections (T1/2, T3), Nacelle and Blades. (Deepest draft = 43% hull depth.)

Ballasted to DNV GL (WMS 11.10.9.4) draft guidance value with fixed liquid ballast (3P/S: 55%, 4P/S: 55%, 5P/S: 75% & 6P/S: 75%) and active ballast (in #2 P/S and #7 P/S tanks) as required to offload cargo in any order. The ballast sequence is the same as Base Case 0-0 above.

B.3 Ballast Plan for Sensitivity Case with Three Tower Sections – Sensitivity 1-0

Barge with Fender Wall and other outfit transporting three (3) Tower sections (T3, T2, T1), Nacelle and Blades. (Deepest draft = 29% hull depth.)

Ballasted to minimum ballast required to offload cargo in any order with ballast sequence as follows:

		UNLOADING PORT TO STARBOARD								RANGE OF		BALLAST TANKS % OF LOADING					
LCF Draft (ft)	Trim per 400 ft	SEQUENCE	CONDITION	Origin Depth (ft)	DISPLACEMENT (LT)	TRIM (deg, +aft)	HEEL (deg, +stbd)	MAX SHEAR (LT)	MAX BENDING (LT-ft)	POSITIVE RA (deg)	GM (ft)	2.C	2.P	2.S	7.C	7.P	7.S
7.136	1.669	0	FULL LOAD - 1 TO 2 FT AFT TRIM (MIN DRAFT)	6.319	7,141.76	0.24	0.21	- 839	38,369	1	107.8	0%	5%	15%	0%	30%	75%
7.132	0.042	0	FULL LOAD - NO TRIM	7.112	7,139.95	0.01	0.22	- 833	39,335	1	108.1	0%	15%	25%	0%	20%	65%
6.317	2.625	0	BALLAST (STILL FOR FULL LOAD-NO TRIM) REMOVE NACELLE (MIN DRAFT)	5.028	6,281.92	0.38	0.74	- 497	45,683	1	126.7	0%	15%	25%	0%	20%	65%
6.314	0.147	1	BALLAST (P2S1) REMOVE NACELLE (MIN DRAFT)	6.243	6,279.65	0.02	0.16	- 580	48,937	1	126.7	0%	34%	36%	0%	13%	42%
6.092	0.265	1	BALLAST (P2S1) REMOVED: NACELLE AND TOWER SECTION T3 (MIN DRAFT)	5.961	6,046.65	0.04	0.20	- 629	56,359	1	135.5	0%	34%	36%	0%	13%	42%
6.091	0.098	2	BALLAST (P2S2) REMOVED: NACELLE AND TOWER SECTION T3 (MIN DRAFT)	6.043	6,046.48	0.01	0.16	- 635	56,543	1	135.5	0%	36%	36%	0%	12%	41%
5.794	- 0.377	2	BALLAST (P2S2) REMOVED: TOWER SECTIONS 3 & 2 AND NACELLE (MIN DRAFT)	5.976	5,736.48	- 0.05	0.22	- 659	61,553	1	147.6	0%	36%	36%	0%	12%	41%
5.794	0.133	3	BALLAST (P2S3) REMOVED: TOWER SECTIONS 3 & 2 AND NACELLE (MIN DRAFT)	5.731	5,736.94	0.02	0.17	- 643	61,113	1	147.5	0%	39%	27%	0%	10%	49%
5.509	- 0.956	3	BALLAST (P2S3) REMOVED: ALL TOWER SECTIONS (3 2 1) AND NACELLE (MIN DRAFT)	5.969	5,438.93	- 0.14	0.23	- 624	59,727	1	157.9	0%	39%	27%	0%	10%	49%
5.508	0.168	4	BALLAST (P2S4) REMOVED: ALL TOWER SECTIONS (3 2 1) AND NACELLE (MIN DRAFT)	5.429	5,439.93	0.02	0.14	- 590	58,948	1	158.8	0%	32%	21%	0%	19%	53%
5.221	0.859	4	BALLAST (P2S3) REMOVE ALL (MIN DRAFT)	4.803	5,143.96	0.12	- 0.61	- 512	52,456	1	170.1	0%	32%	21%	0%	19%	53%
5.221	0.258	5	BALLAST (P2S4) REMOVE ALL (MIN DRAFT)	5.095	5,143.36	0.04	- 0.03	- 532	52,895	1	169.6	0%	23%	37%	0%	15%	50%
5.225	1.382	5	LOAD DISCHARGED - 1 TO 2 FT AFT TRIM (MIN DRAFT)	4.552	5,144.31	0.20	0.01	517	52,229	1	170.8	0%	16%	31%	0%	21%	57%

		UNLOADING STARBOARD TO PORT								RANGE OF		BALLAST TANKS % OF LOADING					
LCF Draft (ft)	Trim per 400 ft	SEQUENCE	CONDITION	Origin Depth (ft)	DISPLACEMENT (LT)	TRIM (deg, +aft)	HEEL (deg, +stbd)	MAX SHEAR (LT)	MAX BENDING (LT-ft)	POSITIVE RA (deg)	GM (ft)	2.C	2.P	2.S	7.C	7.P	7.S
7.136	1.669	0	FULL LOAD - 1 TO 2 FT AFT TRIM (MIN DRAFT)	6.319	7,141.76	0.24	0.21	- 839	38,369	1	107.8	0%	5%	15%	0%	30%	75%
7.132	0.042	0	FULL LOAD - NO TRIM	7.112	7,139.95	0.01	0.22	- 833	39,335	1	108.1	0%	15%	25%	0%	20%	65%
6.848	0.698	0	BALLAST (STILL FOR FULL LOAD-NO TRIM) REMOVE BLADES & RACKS (MIN DRAFT)	6.507	6,843.98	0.10	- 0.62	- 832	34,111	1	115.1	0%	15%	25%	0%	20%	65%
6.582	- 0.098	1	BALLAST (S2P1) REMOVE BLADES & RACKS (MIN DRAFT)	6.901	6,843.36	- 0.01	0.01	- 830	34,766	1	114.7	0%	7%	43%	0%	15%	60%
6.570	- 1.145	1	BALLAST (S2P1) REMOVE BLADES & RACKS AND TOWER SECTION T1 (MIN DRAFT)	7.123	6,545.36	- 0.16	0.08	- 825	34,766	1	122.8	0%	7%	43%	0%	15%	60%
6.569	- 0.063	2	BALLAST (S2P2) REMOVE BLADES & RACKS AND TOWER SECTION T1 (MIN DRAFT)	6.600	6,546.00	- 0.01	- 0.01	- 830	34,413	1	122.6	0%	7%	30%	0%	17%	71%
6.273	- 0.531	2	BALLAST (S2P2) REMOVE BLADES & RACKS AND TOWER SECTIONS T1 & T2 (MIN DRAFT)	6.531	6,236.00	- 0.08	0.06	- 890	45,129	1	133.1	0%	7%	30%	0%	17%	71%
6.274	0.049	3	BALLAST (S2P3) REMOVE BLADES & RACKS AND TOWER SECTIONS T1 & T2 (MIN DRAFT)	6.250	6,236.74	0.01	0.01	- 892	45,054	1	133.0	0%	5%	25%	0%	20%	75%
6.051	0.175	3	BALLAST (S2P3) REMOVE BLADES & RACKS NACELLE AND ALL TOWER SECTIONS (MIN DF	5.968	6,003.79	0.03	0.06	- 986	50,702	1	142.1	0%	5%	25%	0%	20%	75%
6.051	0.168	4	BALLAST (S2P4) REMOVE BLADES & RACKS NACELLE AND ALL TOWER SECTIONS (MIN DF	5.969	6,003.76	0.02	0.02	- 986	50,691	1	142.0	0%	10%	20%	0%	16%	79%
5.232	2.827	3	BALLAST (S2P4) REMOVE ALL (MIN DRAFT)	3.841	5,145.72	0.41	0.50	547	51,250	1	170.7	0%	10%	20%	0%	16%	79%
5.221	0.091	4	BALLAST (S2P5) REMOVE ALL (MIN DRAFT)	5.178	5,143.29	0.01	0.00	- 538	53,009	1	169.5	0%	26%	36%	0%	11%	52%
5.225	1.382	5	LOAD DISCHARGED - 1 TO 2 FT AFT TRIM (MIN DRAFT)	4.552	5,144.31	0.20	0.01	517	52,229	1	170.8	0%	16%	31%	0%	21%	57%

Table 7 – Sensitivity 1-0, Ballast Plan, Three Tower Sections

B.4 Ballast Plan for Sensitivity Case with Three Tower Sections – Sensitivity 1-1

Barge with Fender Wall and other outfit transporting three (3) Tower sections (T3, T2, T1), Nacelle and Blades. (Deepest draft = 45% hull depth.)

Ballasted to DNV GL (WMS 11.10.9.4) draft guidance value with fixed liquid ballast (3P/S: 55%, 4P/S: 55%, 5P/S: 75% & 6P/S: 75%) and active ballast (in #2 P/S and #7 P/S tanks) as required to offload cargo in any order. The ballast sequence is the same as Sensitivity Case 1-0 above.

Appendix C. Stability Analysis

C.1 Stability Analysis – Max KG Curves

Limiting Vertical Center of Gravity (Max KG) Curves were developed for the applicable stability criteria. Each step of cargo transloading off load is analyzed and shown below.

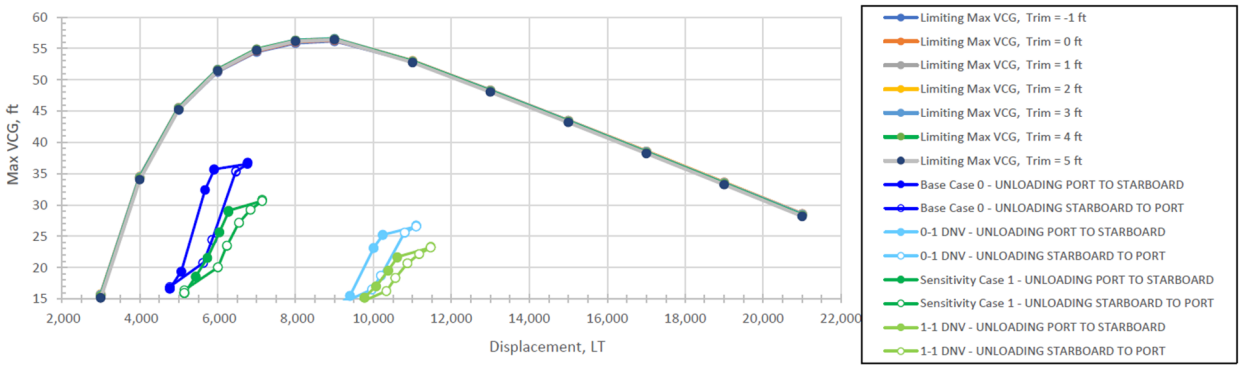

Figure 7 – Load Conditions on Max KG Curve – with 70 knot wind

The Maximum VCG Curves for each stability criteria were calculated for a range of trim from 1 ft forward to 5 ft aft trim over a range of displacement from 3,000 LT to 21,000 LT. Composite limits were developed by selecting the lowest Maximum KG value from all cases:

MAXIMUM VCG vs. DISPLACEMENT
Heeling both Port and Stbd

Note: 11.10.2.5 offers an alternate range criteria based on amplitudes of motions.

v

70 knot wind

Trim = 0.00 /400.0 at zero heel (trim righting arm held at zero)

Limiting Criteria	Displacement LONG TONS	Limiting Max VCG	174015 Max VCG	IMOB2241 Max VCG	IMOB2242 Max VCG	DNV10641 Max VCG	DNV11102 Max VCG	DNV11103 Max VCG	Min Fbd (ft)	Max Wave Ht (ft)	Max Wave Ht (m)
DNV11103	3,000.00	**15.64**	211.89	123.13	192.37	304.64	66.43	**15.64**	21.88	40.49	12.34
DNV11103	4,000.00	**34.39**	174.69	117.24	165.90	232.05	65.60	**34.39**	20.89	38.50	11.74
DNV11103	5,000.00	**45.37**	149.41	112.10	145.42	188.43	64.65	**45.37**	19.92	36.55	11.14
DNV11103	6,000.00	**51.45**	131.73	107.49	129.44	159.09	63.24	**51.45**	18.95	34.62	10.55
DNV11103	7,000.00	**54.64**	118.30	103.27	116.85	138.44	61.47	**54.64**	18.00	32.72	9.97
DNV11103	8,000.00	**56.07**	107.90	99.36	107.12	122.78	59.52	**56.07**	17.06	30.83	9.40
DNV11103	9,000.00	**56.35**	99.38	95.70	98.74	110.89	57.42	**56.35**	16.12	28.96	8.83
DNV11102	11,000.00	**52.96**	86.81	86.75	82.93	93.60	**52.96**	54.68	14.29	25.29	7.71
DNV11102	13,000.00	**48.28**	77.27	77.26	71.80	81.95	**48.28**	51.24	12.48	21.69	6.61
DNV11102	15,000.00	**43.45**	67.62	67.59	63.40	73.51	**43.45**	46.69	10.72	18.15	5.53
DNV11102	17,000.00	**38.55**	58.06	58.00	56.53	67.21	**38.55**	41.38	8.98	14.68	4.47
DNV11102	19,000.00	**33.58**	48.73	48.76	50.40	62.41	**33.58**	35.55	7.27	11.26	3.43
DNV11102	21,000.00	**28.57**	39.26	39.21	43.85	58.18	**28.57**	29.33	5.58	7.89	2.40

Table 8 – Maximum VCG with No Trim – with 70 knot wind

C.2 Stability Analysis for Base Case with Two Tower Sections

Barge with Fender Wall and other outfit transporting two (2) Tower sections (T1/2, T3), Nacelle and Blades.

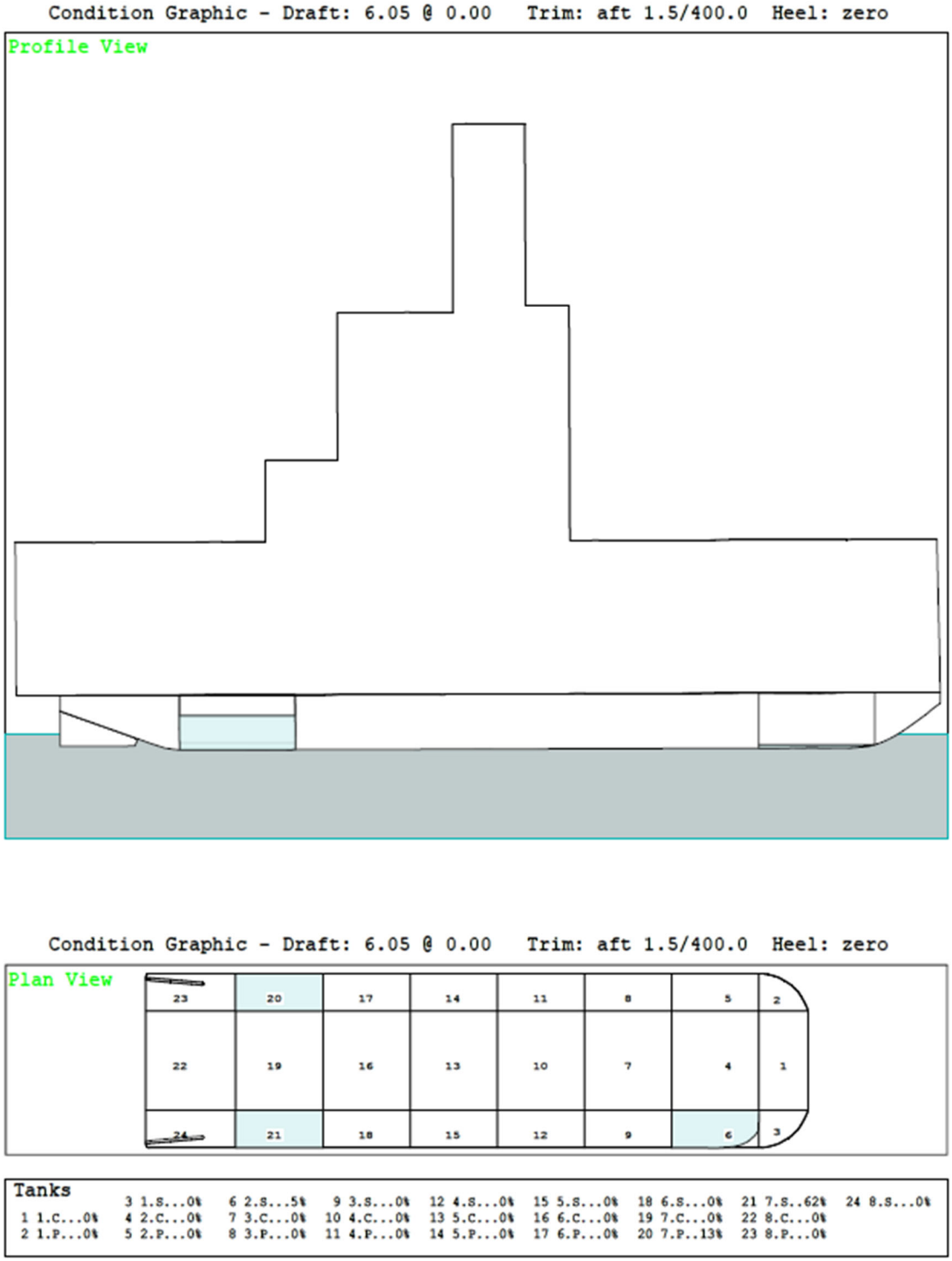

Figure 8 – Stability Base Case 0-0, Full Load, Trimmed for Voyage (Layout)

SUMMARY OF LOADING

174,270.4 Gals. (2%) SALT WATER

343.00 LT	110 FENDER WALL	176.00 LT	Misc. Weights
80.00 LT	Storage Containers (2	841.00 LT	Tower Section T
893.00 LT	Nacelle	296.00 LT	Blades & Racks

WEIGHT and DISPLACEMENT STATUS
Baseline draft: 6.049 @ Origin
Trim: Aft 1.5/400.0, Heel: zero

Part	Weight(LT)	LCG	TCG	VCG	
LIGHT SHIP	3,473.67	198.12a	0.76p	14.07	
110 FENDER WALL	343.00	187.75a	48.82p	38.82	
300 Electrical System	50.00	200.00a	0.00	31.00	
529 BALLAST SYSTEM	6.00	191.82a	0.00	17.48	
582 Mooring system	25.00	187.75a	0.00	51.00	
600 Outfitting	10.00	187.75a	0.00	51.00	
Storage Containers (20')	80.00	39.75a	0.00	29.93	
Tower Section T1	298.00	207.50a	3.25p	76.33	
Tower Section T2	310.00	207.50a	3.25p	203.95	
T1 & T2 Seafasteng/Grill	61.00	207.50a	3.25p	27.08	
Tower Section T3	233.00	260.17a	3.25p	113.73	
T3 Seafastening/Grillage	24.00	260.17a	3.25p	27.08	
Nacelle w/Transpt Fr	858.00	141.67a	8.63p	42.21	
Nacelle Seafasten/Grill	35.00	141.67a	8.63p	27.08	
Blades & Racks	296.00	134.33a	39.18s	64.00	
Total Fixed--------->	6,102.67	187.70a	3.03p	39.15	

Load	SpGr	Weight(LT)	LCG	TCG	VCG	RefHt
2.S 0.050	1.025	41.33	59.40a	40.55s	0.75	-1.22
7.P 0.130	1.025	108.19	319.68a	41.11p	1.66	-2.09
7.S 0.620	1.025	515.98	319.47a	41.22s	7.78	-14.32
Total Tanks--------->		665.50	303.35a	27.79s	6.35	
Total Weight-------->		6,768.17	199.07a	0.00	35.92	

		Displ(LT)	LCB	TCB	VCB	
HULL	1.025	6,768.09	199.20a	0.00	3.48	-6.05

Righting Arms: 0.01a 0.00

Distances in FEET.

HYDROSTATIC PROPERTIES
Trim: Aft 1.5/400.0, No Heel, VCG = 35.92

LCF Draft	Displacement Weight(LT)	Buoyancy-Ctr. LCB	VCB	Weight/ Inch	Moment/ LCF	In trim	GML	GMT
6.783	6,768.09	199.20a	3.48	87.88	196.09a	2215.96	1571.6	109.59

Distances in FEET. Specific Gravity = 1.025. Moment in Ft-LT.
Trim is per 400.00Ft
Draft is from Baseline. Formal Free Surface included.

Note: GMT includes the formal free surface moment 5627.4 Ft-LT

Figure 9 – Stability Base Case 0-0, Full Load, Trimmed for Voyage (Loading)

Criteria: DNVGL-FBD per 10.6.4.2

FREEBOARD STATUS
Baseline draft: 2.052 @ Origin
Trim: Aft 0.03/121.92, Heel: zero
Least freeboard is 5.538 m. located at 121.920a

FREEBOARD = 5.538 M
MAX PERMITTED WAVE HEIGHT PER DNV-GL 10.6.4.2 = 10.076m

Figure 10 – Base Case 0-0, Minimum Freeboard and Limiting Wave Height

Criteria: IMO Code on Intact stability, Part B Section 2.2.4.1 & 3

RIGHTING ARMS vs HEEL ANGLE
Total CG: LCG = 60.677a TCG = 0.000 VCG = 10.949
Free Surface Adjustment: 0.253
Adjusted CG: LCG = 60.676a TCG = 0.000 VCG = 11.203

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Righting Arms in Trim	in Heel	---> Area
1.844	0.21a	0.00	6,876.7	0.002f	0.000	0.0000
1.837	0.20a	5.00s	6,876.8	0.000	2.924	0.1276
1.723	0.19a	10.00s	6,876.7	0.000	5.363	0.4927
1.323	0.17a	15.00s	6,876.8	0.000	6.190	1.0046
0.914	0.15a	18.65s	6,876.8	0.000	6.310	1.4054
0.745	0.14a	20.00s	6,876.8	0.000	6.294	1.5534
0.044	0.10a	25.00s	6,876.8	0.000	6.041	2.0951
-0.722	0.09a	30.00s	6,876.8	0.000	5.489	2.6003
-1.489	0.07a	35.00s	6,876.8	0.000	4.700	3.0466
-2.247	0.06a	40.00s	6,876.8	0.000	3.767	3.4171
-2.989	0.05a	45.00s	6,876.8	0.000	2.743	3.7019
-3.709	0.03a	50.00s	6,876.8	0.000	1.658	3.8944
-4.402	0.02a	55.00s	6,876.8	0.000	0.534	3.9903
-4.713	0.01a	57.34s	6,878.8	0.000	-0.000	4.0012
-5.061	0.01a	60.00s	6,876.8	0.000	-0.611	3.9871

Distances in METERS.---Specific Gravity = 1.025.---Area in m.-Rad.

Note: The Weight and Center of Gravity used for the righting arms above include tank loads. However, the tank load centers were NOT ALLOWED TO SHIFT with heel and trim changes. Rather, a constant Free Surface Moment of 1742.8 m.-MT was applied to artificially modify the CG.

LIM	IMO-PONTOON ENERGY B2.2.4.1&.3	Min/Max	Margin
(1)	Area from abs 0.000 deg to MaxRA	> 0.0800 m.-Rad	1657%
(2)	Angle from abs 0.000 deg to RAzero	> 15.00 deg	42 deg

Relative angles measured from 0.000

Figure 11 – Base Case 0-0, IMO Pontoon Code (Limiting Portion of Criteria)

Criteria: DNVGL-WIND per 11.10.3 with 70 knot wind profile

HEELING MOMENT specification
Lateral Plane Method
Wind pressure toward starboard
Baseline draft: 1.844 @ Origin
Trim: Aft 0.46/121.92, Heel: zero

Part	LPA*SF	HCP	Arm	Pressure	Moment
HULL	664.4	2.801	3.802	0.08616	217.64
SAIL	4127.5	26.771	27.773	0.15100	17,309.23
Total wind heeling moment to starboard---------->					17,526.88

Distances in METERS.-----Pressure in MT/Sqm.----------Moment in m.-MT

WIND PRESSURE vs. HEIGHT

Height	Pressure
0.000	0.00000
0.100	0.02300
0.350	0.04200
1.000	0.06200
2.500	0.08400
5.000	0.10200
10.000	0.12200
20.000	0.14400
50.000	0.17500
100.000	0.20100

Height in meters---Pressure in MT/Sqm.

RESIDUAL RIGHTING ARMS vs HEEL ANGLE

Total CG: LCG = 60.677a TCG = 0.000 VCG = 10.949
Free Surface Adjustment: 0.253
Adjusted CG: LCG = 60.676a TCG = 0.000 VCG = 11.203

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Residual Arms in Trim	in Heel	Res. Area
1.844	0.21a	0.00	6,876.7	0.000	-2.549	0.0000
1.838	0.20a	4.62s	6,876.7	0.000	0.000	-0.1028
1.837	0.20a	5.00s	6,876.8	0.000	0.211	-0.1021
1.723	0.19a	10.00s	6,876.7	0.000	2.508	0.0286
1.323	0.17a	15.00s	6,876.7	0.000	3.205	0.2855
1.059	0.15a	17.44s	6,876.7	0.000	3.258	0.4238
0.745	0.14a	20.00s	6,876.7	0.000	3.199	0.5687
0.044	0.10a	25.00s	6,876.8	0.000	2.865	0.8366
-0.722	0.09a	30.00s	6,876.8	0.000	2.298	1.0635
-1.489	0.07a	35.00s	6,876.8	0.000	1.521	1.2317
-2.247	0.06a	40.00s	6,876.8	0.000	0.632	1.3265
-2.746	0.05a	43.35s	6,876.5	0.000	0.000	1.3451
-2.989	0.05a	45.00s	6,876.8	0.000	-0.319	1.3405
-3.709	0.03a	50.00s	6,876.8	0.000	-1.297	1.2702
-4.402	0.02a	55.00s	6,876.8	0.000	-2.267	1.1147
-5.061	0.01a	60.00s	6,876.8	0.000	-3.245	0.8742

Distances in METERS.---Specific Gravity = 1.025.---Area in m.-Rad.

Note: The Weight and Center of Gravity used for the righting arms above include tank loads. However, the tank load centers were NOT ALLOWED TO SHIFT with heel and trim changes. Rather, a constant Free Surface Moment of 1742.8 m.-MT was applied to artificially modify the CG.

Note: The Residual Righting Arms shown above are in excess of the wind heeling arms derived from the projected wind plane at each heel angle, using the given wind pressure from port.

LIM	DNV-GL WIND 11.10.3 CRITERION	Min/Max	Margin
(1)	Absolute Area Ratio from abs 0 deg to RAzero	> 1.400	14%

Figure 12 – Base Case 0-0, Wind Criteria with 70 knot Wind

C.3 Stability Analysis for Sensitivity Case with Three Tower Sections

Barge/Fender Wall and other outfit transporting three (3) Tower sections (T3, T2, T1), Nacelle and Blades.

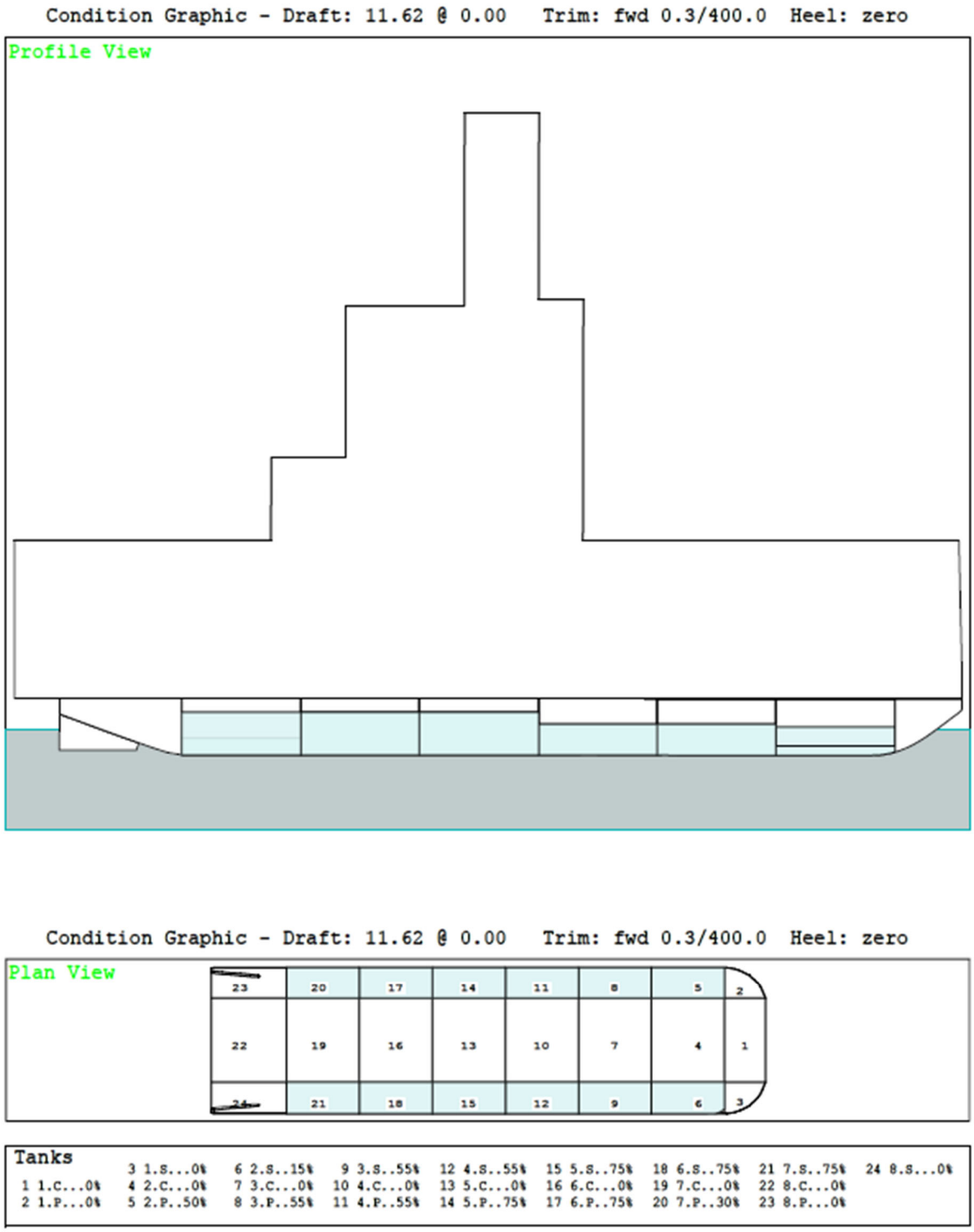

Figure 13 – Stability Sensitivity 1-0, Full Load, Trimmed for Voyage (Layout)

SUMMARY OF LOADING

1,502,431.3 Gals. (21%) SALT WATER

343.00 LT	110 FENDER WALL	115.00 LT	Misc. Weights
80.00 LT	Storage Containers (2	841.00 LT	Tower Section T
61.00 LT	Seafasteng	893.00 LT	Nacelle
296.00 LT	Blades & Racks		

WEIGHT and DISPLACEMENT STATUS
Baseline draft: 11.620 @ Origin
Trim: Fwd 0.3/400.0, Heel: zero

Part	Weight(LT)	LCG	TCG	VCG
LIGHT SHIP	3,473.67	198.12a	3.55s	14.07
110 FENDER WALL	343.00	187.75a	48.82p	38.82
300 Electrical System	50.00	200.00a	0.00	31.00
529 BALLAST SYSTEM	6.00	191.82a	0.00	17.48
582 Mooring system	25.00	187.75a	0.00	51.00
600 Outfitting	10.00	187.75a	0.00	51.00
Storage Containers (20')	80.00	39.75a	0.00	29.93
Tower Section T3	233.00	181.17a	3.25p	113.73
T3 Seafastening/Grillage	24.00	181.17a	3.25p	27.08
Tower Section T2	310.00	233.83a	3.25p	102.25
T2 Seafasteng/Grill	31.00	233.83a	3.25p	27.08
Tower Section T1	298.00	286.50a	3.25p	76.33
T1 Seafasteng/Grill	30.00	286.50a	3.25p	27.08
Nacelle w/Transpt Fr	858.00	115.33a	8.63p	42.21
Nacelle Seafasten/Grill	35.00	115.33a	8.63p	27.08
Blades & Racks	296.00	134.33a	39.18s	64.00
Total Fixed--------->	6,102.67	186.23a	0.58p	33.98

	Load	SpGr	Weight(LT)	LCG	TCG	VCG	RefHt
2.P	0.500	1.025	412.32	56.47a	41.12p	6.43	-12.68
2.S	0.150	1.025	123.70	57.32a	40.85s	2.06	-4.01
3.P	0.550	1.025	457.72	108.74a	41.22p	6.90	-13.85
3.S	0.550	1.025	457.72	108.74a	41.22s	6.90	-13.85
4.P	0.550	1.025	457.73	161.40a	41.22p	6.90	-13.89
4.S	0.550	1.025	457.73	161.40a	41.22s	6.90	-13.89
5.P	0.750	1.025	624.18	214.07a	41.23p	9.40	-18.92
5.S	0.750	1.025	624.18	214.07a	41.23s	9.40	-18.92
6.P	0.750	1.025	624.17	266.74a	41.23p	9.40	-18.96
6.S	0.750	1.025	624.17	266.74a	41.23s	9.40	-18.96
7.P	0.300	1.025	249.67	319.39a	41.19p	3.78	-7.77
7.S	0.750	1.025	624.17	319.41a	41.23s	9.40	-19.00
Total Tanks--------->			5,737.44	201.66a	0.62s	7.99	
Total Weight-------->			11,840.11	193.71a	0.00	21.39	

		Displ(LT)	LCB	TCB	VCB	
HULL	1.025	11,838.32	193.69a	0.00	5.90	-11.62

Righting Arms: 0.01f 0.00

Distances in FEET.

HYDROSTATIC PROPERTIES
Trim: Fwd 0.3/400.0, No Heel, VCG = 21.39

LCF Draft	Displacement Weight(LT)	Buoyancy-Ctr. LCB	VCB	Weight/ Inch	Moment/ LCF	In trim	GML	GMT
11.473	11,838.32	193.69a	5.90	92.33	197.51a	2569.86	1042.0	69.58

Distances in FEET. Specific Gravity = 1.025. Moment in Ft-LT.
Trim is per 400.00Ft
Draft is from Baseline. Formal Free Surface included.

Note: GMT includes the formal free surface moment 5627.4 Ft-LT

Figure 14 – Stability Sensitivity 1-0, Full Load, Trimmed for Voyage (Loading)

```
Criteria: DNVGL-FBD per 10.6.4.2


                    FREEBOARD STATUS
                Baseline draft: 3.396 @ Origin
                Trim: 0.00/121.92,  Heel: zero
          Least freeboard is 4.224 m. located at 2.454a

                    FREEBOARD = 4.224 M
     MAX PERMITTED WAVE HEIGHT PER DNV-GL 10.6.4.2 = 7.448m
```

Figure 15 – Sensitivity 1-0, Minimum Freeboard and Limiting Wave Height

```
Criteria: IMO Code on Intact stability, Part B Section 2.2.4.1 & 3

                    RIGHTING ARMS vs HEEL ANGLE
    Total CG:  LCG = 59.042a  TCG = 0.000   VCG =  6.518
                       Free Surface Adjustment:   0.145
 Adjusted CG:  LCG = 59.042a  TCG = 0.000   VCG =  6.663

  Origin    Degrees of   Displacement    Righting Arms
   Depth---Trim----Heel----Weight(MT)---in Trim--in Heel---> Area
   3.541   0.04f   0.00       12,028      0.002a   0.000    0.0000
   3.533   0.06f   5.00s      12,030      0.000    1.861    0.0812
   3.500   0.09f  10.00s      12,030      0.000    3.739    0.3254
   3.406   0.16f  15.00s      12,029      0.000    5.416    0.7263
   3.217   0.26f  20.00s      12,030      0.000    6.061    1.2347
   3.111   0.31f  22.47s      12,030      0.000    6.110    1.4981
   2.999   0.35f  25.00s      12,030      0.000    6.059    1.7669
   2.760   0.45f  30.00s      12,030      0.000    5.770    2.2860
   2.502   0.54f  35.00s      12,030      0.000    5.322    2.7711
   2.227   0.63f  40.00s      12,030      0.000    4.772    3.2123
   1.937   0.71f  45.00s      12,030      0.000    4.148    3.6020
   1.633   0.79f  50.00s      12,030      0.000    3.470    3.9348
   1.318   0.87f  55.00s      12,030      0.000    2.751    4.2066
   0.994   0.94f  60.00s      12,030      0.000    2.000    4.4141
   0.661   1.01f  65.00s      12,030      0.000    1.228    4.5551
   0.323   1.06f  70.00s      12,030      0.000    0.441    4.6280
   0.133   1.09f  72.78s      12,030      0.000    0.000    4.6387
  -0.019   1.10f  75.00s      12,030      0.000   -0.353    4.6318
  Distances in METERS.---Specific Gravity = 1.025.---Area in m.-Rad.

 Note:  The Weight and Center of Gravity used for the righting arms
        above include tank loads.  However, the tank load centers
        were NOT ALLOWED TO SHIFT with heel and trim changes.  Rather,
        a constant Free Surface Moment of 1742.8 m.-MT was applied
        to artificially modify the CG.

LIM-------------IMO-PONTOON ENERGY B2.2.4.1&.3-------Min/Max----------Margin
(1) Area from abs 0.000 deg to MaxRA              >   0.0800 m.-Rad 1773%
(2) Angle from abs 0.000 deg to RAzero            >    15.00 deg      58 deg
-------------------Relative angles measured from 0.000 --------------------
```

Figure 16 – Sensitivity 1-0, IMO Pontoon Code (Limiting Portion of Criteria)

Criteria: DNVGL-WIND per 11.10.3 with 70 knot wind profile

HEELING MOMENT specification
Lateral Plane Method
Wind pressure toward starboard
Baseline draft: 3.542 @ Origin
Trim: Fwd 0.09/121.92, Heel: zero

Part	LPA*SF	HCP	Arm	Pressure	Moment
HULL	498.4	2.073	3.765	0.07773	145.89
SAIL	4127.5	25.367	27.060	0.14955	16,702.96
Total wind heeling moment to starboard---------->					16,848.85

Distances in METERS.-----Pressure in MT/Sqm.----------Moment in m.-MT

WIND PRESSURE vs. HEIGHT

Height	Pressure
0.000	0.00000
0.100	0.02300
0.350	0.04200
1.000	0.06200
2.500	0.08400
5.000	0.10200
10.000	0.12200
20.000	0.14400
50.000	0.17500
100.000	0.20100

Height in meters---Pressure in MT/Sqm.

RESIDUAL Rrighting ARMS vs HEEL ANGLE

Total CG: LCG = 59.042a TCG = 0.000 VCG = 6.518
Free Surface Adjustment: 0.145
Adjusted CG: LCG = 59.042a TCG = 0.000 VCG = 6.663

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Residual Arms in Trim	in Heel	Res. Area
3.541	0.04f	0.00	12,028	0.002a	-1.401	0.0000
3.537	0.05f	3.95s	12,030	0.002f	0.000	-0.0483
3.533	0.06f	5.00s	12,030	0.000	0.373	-0.0449
3.500	0.09f	10.00s	12,030	0.000	2.178	0.0661
3.406	0.16f	15.00s	12,029	0.000	3.800	0.3283
3.217	0.26f	20.00s	12,030	0.000	4.428	0.6945
3.114	0.30f	22.42s	12,030	0.000	4.473	0.8832
2.999	0.35f	25.00s	12,030	0.000	4.423	1.0839
2.760	0.45f	30.00s	12,030	0.000	4.147	1.4607
2.502	0.54f	35.00s	12,030	0.000	3.728	1.8053
2.227	0.63f	40.00s	12,030	0.000	3.225	2.1093
1.937	0.71f	45.00s	12,030	0.000	2.674	2.3670
1.633	0.79f	50.00s	12,030	0.000	2.082	2.5748
1.318	0.87f	55.00s	12,030	0.000	1.460	2.7296
0.994	0.94f	60.00s	12,030	0.000	0.811	2.8289
0.661	1.01f	65.00s	12,030	0.000	0.145	2.8707
0.589	1.02f	66.08s	12,030	0.000	0.000	2.8721
0.323	1.06f	70.00s	12,030	0.000	-0.533	2.8539

Distances in METERS.---Specific Gravity = 1.025.---Area in m.-Rad.

Note: The Weight and Center of Gravity used for the righting arms above include tank loads. However, the tank load centers were NOT ALLOWED TO SHIFT with heel and trim changes. Rather, a constant Free Surface Moment of 1742.8 m.-MT was applied to artificially modify the CG.

Note: The Residual Righting Arms shown above are in excess of the wind heeling arms derived from the projected wind plane at each heel angle, using the given wind pressure from port.

LIM	DNV-GL WIND 11.10.3 CRITERION	Min/Max	Margin
(1)	Absolute Area Ratio from abs 0 deg to RAzero >	1.400	92%

Figure 17 – Sensitivity 1-0, Wind Criteria with 70 knot Wind

C.4 General HydroStatics (GHS) GeoFile for Analysis

Barge model includes the hull with deck edge, the ballast tanks and a sail representing the fender wall, both the two (2) Tower section (T1/2, T3) and the three (3) Tower section (T3, T2, T1) configurations, the Nacelle and the Blades.

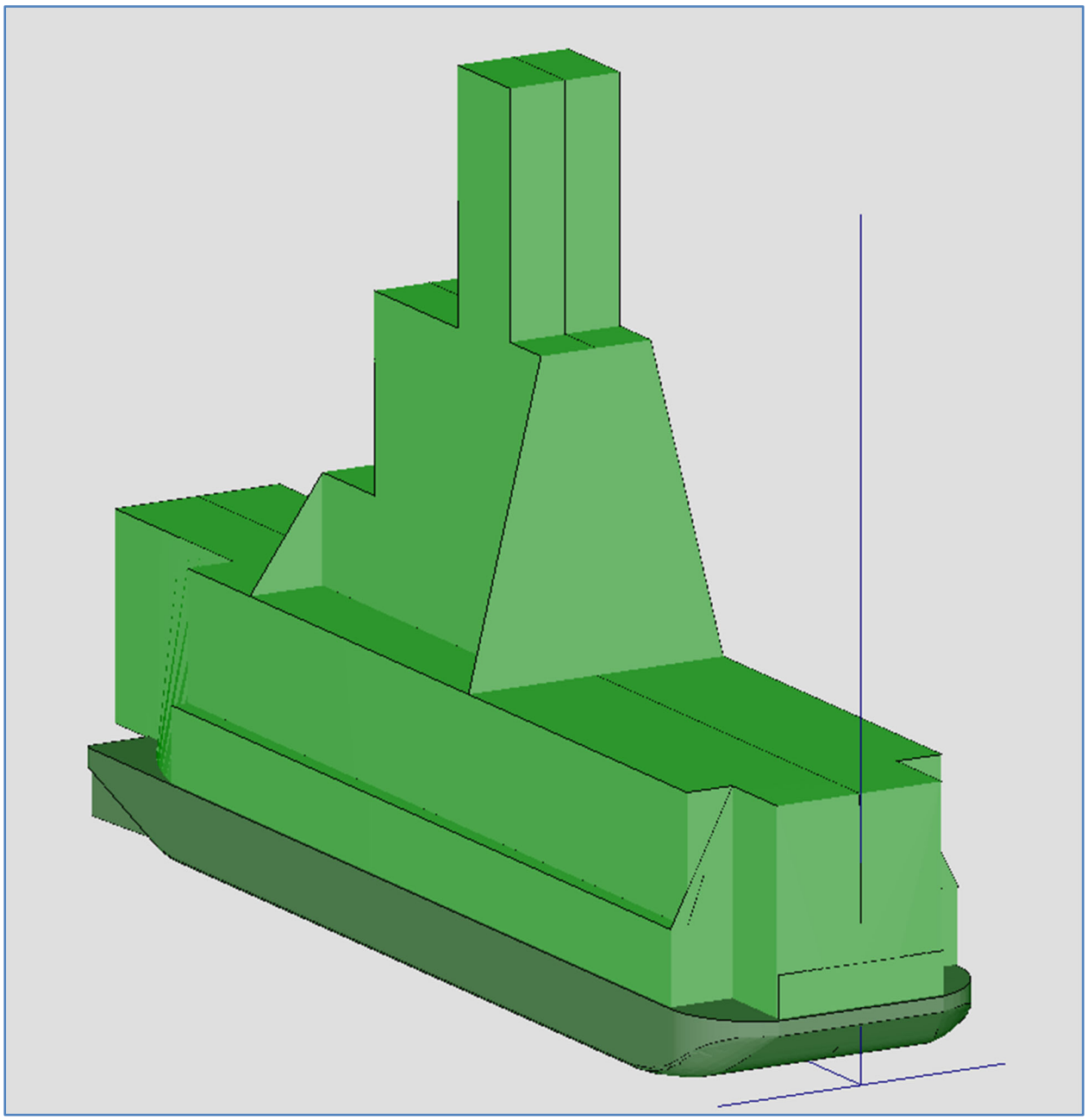

Figure 18 – GHS GeoFile