ROPAX FERRY FOR THE GULF OF ST. LAWRENCE

DR. JAMES A. LISNYK STUDENT SHIP DESIGN COMPETITION

MAY 2023

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Faculty Advisor Statement

By this statement, I certify that the work done for this design competition was completed by the student team members.

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LIST OF ABBREVIATIONS

ABS	American Bureau of Shipping
CFD	Computational Fluid Dynamics
CIS	Canadian Ice Services
CPP	Controllable Pitch Propeller
DNV	Det Norske Veritas
EPIRP	Emergency Position Indicating Radio Beacon
FPP	Fixed Pitch Propeller
GHS	General Hydrostatics
HVAC	Heating, Ventilation, and Air Conditioning
IMO	International Maritime Organization
JONSWAP	Joint North Sea Wave Project
LFO	Liquified Fuel Oil
LNG	Liquified Natural Gas
LM	Lane Meters
MCR	Maximum Continuous Rating
MDO	Marine Diesel Oil
MARPOL	International Convention for the Prevention of Pollution from Ships
MSI	Motion Sickness Incidence
MOHS	Maritime Occupational Health and Safety Regulations
NATO	North Atlantic Treaty Organization
NL	Newfoundland and Labrador
NORDFORSK	Nordic Co-Operative Organization for Applied Research
NS	Nova Scotia
PAB	Port aux Basques
POLARIS	Polar Operational Limit Assessment Risk Indexing System
RIO	Risk Index Outcome
RIVs	Risk Index Values
RoPax	Roll On Roll Off Passengers
SOLAS	Safety of Life at Sea
TC	Transport Canada
USCG	United States Coast Guard

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SUMMARY

This report documents the preliminary design work completed to develop a 3000-lane meter RoPax ferry for Marine Atlantic. The scope of this concept design includes the following:

- The development of a bespoke hull form
- General arrangements
- Resistance and powering predictions
- Structural calculations and a conceptual midship section
- Intact and damaged stability analyses
- Seakeeping predictions
- Weight estimates, and
- Cost estimates

The principal particulars provided in Table 1 result from multiple iterations of the design.

Table 1: Principal Particulars

Length Overall (m)	204.0
Waterline Between Perpendiculars (m)	188.0
Beam (m)	28.0
Draft (m)	6.7
Displacement (t)	24,578.0
Deadweight (t)	4355.0
Service Speed (knots)	14.0
Maximum Speed (Knots)	20.0
Installed Power (kW)	21,600
C_B	0.63
Vehicle Capacity (lane meters)	3263
Passenger Capacity	1000
Crew	99

Figure 1: Rendering of the Proposed Vessel

1 INTRODUCTION

The MV Leif Ericson currently serves Marine Atlantic on the Port aux Basques, Newfoundland and Labrador (NL) to North Sydney, Nova Scotia (NS) route as an exclusively commercial vehicle carrier. This vessel has been in operation since 1991 and is approaching the end of her service life. Marine Atlantic is seeking to replace the vessel with a new build that can transport commercial and passenger vehicles on both the North Sydney to Argentia and North Sydney to Port aux Basques routes.

Leif Ericson's replacement creates an opportunity to modernise the Marine Atlantic fleet and increase its passenger and vehicle carrying capacity. With the growing demand for travel to and from the island of Newfoundland, particularly during the summer months, expanding the ferry service is essential to Newfoundland and Labrador's tourism industry.

2 BACKGROUND INFORMATION

2.1 MARINE ATLANTIC

Marine Atlantic is a Crown Corporation established in 1986. They currently operate a fleet of four ships – MV Atlantic Vision, MV Blue Puttees, MV Highlanders, and MV Leif Ericson. In 2019 (prior to the COVID-19 pandemic), Marine Atlantic's ferries carried a combined 311,499 passengers, 120,426 passenger vehicles, and 82,194 commercial vehicles across 1632 total sailings [1].

2.2 ROUTE

Marine Atlantic ferries operate on two routes – North Sydney to Port aux Basques and North Sydney to Argentia.

2.2.1 North Sydney to Port aux Basques

The North Sydney to Port aux Basques route is a 96 nautical mile (nm) daily ferry service. A typical crossing takes 7 hours to complete at an average speed of 14 knots. The ferry will depart from the Port aux Basques or North Sydney terminal at 11:45 and arrive at the opposite terminal at 18:45. The evening ferry will depart at 23:15 and arrive at the opposite terminal at 07:30. There is a four-hour turnaround period between each sailing to embark/disembark all passengers and vehicles, take on new provisions, refuel if necessary, and clean the passenger accommodations.

2.2.2 North Sydney to Argentia

The North Sydney to Argentia route is a 280nm service. It is only offered between mid-June and late-September to accommodate tourists travelling to St. John's, NL. This is a much longer route compared to the North Sydney to Port Aux Basques crossing and usually takes 16.5 hours to complete at an average speed of 17 knots. The ferry will depart from the North Sydney or Argentia terminal at 17:00 and arrive at the opposite terminal at 09:00 the following morning. There is an eight-hour turnaround period between each crossing.

Figure 2 below shows the ferry routes and corresponding distances.

Figure 2: Marine Atlantic Service Routes [1]

2.3 Operational Profile

The typical operating profile of a Marine Atlantic ferry is shown in Figure 3. Most of the ferry's time is spent in transit between North Sydney and Port aux Basques. In 2022, this route was crossed 1727 times [2]. A third of the ferry's time is spent in port loading and unloading vehicles. The Argentia crossing represents only 15% of the ferry's operating profile. This is because the Argentia service is only provided between June and September. In 2022, only 76 Argentia crossings were completed [2]. The remaining time is considered downtime. This includes pauses in operation for maintenance or crossings cancelled due to poor weather.

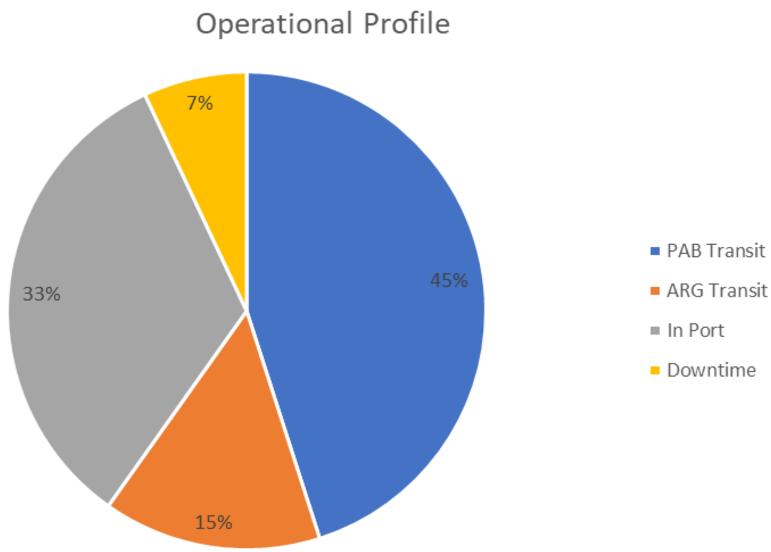

Figure 3: Operational Profile of Current Marine Atlantic Fleet

2.4 Environmental Conditions

2.4.1 Waves

Conditions can be very rough in the Cabot Strait, particularly in winter (November through March), when the mean wave heights are between 1.9m and 2.7m (Figure 4). Maximum wave heights in the strait that exceed 10m are also recorded numerous times each year (Figure 5). From May to August, the sea-state is calmer, with average significant wave heights between 1.4m and 2.0m [3].

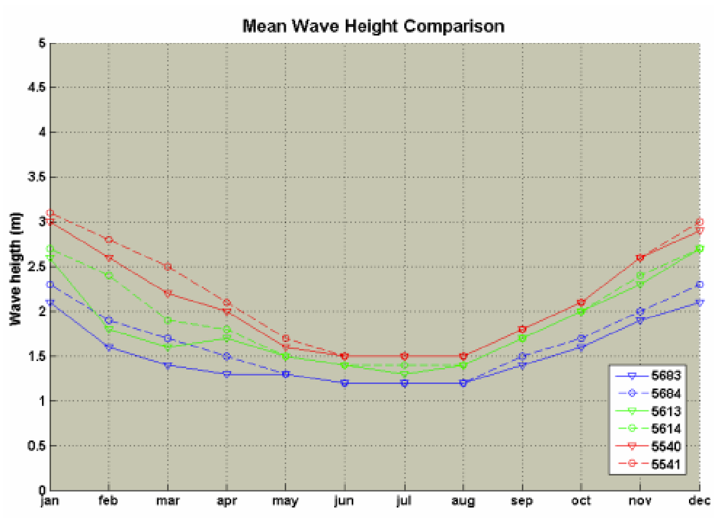

Figure 4: Mean Wave Height in the Cabot Strait [3]

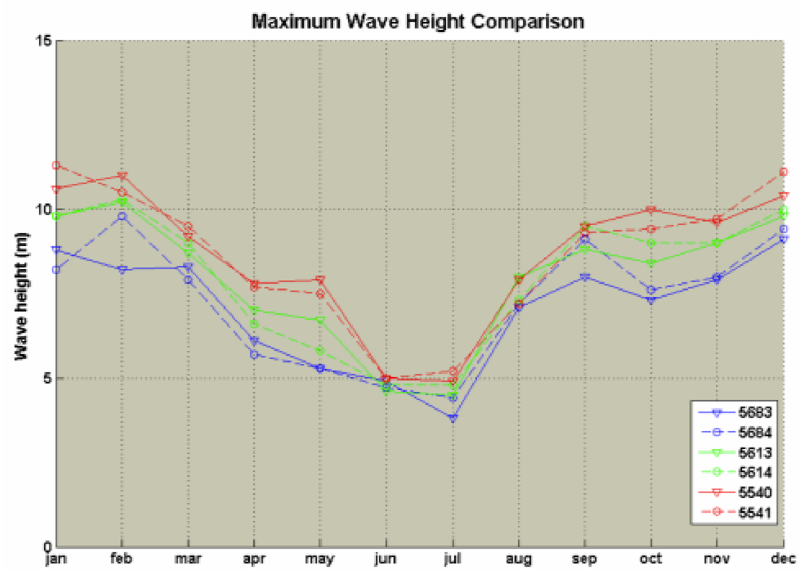

Figure 5: Maximum Wave Height in the Cabot Strait [3]

Table 2 below summarises the sea states for each month of the year based on the past 40 years of collected weather data.

Table 2: Monthly Mean and Maximum Wave Parameters [3]

Month	MEAN HSIG (M)	MEAN TP (S)	MAX. HSIG (M)	TP OF MAX. HSIG (S)	MAX TP (S)
January	2.7	8.4	9.8	12.2	15.6
February	2.4	8.1	10.3	14.1	14.7
March	1.9	7.1	9.0	11.9	16.1
April	1.8	7.6	6.6	11.8	16.0
May	1.5	7.5	5.8	9.8	19.3
June	1.4	7.4	4.8	10.4	16.1
July	1.4	7.4	4.8	10.1	17.5
August	1.4	7.3	7.3	13.0	16.2
September	1.7	7.7	9.5	12.8	18.5
October	2.0	7.5	9.0	12.7	17.7
November	2.4	7.9	9.0	14.1	14.5
December	2.7	8.4	10.0	13.0	15.6
Average	**1.9**	**7.7**	**10.3**	**14.1**	**19.3**

2.4.2 Ice

Ice patches often build up around Cape Breton between January and May each year. Figure 6 shows a particularly large ice pack around Cape Breton in March 2015. The ice that accumulates typically consists of new ice or winter ice. Ice concentrations vary, but it is common for patches to be large, highly concentrated (9+), and consist primarily of first-year ice [4].

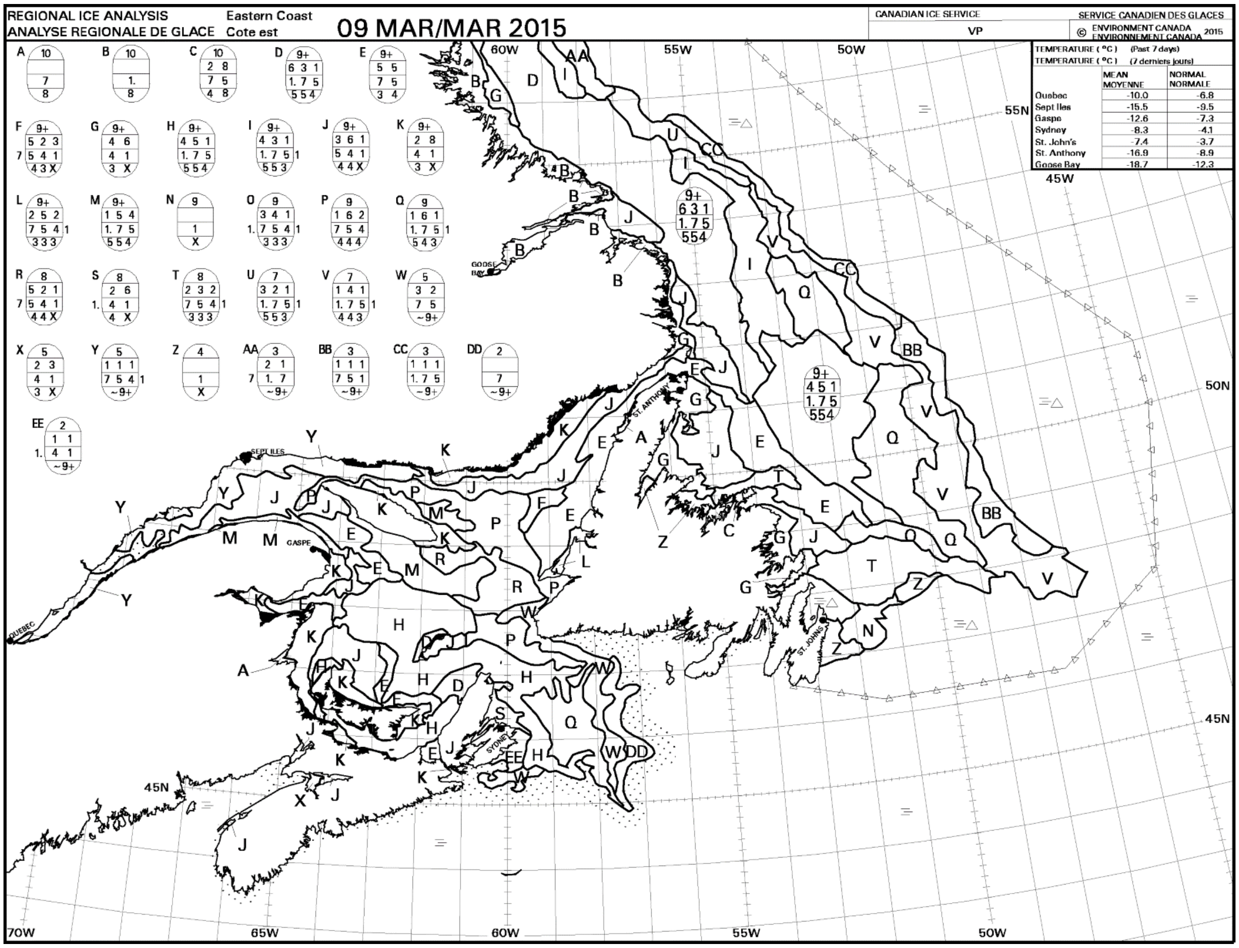

Figure 6: Regional Ice Analysis, March 2015 [4]

2.4.3 Vessel Icing

Moderate or worse icing is expected 15% – 20% of the time in January and February. Conditions improve in March, with moderate or worse icing expected 5% - 10% of the time. Icing conditions in December are similar to those expected in March [3].

2.4.4 Wind

Winds often reach gale forces in the Cabot Strait. High winds are one of the most common causes of delays to the ferry service. Additionally, Port aux Basques has a reputation for being a particularly difficult port to navigate due to the frequency of high winds experienced in the area. Marine Atlantic has retrofitted two of its ships with an additional bow thruster to improve manoeuvrability in high winds.

3 REQUIREMENTS

The requirements for the vessel are summarised below. A detailed list of requirements can be found in the owner's requirements provided in Appendix A.

The vessel will operate year-round between Nova Scotia and Newfoundland and must integrate seamlessly with the existing boarding infrastructure at the three Marine Atlantic terminals. It must also maintain the current timetable and be capable of operating in ice conditions common around Cape Breton.

Key requirements for the vessel include accommodations for 1000 passengers, 100 crew, and 3000 lane meters of vehicle capacity. It must also be in service for 40 years, which has a significant impact on the structural arrangements, accommodations, and propulsion system.

The vessel will be classed with Det Norske Veritas (DNV), as with all of Marine Atlantic's ferries. It must therefore be designed following the relevant DNV rules and regulations for classification. It must also comply with the following rules and codes as they pertain to RoPax vessels:

- International Maritime Organization (IMO)
- Transport Canada (TC)
- International Convention for the Safety of Life at Sea (SOLAS)
- International Load Line Convention (LLC)
- International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Maritime Dangerous Goods (IMDG) Code
- Canadian Transportation Agency's Ferry Accessibility for Persons with Disability Code of Practice

4 DESIGN CONSIDERATIONS

4.1 BOARDING INFRASTRUCTURE

4.1.1 North Sydney

The North Sydney terminal allows two-level vehicle loading/unloading via two ramps. It has facilities which allow the current fleet of ferries to connect to shore power during turnaround periods.

4.1.2 Port aux Basques

Port aux Basques also allows for two levels of vehicle loading/unloading and allows ferries to connect to shore power.

4.1.3 Argentia

The Argentia terminal is much smaller in comparison to the North Sydney and Port aux Basques terminals. It only has single ramp loading and does not have the infrastructure in place which would allow vessels to connect to shore power. However, this capability is expected to be added in the future.

4.2 Crewing

The crewing arrangements on Marine Atlantic ferries typically consist of between 70 to 90 crew members [2]. Most of the crew are part of the passenger services department, and as a result, the crew size varies based on the route. There will be more service staff onboard for the Argentia route since over 90% of passengers are tourists, whereas just under 60% of passengers are tourists on the Port aux Basques route [2]. The new ferry must have significantly more cabins than any of the ships in the current fleet. This requires an increase in the number of service staff to ensure all the cabins can be cleaned for new passengers within the four-hour turnaround period. The number of crew is also subject to Transport Canada Marine Personnel regulations [6]. Table 3 provides a summary of the maximum crew complement.

Table 3: Anticipated Maximum Crew Complement on the Atlantic Puffin

Position	Number
Master	1
Deck Officers	6
Chief Engineer	1
Engineers	6
Crew	25
Service Staff	60
Total	**99**

4.3 Passenger and Crew Accommodations

Passenger accommodations should be located as far away as possible from the engines and other mechanical equipment to minimize disruption due to vibration and noise. The vessel will be expected to obtain COMF (V-1, C-1) notation from DNV. There will be various cabin grades, including suites, window cabins, inside cabins, as well as fully accessible cabins.

There must be a private head in each cabin which includes a small shower, toilet, and sink. Most cabins may be two berths with an additional two berths that are lowered from the deck head.

Marine Atlantic crew work a monthly tour pattern which consists of 15 days working on the ship and 15 days of leave. As a result, crew accommodations are required. Each crew cabin will have its own head and shower, a desk, and a chair, as recommended by the Canadian Maritime Occupational Health and Safety (MOHS) regulations [6].

There will also be pet-friendly accommodations which will allow passengers to bring their pets into the cabin rather than leaving them in vehicles or kennel facilities. These designated cabins will represent 10% of all cabins and will include alternative deck covering to carpeting so they can be easily cleaned.

4.4 Typical Loads

The following loading estimates (Figure 7) are based on traffic data provided by Marine Atlantic for the 2022 season [2]. The average vehicle distribution on the Port aux Basques service in 2022 consisted primarily of passenger vehicles (57%) and a nearly equal split between drop units (trailers not connected to a truck) and live units (connected truck and trailer).

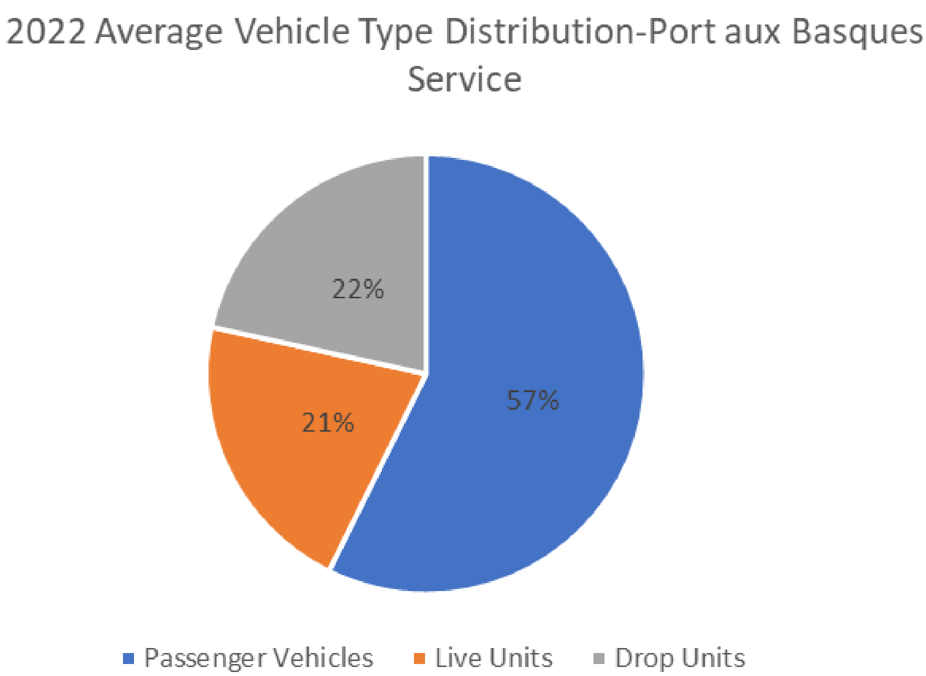

Figure 7: Average Vehicle Type Distribution - Port aux Basques Service

A similar distribution was created for the Argentia service (Figure 8). This crossing caters towards tourists headed for St. John's, which is reflected in most vehicles being passenger cars. Only 3% of a typical load consists of commercial traffic.

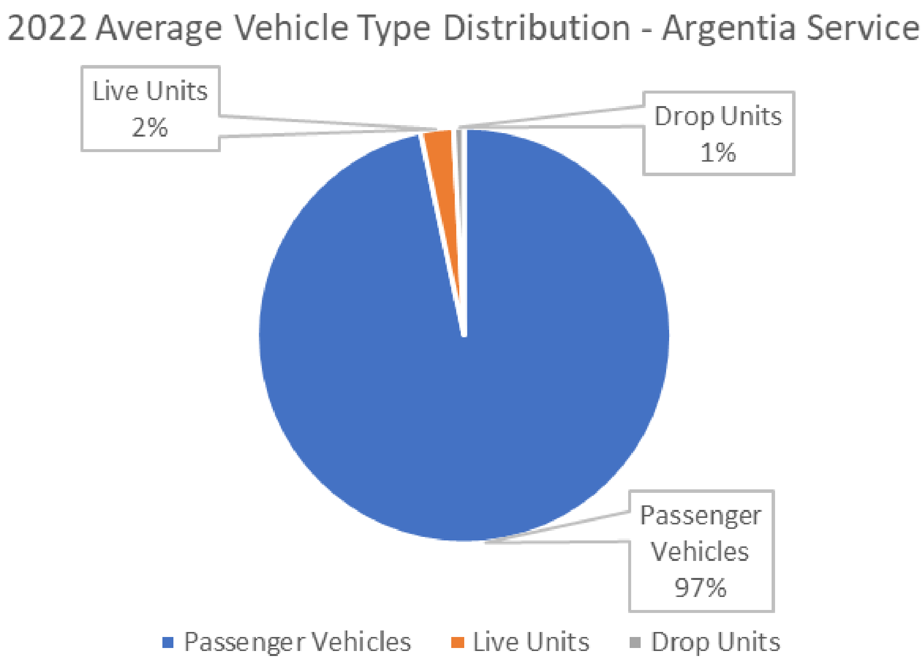

Figure 8: Average Vehicle Type Distribution - Argentia Service

4.5 Parametric Study

A parametric study was completed to help determine the guiding particulars of the vessel. Some key aspects of the comparison are provided in Table 4.

Table 4: Comparison of Relevant Particulars

Vessel	Length (m)	Beam (m)	Draft (m)	Passenger Capacity	Vehicle Capacity (Lane Meters)	Service Speed (kn)	Installed Power (kW)	GRT
Atlantic Vision	203	25	6.7	700	2425	25.5	40,080	30,285
Blue Puttees/ Highlanders	200	26.7	6.2	1000	2840	18	21,600	28,460
Stena Edda	215	27.8	6.4	1000	2723	22	25,200	42,400
Rusadir	187.4	31	6.6	1680	2600	22	-	42,000
Gotland	200	32	6.4	1500	1600	28.5	50,400	29,746
Megastar	212	30.6	6.7	2800	3653	27	40,600	49,134

Using the parametric study and the physical design constraints provided by Marine Atlantic [2], the preliminary principal particulars, shown in Table 5, were determined.

Table 5: Guiding Principal Particulars

Length Overall (m)	204
Beam (m)	28
Draft (m)	6.7
Displacement (t)	25,000
Deadweight (t)	4500
Service Speed (kn)	14
Maximum Speed (kn)	20
Installed Power (kW)	24,000
Block Coefficient	0.60

5 PROPULSION OPTION ANALYSIS

5.1 FUEL TYPE

Given the vessel's expected 40-year service life, it is necessary to consider alternative fuel sources to ensure it will comply with increasingly strict emissions regulations. Five factors were considered in selecting a suitable alternative fuel source for the vessel:

1. Emissions – Environmental impact and compliance with future regulations
2. Availability – Ease of obtaining fuel and existence of necessary infrastructure in North Sydney
3. Fuel Cost – Cost of obtaining the fuel
4. Build Cost – Impact on capital expenses due to additional machinery and complexity
5. Volumetric Energy Density – Space required to store the fuel

After a review of vessels that have been designed to operate on alternatives to diesel, the following six energy sources were identified as potential fuels for the vessel:

- Liquified Natural Gas (LNG)
- Ammonia
- Methanol
- Hydrogen
- Dual Fuel (LNG and MDO)
- Hybrid

A comparison of energy densities for each of the fuel types considered is provided in Table 6.

Table 6: Comparison of Fuel Energy Densities [7]

Fuel Type	Energy Density (kWh/kg)	Volumetric Energy Density kWh/L)	Density (kg/m^3)
MDO (Baseline)	11.9	9.97	838
LNG	13.5	5.93	440
Ammonia	5.2	3.53	682
Methanol	5.5	4.44	1232
Hydrogen (Liquid)	33.3	2.36	71

A scoring matrix was then used to assess the suitability of each fuel type, as shown in Table 7:

Table 7: Fuel Type Scoring Matrix

		Dual Fuel	LNG	Ammonia	Methanol	Hydrogen	Hybrid
Factor	***Weight***	***Score***	***Score***	***Score***	***Score***	***Score***	***Score***
Emissions	15%	2	4	3	3	5	3
Availability	30%	5	2	2	1	1	5
Fuel Cost	25%	4	4	2	2	3	5
Build Costs	20%	3	3	3	4	2	2
Volume	10%	2	3	2	2	1	1
Weighted Score		**3.6**	**3.1**	**2.35**	**2.25**	**2.3**	**3.7**

Based on the scores obtained from the scoring matrix and considerations given to the vessel's long service life, a dual fuel (LNG-MDO)-battery hybrid system will be used. Using pure LNG would have been preferable; however, North Sydney currently has no bunkering facilities. There are plans to add LNG bunkering infrastructure in the future, so the vessel will be LNG fuel ready for when LNG becomes available.

The vessel will also incorporate batteries into the propulsion system. These will primarily be used when the vessel is manoeuvring into and out of the Marine Atlantic terminals to reduce the vessels' emissions and noise when near the port communities.

The proposed arrangement would be more expensive than a pure MDO system. However, it is likely that if such an arrangement is not installed when the vessel is initially built, it would need to be retrofitted later in its career to meet emissions regulations at considerable expense.

5.2 Machinery Configuration

Five machinery configurations that are typical for passenger ferries were considered:

1. Dual Fuel-Electric with Pods

2. Dual Fuel-Electric with Fixed Pitch Propeller (FPP)
3. Dual Fuel-Electric with Controllable Pitch Propeller (CPP)
4. Medium Speed Dual Fuel with FPP
5. Medium Speed Dual Fuel with CPP

Most of the ferries included in the parametric study were designed with a twin-screw diesel-electric arrangement. This arrangement provides a high level of flexibility in the placement of the main engines and is very reliable. Medium-speed diesels are also common among RoPax ferries. They are reliable, compact, and relatively low-cost. However, due to the frequently changing electrical demands of the vessel and the simplicity of incorporating a battery hybrid system, a diesel-electric arrangement was selected.

Podded propulsors offer greater manoeuvrability compared to CPP or FPP and reduced vibrations [7]. Both are significant advantages, particularly for this application where passenger comfort is crucial and manoeuvring in Port aux Basques is notoriously difficult. Pods also can reduce fuel consumption, which would help the vessel achieve its emission targets.

Pods are more expensive than a CPP or FPP arrangement and require the vessel to have a specific stern shape. They are also not ideal for vessels with a relatively shallow draft.

Ultimately, pods were chosen due to the considerable benefit they provide to the vessel's manoeuvrability and passenger comfort. This result aligns with a study commissioned by Marine Atlantic in 2008 to develop a notional 200m ferry concept [8]. In that study, pods were recommended, although Marine Atlantic was not in favour of a podded arrangement at the time as pods were still relatively new and there were reliability concerns. They have since become more reliable and popular, particularly on passenger ships.

6 ICE CLASS

6.1 ICE CLASS SELECTION

The ferry will be operating in an area where ice builds up during the winter months. It, therefore, requires some level of ice-strengthening or icebreaking capability. The Polaris Code was used in combination with archived ice data from the Canadian Ice Services (CIS) [4] to determine the required ice-breaking class.

This method involves identifying the worst ice conditions likely to be experienced in the area of operation and using Risk Index Values (RIVs) corresponding to the desired ice class to then calculate the Risk Index Outcome (RIO). The resulting RIO can be evaluated to determine the operational risk associated with sailing the vessel through the worst expected ice conditions.

The equation shown below is used to calculate the RIO. The variable C_i represents the concentration of ice types within an ice regime, and V_i is the value corresponding to C_i obtained from Figure 9.

$$RIO = [C_1 \times RIV_1] + [C_2 \times RIV_2] + [C_3 \times RIV_3] + [C_4 \times RIV_4]$$

	RISK INDEX VALUES (RIVs) for each Ice Type											
	ICE FREE	NEW ICE	GREY ICE	GREY WHITE ICE	THIN FIRST YEAR 1ST STAGE	THIN FIRST YEAR 2ND STAGE	MEDIUM FIRST YEAR	MEDIUM FIRST YEAR 2ND STAGE	THICK FIRST YEAR	SECOND YEAR	MULTI YEAR	HEAVY MULTI YEAR
PC 1	3	3	3	3	2	2	2	2	2	2	1	1
PC 2	3	3	3	3	2	2	2	2	2	1	1	0
PC 3	3	3	3	3	2	2	2	2	2	1	0	-1
PC 4	3	3	3	3	2	2	2	2	1	0	-1	-2
PC 5	3	3	3	3	2	2	1	1	0	-1	-2	-2
PC 6	3	2	2	2	2	1	1	0	-1	-2	-3	-3
PC 7	3	2	2	2	1	1	0	-1	-2	-3	-3	-3
IAS	3	2	2	2	2	1	0	-1	-2	-3	-4	-4
IA	3	2	2	2	1	0	-1	-2	-3	-4	-5	-5
IB	3	2	2	1	0	-1	-2	-3	-4	-5	-6	-6
IC	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
No Ice Class	3	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-8

Figure 9: Risk Index Values for each Ice Type [10]

To operate safely in the worst ice conditions expected, the ferry must attain an RIO greater than zero, as shown in Table 8.

Table 8: Risk Index Outcomes and Ice Class Guidelines [10]

RIO_{Ship}	Ice Classes PC1-PC7	Ice Classes below PC7 and ships not assigned an ice class
RIO ≥ 0	Normal Operation	Normal Operation
-10 ≤ RIO < 0	Elevated operational risk	Operation subject to special consideration
RIO < -10	Operation subject to special consideration	Operation subject to special consideration

To determine a suitable ice class for the ferry, ice condition data along the route was collected from 2015 to 2022. This data was then used to calculate the RIOs for a Finnish-Swedish 1AS, 1A, 1B, and 1C class vessel. It was then possible to determine the number of instances when the vessel would operate at an elevated risk or was subject to special consideration. This data can be found in Appendix B.

These results showed that there were no instances where a 1AS vessel would be at an elevated operational risk. For a 1A class vessel, only once between 2015 and 2022 would the vessel be at an elevated operational risk. A 1B vessel was subject to special consideration 22 times, and a 1C vessel was subject to special consideration 53 times.

The costs associated with building a ship to meet an ice class can be quite high. It is, therefore, acceptable for the ferry to occasionally operate subject to special considerations if a lower ice class is feasible. It, therefore, does not need to be 1AS; however, the 22 instances where a 1B vessel would be at an elevated risk is too frequent of an occurrence. The ferry will consequently comply with Baltic 1A ice class rules.

6.2 FINNISH-SWDISH 1A REQUIREMENTS

Finnish-Swedish 1A ice class falls into Category C of the polar ship categories. Ships within this category are designed to navigate difficult ice conditions with the assistance of an icebreaker when necessary. Finnish-Swedish 1A class vessels must be able to achieve a speed of at least five knots in brash ice measuring 1.0m thick [11].

6.2.1 Strengthened Regions

Per DNV-RU-SHIP Pt. 6 Chapter 6 Cold Climate [11], for the purposes of ice strengthening, the vessel is divided into three regions – bow, midbody, and stern (Figure 10). The bow region extends from the stem to a line drawn parallel to, and aft of the forward borderline of the area of the hull where the waterlines are parallel to the centerline. The midbody region begins where the bow region ends and stretches to a line drawn parallel to, and aft of the area of the hull where the waterlines run parallel to the centerline. The stern region is then simply the region which begins immediately aft of the midbody region and extends to the stern of the vessel [12].

The shell plating within the ice belt is required to extend 0.5m above the Upper Ice Waterline (UIWL) in all regions, and 0.9m below the Lower Ice Waterline (LIWL) in the bow region, and 0.75 in the midbody and stern regions [12].

Transverse and longitudinal frames must also be strengthened in the ice belt. At the bow, the strengthening for frames extends 1.0m above the UIWL for all regions, 1.6m below the LIWL in the stern region, 1.6m in the bow region, 1.3m in the midship region, and 1.0m in the stern region.

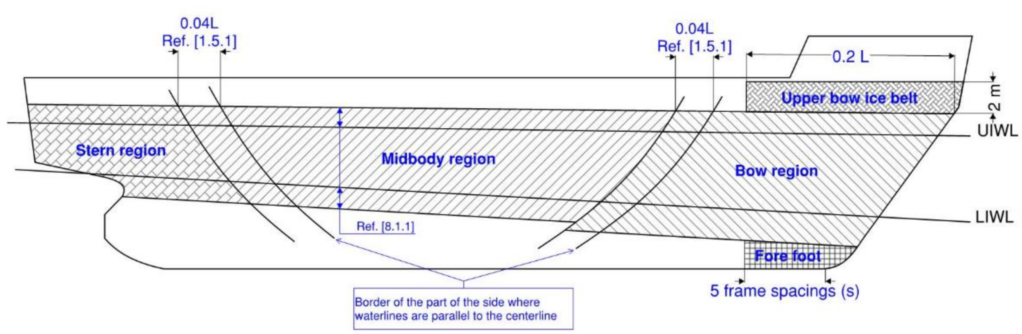

Figure 10: Extent of Ice Strengthening [12]

7 Structure

7.1 Applicable Regulations

The vessel must comply with all applicable regulations from DNV-RU-SHIP Pt. 2 Materials and Welding [13], DNV-RU-SHIP Pt. 3 Hull [14], DNV-RU-SHIP Pt. 5 Chapter 3 RO/RO Ships [15], DNV-RU-SHIP Pt 5 Chapter 4 Passenger Ships [16], and DNV-RU-SHIP Pt. 6 Chapter 6 Cold Climate [12].

7.2 Framing System

Long ships will typically utilize either a longitudinal or mixed framing system. Longitudinal framing is more efficient as less material is required to resist the large bending loads on the hull, allowing for a higher deadweight capacity. However, a pure longitudinal arrangement requires deep web frames, which would intrude on the vehicle decks. The nature of ro-ro ferries necessitates having large unobstructed decks for faster vehicle loading and higher vehicle capacities. The vessel will therefore use a mixed framing system to maximize the available vehicle deck space and minimize structural weight.

7.3 Material

According to DNV-RU-SHIP Pt.3 Chapter 3: Hull [17], ice-strengthened ships must use a minimum steel grade of either B or AH for shell strakes in ice-strengthened areas for plates.

In non-ice-strengthened areas, primary structural members must be Class II within 0.4L amidships and grade A/AH steel outside of 0.4L amidships. Secondary structural members in non-ice-strengthened areas must be Class I within 0.4L amidships and grade A/AH steel outside of 0.4L amidships.

These requirements, along with discussions with representatives from the American Bureau of Shipping (ABS), who are familiar with ice conditions in the area of operation, ultimately led to the decision to use AH36 steel for most of the vessel's structure.

7.4 Midship Section Modulus

The minimum midship section modulus was estimated using the two methods described in DNV-RU-SHIP Pt 3 Section 1.3 and 1.4 [17]. The first method (Table 9) is based on the vessel's hull parameters and material. The second method (Table 10) is based on estimated still water and wave induced bending moments in hogging and sagging conditions. The larger value produced by the two estimates was taken as the minimum required section modulus.

Table 9: Midship Section Modulus (Method 1)

Parameter		Value
Rule Length (m)	L	188
Beam (m)	B	28
Block Coefficient	C_B	0.63
Material Factor	k	0.72
Reduction Factor	f_r	1
Wave Parameter	C_{wo}	9.56
Minimum Section Modulus (m^3)	$Z_{R\text{-}gr}$	9.06

Table 10: Minimum Section Modulus (Method 2)

Parameter		Value
Vertical wave bending moment for strength assessment amidships in hogging condition (kNm)	$M_{wv\text{-}h\text{-}mid}$	1133024.7
Vertical wave bending moment for strength assessment amidships in sagging condition (kNm)	$M_{wv\text{-}s\text{-}mid}$	-1384694.7
Bending moment in hogging Condition (kNm)	$M_{sw\text{-}h\text{-}min}$	1019722.3
Bending moment in sagging Condition (kNm)	$M_{sw\text{-}s\text{-}min}$	-652844.4
Permissible hull girder bending stress (N/mm^2)	σ_{perm}	243.1
Minimum section modulus, hogging (m^3)	$Z_{GR\text{-}h}$	8.86
Minimum section modulus, sagging (m^3)	$Z_{GR\text{-}s}$	8.38

7.5 Hull Scantlings

Estimates for the hull scantlings were obtained from DNV-RU-SHIP Pt 3 Chapter 3: Structural Design Principles [17] and DNV-RU-SHIP Pt 3 Chapter 6: Local Hull Scantling [18]. The Net Scantling Approach was taken to determine the gross thickness, considering anticipated corrosion over the forty-year life of the vessel. All values were rounded up for conservatism. Detailed calculations and a complete list of scantlings are included in Appendix C, and a summary of obtained values are shown in Table 11 below.

Table 11: Calculated Hull Scantlings

Bottom Plating Thickness (mm)	15.0
Bilge Strake Thickness (mm)	13.0
Centerline Girder Thickness (mm)	13.0
Side Shell Thickness (mm)	12.0
Bottom Longitudinal Thickness (mm)	11.0
Weather Deck Plate Thickness (mm)	10.0

7.6 VEHICLE DECK SCANTLINGS

The required thickness of the vehicle deck plating was estimated from DNV-RU-SHIP Pt 3 Chapter 10: Special Requirements [19]. The process of calculating the minimum plate thickness involves estimating vertical accelerations and tire patch areas to determine a design pressure while at sea. The vehicle load and tire patch area values were based on a fully loaded tractor-semitrailer. Full calculations are included in Appendix C, and a summarized list is shown in Table 12.

Table 12: Vehicle Deck Calculated Scantlings

Minimum Required Thickness (mm)	11.4
Design Thickness (mm)	14.0

7.7 ICE STRENGTHENING

The plating at the ice belt is required to be thicker than the plating in other areas to withstand impacts with ice. The thickness of the plating in ice-strengthened areas was determined based on a procedure outlined in DNV-RU-SHIP Pt. 6 Chapter 6: Cold Climates [12]. The minimum thickness includes a 2mm addition as required by DNV to account for abrasion and corrosion. The final value was further increased to 30.0 mm for added conservatism and to account for the particularly long service life of the vessel. The full calculations are provided in Appendix C, and the resultant ice-strengthening values at the midship section are shown in Table 13.

Table 13: Ice Strengthening Calculation Results

R_{eH} (MPa)	355
Minimum t (mm)	26.4
Design t (mm)	30.0

7.8 MIDSHIP SECTION

The midship section drawing provided in Appendix D shows the preliminary structural arrangements of both ordinary and web frames. The scantlings specified in the drawing reflect the estimates above, but further structure optimisation should be performed to reduce structural weight.

The section modulus realized in the midship section drawing exceeds the minimum required by DNV. This ensures that the vessel will be able to operate for 40 years without serious concerns related to fatigue. The midship section modulus results are provided in Table 14 below.

Table 14: Midship Section Modulus Results

Required Section Modulus (m^3)	9.06
Designed Section Modulus, Deck(m^3)	13.1
Designed Section Modulus, Keel (m^3)	17.7

Appendix C contains detailed structural calculations and the scantlings for various structural elements.

8 WEIGHT ESTIMATE

8.1 LIGHTSHIP WEIGHTS AND CENTRES ESTIMATE

The preliminary lightship weights and centres estimates were produced using a series of parametric equations provided in Chapter 11 of SNAME's *Ship Design and Construction Volume 1* [20]. The method separates the total lightship weight into four weight groups:

- Structural Weight (W_S)
- Machinery Weight (W_M)
- Outfit Weight (W_O)
- Weight Margin (W_{Margin})

The four groups can then be summed to estimate the lightship weight. The complete calculation is provided in Appendix E.

The total lightship weight is provided in Table 15. Watson and Gilfillan recommend applying a 3% margin to the weight estimate derived from the equations they developed [20]. Due to the added complexity of LNG and podded propulsors, a more conservative 5% margin was used.

Table 15: Vessel Component Weights for Weight Margin

Component	Weight (Tonnes)
Structure	10160
Machinery	1731
Outfit	7370
Total	19260
5% Margin	**20223**

The centres were also estimated using formulas provided in Ship Design and Construction Volume 1 [20]. The centres are divided into three groups – structure, outfit, and machinery. Table 16 summarizes the centres for each group.

Table 16: Centres of Gravity

Group	LCG (m)	TCG (m)	VCG (m)
Hull	96.9	0	8.4
Superstructure	94.5	0	26.0
Deckhouse	113.0	0	33.0
Outfit	91.3	0	18.9
Machinery	54.5	0	4.1
Net	**91.1**	**0**	**13.34**

8.2 DEADWEIGHT ESTIMATE

The following elements (Table 17) of the deadweight estimate were obtained from SNAME's Ship Design and Construction Volume 1 [20].

Table 17: Deadweight Component Estimates [20]

Component	Weight (tonnes)
Freshwater	0.17/person
Crew and Effects	0.17/person
Passengers and Effects	0.17/person
Provisions	0.01/person/day

The weight of a passenger vehicle was based on an automotive trends study conducted by the U.S. Environmental Protection Agency [21]. The study reported an average vehicle curb weight (weight of the vehicle plus consumables such as fuel and brake fluid) of 1885kg [22]. The study also indicated that average vehicle weight is expected to grow as electric vehicles, which typically weigh more than their fuel counterparts, become increasingly popular [22]. To account for this growth, an average passenger vehicle weight of 2000kg was assumed.

The weight of live and drop units was based on the truck weight limits defined in Newfoundland and Labrador Regulation 105/14 Vehicle Regulations [23] and the equivalent regulations for Nova Scotia [24]. These limits correspond to the number of axles on the truck and trailer, as well as their tire spread. For example, in Nova Scotia, a five-axle tractor semitrailer with a 3.6m - 3.7m spread (referring to the longitudinal distance between the centres of extreme axles in an axle group) cannot exceed 32,600kg in gross weight [24]. A conservative 35,000kg was therefore assumed to be the average weight of a live unit, and 25,000kg was assumed to be the average weight of a drop unit. A summary of the deadweight components is shown below in Table 18.

Table 18: Deadweight Components

Component	Weight (Tonnes)
Lube Oil	42
Fuel (LNG)	389
Freshwater	384
Crew and Effects	16
Passengers and Effects	170
Provisions	22
Passenger Vehicles	400
Live Units	1575
Drop Units	875
Total	**3872**

8.3 Weight Estimate Summary

A summary of the vessel's weight for each loading condition is provided in Table 19.

Table 19: Summary of weights

	Loading Condition				
Component	**Lightship**	**Full Load - Departure**	**Full Load - Arrival**	**Light Operating Condition**	**Worst Operating Condition**
Lightship	20223.0	20223.0	20223.0	20223.0	20223.0
Fuel					
LNG	0.0	208.4	21.3	208.4	4.3
LNG	0.0	208.4	21.3	208.4	4.3
Emergency Gen Diesel	0.0	59.5	59.5	59.5	1.2
Day Tank	0.0	79.4	8.1	79.4	1.6
Day Tank	0.0	79.4	8.1	79.4	1.6
Water					
Technical Water	0.0	76.0	7.8	76.0	1.6
Freshwater	0.0	188.2	19.2	188.2	3.8
Freshwater	0.0	188.2	19.2	188.2	3.8
Black Water	0.0	20.9	204.9	20.9	4.2
Grey Water	0.0	20.9	204.9	20.9	4.2
Oil					
Lube Oil	0.0	20.4	2.1	20.4	20.4
Lube Oil	0.0	20.4	2.1	20.4	20.4
Dirty Oil	0.0	3.2	31.8	3.2	3.2

Sludge	0.0	5.0	48.9	5.0	5.0
Passengers and Effects	0.0	170.0	170.0	0.0	170.0
Crew and Effects	0.0	17.0	17.0	17.0	17.0
Passenger Vehicles	0.0	400.0	400.0	0.0	400.0
Live Units	0.0	1564.0	1564.0	0.0	1564.0
Drop Units	0.0	875.0	875.0	0.0	875.0
Provisions	0.0	22.0	22.0	22.0	22.0
Total	**20223.0**	**24449.2**	**23930.1**	**21440.2**	**23350.5**

9 HULL FORM

9.1 DEVELOPMENT

Four factors guided the hull form development:

- Compatibility with boarding infrastructure
- Efficiency at high operating speeds
- Comfortable motion in a seaway
- Adequate volume for required vehicle and passenger capacities

A bespoke hull form was developed using DELFTship. Multiple iterations of the hull were completed to obtain a shape which would balance the previously mentioned factors.

The vessel has a fine hull entry and a relatively low block coefficient, reflecting the high service speed required to maintain Marine Atlantic's existing timetable. The ferry will be operating at a consistent speed, so a bulbous bow was added to improve the efficiency of the hull at the service speed. At this stage of development, the bulbous bow shown in the model and lines plan has not been optimized. This is work that would need to be completed in subsequent design phases.

The vessel also features a skeg to improve directional stability.

Like most large displacement ferries which operate around F_n = 0.25, the aft sections and buttocks were made wide and flat, and the transom edge was kept above the still waterline. This is done to minimize the risk of transverse waves being generated. Like the bulbous bow, the afterbody will need to be refined to ensure optimal flow and wave-generating characteristics.

The length and beam of the hull were limited by the terminal infrastructure. The vessel is as long and wide as permitted to meet the capacity requirements. The draft was similarly constrained by the minimum water depth at the Marine Atlantic terminals and by the size of the selected podded propulsors.

The finalized preliminary design particulars are shown in Table 20 below.

Table 20: Finalized Vessel Particulars

Length Overall (m)	204.0
Waterline Length (m)	188.0
Beam (m)	28.0
Draft (m)	6.7
Displaced Volume (m^3)	23,979.0
Displacement (Tonnes)	24,578.0
Lightship (Tonnes)	19,831.0
Deadweight (Tonnes)	4355.0
Service Speed (knots)	14.0
Maximum Speed (Knots)	20.0
Block Coefficient	0.627
Froude Number (@ 20kts)	0.24
Prismatic Coefficient	0.645
Waterplane Coefficient	0.790
Midship Coefficient	0.972
Longitudinal Centre of Buoyancy	-2.63%
Wetted Surface Area (m^2)	6080.4

Figure 11: Forward View of the Hull

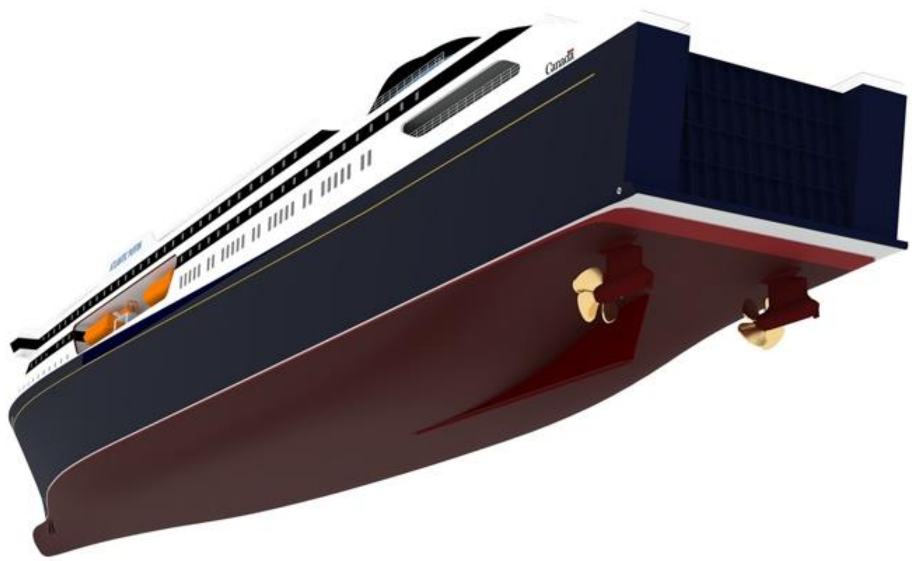

Figure 12: Aft View of the Hull

9.2 SECTIONAL AREAS CURVE

The sectional areas curve at the design draft of 6.7m was produced using DELFTship. It is shown in Figure 13.

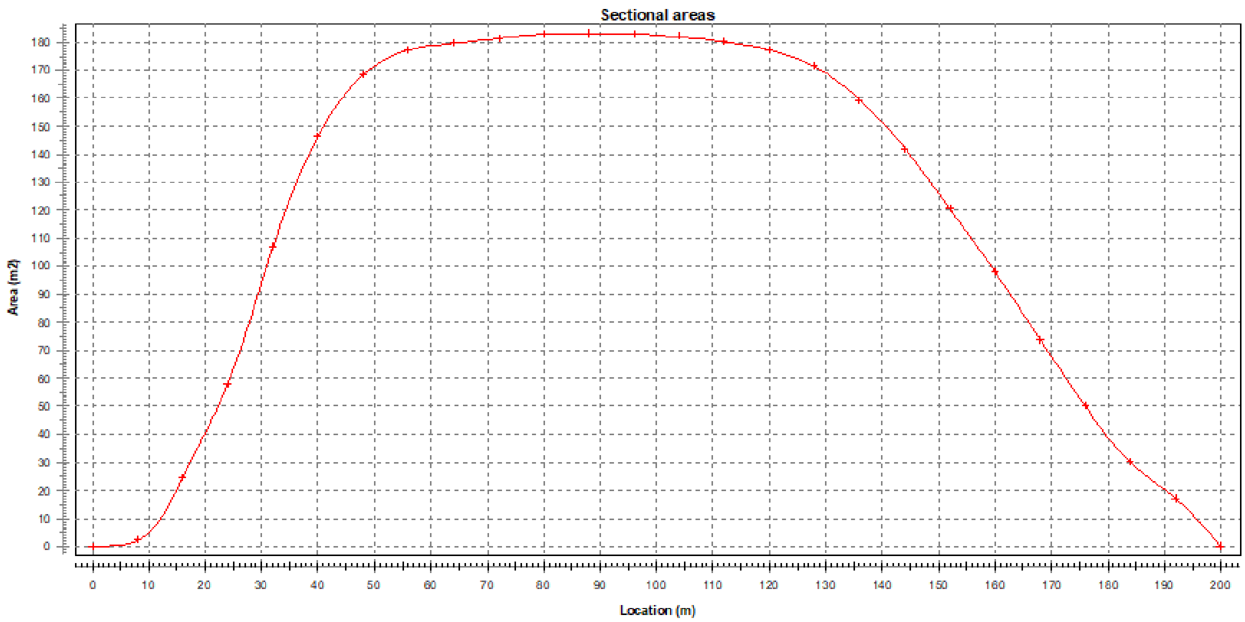

Figure 13: Curve of Areas

9.3 HYDROSTATICS

The vessels curves of form are shown in Figure 14. These curves were produced using DELFTship. Hydrostatic curves provide insight into various characteristics of the hull at varying drafts. They can also be used to determine the change in the draft due to the addition or removal of weights as well as determining the change in trim and heel due to relocating weights. The cross curves of stability, shown in Figure 15, were created using GHS.

A more detailed hydrostatics report is included in Appendix F.

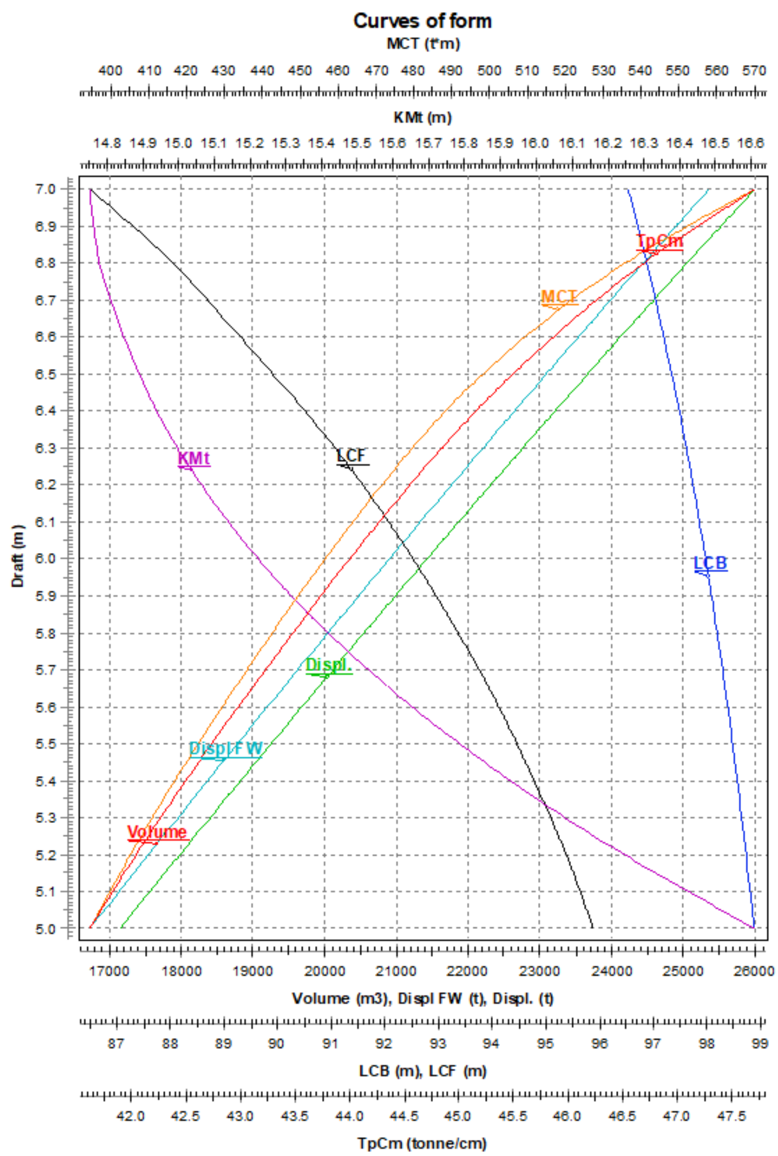

Figure 14: Hydrostatic Curves

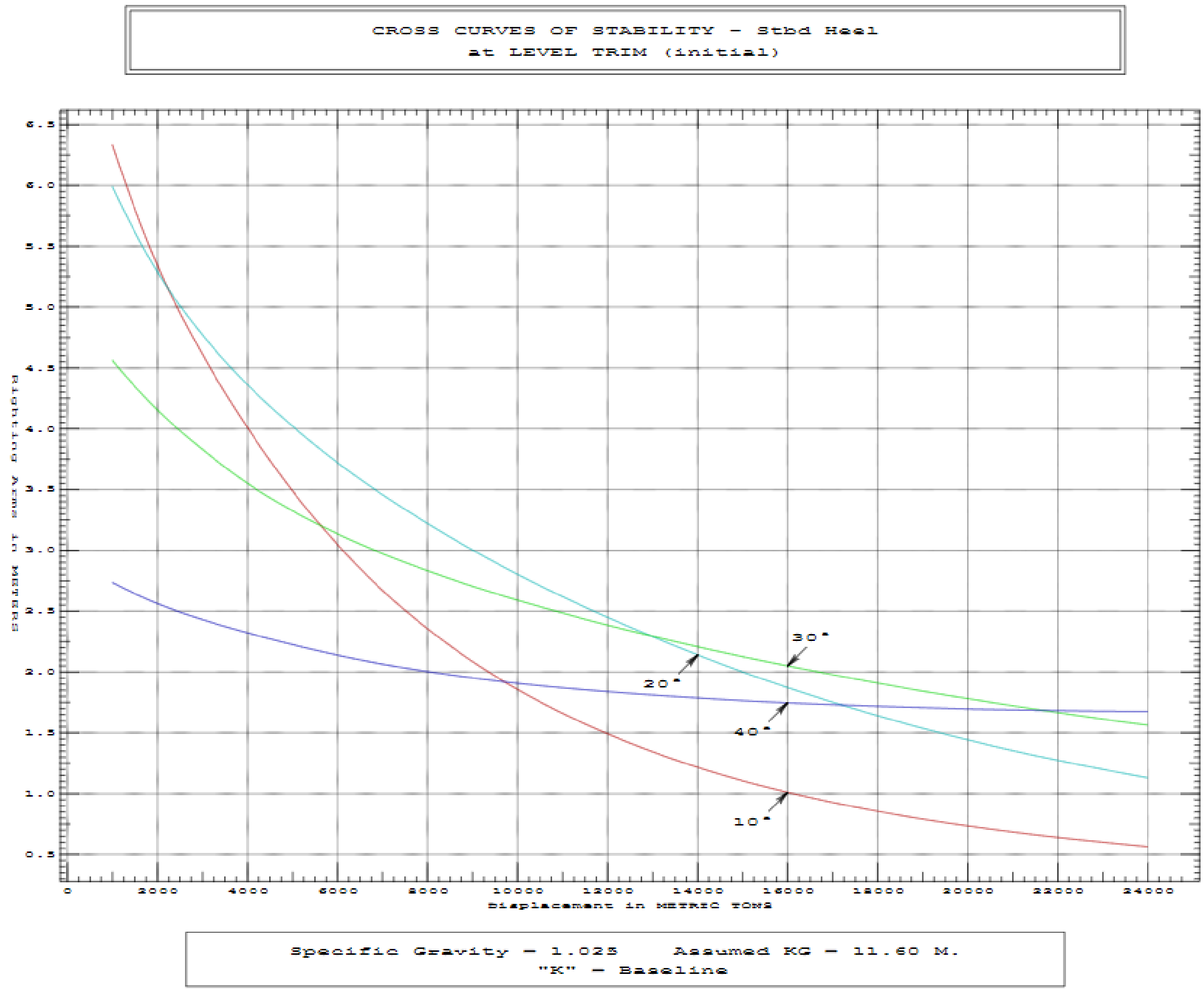

Figure 15: Cross Curves of Stability

9.4 Lines Plan

The lines plan was created using DELFTship. While the stern and midbody appear very fair, there are regions at the bow, particularly near the bulbous bow and the bow shoulder, which would require refinement. These refinements were not completed at this stage of design since the hull is bespoke and is expected to undergo numerous changes in later design stages as model tests and Computational Fluid Dynamic (CFD) simulations are performed. The lines plan is included in Appendix G.

10 Resistance and Powering Predictions

NavCAD 2019 was used to perform the initial resistance and powering predictions. The hull parameters used in this prediction are included in the Resistance and Propulsion Reports, provided in Appendix H.

10.1 Resistance Prediction

The Holtrop-Mennen Method was used for the resistance predictions. This method is based on data collected from model tests of a wide variety of ship types, including ferries. The application of the method is limited to vessels with characteristics that fall within the ranges shown in Table 21. The ferry falls within the defined range, with the exception of the beam at the waterline to draft ratio, which it slightly exceeds. Although this is not ideal, the results will still be reasonably accurate and are sufficient for the purposes of predicting resistance at this stage of design.

Table 21: Holtrop Parameters

Parameter	Range	Value
Fn (at design speed)	0.06 – 0.4	0.17
C_P	0.55 – 0.85	0.70
LWL/BWL	3.90 – 14.90	6.71
BWL/T	2.10 – 4.00	4.18

The bare hull resistance at various speeds in open water predicted using the Holtrop-Mennen method is summarized in Table 22 and Figure 16 below.

Table 22: Vessel Total Resistance

Speed [Knots]	Total Resistance [kN]
13.00	263.41
14.00	***309.52***
15.00	362.90
16.00	425.09
17.00	497.55
18.00	582.10
19.00	681.52
20.00	***793.26***
21.00	915.23
22.00	1060.40

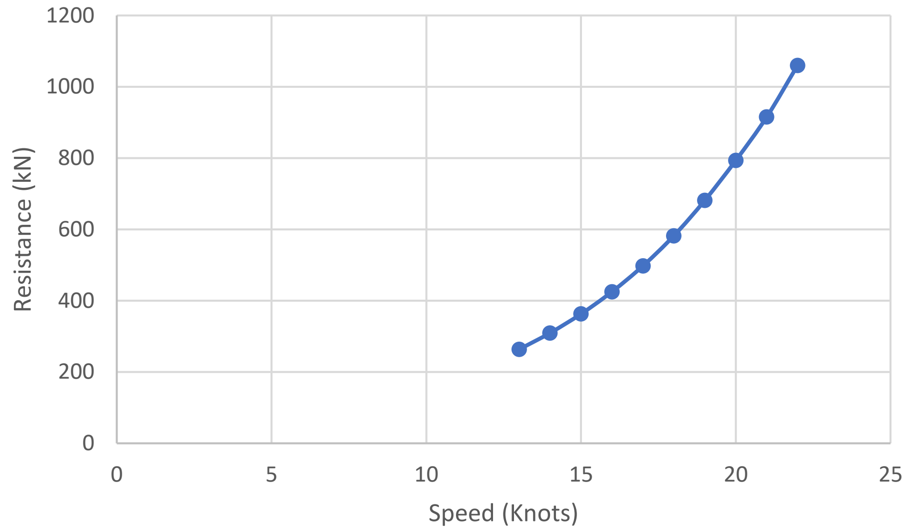

Figure 16: Speed versus Total Resistance Relationship

10.2 Powering Prediction

The propulsion prediction was also conducted using NavCAD 2019. In this prediction, the overall propulsion efficiency, total vessel brake power, and peak back cavitation percentages were estimated. The preliminary propulsor specifications used in this prediction are provided in Table 23.

Table 23: Design Propeller Data

Count	2
Propeller Type	FPP
Propeller Series	B-Series
Blade Count	4
Expanded Area Ratio	0.6500
Propeller Diameter	4750.0 mm
Propeller Mean Pitch	4250.0 mm
Hub Immersion	4211.0 mm

The propulsion prediction results are summarized in Table 24, and an SHP versus speed plot is provided in Figure 17.

Table 24: Propulsion Prediction Data

Speed [kn]	Overall Propulsion Efficiency	SHP [kW]	Peak Back Cavitation Percentage [%]
13.00	0.6467	2724.0	2.0
14.00	***0.6464***	***3448.8***	***2.0***

15.00	0.6459	4335.7	2.0
16.00	0.6452	5423.4	2.0
17.00	0.6441	6755.6	2.0
18.00	0.6427	8387.4	2.0
19.00	0.6407	10,397.3	2.0
20.00	***0.6384***	***12,783.9***	***2.0***
21.00	0.6361	15,544.0	2.8
22.00	0.6330	18,959.7	4.1

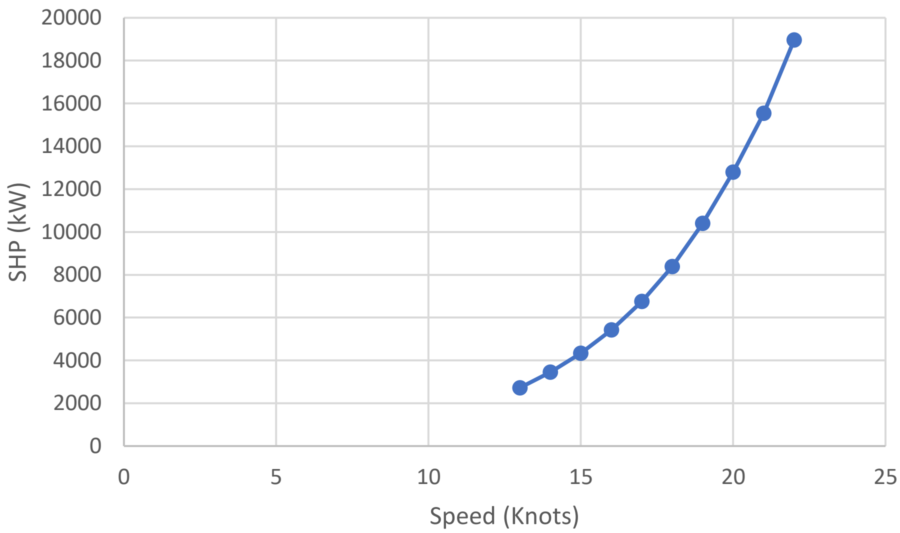

Figure 17: Speed versus SHP

Approximately 12,784 kW of power would be required to attain the maximum speed of 20.0 knots. A 15% margin was applied to this estimate for conservatism. The required power is, therefore, 14,700 kW.

11 Seakeeping Analysis

The Cabot Strait between Newfoundland and Nova Scotia can be very rough. For people who are not used to the motion of a ship, such as passengers, the experience can be very uncomfortable. It is also not feasible to lash all vehicles carried by the ferry when rough weather is expected. To prevent damage to vehicles and ensure passenger comfort, the ferry must meet strict seakeeping limits. A seakeeping analysis for the hull form was completed using ShipMO3D developed by Defence Research and Development Canada. ShipMO3D uses 2-D potential flow theory to determine the seakeeping characteristics of the hull [25].

11.1 Sea State

Based on weather data collected for the Gulf of St. Lawrence, it was determined that the vessel should be assessed in Sea State 6 conditions as defined by the World Meteorological Organization (WMO) [5].

The WMO describes sea state six as “strong breezes of 22-27 knots, with wave heights of 9ft up to a maximum of 12 feet” [26]. Large waves begin to form in this state, with white foam crests being more prominent, typically with some spray occurring [26].

The Joint North Sea Wave Project (JONSWAP) wave spectrum was used for this analysis. It is best suited for fetch-limited areas, such as the North Sea and Offshore Eastern Canada [27].

Table 25 summarizes the sea condition inputs.

Table 25: Wave parameters

Wave Spectrum	JONSWAP
Wave Frequencies (rad/s)	0.2 – 2.0 (0.05 increments)
Significant Wave Height (m)	5.0
Peak Period (s)	12.0

11.2 Criteria

There are no seakeeping requirements that the ferry must be designed to meet from DNV, Transport Canada, or other regulatory bodies. However, several seakeeping criteria have been developed. Some of the most common are the North Atlantic Treaty Organization Standardization Agreement (NATO STANAG) 4154, Nordic Co-Operative Organization for Applied Research (NORDFORSK 1987), and United States Coast Guard (USCG) Cutter Certification.

The vessel is required to meet the NORDFORK 1987 seakeeping limits for merchant ships. NORDFORSK limits were ultimately selected since they provide very strict limits specifically for passenger vessels. For the ferry to pass, vertical accelerations must be less than 0.1g and lateral accelerations less than 0.05g in passenger areas. These values correspond to the 0.5-hour exposure period for people not accustomed to ship motions.

A summary of the NORDFORSK (1987) limits is provided in Table 26.

Table 26: NORDFORSK (1987) Operating Limits for Merchant Vessels

Limiting Criteria	Limits (Merchant Vessels)
RMS of vertical accelerations at FP	0.275g
RMS of vertical accelerations at Bridge	0.15g
RMS of lateral accelerations at Bridge	0.12g
RMS of Roll	6.0 deg

Criteria Regarding Acceleration and Roll (RMS)	Vertical Acceleration	Lateral Acceleration	Roll
Light Manual Work	0.2g	0.10g	6.0 deg
Heavy Manual Work	0.15g	0.07g	4.0 deg
Intellectual Work	0.10g	0.05g	3.0 deg
Transit Passengers	0.05g	0.04g	2.0 deg
Cruise Liner	0.02g	0.03g	2.0 deg

11.3 Locations Assessed

Three areas throughout the vessel were assessed:

- Bridge
- Forward Perpendicular
- Passenger Accommodation

Their approximate locations are shown in Figure 18.

To assess motions in the passenger accommodation areas, a passenger cabin located at midships on the far starboard side of the uppermost passenger deck was chosen. At this location, the vertical accelerations due to rolling will be greatest. The cafeteria is the largest public area on the vessel, and many passengers are likely to sit in this space for the duration of the voyage. Its location at the forward end of the ship also means that it would be one of the more uncomfortable locations when sea conditions are rough, and therefore an important area to assess. The cafeteria is located directly beneath the bridge, so accelerations in the cafeteria can be measured using the results from the bridge.

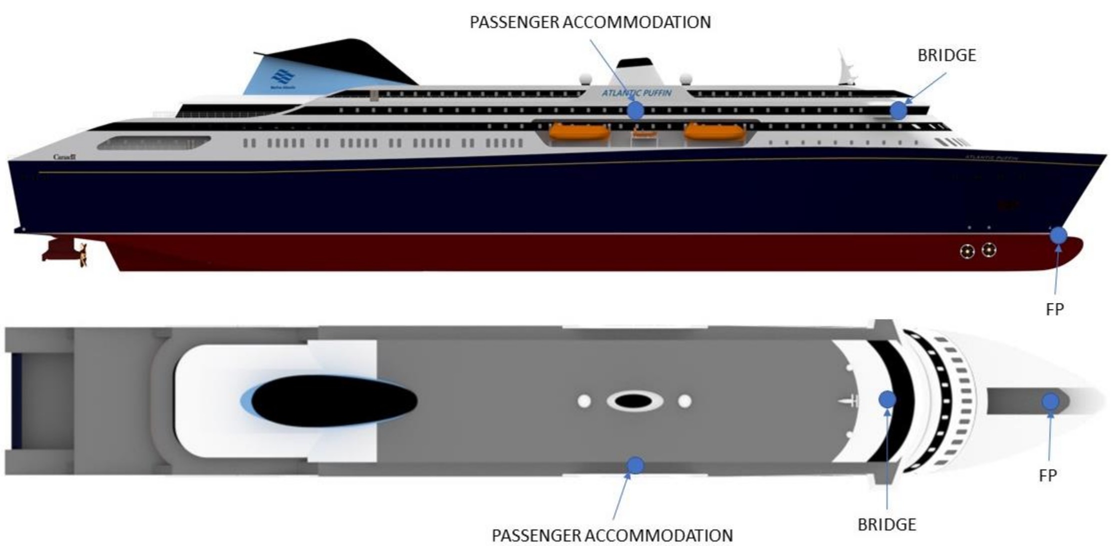

Figure 18: Locations of Areas Assessed

11.4 Zero Speed Analysis

A seakeeping analysis was completed for the vessel at a speed of zero knots. Results from this analysis are compiled below in Table 27.

Table 27: Zero Speed Seakeeping Analysis Results

Location	Sea Heading (deg)	RMS Vert. Acc. (g)	RMS Lat. Acc. (g)	Pass (Y/N)
Bridge/Cafeteria	0	0.0310	0.0000	Y
	45	0.0425	0.0160	Y
	90	0.0555	0.0345	Y
	135	0.0493	0.0165	Y
	180	0.0381	0.0000	Y
Forward Perpendicular	0	0.0402	0.0000	Y
	45	0.0534	0.0246	Y
	90	0.0565	0.0372	Y
	135	0.0607	0.0254	Y
	180	0.0473	0.0000	Y
Passenger Accommodations	0	0.0104	0.0000	Y
	45	0.0235	0.0104	Y
	90	0.0516	0.0335	Y
	135	0.0210	0.0106	Y
	180	0.0152	0.0000	Y

11.5 Design Speed Analysis

A seakeeping analysis was also completed for the vessel at its design speed of 14 knots. Results from this analysis are compiled below in Table 28.

Table 28: Design Speed Seakeeping Analysis Results

Location	Sea Heading (deg)	RMS Vert. Acc. (g)	RMS Lat. Acc. (g)	Pass (Y/N)
Bridge/Cafeteria	0	0.0079	0.0000	Y
	45	0.0137	0.0148	Y
	90	0.0517	0.0455	Y
	135	0.0962	0.0184	Y
	180	0.0952	0.0000	Y
Forward Perpendicular	0	0.0099	0.0000	Y
	45	0.0166	0.0191	Y
	90	0.0517	0.0373	Y
	135	0.1272	0.0295	Y

	180	0.1274	0.0000	Y
Passenger Accommodations	0	0.0034	0.0000	Y
	45	0.0133	0.0088	Y
	90	0.0505	0.0335	Y
	135	0.0519	0.0125	Y
	180	0.0487	0.0000	Y

11.6 Results

The vessel passes the NORDFORSK (1987) criteria for all cases and sea directions. However, accelerations at the bridge/cafeteria are close to exceeding the 0.1g limit when the ship travels at 14 knots, and the sea direction is between 125° and 180°. It is worth noting that ShipMO3D did not account for the fin stabilisers or bilge keels for this preliminary analysis. With bilge keels and the two fin stabilizers extended it is likely that the vessel would be comfortably within the limits for those two scenarios.

12 Powering

12.1 Electric Load Analysis

An electric load analysis was conducted to determine the power required for the vessel (Table 29). This takes into account the propulsion loads, hotel loads, and auxiliary loads for six different operational scenarios. The powering loads were determined from the resistance and propulsion predictions.

Data on hotel loads and auxiliary loads for a vessel of this size and type were challenging to obtain. As a result, for this early estimate, the hotel loads of a cruise ship were used and scaled based on the total installed power [31]. The hotel load of a cruise ship relative to its powering load is proportionally much larger than that of a RoPax ferry because of the more extensive passenger facilities. The results are therefore expected to be conservative; however, an additional 10% margin was applied to the total required power for each scenario to account for systems such as electric vehicle chargers, reefer unit electrical connections, and other miscellaneous items that may not have been accounted for originally.

From this analysis, the vessel will require a minimum of 21,200kW of installed power.

Table 29: Electric Load Analysis

	Operating Scenario						
Systems	***Total Power (kW)***	***Port (kW)***	***Manoeuvring (kW)***	***Service Speed – Winter (kW)***	***Service Speed - Summer (kW)***	***Max Speed – Winter (kW)***	***Max Speed – Summer (kW)***
Chiller and HVAC	2000	1624.9	1700.0	1752.8	1721.3	1752.8	1721.3
Galleys	430	330.5	300.0	427.5	425.0	427.5	425.0
Laundry	140	140.0	50.0	85.5	85.0	85.5	85.0
Lighting	110	110.0	110.0	106.9	85.0	106.9	85.0
Emergency Systems	150	110.2	110.0	150.0	150.0	150.0	150.0
Sockets	85	55.1	75.0	85.0	85.0	85.0	85.0
Lifts	55	55.0	50.0	42.8	42.5	42.8	42.5
Leisure Facilities	35	27.5	25.0	35.0	35.0	35.0	35.0
Water Handling	400	275.4	325.0	400.0	400.0	400.0	400.0
Auxiliary	1500	220.3	350.0	1500.0	1500.0	1500.0	1500.0
Propulsion	15000	0.0	1000.0	3591.0	3612.5	14700.0	14700.0
Bow Thrusters	3300	0.0	1000.0	0.0	0.0	0.0	0.0
Total	23205	2948.8	5095.0	8176.4	8141.3	19585.4	19528.8
Total (10% Margin)	**25525.5**	**3243.7**	**5604.5**	**8994.0**	**8955.4**	**21192.3**	**21151.6**

12.2 ENGINE/GENERATOR SELECTION

Based on the machinery arrangements of other RoPax ferries, four engines will be used to power the vessel. This arrangement provides greater flexibility in power.

Only dual-fuel LNG engines that meet IMO Tier III emissions requirements were considered. Splitting the required power equally between four engines equates to each engine needing to produce 5400kW.

One of the machinery arrangements considered was to use two Wartsila 10V31DF engines and two Wartsila 8V31DF engines. Each 8V31DF outputs 4080kW at 85% MCR. This would supply the necessary power for the hotel load, thus eliminating the need for a fifth small genset to provide power while in port. When in transit at full speed, the two 10V31DFs and two 8V31DFs would produce a combined 21,600kW, which exceeds the minimum power required. This arrangement was ultimately selected. A comparison of the engines considered is provided in Table 30, and Tables 31 and 32 provide a summary of the engine loads for the six operating scenarios.

Table 30: Comparison of Suitable Engines

Engine Manufacture	Engine Model	Cylinder Count	RPM	Output at 85% MCR	Output of 4 Engines (kW)	LFO Fuel Consumption at MCR (g/kW)
Bergen	B33:45L	9	720	5400	21,600	171.0
Wartsila	8V31DF	8	750	4080	16,320	179.0
Wartsila	10V31DF	10	720	5800	23,200	178.2
Wartsila	12V34DF	12	720	5760	23,040	185.2

Table 31: Engine Loads for Port, Manoeuvring, and Service Speed Sailing Scenarios

Engine Model	Port (kW)	%MCR	Manoeuvring (kW)	%MCR	Sailing @ Service Speed – Winter (kW)	%MCR	Sailing @ Service Speed - Summer (kW)	%MCR
10V31DF	0	0%	5604.5	93%	5100	85%	5100	85%
10V31DF	0	0%	0	0%	0	0%	0	0%
8V31DF	3243.7	68%	0	0%	3894	81%	3855	80%
8V31DF	0	0%	0	0%	0	0%	0	0%
Total (kW)	**3243.7**		**5604.5**		**8994.0**		**8955.4**	

Table 32: Engine Loads for Maximum Speed Sailing Scenarios

Engine Model	Sailing @ Max Speed - Winter	%MCR	Sailing @ Max Speed - Summer	%MCR
10V31DF	5796	97%	5776	96%
10V31DF	5796	97%	5776	96%
8V31DF	4800	100%	4800	100%
8V31DF	4800	100%	4800	100%
Total (kW)	**21192**		**21152**	

12.3 Podded Thruster Selection

Based on the NavCAD powering prediction, the vessel requires 14,700 kW of power to attain the required 20kt maximum speed. Since the ferry will be operating in ice, an ice-strengthened pod was required. ABB has two Ice strengthened models- Azipod ICE and Azipod VI. The ICE models are only suitable for applications requiring 2MW – 5MW, while the Azipod VI model is suitable for applications which require power in the range of 6MW – 17MW [9]. The ferry will have two pods; therefore, each pod is required to produce 7350kW [9]. The Azipod VI was consequently selected.

12.4 Bow Thruster Selection

Wartsila provides a simple way of estimating the required bow thruster power based on the windage area of the vessel. The power of bow thrusters on ferries is generally between 0.6kW/m^2 and 0.8kW/m^2 [31]. The windage area of the vessel is 5095 m^2. Bow thruster power should therefore be between 3057kW and 4076kW.

Marine Atlantic commissioned a study in 2015 by Oceanic Consulting Corporation to advise them on a suitable propulsion arrangement for a future vessel [8]. In this study, Oceanic determined that a 200m vessel with 2980kW of bow thruster power would be successful in navigating the harbours in east-northeast winds at the 40-knot mark, “the most challenging with respect to completing the docking manoeuvre successfully” [8]. It was therefore decided to use two Wartsila WTT-16 transverse thrusters, each with an output of 1650kW for a combined 3300kW of power [32]. This, combined with the podded propulsors, will ensure the vessel is highly manoeuvrable.

12.5 Fuel Endurance

Fuel requirements were assessed for the two routes Marine Atlantic services, as well as a transatlantic crossing to ensure the vessel is capable of repositioning from the shipyard where it will be built to Canada. The route lengths are provided below:

1. North Sydney to Port aux Basques (7hrs, 96nm)
2. North Sydney to Argentia (16.5hrs, 280nm)
3. Atlantic Crossing (166 hrs, 2320nm)

Table 33 and Table 34 summarize the required fuel capacity for each route for diesel and LNG fuel.

Table 33: Required Fuel Capacities when using MDO

Route	Consumption (Tonnes/kWh)	Time (hrs)	Power (kW)	Required Fuel (Tonnes)	Density (Tonnes/m^3)	Volume (m^3)	15% Reserve (m^3)
PAB	0.000179	7	9000	11.3	0.85	13.27	15.26
ARG	0.000179	17	12500	38.0	0.85	44.75	51.46
Atlantic	0.000179	166	9000	267.4	0.85	314.62	361.81

Table 34: Required Fuel Capacity when using LNG

Route	Consumption (MJ/kWh)	Time (hrs)	Power (kW)	Required Fuel (MJ)	Density (MJ/L)	Volume (m^3)	15% Reserve (m^3)
PAB	7.109	7	9000	447867.0	22.2	20.17	23.20
ARG	7.109	17	12500	1510662.5	22.2	68.05	78.26
Atlantic	7.109	166	9000	10620846.0	22.2	478.42	550.18

12.5.1 Emergency Generator

The ferry is required to have an emergency generator to supply power to critical systems in the event of an emergency. On passenger ships, the emergency generator must supply continuous power for at least 36 hours after a power failure. A Wartsila 8L32 genset was selected for this application. The fuel required to operate for 36 hours is calculated in Table 35.

Table 35: Emergency Generator Fuel Requirements

Wartsila 8L32 Emergency Generator		
Consumption	0.000183	Tonnes/kWh
Time	36	hours
Power	3944	kW
Required fuel	26.0	Tonnes
Fuel Density	0.9	Tonnes/m^3
Tank Volume	28.9	m^3
15% Reserve	33.2	m^3

12.6 Energy Storage System

The purpose of incorporating batteries into the propulsion system is to reduce emissions when near to shore. The ferry will operate solely on batteries while manoeuvring into and out of port, and they may also be used to power the hotel load when the vessel is tied up at the terminal. To determine a suitable battery size, it was assumed that manoeuvres take 0.5 hours to complete and that the batteries should be able to meet the electrical demands of the vessel when in port for up to 2 hours. A capacity of at least 9.3MWh was estimated, as shown in Table 36 below.

Table 36: Required battery capacity estimate

Scenario	Time (hrs)	Power (kW)	Required Energy (kWh)
Manoeuvring	0.5	5604.5	2802.3
In Port	2	3243.7	6487.4
Total (MWh)			**9.3**

This is quite a large battery for a ship; however, similar arrangements have been used aboard Color Line's MS Color Hybrid (5.0MWh) and Brittany Ferries' MS Saint-Malo (11.5MWh).

13 STABILITY

13.1 APPLICABLE REGULATIONS

A stability analysis was performed using GHS for five different loading conditions. The ferry is required to comply with the following two sets of criteria published by Transport Canada:

- *TP 7301 E - Stability, Subdivision, and Load Line Standards* [33]
- *TP 10943 E - Passenger Vessel Operations and Damaged Stability Standards (Non-Convention Vessels)* [34]

Transport Canada mandates that the stability of newbuild Ro-Ro passenger vessels must withstand the flooding of any two adjacent main compartments. In the case of symmetrical flooding, Transport Canada requires that there be a positive residual metacentric height of at least 0.05m. In the case of asymmetrical flooding, the equilibrium angle of heel for one-compartment flooding shall not exceed 7°. The area under the righting lever (GZ) curve must be greater than 0.015 meters, and the positive residual righting lever curve must have a minimum range of 10 to 15 degrees beyond the angle of equilibrium.

13.2 FLOODABLE LENGTHS

Traditional watertight bulkheads on the vehicle decks of a Ro-Ro ferry would make loading vehicles a very complex and time-consuming process. They would also reduce the vehicle-carrying capacity of the ferry. As a result, watertight bulkheads do not extend through vehicle decks and will typically only reach just above the waterline. Should the vehicle decks flood, the free surface effect will take hold, which could lead to the vessel capsizing.

To mitigate the risks inherent in Ro-Ro ferry design, great care and an abundance of caution were given to the floodable length computations and bulkhead arrangements in the hull. DNV-RU-SHIP Pt 3 Chapter 2: General Arrangement Design [35] recommends vessels between 190m and 225m in length to have ten transverse subdivisions; however, this is subject to damaged stability calculations. The vessel was designed with 16 watertight subdivisions, each spaced 10m apart, except for the two engine compartments and the two LNG compartments, both of which extend 20m but are separated by a longitudinal watertight bulkhead.

The floodable lengths, demonstrating two-compartment flooding as per Transport Canada TP 10943 E [34] requirements, are shown in Figure 19. Ideally, with floodable lengths calculations, the arrangement of watertight subdivisions maximizes the length of each compartment such that they are close to the floodable lengths curve. As shown in Figure 19 below, there is a significant margin between the allowable compartment size and the subdivision arrangements as designed. This level of subdivision is typical on large ro-ro ferries.

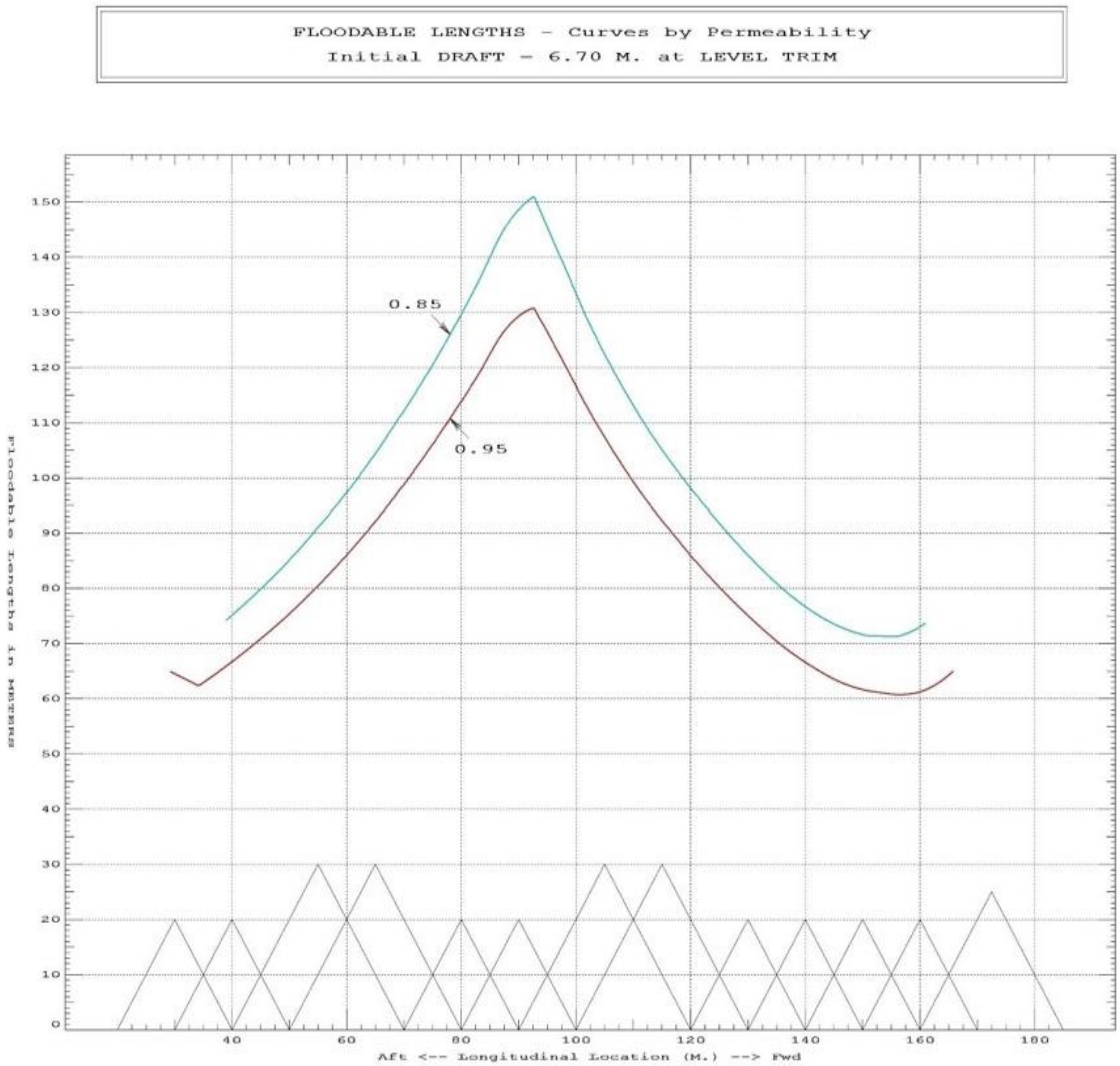

Figure 19: Floodable Lengths Curve

13.3 Loading Conditions

A stability analysis was performed using GHS for five loading conditions – lightship, departure, arrival, light operating, and worst-case operating. The loading conditions are defined in TP 7301E Stab 5 [33].

13.3.1 Worst-Case Operating Condition

The worst-case loading condition is defined as any condition likely to be encountered in service that reduces the GM and/or GZ values more than the other loading conditions. For this vessel, the worst-case operating condition was similar to the full departure condition but placed the heavy tractor semi-trailers on the uppermost deck and the lighter passenger vehicles loaded on the lower decks. This results in the VCG being approximately 0.7m higher than the VCG estimated for the full load departure condition.

13.3.2 Light Operating Condition

The light operating condition is defined as the lightship condition, plus crew, fuel, water, and stores. The vessel will likely be built at an overseas shipyard, so this is a scenario the vessel will likely experience when it is repositioning from the shipyard to Newfoundland.

A summary of the loading conditions is provided below in Table 37.

Table 37: Loading Conditions for Stability Analysis

	Lightship	Full Load Departure	Full Load Arrival	Light Operating	Worst Case Operating
Fuel	0%	98%	10%	98%	98%
L.O.	0%	98%	10%	10%	98%
Sludge	0%	10%	98%	10%	2%
FW	0%	98%	10%	98%	98%
GW	0%	10%	98%	10%	2%
BW	0%	10%	98%	10%	2%
Passenger Vehicles	0	200	200	0	200
Live Units	0	45	45	0	45
Drop Units	0	35	35	0	35
Passengers and Effects	0	1000	1000	0	1000
Crew and Effects	0	100	100	100	100
Provisions	0	22	22	22	22

13.3.3 Ice Accretion

The impact of ice accretion on the vessel's stability was assessed for each loading condition. As per the Polar Code [10], ice accumulation was accounted for by assuming a weight of 30kg/m^2 on the vessel’s exterior decks and 7.5kg/m^2 on the sides of the vessel [10].

13.4 INTACT STABILITY

13.4.1 Criteria

The intact stability analysis was performed to ensure that the design met the following criteria listed in TP 7301 E [30]:

1. The area under the righting lever (GZ) curve must be greater than 0.055m-radians up to a 30° angle of heel
2. The area under the righting lever (GZ) curve must be greater than 0.09m-radians up to 40° angle of heel or the angle of down flooding if it is less than 40°
3. The metacentric height (GM) must be greater than 0.15m when the vessel is upright
4. The area under the righting lever (GZ) must be less than 0.03m-radians between 30° and 40°, or between 30° and the down flooding angle if the down flooding angle is less than 40°
5. The righting lever (GZ) must have a value of 0.20m at a heel angle of at least 30°
6. The maximum righting lever (GZ) must occur at an angle of heel that is greater than 25°

Additionally, the vessel must meet the following IMO Severe Wind and Rolling Criteria:

1. Residual area ratio from roll to 50 degrees greater than 1
2. Residual area ratio from roll to flood or righting arm 0 greater than 1
3. Absolute angle at pre-roll less than 16 degrees
4. Angle from pre-roll to 80% deck immersion angle greater than 0 degrees

13.4.2 Results

Table 38 provides a summary of the intact stability results from GHS. The ferry passes all the Transport Canada criteria. For more detailed intact stavility results refer to Appendix I.

Table 38: Intact Stability Result Summary

Req.	Limit	Light	Depart	Arrival	Arrival (Ice)	Light Op.	Worst Op.	Worst Op. (Ice)	Pass (Y/N)
1	>0.055 m-rad	0.3049	0.2206	0.2211	0.2010	0.4161	0.1637	0.1429	Y
2	>0.09 m-rad	0.4375	0.3621	0.3629	0.3297	0.6981	0.2414	0.2069	Y
3	> 0.03 m-rad	0.1327	0.1415	0.1418	0.1286	0.2820	0.0776	0.0641	Y
4	> 0.15m	2.130	1.360	1.202	1.060	2.432	1.046	0.915	Y
5	> 0.2m	0.899	0.822	0.824	0.751	1.809	0.529	0.457	Y
6	> 25°	26.42	33.49	33.28	32.90	57.76	27.97	27.59	Y
7	> 1	1.902	4.098	4.130	3.960	3.005	2.212	1.860	Y
8	>1	1.908	5.174	5.315	5.015	3.961	2.226	1.953	Y

8	>1	1.908	5.174	5.315	5.015	3.961	2.226	1.953	Y
9	< 16	2.11	2.26	2.48	2.57	1.82	3.07	3.36	Y
10	> 0	39.56	35.74	35.46	35.24	38.14	36.36	35.95	Y

13.5 DAMAGED STABILITY

13.5.1 Criteria

A damaged stability analysis was performed to ensure that the design met the following criteria as listed in TP 10943 E [34]:

1. The metacentric height (GM) must exceed 0.10m.
2. The righting lever (GZ) at the maximum righting angle must be greater than 0.050m.
3. The absolute angle at equilibrium must be less than 7°.
4. Angle from Equilibrium to deck margin Immersion >0
5. The area under the righting lever (GZ) curve must be greater than 0.015m-radians when the ship is at a 22° heel angle or when down flooding occurs.

13.5.2 Critical Points

Three critical points were checked. Their locations are approximated in Figure 20. The uppermost vehicle deck is an open deck to provide ventilation for vehicles carrying hazardous cargo. In damaged conditions where the bow or stern sinks lower in the water, the vehicle deck could flood from the open bow/stern ends. If water enters the deck, it could then flood the lower compartments via the main stairwell which connects to all the vessel's decks.

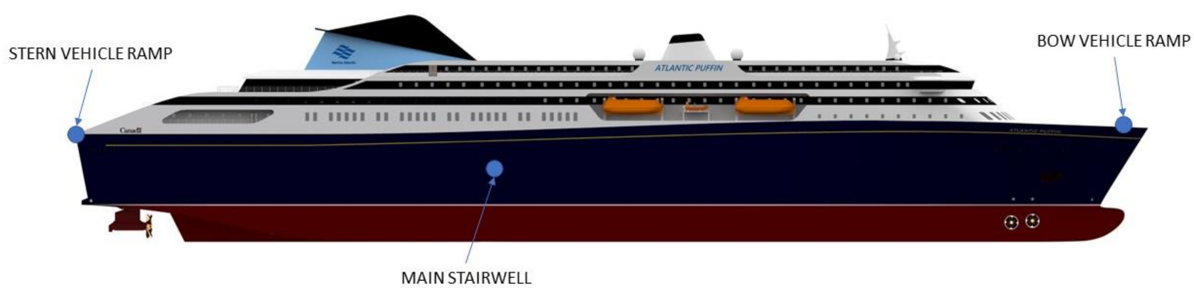

Figure 20: Locations of Critical Points

13.5.3 Results

The ferry passes all the listed damage criteria, with the exception of damaged departure and arrival scenarios when compartments 7 and 8 are flooded. Compartment 8 houses the LNG tanks and is double the length of a typical compartment. In the next iteration of the design, the size of the surrounding compartments should be reduced.

The results for the damaged stability under all loading conditions and flooded compartment combinations are presented in Tables 39 through 43. For more detailed results on the failing cases, refer to Appendix J, which presents the GHS reports for each scenario.

Table 39: Departure Damage Stability Results

COMPARTMENT	REQUIREMENTS					
	GM Upright	Absolute Angle at Max. RA	Absolute Angle at Equilibrium	Angle from Equilibrium to Deck/Margin Immersion	Area from Equilibrium to abs 22° or Flood	Pass
	> 0.1m	> 0.05m	< 7°	> 0°	> 0.015m-rad	Y/N
1&2	1.614	1.018	0.00	47.66	0.1486	Y
2&3	1.604	1.190	0.00	46.69	0.1522	Y
3&4	1.389	1.324	0.00	45.69	0.1414	Y
4&5	0.947	1.310	0.00	44.33	0.0696	Y
5&6	1.044	1.288	0.00	45.09	0.0892	Y
6&7	1.307	1.321	0.00	45.28	0.0960	Y
7&8	1.439	1.409	0.00	44.32	0.0562	Y
8&9	1.479	1.553	0.00	45.34	0.1167	Y
9&10	1.748	1.390	0.00	47.14	0.1378	Y
10&11	1.585	1.334	0.00	47.65	0.1339	Y
11&12	1.221	1.608	0.00	47.43	0.1279	Y
12&13	1.021	1.598	0.00	46.12	0.1190	Y
13&14	1.375	0.989	0.00	49.17	0.1161	Y
14&15	1.208	0.904	0.00	49.46	0.1028	Y
15&16	0.670	1.096	0.00	49.63	0.0919	Y
16&17	1.083	1.034	0.00	49.63	0.1198	Y

Table 40: Arrival Damage Stability Results

COMPARTMENT	REQUIREMENTS					
	GM Upright	Absolute Angle at Max. RA	Absolute Angle at Equilibrium	Angle from Equilibrium to Deck/Margin Immersion	Area from Equilibrium to abs 22° or Flood	Pass
	> 0.1m	> 0.05m	< 7°	> 0°	> 0.015m-rad	Y/N
1&2	1.392	0.967	0.00	46.18	0.1249	Y
2&3	1.090	0.983	0.00	45.15	0.1085	Y
3&4	0.878	0.930	0.00	45.16	0.0946	Y
4&5	0.146	1.819	0.00	42.31	0.0767	Y
5&6	0.763	1.892	0.00	42.59	0.1017	Y
6&7	0.857	1.925	0.00	42.89	0.1084	Y
7&8	0.167	2.172	0.00	40.90	0.0775	Y
8&9	0.945	2.090	0.00	42.92	0.1262	Y
9&10	1.149	1.795	0.00	45.02	0.1360	Y
10&11	1.072	1.884	0.00	45.21	0.1380	Y
11&12	0.988	1.894	0.00	45.04	0.1222	Y

12&13	0.920	1.953	0.00	43.71	0.1121	Y
13&14	1.202	1.991	0.00	45.21	0.1400	Y
14&15	1.036	2.008	0.00	44.94	0.1332	Y
15&16	0.603	1.914	0.00	45.56	0.1062	Y
16&17	0.804	1.859	0.00	46.84	0.1253	Y

Table 41: Arrival with Ice Damage Stability Results

	REQUIREMENTS					
COMPARTMENT	**GM Upright**	**Absolute Angle at Max. RA**	**Absolute Angle at Equilibrium**	**Angle from Equilibrium to Deck/Margin Immersion**	**Area from Equilibrium to abs 22° or Flood**	**Pass**
	> 0.1m	**> 0.05m**	**< 7°**	**> 0°**	**> 0.015m-rad**	**Y/N**
1&2	1.248	0.889	0.00	46.03	0.1135	Y
2&3	0.947	0.899	0.00	45.00	0.0973	Y
3&4	0.735	0.851	0.00	45.00	0.0834	Y
4&5	0.204	1.875	0.00	41.87	0.0755	Y
5&6	0.814	1.948	0.00	42.16	0.1010	Y
6&7	0.815	1.979	0.00	42.45	0.1072	Y
7&8	0.032	2.079	0.00	40.75	0.0682	N
8&9	0.776	1.996	0.00	42.76	0.1159	Y
9&10	0.994	1.700	0.00	44.88	0.1253	Y
10&11	0.919	1.790	0.00	45.06	0.1273	Y
11&12	0.835	1.799	0.00	44.75	0.1117	Y
12&13	0.769	1.858	0.00	43.40	0.0984	Y
13&14	1.052	1.896	0.00	44.93	0.1295	Y
14&15	0.888	1.914	0.00	44.65	0.1228	Y
15&16	0.458	1.820	0.00	45.25	0.0959	Y
16&17	0.661	1.766	0.00	46.70	0.1145	Y

Table 42: Light Operating Damage Stability Results

	REQUIREMENTS					
COMPARTMENT	**GM Upright**	**Absolute Angle at Max. RA**	**Absolute Angle at Equilibrium**	**Angle from Equilibrium to Deck/Margin Immersion**	**Area from Equilibrium to abs 22° or Flood**	**Pass**
	> 0.1m	**> 0.05m**	**< 7°**	**> 0°**	**> 0.015m-rad**	**Y/N**
1&2	2.495	2.003	0.00	46.58	0.2280	Y
2&3	2.242	2.050	0.00	45.57	0.2113	Y
3&4	2.114	1.995	0.00	45.56	0.1998	Y
4&5	1.398	1.980	0.00	44.21	0.1259	Y
5&6	1.780	1.967	0.00	44.97	0.1473	Y
6&7	1.363	2.078	0.00	44.70	0.1523	Y
7&8	1.558	2.003	0.00	44.23	0.1062	Y
8&9	2.152	2.244	0.00	44.87	0.1733	Y
9&10	2.388	2.078	0.00	46.51	0.1934	Y

10&11	2.294	2.023	0.00	47.04	0.1897	Y
11&12	1.970	2.285	0.00	46.83	0.1852	Y
12&13	1.863	2.435	0.00	47.18	0.1854	Y
13&14	2.215	1.871	0.00	48.28	0.1807	Y
14&15	2.104	1.759	0.00	48.55	0.1673	Y
15&16	1.524	1.947	0.00	48.72	0.1566	Y
16&17	1.890	1.888	0.00	48.73	0.1853	Y

Table 43: Worst Case Operating Damage Stability Results

	REQUIREMENTS					
COMPARTMENT	**GM Upright**	**Absolute Angle at Max. RA**	**Absolute Angle at Equilibrium**	**Angle from Equilibrium to Deck/Margin Immersion**	**Area from Equilibrium to abs 22° or Flood**	**Pass**
	> 0.1m	**> 0.05m**	**< 7°**	**> 0°**	**> 0.015m-rad**	**Y/N**
1&2	0.718	0.612	0.00	47.03	0.0877	Y
2&3	0.317	0.584	0.00	46.01	0.0704	Y
3&4	0.569	0.916	0.00	44.78	0.0874	Y
4&5	0.143	2.055	0.00	41.95	0.0881	Y
5&6	0.201	1.658	0.00	42.45	0.0815	Y
6&7	0.124	0.947	0.00	44.64	0.0507	Y
7&8	-0.725	1.381	13.04	28.57	0.0230	N
8&9	0.593	0.577	0.00	45.47	0.0390	Y
9&10	1.015	0.451	0.00	47.23	0.0603	Y
10&11	0.941	0.470	0.00	47.71	0.0586	Y
11&12	0.437	0.651	0.00	47.49	0.0542	Y
12&13	0.198	0.619	0.00	48.16	0.0451	Y
13&14	0.534	0.470	0.00	49.17	0.0548	Y
14&15	0.365	0.422	0.00	49.46	0.0415	Y
15&16	0.209	1.341	0.00	46.57	0.0714	Y
16&17	0.531	0.392	0.00	49.67	0.0511	Y

14 Vehicle Handling and Vehicle Deck Requirements

14.1 Hazardous Cargo

The vehicle deck on A deck is open at the stern and bow to provide ventilation for vehicles carrying hazardous goods. The vehicle decks on B deck and C deck are ventilated using air exchangers. This ensures that gasses do not accumulate to create a dangerous environment. SOLAS regulations require a minimum of 10 air changes per hour in vehicle decks for RO-RO vessels carrying more than 36 passengers [33].

14.2 Bow and Stern Doors/Ramps

The ferry has four ramps to allow for simultaneous two-deck loading from both the bow and stern. The ramp at the bow on B deck is protected by clam-type bow doors. A visor-type bow door protects the A deck bow ramp. Both stern ramps are a straight type.

Several rules should be followed regarding the bow and stern doors/ramps. The bow doors must be located above the freeboard deck. Where the bow doors lead into a complete or a long forward enclosed superstructure, an inner door must be fitted, as in this preliminary ferry design. Outer doors need to be fitted to ensure water tightness consistent with operational conditions and effectively protect the inner doors. Inner doors forming part of the collision bulkhead have to be weather-tight over the cargo space's full height and be arranged with supports on the aft side of the doors.

Bow doors have to be arranged to preclude the possibility of the outer door causing structural damage to the collision bulkhead and the inner door in the case of damage or detachment of the door. To comply with requirements, the outer bow door is not be attached to structural elements which form part of the collision bulkhead or to the upper deck at a position aft of the collision bulkhead at the point of attachment [36]. It is also important to note that the bow/stern doors must be of a similar material to the rest of the hull.

14.3 Between Deck Ramps

The vessel has been arranged with two hoistable internal ramps to allow vehicles to move between decks. When closed, these ramps act as watertight doors and must prevent water from flooding down to the lower vehicle decks. These ramps typically require a length that is eight times the height between the decks [37]. The full height of the main vehicle decks is 5.5m. The ramp joining A deck and B deck must therefore be at least 44m long. The lower vehicle deck, located on C deck, will not be used for large commercial trucks. The ramp can therefore have a larger slope. A ratio of 5:1 was used, giving the ramp a length of 17.5m.

MACGREGOR manufactures these types of ramps for RoPax ferries [37]. Exact dimensions, placement, and loading requirements would be determined in later design stages in consultation with representatives of MACGREGOR.

14.4 Vehicle Chargers

A study was conducted to determine appropriate electric vehicle charging stations for the vessel. A Level 2 charger has been deemed the most suitable to meet the requirements of the consumers. The vehicle chargers would be arranged along the central trunk on A and B deck, with chargers being spaced 5m apart to accommodate both pickup trucks and cars. This will allow up to 64 vehicles to charge at once.

15 Equipment Selection

15.1 Life-Saving Equipment

15.1.1 Lifeboat Selection

Vessels on short voyages must carry totally enclosed lifeboats with the capacity to hold at least 30% of the total number of persons on board [10].

The Viking Norsafe Maxima – 120 MKI (Figure 21) was selected for its 150-person capacity and relatively small size. The ferry will have four of these boats (two on each side). Combined, these boats can carry 600 people or 54.5% of all persons onboard. These boats are built in accordance with IMO and SOLAS requirements and have positive stability up to 180°. They are launched by a cantilevered platform davit and are constructed with fire-retardant glass-fibre reinforced polyester [46].

Figure 21: Viking Norsafe Maxima - 120MKI [46]

15.1.2 Fast Rescue Craft Selection

Passenger vessels over 500 gross tonnage are required to have a Fast Rescue Craft (FRC) on both sides of the vessel [10]. The Narwhal FRB-700 (Figure 22) will act as the FRC for this ferry. Each of the FRCs will be located adjacent to the lifeboats near the centre of the vessel. The FRD-700 is equipped with a Volvo DS-220 HP engine, water jet propulsion, and has a fuel endurance of 4 hours [47]. This craft can serve multiple roles by towing life rafts and rescuing passengers who have fallen overboard. In desperate situations, the craft can reach land from anywhere along the Port-aux-Basque route at a maximum speed with four passengers on board of 32 knots [47].

Figure 22: Narwhal FRB-700 [47]

15.1.3 Life Raft Selection

The Viking 150DKS (Figure 23) was selected as part of the evacuation equipment. These rafts can hold 153 persons and can be connected to the vessel using a chute or slide for rapid evacuation. There will be two of these rafts on either side, totalling 612-person capacity. These have a lifespan of 15-20 years, are SOLAS approved, and self-righting [48]. They will need to be replaced at least once during the ferry's service life.

Figure 23: Viking 150DKS [48]

16 General Arrangements

The general arrangement drawings of the ferry are provided in Appendix K. The ship is split into eight decks. The upper decks (1 – 4) are reserved for passenger and crew accommodations. Decks A and B are the main vehicle decks and decks C – Tank Top are for machinery. Four main vertical zones extend the height of the ship. A detailed description of each deck is provided below.

16.1 Accommodation Deck Arrangements

Accommodations can be found on decks one through four, as described below.

16.1.1 Deck 4

The top deck houses 92 single crew cabins, each with a private washroom, closet, and desk, as recommended in the Maritime Occupational Health and Safety Regulations (MOHS) [6]. Two laundry rooms and linen storage closets are located on this deck to keep up with the housekeeping demands of the crew. The crew's galley and mess are also located at the forward end of this deck. The galley is equipped with a service elevator to make transporting provisions from the store's rooms on the lower deck up to the galley easier and faster. There is also a gym and a quiet lounge for crew only. An additional elevator located across from the laundry rooms has been included to allow the crew to move about the ship more quickly.

Three service trunks extend nearly the hull height of the vessel. They connect to the HVAC spaces in order to supply conditioned air to all decks.

16.1.2 Deck 3

The second deck from the top houses 91 passenger cabins, each equipped with four berths and a private head and shower. There are also six wheelchair cabins located close to the elevators. It is a requirement for at least 5% of all passenger cabins to be wheelchair accessible [49]. There are 200 cabins on the ship, therefore, ten cabins must be fully accessible. Six wheelchair cabins are located on Deck 3, with the remaining four on Deck 2.

The aft end of the deck houses a passenger lounge area with access to exterior decks on both port and starboard sides.

The bridge is located at the forward end of this deck and is arranged with a central navigation station as well as a control station located on both the port and starboard bridge wings to assist in manoeuvring the vessel. The aft end of the bridge is equipped with a chart room, storage space and a heads compartment. A conference room, officer's mess, stores office, and ships office are located directly aft of the bridge. Four senior officer cabins, a commanding officer cabin, and a chief engineer cabin are located immediately aft of the bridge to allow easy and quick access if needed.
Four HVAC spaces have been allocated on this deck, one large compartment within the two aft main vertical zones and two smaller compartments in the forward main vertical zones.

16.1.3 Deck 2

The third deck from the top contains 116 cabins. There are four wheelchair-accessible cabins located near elevators. The vessel also has eight suites located at the forward end of the superstructure. A large exterior deck can be accessed at the aft end. This area is also where the kennels are located. The pet-friendly cabins are also at the aft end, so they are close to the exterior deck.

Access to the life rafts located on the deck below can be found toward midship by stairs connecting to the lower deck.

The emergency generator is located at the aft end of the deck to provide power for essential systems in an emergency.

16.1.4 Deck 1

Deck 1 is the main public deck. Most passenger amenities are on this deck, including a truck drivers lounge, gym, arcade, two small cinemas, quiet lounge, a larger lounge, travel items shop, pursers office (service desk), and a cafeteria.

Within the cafeteria space is a galley and small stores room. The main stores are located at the bottom of the ship; however, the service lift located inside the cafeteria stores leads directly to the main stores.

The primary access to the lifeboats and rafts is also on this deck. The main lounge, which acts as the primary muster station, is centrally located with multiple points of access to ensure passengers can quickly reach the station. IMO requires a minimum of $0.35m^2$ per person of deck space for each person assigned to the muster station. For 1100 people on board, the muster station must be at least $385m^2$. The lounge is $560m^2$, so it will provide more than enough space for the passengers to gather prior to evacuating the vessel.

16.2 Vehicle Deck Arrangements

Vehicle decks can be found on the A, B, and C decks. Decks A and B are the main vehicle decks with a clear height of 5.0m, while deck C is reserved for cars only and has a free deck height of 3.0m.

16.2.1 A Deck

The first vehicle deck is located on A deck and has 1566 lane meters. A hoistable ramp is located toward the vessel's port side to allow vehicles to move between Deck A and Deck B. This is important for the North Sydney to Argentia route, as the Argentia terminal only allows for single-deck loading. Mooring stations are located at the bow and stern on both sides of the vessel.

16.2.2 B Deck

The second vehicle deck is located on B deck and has a 1465 lane meter capacity. There is a second hoistable ramp located on the starboard side to allow vehicles to access the smaller vehicle deck on Deck C. Rope stores are located directly below the mooring stations on A deck.

16.2.3 C Deck

C deck contains the small vehicle deck located toward the bow with a 232 lane meter vehicle capacity.

16.3 Machinery Arrangements

Machinery arrangements can be found on the C, D, and tank top decks. The Machinery Arrangement drawings can be found in Appendix L.

16.3.1 C Deck

C deck is the uppermost deck containing machinery spaces. At the aft end of the deck are the azimuth compartments. A longitudinal watertight bulkhead separates the port pod compartment from the starboard pod compartment. Forward of that is the electrical compartment, battery compartments, and incinerator and waste storage and sorting compartments. At the forward end of the deck are spaces dedicated to food stores and the lower vehicle deck, which is accessible via a hoistable ramp. The Air Lubrication System compressors are also located on this deck, as are hookups for the shore power connection.

16.3.2 D Deck

Deck D has access to the engines from above as well as a domestic machinery space and Engine Control Room (ECR). Aft of the engine rooms is the switchboard compartment. A gas handling room is located aft of the LNG tank compartment and is outfitted with airlocks to provide access to the tanks.

Forward of the LNG tanks water treatment plants, stores compartments, and a pump compartment. The forwardmost compartment contains the two bow thrusters.

16.3.3 Tank top

A pump room is located on the aft end of this deck with the engine compartment forward of it. Forward of the engine compartment are various workshops and an auxiliary machinery space. There is also a second pump room. The second pump room has access points into the LNG tank compartment through airlocks. The aft end of the LNG compartment is also equipped with airlocks, thus allowing access from both the forward and aft ends. Forward of the LNG tank compartment is the freshwater generator plant. Stores compartments and the third pump room can be found at the forward end. The housings for the active fin stabilizers are also on this deck.

16.4 Tank Arrangements

There are two LNG fuel tanks that supply the four engines. They have a combined volume of 900m^3. This amount of fuel is more than would be needed to complete the North Sydney to Argentia crossing (the longest voyage Marine Atlantic services) but would enable the ferry to potentially make a transatlantic crossing if the vessel is built overseas or used on a longer route should the vessel be sold in the future. It also allows multiple crossings to be completed without needing to refuel.

The LNG must be stored at high pressure (~9 bar) and low temperature (~-160℃). This requires a specialized cylindrical tank design that can withstand the pressure and be easily insulated. Each of the eight tanks is 5.5m in diameter and 16m long. They are divided into two watertight compartments and are located above the double bottom. There is space under each tank for a drip tray to catch and identify potential leaks.

The vessel has two sea bays and eight sea chests (four lower chests and four higher chests for when the vessel is transiting through the ice). These are located at the forward end of the engine compartment and near the auxiliary machinery compartment.

The vessel also has two-day tanks – one in each engine room for when it is operating on MDO.

The lubrication oil is stored in two tanks in the compartment directly aft of the engine room. This placement reduces the length of pipe required to service the machinery contained within the engineering spaces. The tanks have been sized to hold 21 tonnes of oil each. Figure 24 provides a visualization of the tank and watertight compartment arrangements.

Detailed tank arrangements are included in the capacity plan provided in Appendix M.

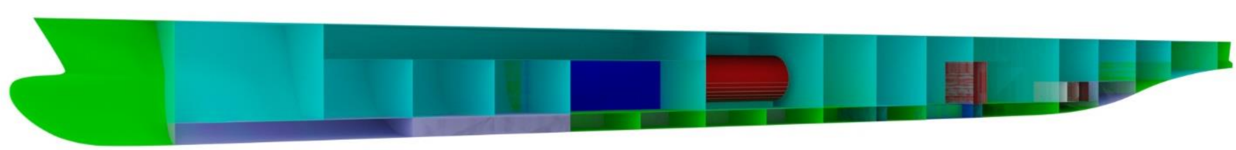

Figure 24: Visualization of the Tank Arrangement

16.5 Main Vertical Fire Zones

The vessel is divided into four main vertical fire zones to comply with SOLAS Chapter II – Fire Protection and Detection and Extinction Regulations [50].

As per regulation 2.2.1.1, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck are in line with the watertight subdivision bulkheads below the bulkhead deck. The length and width of the main vertical zones can be a maximum of 48 meters or no greater than 1600 m^2 on any deck.

17 AREA/VOLUMES SUMMARY

A summary of the total deck area and volume is provided in Table 44. A detailed deck-by-deck area/volume summary is included in Appendix N.

Table 44: Per deck area/volume summary

Deck	Area (m^2)	Enclosed Volume (m^3)
Below Tank Top	3376	6751
Above Tank Top	3306	9917
D Deck	4056	12169
C Deck	4710	16485
B Deck	4818	26497
A Deck	5055	27803
Deck 1	3738	11215
Deck 2	3470	10411
Deck 3	3660	10981
Deck 4	2066	6198
Total	**38255**	**138426**

18 SYSTEMS

18.1 Firefighting Systems

The purpose of the firefighting systems is to suppress and extinguish a fire in its place of origin efficiently. The following functional requirements will be met:

- Fixed fire-extinguishing systems shall be installed, having regard to the fire growth potential of protected spaces; and
- Fire extinguishing equipment will be made readily available.

The vessel's firefighting systems will be designed to meet the International Convention for the Safety of Life at Sea (SOLAS) regulations as outlined in Part C- Suppression of Fire, Regulation 10 – Firefighting [50].

The firefighting arrangements will be determined in later stages of design; however, there are some important elements which should be considered when planning out spaces early on in the vessel's design.

At least three independently driven fire pumps should be integrated into the design (2.2.2.1). They will be arranged such that in the event of a fire in any one compartment, all fire pumps will not be put out of action (2.2.3.1.1). The space containing the fire pump will not be adjacent to the boundaries of the machinery spaces of category A (spaces or trunks to spaces which contain internal combustion machinery [51] or those spaces which contain the main fire pumps). There should not be direct access between the machinery space and the space housing the emergency fire pump and its power source (2.2.3.2.2).

For passenger ships, each machinery space of category A must be provided with at least two suitable water fog applicators (5.5). Machinery spaces of category A above 500m^3 will need to be protected by an approved type of fixed water-based or equivalent firefighting system in addition to a fixed firefighting system.

The vessel will also be equipped with an automatic sprinkler, fire detection, and fire alarm system of an approved type that complies with the fire safety systems code in all control stations, accommodation, and service spaces, including corridors and stairways. For control stations where water could cause damage to essential equipment, an approved fixed firefighting system of another type can be used (6.1.1).

18.2 HVAC

A ship's heating, ventilation, and air conditioning (HVAC) is usually the second largest power consumer after the propulsion systems. The extensive accommodation areas will require a substantial HVAC plant onboard the vessel.

HVAC is particularly important in the LNG tank compartments and the gas handling room. As per DNV-RU-SHIP Pt. 6 Chapter 8 Living and Working Conditions [52] all hazardous compartments will be fitted with a ventilation system capable of exchanging the air within the compartment 30 times within an hour (one complete air exchange every two minutes). Each hazardous compartment’s ventilation system also must be independent.

A dedicated ventilation shaft was added, which leads directly from the LNG tank spaces to a funnel on the uppermost deck. This ensures boil-off gases do not build up in the tank compartments.

18.3 Air Lubrication System

An Air Lubrication System (ALS) will be used to reduce the vessel's fuel consumption further. Based on data collected from a number of ships which utilise ALS, improvements in a vessel's efficiency can be increased by up to 8% [43]. The specifics of the ALS system will be further developed in the next design phase in consultation with a specialist; however, space allocations can be made for this preliminary design. An ALS system requires compressors to release air through outlets on the bottom of the hull. To determine the space necessary for an ALS, vessels with an ALS installed were studied. For a ship matching the size of this RoPax ferry, up to six compressors may be needed. These compressors will be installed on Deck C near the bow to reduce the trunking lengths required to supply the compressors with sufficient air and to reduce the piping lengths between the compressors and the air release units.

19 Safety Considerations

19.1 Evacuation Plan

The ferry's evacuation plan will be designed to meet SOLAS regulations such that persons onboard can safely and swiftly escape to the lifeboat and life raft embarkation deck.

Specific evacuation details are discussed in the following sections and are made in reference to SOLAS Regulation Part D – Escape, Regulation 13 – Means of Escape [53].

The following sections summarise key safety requirements that were considered in the general arrangements.

19.1.1 Escape from Control Stations, Accommodation Spaces, and Service Spaces

Following SOLAS regulations as outlined in Part D Section 3 [53], stairways and ladders have been arranged such that they provide a means of escape to the lifeboat and life raft embarkation deck, from passenger and crew accommodation spaces and from spaces where the crew is usually employed, other than machinery spaces (3.1.1).

Doors in way of escape routes, in general, must open in the way of the direction of the escape route except for the following cases (3.1.5):

- Individual cabin doors may open into the cabins (3.1.5.1)
- Doors in vertical emergency escape trunks may open out of the trunk (3.1.5.2)

19.1.2 Means of Escape Requirements for Passenger Ships

Two means of escape are required in spaces below the bulkhead deck. At least one must be independent of watertight doors. Stairways leading up from below the bulkhead deck have to be at least 800mm wide with handrails on both sides (3.2.1.2).

Above the bulkhead deck, there must be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces. At least one space will provide access to a stairway forming a vertical escape.

Stairway enclosures in accommodation and service spaces are required to have direct access from the corridors and be large enough to prevent congestion. Within the stairway enclosures, only public toilets, lockers, and non-combustible material providing storage for non-hazardous safety equipment and open information counters are permitted. Only public spaces, corridors, lifts, public toilets, and open ro-ro spaces to which any passengers can access and external areas are allowed direct access to these stairway enclosures. Small corridors used to separate an enclosed stairway from galleys or laundries may have direct access to the stairway provided they have a minimum deck area of $4.5m^2$ and a width of no less than 900mm.

At least one method of escape will consist of an easily accessible enclosed stairway. The stairway will provide continuous fire shelter from the level of its origin to the appropriate lifeboat and life raft embarkation decks. Protection of access from stairway enclosures to the lifeboat and life raft embarkation areas will be provided either directly or through protected internal routes which have fire integrity (3.2.4.2).

19.1.3 Escape from Machinery Spaces

Where the space is located below the bulkhead deck, two means of escape will consist of either:

- Two sets of steel ladders, as widely separated as possible, leading to doors in the upper part of the space, which are similarly separated, providing access to the appropriate lifeboat and life raft embarkation deck (4.1.1.1). The enclosure is required to have minimum internal dimensions of at least 800mm x 800mm (4.1.1.1)
- One steel ladder leading to a door located in the upper part of the space from which access is provided to the embarkation deck.

When the space is above the bulkhead deck, two means of escape must be as widely separated as possible, with the doors providing access to the appropriate lifeboat and life raft embarkation decks.

19.1.4 Escape From Machinery Control Rooms

Two means of escape are required from a machinery control room located within the machinery space; at least one is to provide continuous fire shelter to a safe area outside the machinery space.

19.1.5 Escape from Ro-Ro Spaces

At least two means of escape must be provided in ro-ro spaces where the crew are usually employed. The escape routes must provide a safe escape to the lifeboat and life-raft embarkation decks and must be located in the fore and aft ends of the ro-ro decks.

19.2 VEHICLE DECK FLOODING

One important design consideration in RoPax vessels is the vehicle deck. Usually, this deck is completely open, extending from the fore to aft without any transverse subdivisions. This can lead to large areas of flooding, insecure unstable cargo, and free surface effects. To mitigate flood risk, the central trunk acts as a watertight barrier to prevent water from freely sloshing the full beam.

To further mitigate concerns over the flooding of the vehicle decks, flood control doors will be used. There are several types of flood control doors; however, the most common are side and top stowing Jalousie doors, hemicyclic doors, and side rolling doors.

Jalousie doors use slats (or louvres) and tracks, allowing them to be rolled into position. When not being used, side stowing can be stowed alongside the central trunk or side shell to allow for easy loading. Top stowing doors can be stowed on the deckhead, which reduces the free deck height but interferes with loading the least [54]. Side-stowing Jalousie doors can be used above hoistable ramps, but top-stowing doors cannot.

Hemicyclic doors are large gates which pivot out from the central trunk and/or the side shell. They typically do not extend the full height of the deck but are stronger than Jalousie doors [54]. These doors can be used above hoistable ramps.

Side rolling doors consist of a series of gates which telescope outwards from the central trunk or side shell. They can be partially opened or closed to allow for easy loading [54]. These doors can be used above hoistable ramps.

Side-stowing Jalousie flood control doors (shown in Figure 33) were selected for this vessel. Of the three door types, side-stowing Jalousie doors are one of the least obstructive when loading, provide one of the most robust watertight barriers, can be used with hoistable ramps, and are simple to incorporate.

Figure 25: Top stowing Jalousie flood control door [55]

20 Cost Estimate

The cost estimate of the vessel was produced based on formulas provided in Ship Design and Construction Volume 1 [20].

The estimated cost of a new commercial vessel is calculated based on several shipyards over decades of data and on gross tonnage per USD. It should be noted that much of the data provided in this text is outdated. To account for inflation since 1993, a 110% inflation factor was assumed and applied to the total cost.

20.1 Structural Cost

Figure 26 relates the total structural weight to the total structural cost in order to estimate the vessel's structural cost. Included in this cost is the cost of materials, labour and overhead. From the weight estimate, the structural weight of the vessel was estimated to be 10,160 tonnes. Based on Figure 26, passenger ships cost approximately $3050/tonne. Correcting for inflation results in a cost of $6405/tonne in 2023. With a total structural weight of 10,160 tonnes, the total structural weight is estimated at $65,075,000.

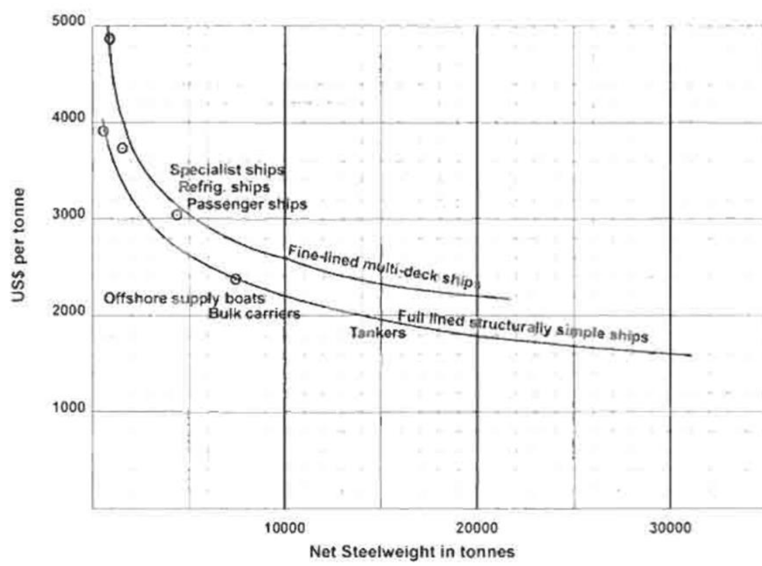

Figure 26: Structural weight versus cost per tonne

20.2 Outfitting Costs

Ferries generally have higher than average outfitting costs because of the relatively high specification list. For this preliminary estimate, Figure 27 was used. The outfitting weight of the ferry was estimated to be 7369.3 tonnes. Therefore, this cost per tonne of outfit weight is $10,000 USD, equivalent to $21,000 in 2023. This yields a total outfitting cost of $154,800,000 USD.

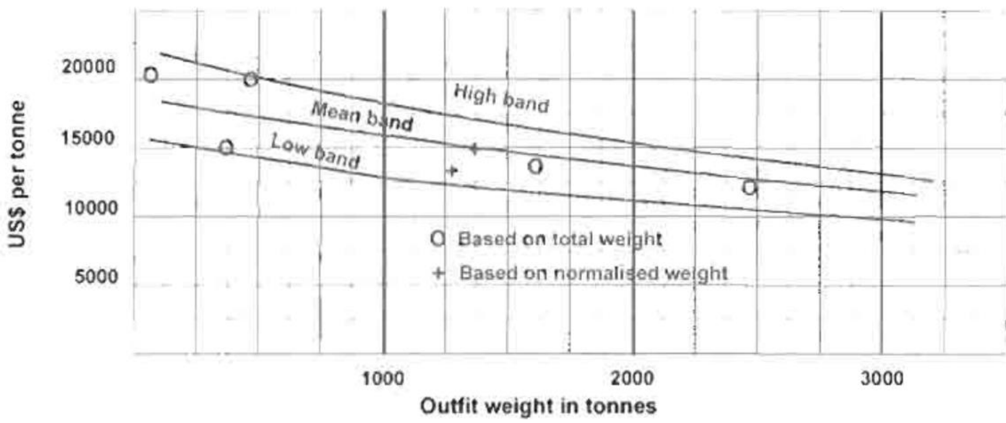

Figure 27: Outfit weight versus cost per tonne [19]

20.3 Total Procurement Cost

Applying a 20% margin to account for the age of the data and uncertainties with the added complexity of an LNG and battery propulsion system yields a total cost of $250,835,000 USD. This aligns with other similarly sized RoPax ferries, such as the Stena Edda ($205,000,000 USD, built in China, completed in 2021) and Rusadir ($215,000,000, built in Germany, completed in 2019).

20.4 Operating Costs

The operating costs of the vessel include wages for crew, as well as vessel repairs and maintenance. Other expenses include insurance, fuel costs and provisions.

The cost estimate for fuel was performed for LNG based on an average cost of LNG in March 2023 of $4.91 USD per Diesel Gallon Equivalent (DGE) [46]. For the annual fuel costs, it was assumed that the vessel would complete 40 trips to PAB per month for eight months and 20 trips to Argentia per month for four months. Table 45 summarises the fuel cost per route.

Table 45: LNG Cost per Trip

Route	Required Fuel (Gallons)	Cost Per Voyage (USD)	Annual Fuel Cost (USD)
Port-Aux-Basque	7133	35,023	11,207,360
Argentia	20,807	102,162	8,172,960
Total			**19,380,320**

Other operating costs can be estimated from Marine Atlantic's 2022 annual report [47]. Although a breakdown of cost per vessel is not outlined in this report, it can be assumed that there is a 15% overhead cost in each cost breakdown as well as a variable cost per vessel.

It was assumed that costs for this vessel would be similar to the Seabridger class (Highlanders and Blue Puttees), given that both this vessel and the Seabridgers have similar passenger capacities, power plants and schedules. Therefore, the salaries, repairs and maintenance, insurance, and provisions would be roughly 25% of the operating costs for 2022. These annual operating costs are provided in Table 46 below.

Table 46: Annual Operating Costs

Item	Cost ($ thousand)
Employee Wages	14,232
Repairs and Maintenance	1,840
Insurance	1,506
Provisions	5,543
Fuel	19,380
Total	42,501

21 Energy Efficiency Design Index

The Energy Efficiency Design Index (EEDI) is a measure of a vessel’s energy efficiency. It takes into account the ship’s emissions, capacity, and speed. The lower a ship’s EEDI, the more energy efficient the design is and the lower its negative impact on the environment [48]. The EEDI of a vessel is determined using the equation shown below:

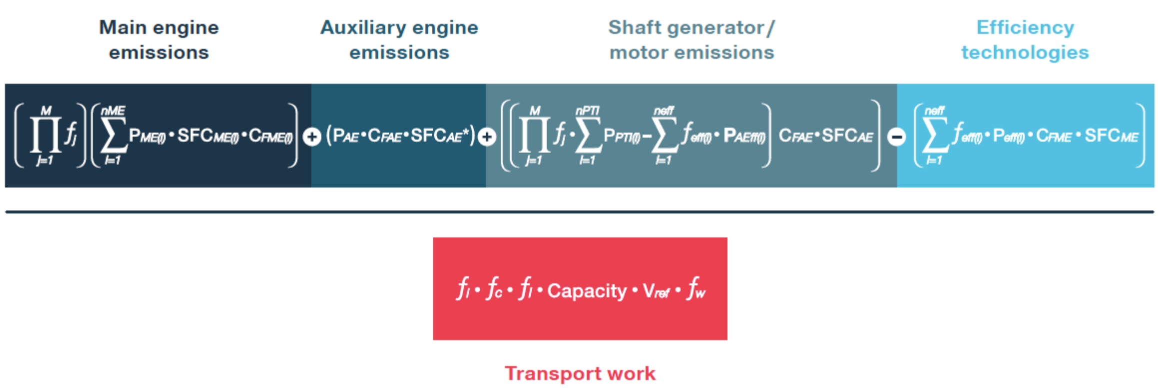

Figure 28: EEDI Formula [49]

The vessel is required to attain an EEDI less than the reference EEDI, which is calculated as:

$$Reference\ EEDI = a * b^{-c}$$

Where *a* and *c* are factors which are specific to passenger ferries, and *b* is the deadweight capacity of the vessel in tonnes. The reference EEDI for this vessel is:

$$Reference\ EEDI = 752.16 * 4355^{-0.381}$$

$$Reference\ EEDI = 29.9$$

The attained EEDI calculation was completed for both LNG and Diesel, as shown in Table 47.

Table 47: Attainted EEDI Values for LNG and MDO

Description	Symbol	Value	Description	Symbol	Value
Length Between Perpendiculars (m)	L_{pp}	188	**Service Speed (knots)**	V_{ref}	14
Beam (m)	B_s	28	**Deadweight (Tonnes)**	DWT	4355
Draft (m)	T_s	6.7	**MCR Rating of Main Engines (kW)**	MCR	6000
Volumetric Displacement (m³)	∇	23978.5	**Ice Correction Factor**	f_i	0.073681
Rated Output of Main Engines (kW)	M_{PP}	16200	**Froude Number**	fn	0.167693
Motor Efficiency	n_{PTI}	0.945	**Correction Exponent**	α	2.5
Generator Efficiency	n_{Gen}	0.97	**Correction Exponent**	β	0.75
Hotel Load (kW)	H_{load}	3405	**Correction Exponent**	γ	0.75
Specific Fuel Consumption (g/kWh)	SFC_AE	179	**Correction Exponent**	δ	1
Gross Registered Tonnage	GRT	43200	**Correction Factor for Ro-Ro Vessel**	f_{roro}	1.092526
Shaft Power (kW)	PPTI	17673.0	**Correction Factor for Ro-Ro Vessel**	f_{roro}	1
Auxilliary Engine Power (kW)	P_AE	3944	**Correction Factor for Ro-Ro Vessel**	f_{c_ropax}	2.06799
Fuel Factor	C_f (MDO)	3.206	**Fuel Factor**	C_f (LNG)	2.75
EEDI (MDO)		**18.48**	**EEDI (LNG)**		**15.84**
Pass Margin		**38%**	**Pass Margin**		**47%**

This vessel satisfies the EEDI requirements in both cases by a comfortable margin.

22 Risk Assessment and Recommendations for Future Work

The concept for Leif Ericson's replacement outlined in this report achieves the goal set out in the statement of requirements to create a notional RoPax ferry design that would provide a safe, comfortable, and reliable service between Newfoundland and Nova Scotia. Key aspects of the design were developed, such as a bespoke hull form, general arrangements, and structural arrangements. Various aspects of the concept were also assessed, such as seakeeping qualities, resistance predictions, and stability.

This RoPax ferry is a large, expensive, and complex ship which Nova Scotia and Newfoundland will rely on for decades to come. It is, therefore, critical that, as the design matures, key aspects are reviewed to ensure the as-built ship meets all the requirements specified by the owners. Risks which could impact the ferry's compliance with the owner's requirements are discussed in the sections that follow.

22.1 Stability

As discussed previously, this preliminary design fails to meet the applicable damaged stability criteria for two cases involving the flooding of the LNG tank compartment and an adjoining compartment. This issue must be addressed in the subsequent design stage by altering the bulkhead placement or adding a longitudinal bulkhead in the failing compartment. The vessel passes the necessary stability criteria by a reasonable margin for all other cases. Intact and damaged stability should be reassessed at each stage of design as the weight estimate, and arrangements become more refined.

22.2 Resistance and Powering

The resistance predictions made using the Holtrop-Mennen method should be verified early in the design through model tests or CFD analyses. The hotel load estimate should also be verified by compiling a detailed list of all electrical consumers and their respective loads. This will ensure that the power plant is appropriately sized for the energy demands of the vessel.

Although the routes are relatively short, it may be worthwhile to perform voyage scenario simulations, such as MARIN's Gulliver simulation [50], to validate the maximum speed of the vessel needed to make up for delays. A reduction in the maximum speed by 1 – 2 knots would reduce the required power by 2000 – 4000 kW. Smaller gensets could then be used, reducing weight, cost, and fuel consumption.

22.3 Manoeuvrability

One of the drivers for the decision to use podded propulsors was to ensure the vessel would be capable of manoeuvring in Port aux Basques in extremely windy conditions. Tests should therefore be carried out to ensure that the pods and bow thrusters selected would provide the power necessary to safely manoeuvre the ship into its berth in 40kts of wind. If the ship handles poorly in such conditions, the ferry service would experience considerable delays, or crossings may be cancelled. The size of the bow thruster compartment would allow for a third bow thruster to be easily added should the tests indicate the vessel manoeuvres poorly.

22.4 SEAKEEPING

The vessel meets the applicable NORDFORSK (1987) seakeeping limits. The seakeeping analysis completed for this preliminary design did not include bilge keels or fin stabilizers. This is something that should be accounted for in later stages of design to aid with the selection of an appropriate active fin stabilizer. Model tests should also be performed to confirm the results of the seakeeping analysis.

22.5 WEIGHT

Weight growth during the design and construction phase was accounted for by including a substantial margin in the weight estimates. However, the number of unique design features, such as pods, LNG fuel systems, batteries, and ice strengthening, may reduce the available margin. As the design becomes more detailed, it will be important to develop a method of weight tracking to reduce the risk of the vessel being delivered overweight and consequently having a lower deadweight capacity.

22.6 ARRANGEMENTS

Detailed equipment sizing estimates should be obtained in consultation with the equipment suppliers. In particular, the space required for the HVAC equipment should be further studied to ensure there is currently enough dedicated HVAC space in the General Arrangement drawings to adequately service all decks. Spaces have been left unallocated throughout the vessel to reduce the risk of having insufficient space for equipment.

22.7 FUNDING

Marine Atlantic, being a Crown Corporation, is subsidised by the Government of Canada. The funding to build the ferry would therefore be provided by the government. According to Marine Atlantic's Corporate Plan Summary, the acquisition process would begin sometime in 2025/26 [51], which coincides with the 45th Federal Election. The budget for the vessel could therefore change significantly. This may result in the need for alterations to the vessel to reduce costs. This was accounted for in the design by including a number of unallocated areas near the machinery spaces, allowing for flexibility in the propulsion arrangements. With several minor changes, the podded propulsors and gensets could be replaced with more traditional and less expensive shafts coupled to medium-speed diesel engines, and the batteries could be removed. If more drastic changes are needed, having a parallel midbody would allow the vessel to be shortened by up to 10m and still have a 3000 lane meter vehicle capacity.

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APPENDIX A – STATEMENT OF REQUIREMENTS

1.0 Physical Design Constraints

The vessel will operate out of the Marine Atlantic terminals in Port aux Basques, NL, Argentia, NL, and North Sydney, NS. Its dimensions are therefore limited by the size restrictions of each terminal.

The limiting parameters are as follows:

Length: The length of the vessel must be less than 205m so that it may manoeuvre in the Port aux Basques turning basin.

Draft: All three harbours are dredged to a minimum depth of 7m. Therefore, the design draft must be less than 7m.

Beam: The beam can be no greater than 28m to allow the vessel to integrate with existing boarding infrastructure.

1.1 Operational Requirements

1.1.1 Speed

The new vessel must be able to maintain Marine Atlantic's existing schedule. It must therefore have sufficient speed to complete the 96nm North Sydney to Port aux Basques route in less than seven hours and the 280nm North Sydney to Argentia route in less than seventeen hours.

1.1.2 Endurance

This vessel must carry provisions for all crew and passengers sufficient for the voyage lengths the ferry will undertake. This vessel must also have the capability to carry enough provisions to cross the Atlantic Ocean, with crew only on board.

1.1.3 Seakeeping

The vessel must undertake voyages in Sea State 6 conditions as defined by the World Meteorological Organizations Sea State [5] code while complying with NORDFORSK (1987) seakeeping limits.

1.1.4 Icebreaking Capability

The vessel must be capable of travelling through any ice that may accumulate on the route between Nova Scotia and Newfoundland. It will therefore be designed to meet the appropriate ice class for the area of operation.

1.1.5 Design Life

The vessel must have a service life of 40 years with regularly scheduled drydocking periods every five years.

1.1.6 Maneuverability

The vessel must manoeuvre into and out of the three Marine Atlantic terminals unaided by tugs.

1.1.7 Passenger and Vehicle Capacity

The vessel must accommodate 1100 passengers and crew and have 3000 lane meters for passenger and commercial vehicle traffic [2].

1.2 Accommodations and Passenger Facilities

1.2.1 Passenger Accommodations

The vessel must have enough cabins to accommodate at least 40% of the passengers at double occupancy [2]. Each cabin must have a private head. The ferry must also have a gym, a shop to purchase snacks and travel items, a buffet-style cafeteria, and two lounges, one of which will be designated as a "quiet" lounge.

1.2.2 Crew Accommodations

There must be sufficient cabins for all crew. Senior officers must have their own cabins near the bridge, and there must be enough single or double-occupancy cabins with private heads to accommodate all other crew members. The ferry must have a crew mess and lounge.

1.2.3 Pet Facilities

Pet-friendly cabins should account for 10% of passenger cabins to accommodate passengers travelling with pets. There must also be kennel facilities with room for 20 large kennels.

1.3 Special Considerations

1.3.1 Vehicle Decks

Vehicle decks must include electrical connection points for reefer units. There must also be an appropriate number of electric vehicle charging stations for passenger vehicles and the capability to add more as required.

1.3.2 Environmental Concerns

The vessel must be designed to have a minimal environmental impact. Therefore, measures must be taken to minimize underwater noise pollution and reduce Greenhouse Gas (GHG) Emissions.

1.3.3 Hazardous Cargo

The vessel must have an open deck for vehicles containing hazardous cargo to be stowed.

1.3.4 Fire Precautions

Vehicle decks must have a fire suppression system capable of extinguishing lithium fires that may originate from an electric vehicle.

1.3.5 Loading Arrangements

The ferry must be capable of loading and offloading vehicles from the bow and stern. It must also have the capability for two-level loading and offloading.

1.4 Regulatory Requirements

All Marine Atlantic vessels are classed with DNV. The new vessel will, therefore, also comply with DNV's rules and regulations for classification.

Additionally, the vessel must be designed in accordance with the following codes and regulations as they pertain to passenger RoPax vessels:

- International Maritime Organization (IMO)
- Transport Canada (TC)
- International Convention for the Safety of Life at Sea (SOLAS)
- International Load Line Convention (LLC)
- International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Maritime Dangerous Goods (IMDG) Code
- Canadian Transportation Agency's Ferry Accessibility for Persons with Disability Code of Practice

APPENDIX B – POLARIS ICE CLASS SELECTION

	ICE FREE	NEW ICE	GREY ICE	GREY WHITE ICE	THIN FIRST YEAR 1ST STAGE	THICK FIRST YEAR 2ND STAGE	MEDIUM FIRST YEAR 2ND STAGE	MEDIUM FIRST YEAR 2ND STAGE	THICK FIRST YEAR	SECOND YEAR	MULTI YEAR	HEAVY MULTI YEAR
1AS	3	2	2	2	2	1	0	-1	-2	-3	-4	-4
1A	3	2	2	2	1	0	-1	-2	-3	-4	-5	-5
1B	3	2	2	1	0	-1	-2	-3	-4	-5	-6	-6
1C	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
Egg code #	0	1	4	5	7	8	1*	4*	7*	8*	9*	9*

Instances where ice forms intrudes on route	Letter	Concentration	2nd row Egg Code			3rd row Egg Code			Corresponding Class Value			1AS	Corresponding Class Value			1A	Corresponding Class Value			1B	Corresponding Class Value			1C
			1 col	2 col	3 col	1 col	2 col	3 col	1 col	2 col	3 col	RIO	1 col	2 col	3 col	RIO	1 col	2 col	3 col	RIO	1 col	2 col	3 col	RIO
2015-02-09	M	9-10/10	1	5	4	7	5	4	2	2	2	20	1	2	2	19	0	1	2	13	-1	0	1	3
2015-02-09	K	9-10/10	2	6	2	5	4	1	2	2	2	20	2	2	2	20	1	2	2	18	0	1	2	10
2015-02-09	U	9-10/10	2	2	1	5	4	1	2	2	2	10	2	2	2	10	1	2	2	8	0	1	2	4
2015-02-16	O	9-10/11	1	5	2	7	5	4	2	2	2	16	1	2	2	15	0	1	2	9	-1	0	1	1
2015-02-16	X	4-6/10	2	1	1	5	4	1	2	2	2	8	2	2	2	8	1	2	2	6	0	1	2	3
2015-02-23	CC	4-6/10	2	1	1	5	4	1	2	2	2	8	2	2	2	8	1	2	2	6	0	1	2	3
2015-02-23	DD	4-6/10	1	2	1	7	5	4	2	2	2	8	1	2	2	7	0	1	2	4	-1	0	1	0
2015-02-23	U	9-10/10	3	4	2	7	5	4	2	2	2	18	1	2	2	15	0	1	2	8	-1	0	1	-1
2015-02-23	L	9-10/10	4	4	2	5	4	1	2	2	2	20	2	2	2	20	1	2	2	16	0	1	2	8
2015-03-02	HH	1-3/10	0	0	0	0	7	0	3	2	3	0	3	1	3	0	3	0	3	0	3	-1	3	0
2015-03-02	Q	4-6/10	6	3	0	4	1	0	2	2	3	18	2	2	3	18	2	2	3	18	1	2	3	12
2015-03-02	V	9-10/10	1	4	2	1	7	5	2	2	2	14	2	1	2	10	2	0	1	4	2	-1	0	-2
2015-03-02	BB	4-6/10	3	2	0	7	5	0	2	2	3	10	1	2	3	7	0	1	3	2	-1	0	3	-3
2015-03-02	M	9-10/10	2	7	1	1*	7	5	0	2	2	16	-1	1	2	7	-2	0	1	-3	-3	-1	0	-13
2015-03-09	S	7-8/10	2	6	0	4	1	0	2	2	3	16	2	2	3	16	2	2	3	16	1	2	3	14
2015-03-09	H	9-10/10	4	5	1	1*	7	5	0	2	2	12	-1	1	2	3	-2	0	1	-7	-3	-1	0	-17
2015-03-09	Q	9-10/10	1	6	1	1*	7	5	0	2	2	14	-1	1	2	7	-2	0	1	-1	-3	-1	0	-9
2015-03-09	W	4-6/10	3	2	0	7	5	0	2	2	3	10	1	2	3	7	0	1	3	2	-1	0	3	-3
2015-03-16	N	9-10/10	2	6	2	4	1*	7	2	0	2	8	2	-1	1	0	2	-2	0	-8	1	-3	-1	-18
2015-03-16	L	9-10/10	3	6	1	1*	7	5	0	2	2	14	-1	1	2	5	-2	0	1	-5	-3	-1	0	-15
2015-03-16	X	4-6/10	3	2	0	7	5	0	2	2	3	10	1	2	3	7	0	1	3	2	-1	0	3	-3
2015-03-16	V	7-8/10	2	4	2	1*	7	5	0	2	2	12	-1	1	2	6	-2	0	1	-2	-3	-1	0	-10
2015-03-23	W	4-6/10	0	0	0	1	0	0	2	3	3	0	2	3	3	0	2	3	3	0	2	3	3	0
2015-03-23	I	9-10/10	2	6	2	4	1*	7	2	0	2	8	2	-1	1	0	2	-2	0	-8	1	-3	-1	-18
2015-03-23	G	9-10/10	3	6	1	1*	7	5	0	2	2	14	-1	1	2	5	-2	0	1	-5	-3	-1	0	-15
2015-03-23	DD	1-3/10	1	2	0	0	1*	7	3	0	2	3	3	-1	1	1	3	-2	0	-1	3	-3	-1	-3
2015-03-23	S	7-8/10	1	5	1	1*	7	5	0	2	2	12	-1	1	2	6	-2	0	1	-1	-3	-1	0	-8
2015-03-30	J	9-10/10	2	2	5	4	1*	7	2	0	2	14	2	-1	1	7	2	-2	0	0	1	-3	-1	-9
2015-03-30	V	4-6/10	1	1	3	4	1*	7	2	0	2	8	2	-1	1	4	2	-2	0	0	1	-3	-1	-5
2015-03-30	DD	1-3/10	1	1	1	4	1*	7	2	0	2	4	2	-1	1	2	2	-2	0	0	1	-3	-1	-3
2015-04-06	S	7-8/10	3	4	1	1*	7	5	0	2	2	10	-1	1	2	3	-2	0	1	-5	-3	-1	0	-13
2015-04-06	L	9-10/10	3	5	1	1*	7	5	0	2	2	12	-1	1	2	4	-2	0	1	-5	-3	-1	0	-14
2015-04-06	FF	1-3/10	2	1	0	1*	7	0	0	2	3	2	-1	1	3	-1	-2	0	3	-4	-3	-1	3	-7
2015-04-13	G	9-10/10	3	6	1	1*	7	5	0	2	2	14	-1	1	2	5	-2	0	1	-5	-3	-1	0	-15
2015-04-13	X	7-8/10	1	5	1	1*	7	5	0	2	2	12	-1	1	2	6	-2	0	1	-1	-3	-1	0	-8
2015-04-13	GG	4-6/10	2	2	0	1*	7	0	0	2	3	4	-1	1	3	0	-2	0	3	-4	-3	-1	3	-8
2015-04-20	FF	1-3/10	1	2	0	1*	7	0	0	2	3	4	-1	1	3	1	-2	0	3	-2	-3	-1	3	-5
2015-04-20	X	7-8/10	1	5	1	1*	7	5	0	2	2	12	-1	1	2	6	-2	0	1	-1	-3	-1	0	-8
2015-04-20	P	9-10/10	2	6	1	1*	7	5	0	2	2	14	-1	1	2	6	-2	0	1	-3	-3	-1	0	-12
2015-04-20	O	9-10/10	2	7	0	7	5	0	2	2	3	18	1	2	3	16	0	1	3	7	-1	0	3	-2
2015-04-27	K	7-8/10	3	5	0	0	1*	7	3	0	2	9	3	-1	1	4	3	-2	0	-1	3	-3	-1	-6
2015-04-27	W	1-3/10	1	2	0	0	1*	7	3	0	2	3	3	-1	1	1	3	-2	0	-1	3	-3	-1	-3
2015-05-04	E	9-10/10	1	4	5	4	1*	7	2	0	2	12	2	-1	1	3	2	-2	0	-6	1	-3	-1	-16
2016-03-28	L	1-3/10	6	3	0	4	1	0	2	2	3	18	2	2	3	18	2	2	3	18	1	2	3	12
2017-03-06	GG	1-3/10	1	1	0	7	5	0	2	2	3	4	1	2	3	3	0	1	3	1	-1	0	3	-1
2017-03-17	R	7-8/10	2	6	0	4	1	0	2	2	3	16	2	2	3	16	2	2	3	16	1	2	3	14
2017-03-17	O	9-10/10	1	3	3	7	5	4	2	2	2	14	1	2	2	13	0	1	2	9	-1	0	1	2
2017-03-17	AA	1-3/10	1	1	1	7	4	1	2	2	2	6	1	2	2	5	0	2	2	4	-1	1	2	2
2017-03-20	HH	4-6/10	1	2	1	7	5	4	2	2	2	8	1	2	2	7	0	1	2	4	-1	0	1	0
2017-03-20	AA	7-8/10	5	2	0	4	1	0	2	2	3	14	2	2	3	14	2	2	3	14	1	2	3	9
2017-03-20	FF	4-6/10	3	2	0	4	1	0	2	2	3	10	2	2	3	10	2	2	3	10	1	2	3	7
2017-03-27	II	4-6/10	1	2	1	7	5	4	2	2	2	8	1	2	2	7	0	1	2	4	-1	0	1	0
2017-03-27	X	7-8/10	3	3	1	7	5	4	2	2	2	14	1	2	2	11	0	1	2	5	-1	0	1	-2
2017-04-10	X	1-3/10	0	0	0	7	0	0	2	3	3	0	1	3	3	0	0	3	3	0	-1	3	3	0
2018-01-29	Y	7-8/10	2	5	1	5	4	1	2	2	2	16	2	2	2	16	1	2	2	14	0	1	2	7
2018-02-05	X	7-8/10	1	5	2	5	4	1	2	2	2	16	2	2	2	16	1	2	2	15	0	1	2	9
2018-02-12	W	7-8/10	2	3	2	5	4	1	2	2	2	14	2	2	2	14	1	2	2	12	0	1	2	7
2018-02-12	BB	1-3/10	1	1	0	5	4	0	2	2	3	4	2	2	3	4	1	2	3	3	0	1	3	1
2018-02-19	DD	1-3/10	1	1	0	4	1	0	2	2	3	4	2	2	3	4	2	2	3	4	1	2	3	3
2018-02-19	O	9-10/10	4	4	1	5	4	1	2	2	2	18	2	2	2	18	1	2	2	14	0	1	2	6
2018-02-19	W	7-8/10	3	2	2	5	4	1	2	2	2	14	2	2	2	14	1	2	2	11	0	1	2	6
2018-02-26	HH	1-3/10	2	1	0	4	1	0	2	2	3	6	2	2	3	6	2	2	3	6	1	2	3	4
2018-02-26	Z	7-8/10	2	4	2	5	4	1	2	2	2	16	2	2	2	16	1	2	2	14	0	1	2	8

2018-02-26	EE	4-6/10	2	3	0	4	1	0	2	2	3	10	2	2	3	10	2	2	3	10	1	2	3	8
2018-03-05	N	9-10/10	2	6	2	7	5	4	2	2	2	20	1	2	2	18	0	1	2	10	-1	0	1	0
2018-03-05	X	7-8/10	2	5	1	5	4	1	2	2	2	16	2	2	2	16	1	2	2	14	0	1	2	7
2018-03-12	D	9-10/10	7	3	0	7	5	0	2	2	3	20	1	2	3	13	0	1	3	3	-1	0	3	-7
2018-04-09	P	1-3/10	2	1	0	7	5	0	2	2	3	6	1	2	3	4	0	1	3	1	-1	0	3	-2
2018-04-16	H	9-10/10	0	0	0	7	0	0	2	3	3	0	1	3	3	0	0	3	3	0	-1	3	3	0
2019-02-04	Z	7-8/10	3	4	0	4	1	0	2	2	3	14	2	2	3	14	2	2	3	14	1	2	3	11
2019-02-04	K	9-10/10	3	6	1	5	4	1	2	2	2	20	2	2	2	20	1	2	2	17	0	1	2	8
2019-02-04	FF	1-3/10	1	1	0	4	1	0	2	2	3	4	2	2	3	4	2	2	3	4	1	2	3	3
2019-02-11	DD	2	2	0	4	1	0	0	2	3	3	16	2	3	3	16	2	3	3	16	2	3	3	16
2019-02-11	F	6	4	0	5	4	0	0	2	3	3	23	2	3	3	23	2	3	3	23	1	3	3	19
2019-02-11	BB	2	2	1	5	4	1	0	2	2	3	21	2	2	3	21	2	2	3	21	1	2	3	19
2019-02-18	BB	7-8/10	3	5	0	4	1	0	2	2	3	16	2	2	3	16	2	2	3	16	1	2	3	13
2019-02-18	AA	7-8/10	5	3	0	5	4	0	2	2	3	16	2	2	3	16	1	2	3	11	0	1	3	3
2019-02-18	I	9-10/10	4	5	1	7	5	4	2	2	2	20	1	2	2	16	0	1	2	7	-1	0	1	-3
2019-02-25	O	9-10/10	1	6	3	7	5	4	2	2	2	20	1	2	2	19	0	1	2	12	-1	0	1	2
2019-02-25	AA	7-8/10	2	4	2	7	5	4	2	2	2	16	1	2	2	14	0	1	2	8	-1	0	1	0
2019-03-04	X	9-10/10	2	3	3	7	5	4	2	2	2	16	1	2	2	14	0	1	2	9	-1	0	1	1
2019-03-04	FF	7-8/10	2	4	1	5	4	1	2	2	2	14	2	2	2	14	1	2	2	12	0	1	2	6
2019-03-04	L	9-10/10	4	5	1	5	4	1	2	2	2	20	2	2	2	20	1	2	2	16	0	1	2	7
2019-03-11	V	7-8/10	5	3	0	4	1	0	2	2	3	16	2	2	3	16	2	2	3	16	1	2	3	11
2019-03-11	Q	9-10/10	3	5	1	7	5	4	2	2	2	18	1	2	2	15	0	1	2	7	-1	0	1	-2
2019-03-11	GG	4-6/10	1	2	1	7	5	4	2	2	2	8	1	2	2	7	0	1	2	4	-1	0	1	0
2019-03-11	T	9-10/10	1	5	3	7	5	4	2	2	2	18	1	2	2	17	0	1	2	11	-1	0	1	2
2019-03-11	HH	1-3/10	2	1	0	5	4	0	2	2	3	6	2	2	3	6	1	2	3	4	0	1	3	1
2019-03-18	Z	7-8/10	2	4	1	7	5	4	2	2	2	14	1	2	2	12	0	1	2	6	-1	0	1	-1
2019-03-18	K	9-10/10	3	5	1	7	5	4	2	2	2	18	1	2	2	15	0	1	2	7	-1	0	1	-2
2019-03-25	W	7-8/10	6	1	0	7	5	0	2	2	3	14	1	2	3	8	0	1	3	1	-1	0	3	-6
2019-03-25	G	9-10/10	1	6	3	1*	7	5	0	2	2	18	-1	1	2	11	-2	0	1	1	-3	-1	0	-9
2019-03-25	EE	4-6/10	1	2	1	7	5	4	2	2	2	8	1	2	2	7	0	1	2	4	-1	0	1	0
2019-04-01	U	7-8/10	5	2	0	7	5	0	2	2	3	14	1	2	3	9	0	1	3	2	-1	0	3	-5
2020-02-17	N	9-10/10	3	5	1	5	4	1	2	2	2	18	2	2	2	18	1	2	2	15	0	1	2	7
2020-02-17	J	9-10/10	2	7	1	7	5	4	2	2	2	20	1	2	2	18	0	1	2	9	-1	0	1	-1
2020-02-24	BB	1-3/10	0	0	0	1	0	0	2	3	3	0	2	3	3	0	2	3	3	0	2	3	3	0
2020-02-24	X	4-6/10	2	4	0	4	1	0	2	2	3	12	2	2	3	12	2	2	3	12	1	2	3	10
2020-02-24	W	4-6/10	5	1	0	5	4	0	2	2	3	12	2	2	3	12	1	2	3	7	0	1	3	1
2020-02-24	X	4-6/10	2	4	0	4	1	0	2	2	3	12	2	2	3	12	2	2	3	12	1	2	3	10
2020-02-24	L	9-10/10	7	2	0	5	4	0	2	2	3	18	2	2	3	18	1	2	3	11	0	1	3	2
2020-03-02	H	9-10/10	4	5	1	7	5	4	2	2	2	20	1	2	2	16	0	1	2	7	-1	0	1	-3
2020-03-02	U	4-6/10	2	2	2	5	4	1	2	2	2	12	2	2	2	12	1	2	2	10	0	1	2	6
2020-03-09	T	7-8/10	3	5	0	7	5	0	2	2	3	16	1	2	3	13	0	1	3	5	-1	0	3	-3
2020-03-09	BB	4-6/10	3	2	0	5	4	0	2	2	3	10	2	2	3	10	1	2	3	7	0	1	3	2
2020-03-16	DD	1-3/10	1	2	0	7	5	0	2	2	3	6	1	2	3	5	0	1	3	2	-1	0	3	-1
2020-03-16	Z	4-6/10	2	3	0	7	5	0	2	2	3	10	1	2	3	8	0	1	3	3	-1	0	3	-2
2020-03-23	T	7-8/10	4	4	0	7	5	0	2	2	3	16	1	2	3	12	0	1	3	4	-1	0	3	-4
2020-03-23	FF	4-6/10	1	1	3	7	5	1	2	2	2	10	1	2	2	9	0	1	2	7	-1	0	2	5
2021-03-08	FF	4-6/10	2	1	1	5	4	1	2	2	2	8	2	2	2	8	1	2	2	6	0	1	2	3
2022-02-28	Y	7-8/10	2	4	1	5	4	1	2	2	2	14	2	2	2	14	1	2	2	12	0	1	2	6
2022-03-07	U	7-8/10	2	5	0	4	1	0	2	2	3	14	2	2	3	14	2	2	3	14	1	2	3	12
2022-03-07	T	7-8/10	4	3	0	5	4	0	2	2	3	14	2	2	3	14	1	2	3	10	0	1	3	3
2022-03-07	CC	1-3/10	1	2	0	5	4	0	2	2	3	6	2	2	3	6	1	2	3	5	0	1	3	2
2022-03-14	EE	4-6/10	3	1	0	7	5	0	2	2	3	8	1	2	3	5	0	1	3	1	-1	0	3	-3
2022-03-14	O	9-10/10	2	5	1	7	5	4	2	2	2	16	1	2	2	14	0	1	2	7	-1	0	1	-1
2022-03-21	P	7-8/10	6	2	0	7	5	0	2	2	3	16	1	2	3	10	0	1	3	2	-1	0	3	-6
2022-03-21	X	4-6/10	4	1	0	7	5	0	2	2	3	10	1	2	3	6	0	1	3	1	-1	0	3	-4
2022-03-28	J	9-10/10	7	2	0	7	5	0	2	2	3	18	1	2	3	11	0	1	3	2	-1	0	3	-7

APPENDIX C – STRUCTURAL CALCULATIONS

STRUCTURAL CALCULATIONS

1.1 MINIMUM SECTION MODULUS

The minimum section modulus was determined using the equations provided in DNV-RU-SHIP Pt. 3 Chapter 5 Hull Girder Strength. Two methods of determining the section modulus are given. The first method bases the required section modulus on the hull geometry and material, while the second method uses still water and wave-induced bending moments. These are shown in Tables 1 and 2. The method which gives the larger section modulus is taken as the minimum. Therefore, the value obtained from the first method was taken as the minimum section modulus. A material factor of 0.72 was used based on the yield strength of AH36 steel.

Table 1: Minimum section modulus, first method

Required Section Modulus		
Parameter	Symbol	Value
Length (m)	L	188
Beam (m)	B	28
Block Coefficient	C_B	0.63
Material Factor	k	0.72
Reduction Factor	f_r	1
Wave Parameter	C_{wo}	9.56
Minimum Section Modulus (m^3)	Z_{R-gr}	9.06

Table 2: Minimum section modulus, second method

Parameter	Symbol	Value
Length (m)	L	188
Beam (m)	B	28
Block Coefficient	C_B	0.63
Wave Coefficient	C_w	9.56
Distribution factor along the ship length	f_{sw}	1
Factor related to the operational profile	f_R	0.85
Coefficient considering non-linear effects applied to hogging	f_{nl-vh}	1
Coefficient considering non-linear effects applied to sagging	f_{nl-vs}	1.22
Distribution factor for strength assessment for vertical wave bending moment along the ship's length	f_m	1
Coefficient for strength assessment	f_p	1
Vertical wave bending moment for strength assessment amidships in hogging condition (kNm)	$M_{wv-h-mid}$	1133024.7

Vertical wave bending moment for strength assessment amidships in sagging condition (kNm)	$M_{wv\text{-}s\text{-}mid}$	-1384694.7
Bending Moment Hogging Condition (kNm)	$M_{sw\text{-}h\text{-}min}$	1019722.3
Bending Moment Sagging Condition (kNm)	$M_{sw\text{-}s\text{-}min}$	-652844.4
Permissible Hull Girder Bending Stress (N/mm^2)	σ_{perm}	243.1
Minimum Section Modulus, hogging (m^3)	$Z_{GR\text{-}h}$	8.86
Minimum Section Modulus, sagging (m^3)	$Z_{GR\text{-}s}$	8.38

1.2 Scantlings

The procedures for calculating various components of the vessel's structure are described below.

1.2.1 Vehicle Deck Plating

The thickness of the vehicle deck plating was determined using the equations and values provided in DNV-RU-SHIP Pt. 3 Chapter 10 Special Requirements. The calculations are shown in Table 3:

Table 3: Vehicle deck plating thickness

Length (m)	L	188
Block Coefficient	C_B	0.63
Deck Plate Length (mm)	a	10000
Deck Plate Width (mm)	b	4000
Aspect Ratio Correction	α_p	1.00952381
Coefficient	k_w	0.35
Factor for wheels parallel to stiffeners	K	2
Gravity (m/s^2)	g	9.81
Factor for number of wheels per axle	w	1.2
Maximum axle load (tonnes)	Q	15.4
Number of load areas per axle	n_0	4
Maximum Tire Pressure (kN/m^2)	p_0	1000
Load area (m^2)	A	0.0453222
Tire Contact Area Width (mm)	a_1	301.0720844
Tire Contact Area Length (mm)	b_1	150.5360422
Local breadth (mm)	c	150.5360422
Stiffener spacing (mm)	b	1000
Acceleration parameter	a_0	0.44
Coefficient for strength assement for load scenario	f_{ps}	1.00
Coefficient for ships with bilge keels	f_{BK}	1.20
Metacentric height (m)	GM	1.96

Roll radius of gyration (mm)	k_r	10.92
Roll period (s)	T_θ	17.99
Roll angle (deg)	θ	30.36
Ratio between loading and scantling draft	f_T	1.00
Wave length (m)	λ_φ	225.60
Pitch period (s)	T_φ	12.02
Pitch Angle (deg)	φ	11.70
Transvers location (m from CL)	y	9.80
Heave acceleration (m/s^2)	a_{heave}	4.3
Roll acceleration (rad/s^2)	a_{roll}	0.065
Pitch acceleration (rad/s^2)	a_{pitch}	0.069
Verical acceleration due to pitch (m/s^2)	$a_{pitch-z}$	8.18
Verical acceleration due to roll (m/s^2)	a_{roll-z}	0.63
Total vertical acceleration (m/s^2)	a_z	8.89
Design presure in harbour (kN/m^2)	P_{wl-1}	898.27
Design presure at sea (kN/m^2)	P_{wl-2}	1588.76
Bending moment factor	m	6.53
Maximum hull girder stress (kN)	σ_{hg}	284.72
Yield Strength	ReH	355
Coefficient	α_a	0.5
Coefficient	β_a	2.1
Permissible bending stress coefficient	C_a	1.70
Minimum plate thickness for vehicle decks (mm)	t	11.4
Increment for abrasion and corrosion (mm)	t_{c1}	1
Increment for abrasion and corrosion (mm)	t_{c2}	1
Reserve thickness (mm)	t_{res}	0.5
Designed plate thickness (mm)	t_{des}	14.0

1.2.2 Ice Belt Scantlings

The scantlings for the ice belt were calculated using equations and values provided in DNV-RU-SHIP Pt. 6 Chapter 6 Cold Climate. The procedure for calculating the side shell thickness of the ice belt is shown in table 4 below:

Table 4: Ice belt side shell plating scantlings

Ice Belt Scantlings		
Displacement (tonnes)	Δf	24578
Power available when sailing through ice (kW)	P_S	14700
Factor	k_1	19.0078
Factors for bow, midbody, and stern regions	a_1	2
Factors for bow, midbody, and stern regions	b_1	286
Factor which accounts for the size and engine power of the ship	c_d	0.324016
Factor that reflects the magnitude of the load expected on the hull area relative to bow area	c_1	0.85
Full length (m)	ℓ_0	0.6
Length of area under consideration (m)	ℓ_a	1.7
Factor which account for the probability that the length of the area under consideration will be under pressure at the same time	c_a	0.59
Design Pressure (kN/m^2)	P	916.2712
Design ice height (m)	h	0.3
Stiffener spacing (m)	s_1	1
Factor for longitudinal framing	f_2	1.93
Increment for abrasion and corrosion (mm)	t_c	2
Yield strength (MPa)	ReH	355
Minimum required thickness (mm)	t	26.4
Designed thickness (mm)	t_{des}	30

1.2.3 Other Scantlings

The scantlings for other components of the ship's structure were calculated based on the DNV-RU-SHIP Pt. 3 Chapter 6 Hull Local Scantling. Tables 5 – 7 below summarise the minimum scantlings of various structural elements.

Table 5: Plating scantlings

<table>
<tr><th colspan="11">Plating</th></tr>
<tr><th>Element</th><th colspan="2">Location</th><th>a</th><th>b</th><th>min t (mm)</th><th>t_{c1} (mm)</th><th>t_{c2} (mm)</th><th>t_{res} (mm)</th><th>t_c (mm)</th><th>Gross t (mm)</th></tr>
<tr><td rowspan="6">Shell</td><td colspan="2">Keel</td><td>5</td><td>0.05</td><td>13.0</td><td>0.5</td><td>0.5</td><td>0.5</td><td>1.5</td><td>15</td></tr>
<tr><td colspan="2">Bottom, Bilge, and Sea Chest Boundaries</td><td>4.5</td><td>0.035</td><td>10.1</td><td>1</td><td>1</td><td>0.5</td><td>2</td><td>13</td></tr>
<tr><td rowspan="4">Side Shell and Superstructure Side</td><td>From upper end of bilge plating to T_{SC} + 4.6</td><td rowspan="4">4</td><td>0.035</td><td>9.6</td><td>1</td><td>1</td><td>0.5</td><td>2</td><td>12</td></tr>
<tr><td>From T_{SC} + 4.6 to T_{SC} + 6.9</td><td>0.025</td><td>4.0</td><td>1</td><td>0.5</td><td>0.5</td><td>1.5</td><td>6</td></tr>
<tr><td>From T_{SC} + 6.9 to T_{SC} + 9.2</td><td>0.015</td><td>2.4</td><td>1</td><td>0.5</td><td>0.5</td><td>1.5</td><td>4</td></tr>
<tr><td>Elsewhere</td><td>0.01</td><td>1.6</td><td>1</td><td>0.5</td><td>0.5</td><td>1.5</td><td>4</td></tr>
<tr><td rowspan="3">Deck</td><td colspan="2">Weather Deck and Strength Deck</td><td rowspan="3">4.5</td><td>0.02</td><td>7.7</td><td>1</td><td>0.5</td><td>0.5</td><td>1.5</td><td>10</td></tr>
<tr><td colspan="2">Boundary for cargo tanks and water ballast tanks and hold intended for cargo in bulk</td><td>0.015</td><td>2.4</td><td>1</td><td>1</td><td>0.5</td><td>2.5</td><td>5</td></tr>
<tr><td colspan="2">Other Decks</td><td>0.01</td><td>1.6</td><td>1</td><td>0.5</td><td>0.5</td><td>2</td><td>4</td></tr>
<tr><td colspan="3">Inner Bottom</td><td>4.5</td><td>0.02</td><td>7.7</td><td>1</td><td>0.5</td><td>0.5</td><td>2</td><td>10</td></tr>
<tr><td rowspan="2">Bulkheads</td><td colspan="2">Bulkhead for cargo and water ballast tanks</td><td rowspan="2">4.5</td><td>0.015</td><td>6.9</td><td>1</td><td>1</td><td>0.5</td><td>2.5</td><td>10</td></tr>
<tr><td colspan="2">Watertight Bulkheads</td><td>0.01</td><td>6.1</td><td>1</td><td>0.5</td><td>0.5</td><td>1.5</td><td>8</td></tr>
</table>

Table 6: Stiffeners and tripping bracket scantlings

<table>
<tr><th colspan="7">Stiffeners and Tripping Brackets</th></tr>
<tr><th>Element</th><th>Location</th><th>min t (mm)</th><th>t_{c1} (mm)</th><th>t_{res} (mm)</th><th>t_c (mm)</th><th>Gross t (mm)</th></tr>
<tr><td rowspan="3">Stiffeners and attached end brackets</td><td>Tank boundary, single strength deck and shell up to freeboard deck</td><td>6.38</td><td>1</td><td>0.5</td><td>2.5</td><td>9</td></tr>
<tr><td>Structures in deckhouse and superstructure</td><td>4</td><td>1</td><td>0.5</td><td>2.5</td><td>7</td></tr>
<tr><td>Other structure</td><td>5.44</td><td>1</td><td>0.5</td><td>2.5</td><td>8</td></tr>
<tr><td colspan="2">Tripping Brackets</td><td>6.38</td><td>1</td><td>0.5</td><td>1.5</td><td>8</td></tr>
</table>

Table 7: Primary supporting members scantlings

Primary Supporting Members							
Element	**a**	**b**	**min t (mm)**	**t_{c1} (mm)**	**t_{res} (mm)**	**t_c (mm)**	**Gross t (mm)**
Bottom centerline girder over full length of ship	5	0.03	9.8	1	0.5	2.5	13.0
Bottom longitudinal girders	5	0.017	7.7	1	0.5	2.5	11.0
Floors in aft peak tanks including reduced floors or floors with large opening	5	0.025	9.0	1	0.5	2.5	12.0
Floors in general	5	0.015	7.4	1	0.5	2.5	10.0
PSM at tank boundaries, single strength deck and shell up to freeboard deck	4.5	0.015	6.9	1	0.5	2.5	10.0
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 D from baseline	4.5	0.01	6.1	1	0.5	2.5	9.0
Primary Supporting Members in general	4.5	0.01	6.1	1	0.5	2.5	9.0

1.3 Designed Section Modulus

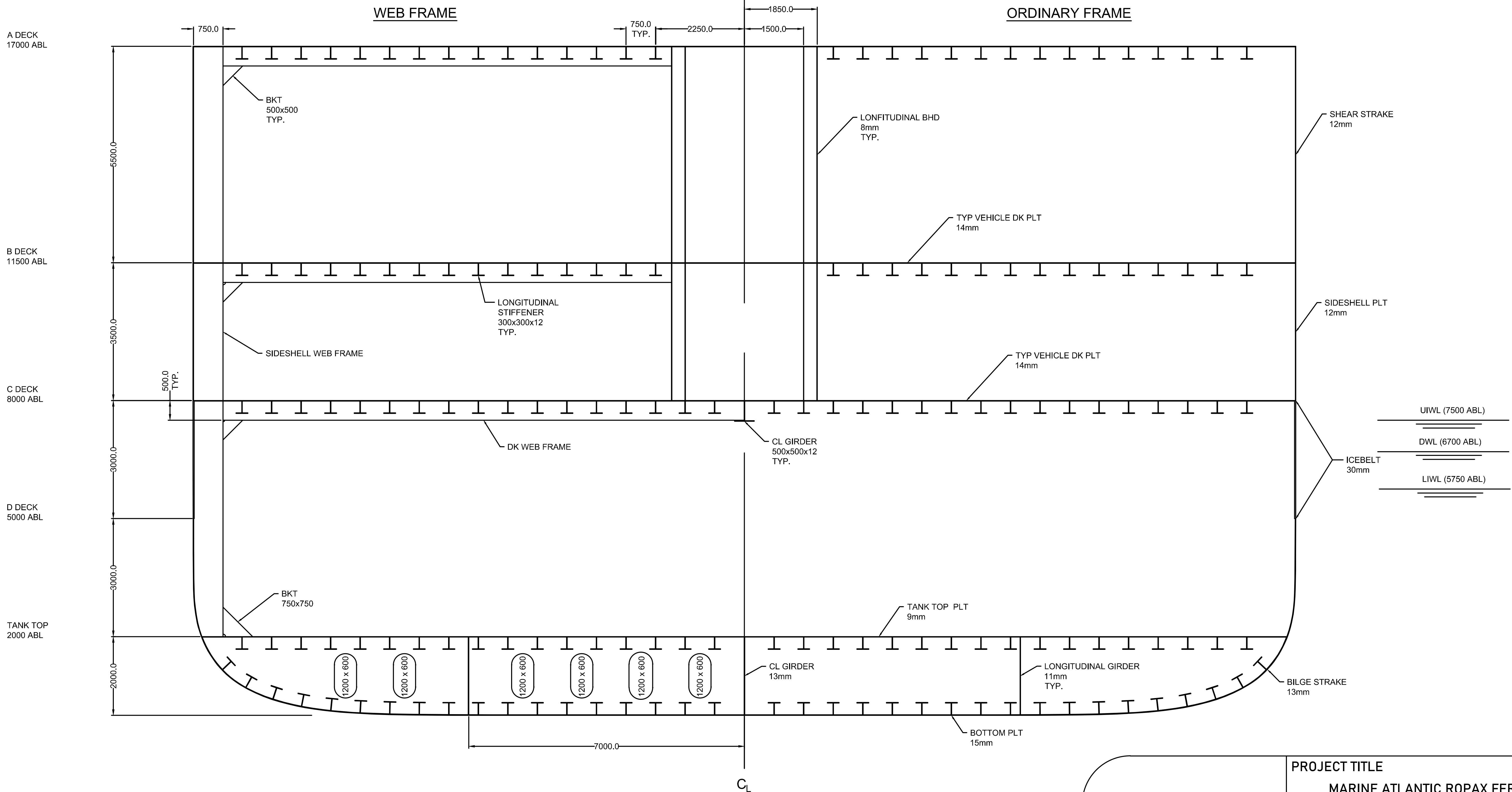
The section modulus of the midship section was determined to be 13.1mm^3, as shown in Table 8 below.

Table 8: Designed section modulus

Item			Qty.	t [mm]	Vertical Span [mm]	Transverse Span [mm]	NA [mm]	A [mm^2]	1st Moment [mm^3]	2nd Moment [mm^4]	Local 2nd Moment [mm^4]
Plating	Shell	Bottom Plating	1	15	0	7000	7.5	105000	787500	5906250	1968750
		Bilge Strake	1	13	-	-	1163.5	148615	172913319.8	2.01185E+11	2092991.8
		Ice Belt	1	30	3000	-	6493	90000	584370000	3.79431E+12	6750000
		Sideshell	1	11	4500	-	12500	49500	618750000	7.73438E+12	499125
	Deck Plates	Tank Top	1	9	-	13774	1995.5	123966	247374153	4.93635E+11	836770.5
		C Deck	1	14	-	13970	7993	195580	1563270940	1.24952E+13	3194473.333
		A Deck	1	14	-	13970	16993	195580	3323490940	5.64761E+13	3194473.333
Primary Structural Members	Girders	Double Bottom CL Girder Girder	1	13	1976	-	1003	25688	25765064	25842359192	361772.6667
		Bottom Girders	1	11	1976	-	1003	21736	21801208	21866611624	219171.3333
		500x500x12 C Deck CL Girder	1	12	-	-	7608	12000	91296000	6.9458E+11	144000
		500x500x12 D Deck CL Girder	1	12	-	-	4613	12000	55356000	2.55357E+11	144000
	Longitudinal Bulkheads	A Deck Bulkhead	2	8	3386	-	15293	54176	828513568	1.26705E+13	288938.6667
		A Deck Bulkhead Coaming	2	8	100	-	11550	1600	18480000	2.13444E+11	8533.333333
		B Deck Bulkhead	2	8	1388	-	10792	22208	239668736	2.5865E+12	118442.6667
		B Deck Bulkhead Coaming	2	8	100	-	8050	1600	12880000	1.03684E+11	8533.333333
Longitudinal Stiffeners	Bilge	300x300x12 Bilge Longitudinal 1	1	12	-	-	244	7200	1756800	428659200	86400
		300x300x12 Bilge Longitudinal 2	1	12	-	-	250	7200	1800000	450000000	86400
		300x300x12 Bilge Longitudinal 3	1	12	-	-	264	7200	1900800	501811200	86400
		300x300x12 Bilge Longitudinal 4	1	12	-	-	291	7200	2095200	609703200	86400
		300x300x12 Bilge Longitudinal 5	1	12	-	-	347.5	7200	2502000	869445000	86400
		300x300x12 Bilge Longitudinal 6	1	12	-	-	452	7200	3254400	1470988800	86400
		300x300x12 Bilge Longitudinal 7	1	12	-	-	630.5	7200	4539600	2862217800	86400
		300x300x12 Bilge Longitudinal 8	1	12	-	-	908	7200	6537600	5936140800	86400
		300x300x12 Bilge Longitudinal 9	1	12	-	-	1319.5	7200	9500400	12535777800	86400
	Decks	300x300x12 Bottom Longitudinals	9	12	-	-	243	64800	15746400	3826375200	777600
		300x300x12 Tank Top Longitudinals	17	12	-	-	1763	122400	215791200	3.8044E+11	1468800
		300x300x12 D Deck Longitudinals	17	12	-	-	4763	122400	582991200	2.77679E+12	1468800
		300x300x12 C Deck Longitudinals	17	12	-	-	7758	122400	949579200	7.36684E+12	1468800
		300x300x12 B Deck Longitudinals	17	12	-	-	11258	122400	1377979200	1.55133E+13	1468800
		300x300x12 A Deck Lonfitudinals	17	12	-	-	16758	122400	2051179200	3.43737E+13	1468800
Sum								1800848.8	13031870629	1.58207E+14	28729175.93

h_NA	7236.515708	mm
I_zz	1.5822E+14	mm^4
I_NA	1.2783E+14	mm^5
Deck y	9763.484292	mm
Keel y	7236.515708	mm
Z Deck	**13092612484**	**mm^3**
Z Keel	**17664511692**	**mm^3**
Z Deck	**13.1**	**mm^3**
Z Keel	**17.7**	**mm^3**

APPENDIX D – MIDSHIP SECTION DRAWING



PRINCIPAL PARTICULARS	
LENGTH OVERALL (m)	204.0
LENGTH BETWEEN PERPENDICULARS (m)	188.0
MOULDED BEAM (m)	28.0
MOULDED DEPTH (m)	17.0
DESIGN DRAFT (m)	6.7
ICE CLASS	1A

ABBREVIATIONS

BKT - BRACKET
DK - DECK
LIWL - LOWER ICE WATERLINE
PLT - PLATE
UIWL - UPPER ICE WATERLINE

NOTES:

1. ALL DIMENSIONS ARE IN MM
2. FRAMES ARE SPACED 1000 MM APART

TRAK

PROJECT TITLE		
MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE		
MIDSHIP SECTION		
SHEET SIZE: ANSI B	DRAWN BY: R.C.	DATE: 02/03/2023
SCALE: 1:100	CHECKED BY: A.B.	DATE: 03/16/2023
DRAWING NO.: AP-02	REV.: 0	PAGE: 1 OF 1

APPENDIX E – WEIGHT ESTIMATE

WEIGHTS AND CENTERS ESTIMATE

1.1 LIGHTSHIP

The preliminary lightship weights and centres estimates were produced using a series of parametric equations created by D.G.M. Watson, provided in SNAME's Ship Design and Construction Volume 1. The method separates the total lightship weight into four weight groups:

- Structural Weight (W_S)
- Machinery Weight (W_M)
- Outfit Weight (W_O)
- Weight Margin (W_{Margin})

The table below contains the inputs used in the following weights and centres estimates.

Length Between Perpendiculars	L (m)	188.0
Beam	B (m)	28.0
Draft	T (m)	6.7
Depth	D (m)	17.0
Block Coefficient	C_b	0.627
Height of the Double Bottom	H_{db} (m)	2.0
Engine Room Overhead Height	D' (m)	8.0
Height of the Main Deck	O (m)	17.0
Longitudinal Center of Buoyancy	LCB (m)	97.05

1.1.1 Structural Weight

The structural weight group is divided into three groups – basic structure weight (W_S), superstructure weight (W_{SS}), and deckhouse(s) weight (W_{dh}). Structural weight is estimated using a modified Lloyd's equipment numeral, E, as the independent variable:

$$E = E_{hull} + E_{SS} + E_{dh}$$

$$E_{hull} = L(B + T) + 0.85(D - T)$$

$$E_{SS} = 0.85 \sum_i \ell_i h_i$$

$$E_{dh} = 0.75 \sum_j \ell_j h_j$$

The projected area of the superstructure and deckhouse is required for the above equations. These values were assumed to be 1328m^2 and 390m^2, respectively and were obtained from the AutoCAD profile drawing of the vessel. The table below shows the calculated Lloyd's numeral.

E_{hull}	**8169.54**
E_{SS}	1128.8
E_{dh}	292.5
E	9590.84

The weight of the hull is then calculated with the equation:

$$W_S = W_S(E) = KE^{1.36}(1 + 0.5(C_b' - 0.7))$$

Where C_b' is the block coefficient correction factor. The structural weight coefficient, K, was taken as 0.038, as recommended for passenger vessels in the following table.

Ship type	*K mean*	*K range*	*Range of E*
Tankers	0.032	±0.003	1500 < E < 40 000
Chemical tankers	0.036	±0.001	1900 < E < 2500
Bulk carriers	0.031	±0.002	3000 < E < 15 000
Container ships	0.036	±0.003	6000 < E < 13 000
Cargo	0.033	±0.004	2000 < E < 7000
Refrigerator ships	0.034	±0.002	4000 < E < 6000
Coasters	0.030	±0.002	1000 < E < 2000
Offshore supply	0.045	±0.005	800 < E < 1300
Tugs	0.044	±0.002	350 < E < 450
Fishing trawlers	0.041	±0.001	250 < E < 1300
Research vessels	0.045	±0.002	1350 < E < 1500
RO-RO ferries	0.031	±0.006	2000 < E < 5000
Passenger ships	0.038	±0.001	5000 < E < 15 000
Frigates/corvettes	0.023		

The weight of the basic structure is then estimated:

$$W_S = 0.038(9590.84)^{1.36}\big(1 + 0.5(0.755 - 0.7)\big) = 10{,}160.0\ tonnes$$

The weight of the superstructure and deckhouse are similarly estimated:

$$W_{SS} = W_S(E_{hull} + E_{SS}) - W_S(E_{hull}) = 1572\ tonnes$$

$$W_{dh} = W_S(E_{hull} + E_{SS} + E_{dh}) - W_S(E_{hull} + E_{SS}) = 419\ tonnes$$

1.1.2 Machinery Weight

The machinery weight is estimated with the following equation, which is recommended for diesel-electric plants:

$$W_M = 0.72(MCR)^{0.78}$$

The ferry's two Wartsila 10V31DF engines produce a combined 12,000kW, and the two 8V31DF produce a combined 9600kW. The total MCR is, therefore, 21,600kW.

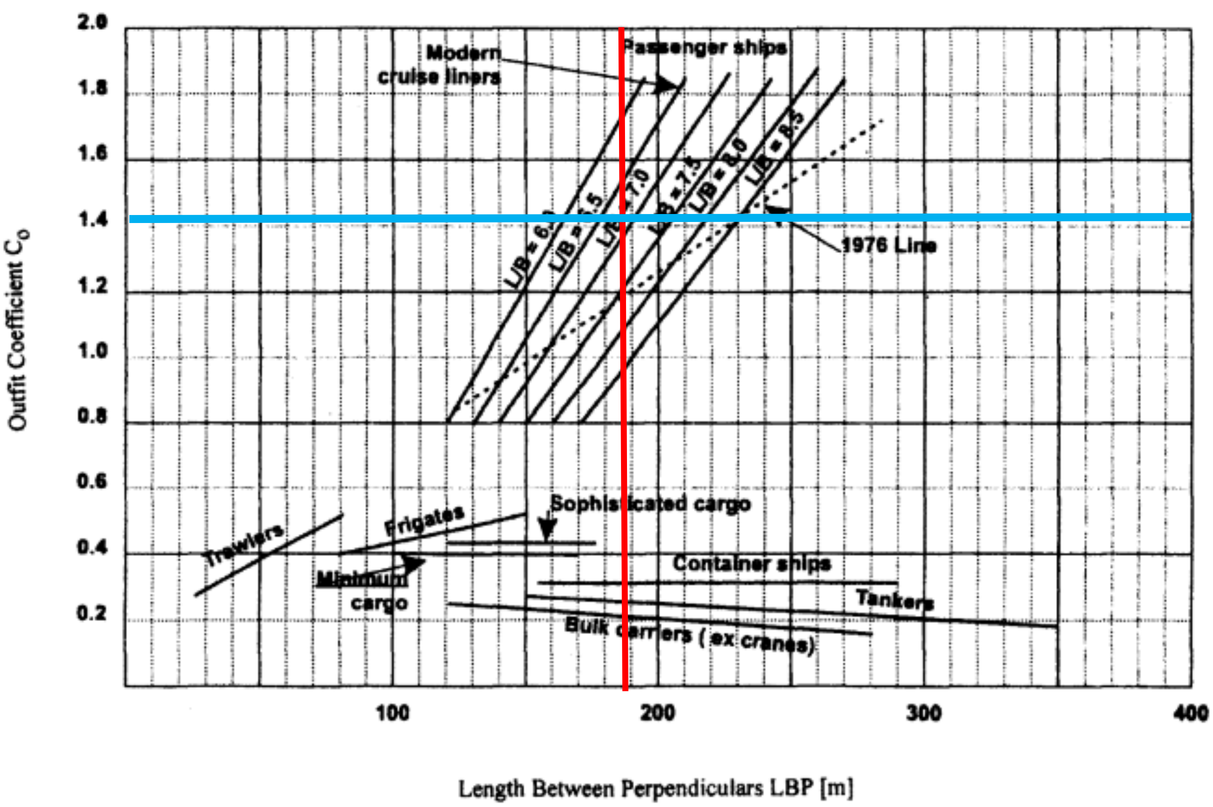
$$W_{M=}0.72(21600)^{0.78} = 1730.6\ tonnes$$

1.1.3 Outfit Weight

Outfit weight is estimated with the equation below:

$$W_o = C_o LB$$

Where C_o is the outfit coefficient. This was taken as 1.4 based on the figure provided below.



The outfit weight is, therefore:

$$W_o = (1.4)(188)(28) = 7369.6\ tonnes$$

1.1.4 Total Lightship

The total lightship weight is the sum of the structural, machinery, and outfit weights, as shown in the following table. Watson recommends a margin of 3%; however, given the vessel's unique hybrid propulsion system and podded propulsors, a 5% margin was instead used.

W_S (tonnes)	**10,160.0**
W_M (tonnes)	1730.6
W_o (tonnes)	7369.6
5% Margin	963.0
Lightship Weight	20,223.0

1.1.5 Centers Estimates

The VCG of the structural weight is divided into three groups – hull, superstructure, and deckhouse. The VCG of the hull is estimated using the equation:

$$VCG_{hull} = 0.01D\left[46.6 + 0.135(0.81 - C_B)\left(\frac{L}{D}\right)^2\right] = 8.4m$$

The VCG of the superstructure and deckhouse were assumed to be 26m and 33m, respectively. These values were obtained from the AutoCAD model of the vessel.

The VCG of the machinery is estimated using the equation:

$$VCG_M = h_{db} + 0.35(D' - h_{db}) = 2 + 0.35(8 - 2) = 4.1$$

The VCG of the outfitting is estimated with the equation:

$$VCG_o = O + 1.25 + 0.01(L - 125) = 18.88$$

And the LCG of the hull was estimated with the equation:

$$LCG_{hull} = -0.15 + LCB = 96.9m$$

The LCG of the superstructure and deckhouse was estimated to be 94.5m and 113m, respectively, using the AutoCAD drawings of the vessel.

The LCG of the machinery was assumed to be at the aft end of the main engines, which is 54.5m forward of the origin point.

The outfit LCG is estimated using the following equation:

$$LCG_O = \frac{0.25W_o(LCG_m) + 0.375W_o(LCG_{dh}) + 0.375W_o(LCG_{midship})}{W_o} = 92.1m$$

Due to the symmetry of the vessel, the TCG for all groups was assumed to be 0.

A summary of the lightship centres is provided in the table below.

Group	**LCG (m)**	**TCG (m)**	**VCG (m)**

Hull	96.9	0	8.4
Superstructure	94.5	0	26.0
Deckhouse	114.0	0	33.0
Outfit	92.1	0	18.88
Machinery	54.5	0	4.1
Net	91.1	0	13.34

1.2 Deadweight Estimate

1.2.1 People, Water, and Provisions

Deadweight estimates were also obtained from SNAME's Ship Design and Construction Volume 1. The centres for freshwater were determined from the tank arrangement. The centres for the provisions were set to be the same as for the passengers. This was done because many of the provisions would be distributed throughout the passenger areas and in the store room behind the cafeteria galley. Many stores are also located lower in this ship, so assuming a VCG higher in the ship adds conservatism. The centres for passenger/crew and effects were assumed to be 1.0m above the deck where their cabins are located. The table below summarizes the recommended weights for people, water, and provisions.

Component	Weight (tonnes)	Total Weight (tonnes)	LCG (m)	TCG (m)	VCG (m)
Freshwater	0.17/person/day	387	134.6	0	5
Crew and Effects	0.17/person	17	119.4	0	32
Passengers and Effects	0.17/person	170	113.3	0	26.9
Provisions	0.01/person/day	22	113.3	0	26.9

1.2.2 Vehicle Weights

An average passenger vehicle weight of 2000kg was assumed based on a 2020 study of automotive trends conducted by the U.S. Environmental Protection Agency and anticipated vehicle weight growth.

The weight of live and drop units was based on the truck weight limits defined in Newfoundland and Labrador Regulation 105/14 Vehicle Regulations and the equivalent regulations for Nova Scotia. A conservative 35,000kg was assumed to be the average weight of a live unit, and 25,000kg was assumed to be the average weight of a drop unit.

APPENDIX F – HYDROSTATICS REPORT

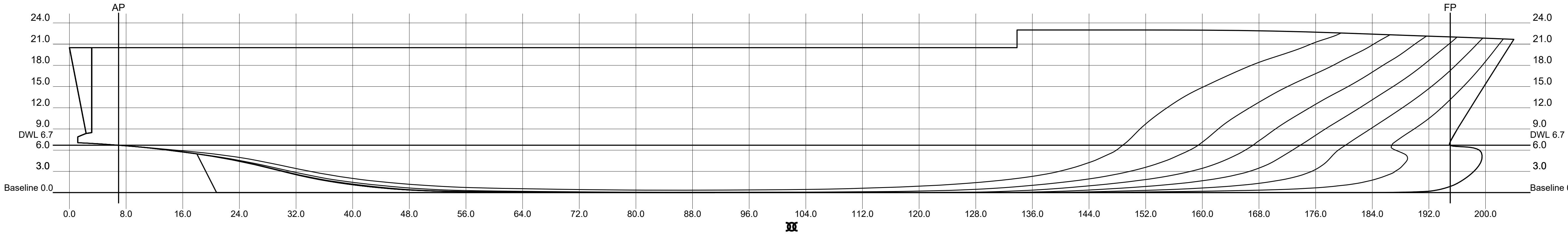
Draft	Volume	Displ FW	Displ.	LCB	VCB	TCB
m	m3	t	t	m	m	m
5.0	16732.47	16732.47	17150.78	98.891	2.746	0
5.1	17139.49	17139.49	17567.98	98.816	2.801	0
5.2	17548.52	17548.52	17987.23	98.74	2.855	0
5.3	17959.76	17959.76	18408.75	98.659	2.91	0
5.4	18373.22	18373.22	18832.55	98.575	2.965	0
5.5	18788.89	18788.89	19258.61	98.488	3.02	0
5.6	19206.91	19206.91	19687.08	98.396	3.075	0
5.7	19627.31	19627.31	20118	98.3	3.13	0
5.8	20050.16	20050.16	20551.41	98.2	3.186	0
5.9	20475.53	20475.53	20987.42	98.095	3.241	0
6.0	20903.41	20903.41	21425.99	97.985	3.296	0
6.1	21333.88	21333.88	21867.23	97.87	3.352	0
6.2	21767.06	21767.06	22311.24	97.75	3.408	0
6.3	22203.02	22203.02	22758.1	97.624	3.463	0
6.4	22641.86	22641.86	23207.91	97.492	3.519	0
6.5	23083.9	23083.9	23661	97.352	3.576	0
6.6	23529.36	23529.36	24117.59	97.205	3.632	0
6.7	23978.67	23978.67	24578.13	97.051	3.688	0
6.8	24432	24432	25042.8	96.89	3.745	0
6.9	24889.62	24889.62	25511.86	96.721	3.802	0
7.0	25352.13	25352.13	25985.94	96.543	3.86	0
7.1	25820.03	25820.03	26465.53	96.353	3.918	0
7.2	26289.34	26289.34	26946.58	96.167	3.975	0
7.3	26759.15	26759.15	27428.13	95.989	4.033	0
7.4	27229.39	27229.39	27910.12	95.817	4.09	0
7.5	27700.03	27700.03	28392.53	95.651	4.147	0
7.6	28171.05	28171.05	28875.33	95.493	4.204	0
7.7	28642.43	28642.43	29358.49	95.34	4.261	0
7.8	29114.19	29114.19	29842.04	95.193	4.317	0
7.9	29586.28	29586.28	30325.94	95.052	4.374	0
8.0	30058.29	30058.29	30809.75	94.917	4.43	0

Draft	Aw	LCF	KMt	KMl	MCT	TpCm
m	m^2	m	m	m	t*m	tonne/cm
5.0	4060.83	95.882	16.609	472.061	394.565	41.624
5.1	4081.09	95.645	16.421	467.072	399.819	41.831
5.2	4102.24	95.38	16.244	462.587	405.358	42.048
5.3	4124.42	95.085	16.08	458.561	411.175	42.275
5.4	4146.5	94.778	15.927	454.667	416.995	42.502
5.5	4169.02	94.47	15.783	451.104	423.013	42.732
5.6	4193.08	94.119	15.652	448.109	429.481	42.979
5.7	4217.19	93.742	15.531	445.18	435.939	43.226
5.8	4241.89	93.36	15.418	442.585	442.661	43.479
5.9	4267.11	92.948	15.316	440.235	449.577	43.738
6.0	4292.56	92.521	15.222	437.984	456.55	43.999
6.1	4318.73	92.071	15.138	436.046	463.814	44.267
6.2	4346.45	91.584	15.065	434.605	471.596	44.551
6.3	4374.02	91.083	14.996	433.192	479.403	44.834
6.4	4405.03	90.507	14.94	432.72	488.277	45.152
6.5	4436.96	89.915	14.89	432.591	497.595	45.479
6.6	4474.14	89.299	14.848	434.378	509.244	45.86
6.7	4513.43	88.683	14.812	436.929	521.973	46.263
6.8	4554.52	88.046	14.78	440.056	535.61	46.684
6.9	4599.6	87.349	14.756	444.379	550.977	47.146
7.0	4653.88	86.488	14.753	451.273	569.924	47.702
7.1	4690.7	85.943	14.715	453.314	583.015	48.08
7.2	4696.19	85.969	14.602	446.835	584.979	48.136
7.3	4700.67	86.015	14.487	440.347	586.631	48.182
7.4	4705.05	86.073	14.376	434.054	588.252	48.227
7.5	4708.92	86.132	14.268	427.856	589.714	48.266
7.6	4712.61	86.193	14.164	421.818	591.115	48.304
7.7	4716.28	86.256	14.064	415.973	592.513	48.342
7.8	4719.92	86.319	13.97	410.303	593.894	48.379
7.9	4722.05	86.409	13.876	404.443	594.729	48.401
8.0	4719.16	86.59	13.776	397.555	593.73	48.371

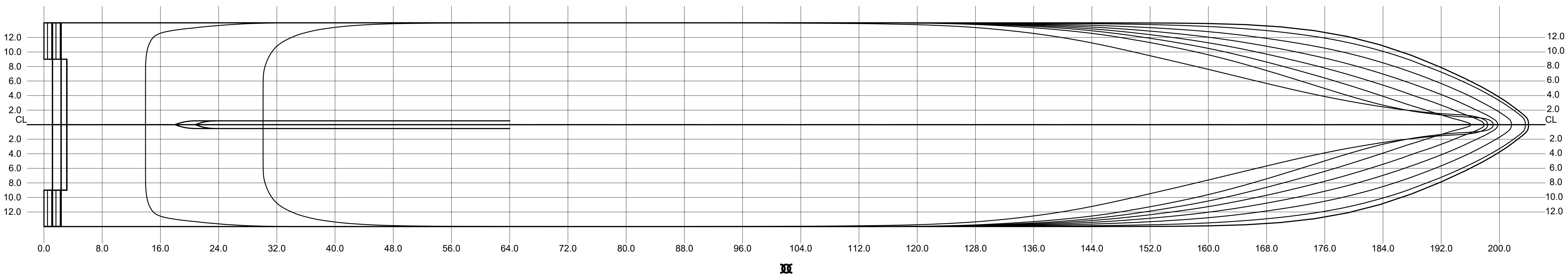
MEMORIAL UNIVERSITY

TRAK

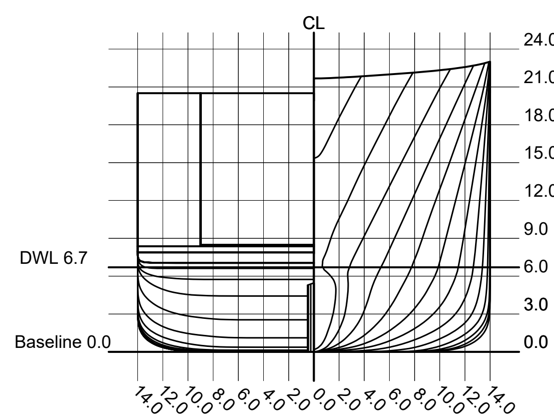
APPENDIX G – LINES PLAN



BUTTOCKS



WATERLINES



STATIONS

PRINCIPAL PARTICULARS

LENGTH OVERALL (m)	204.0
LENGTH BETWEEN PERPENDICULARS (m)	188.0
MOULDED BEAM (m)	28.0
MOULDED DEPTH (m)	17.0
DESIGN DRAFT (m)	6.7
DISPLACEMENT (TONNES)	24,578

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE LINES PLAN		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 02/03/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/16/2023
DRAWING NO. AP-01	REV. 0	PAGE 1 OF 1

APPENDIX H – RESISTANCE AND PROPULSION REPORTS

Propulsion

7 Feb 2023 01:41 PM
HydroComp NavCad 2019 [Premium]

Project ID **Atlantic Puffin**
Description
File name **untitled.hcnc**

Analysis parameters

Hull-propulsor interaction			System analysis	
Technique:	[Calc]	Prediction	Cavitation criteria:	10% cav line
Prediction:		Holtrop	Analysis type:	Free run
Reference ship:			CPP method:	
Max prop diam:		4750.0 mm	Engine RPM:	
Corrections			Mass multiplier:	
Viscous scale corr:	[On]	Standard	RPM constraint:	
Rudder location:		Behind propeller	Limit [RPM/s]:	
Friction line:		ITTC-57	**Water properties**	
Hull form factor:		1.181	Water type:	Salt
Corr allowance:		ITTC-78 (v2008)	Density:	1026.00 kg/m3
Roughness [mm]:	[Off]	0.00	Viscosity:	1.18920e-6 m2/s
Ducted prop corr:	[Off]			
Tunnel stern corr:	[Off]			

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0.17	0.70	6.72	4.18
Range	0.06··0.80	0.55··0.85	3.90··14.90	2.10··4.00

Prediction results [System]

	HULL-PROPULSOR				ENGINE			FUEL PER ENGINE	
SPEED [kt]	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBENG [kW]	LOADENG [% rated]	MDO [t/h]	LNG [t/h]
13.00	1761.6	0.1440	0.1553	0.9907	99	1362.0	0.0	---	---
+ 14.00 +	2229.2	0.1439	0.1553	0.9907	106	1724.4	0.0	---	---
15.00	2800.4	0.1438	0.1553	0.9907	115	2167.9	0.0	---	---
16.00	3498.9	0.1437	0.1553	0.9907	123	2711.7	0.0	---	---
17.00	4351.3	0.1436	0.1553	0.9907	132	3377.8	0.0	---	---
18.00	5390.2	0.1435	0.1553	0.9907	141	4193.7	0.0	---	---
19.00	6661.5	0.1435	0.1553	0.9907	150	5198.7	0.0	---	---
20.00	8161.7	0.1434	0.1553	0.9907	159	6391.9	0.0	---	---
21.00	9887.5	0.1433	0.1553	0.9907	169	7772.0	0.0	---	---
22.00	12001.4	0.1432	0.1553	0.9907	179	9479.8	0.0	---	---

	CO2 PER ENGINE		EFFICIENCY			THRUST	
SPEED [kt]	MDO [t/h]	LNG [t/h]	EFFO	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
13.00	---	---	0.6750	0.6467	0.34527	155.91	263.40
+ 14.00 +	---	---	0.6747	0.6464	0.34737	183.20	309.52
15.00	---	---	0.6743	0.6459	0.3508	214.80	362.90
16.00	---	---	0.6736	0.6452	0.35553	251.61	425.09
17.00	---	---	0.6726	0.6441	0.36142	294.50	497.54
18.00	---	---	0.6711	0.6427	0.36838	344.54	582.10
19.00	---	---	0.6691	0.6407	0.37647	403.39	681.52
20.00	---	---	0.6669	0.6384	0.3845	469.53	793.26
21.00	---	---	0.6645	0.6361	0.39189	541.73	915.23
22.00	---	---	0.6613	0.6330	0.40069	627.66	1060.40

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
13.00	99	128.06	128.06	1334.8	1362.0	2724.0	2724.0	591.8
+ 14.00 +	106	150.16	150.16	1689.9	1724.4	3448.8	3448.8	503.4
15.00	115	175.45	175.45	2124.5	2167.9	4335.7	4335.7	429.0
16.00	123	204.55	204.55	2657.5	2711.7	5423.4	5423.4	365.8
17.00	132	238.05	238.05	3310.3	3377.8	6755.6	6755.6	312.0
18.00	141	276.67	276.67	4109.8	4193.7	8387.4	8387.4	266.1
19.00	150	321.53	321.53	5094.7	5198.7	10397.3	10397.3	226.6
20.00	159	371.59	371.59	6264.1	6391.9	12783.9	12783.9	194.0
21.00	169	425.99	425.99	7616.6	7772.0	15544.0	15544.0	167.5
22.00	179	489.94	489.94	9290.2	9479.8	18959.7	18959.7	143.9

Propulsion

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Project ID **Atlantic Puffin**
Description
File name **untitled.hcnc**

Prediction results [Propulsor]

	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [mm]
13.00	8.45	4.54	0.85	24.52	0.172	13.54	2.0	2.0	3891.5
+ 14.00 +	7.28	3.90	0.73	26.48	0.188	15.91	2.0	2.0	3886.5
15.00	6.34	3.37	0.63	28.49	0.207	18.65	2.0	2.0	3878.4
16.00	5.57	2.92	0.55	30.57	0.229	21.84	2.0	2.0	3867.2
17.00	4.93	2.55	0.48	32.72	0.254	25.57	2.0	2.0	3853.2
18.00	4.40	2.24	0.42	34.95	0.285	29.91	2.0	2.0	3836.4
19.00	3.95	1.97	0.37	37.28	0.322	35.02	2.0	2.0	3816.9
20.00	3.56	1.74	0.33	39.66	0.364	40.76	2.0	2.0	3797.2
21.00	3.23	1.54	0.29	42.07	0.411	47.03	2.8	2.8	3779.0
22.00	2.94	1.37	0.26	44.61	0.470	54.49	4.1	4.1	3757.2

	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KT/J2	KQ/J3	CTH	CP	RNPROP	
13.00	0.7334	0.1105	0.01911	0.20551	0.048458	0.52333	0.78262	2.70e7	
+ 14.00 +	0.7315	0.1114	0.01922	0.20817	0.049102	0.53009	0.79302	2.92e7	
15.00	0.7285	0.1128	0.01940	0.21256	0.05017	0.54129	0.81028	3.14e7	
16.00	0.7244	0.1148	0.01965	0.21879	0.051693	0.55714	0.83487	3.36e7	
17.00	0.7191	0.1173	0.01996	0.22679	0.053667	0.57752	0.86675	3.60e7	
18.00	0.7129	0.1203	0.02033	0.23663	0.056114	0.60256	0.90627	3.84e7	
19.00	0.7055	0.1237	0.02076	0.2486	0.05913	0.63306	0.95498	4.09e7	
20.00	0.6981	0.1272	0.02120	0.26111	0.062317	0.6649	1.0065	4.35e7	
21.00	0.6912	0.1305	0.02161	0.2732	0.065439	0.69571	1.0569	4.61e7	
22.00	0.6828	0.1344	0.02209	0.28837	0.069406	0.73434	1.1209	4.88e7	

Propulsion

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Project ID **Atlantic Puffin**
Description
File name **untitled.hcnc**

Hull data

General		
Configuration:		**Monohull**
Chine type:		**Round/multiple**
Length on WL:		**188.093 m**
Max beam on WL:	[LWL/BWL 6.718]	**28.000 m**
Max molded draft:	[BWL/T 4.179]	**6.700 m**
Displacement:	[CB 0.679]	**24578.14 t**
Wetted surface:	[CS 2.864]	**6080.390 m2**
ITTC-78 (CT)		
LCB fwd TR:	[XCB/LWL 0.516]	**97.051 m**
LCF fwd TR:	[XCF/LWL 0.000]	**0.000 m**
Max section area:	[CX 0.972]	**182.270 m2**
Waterplane area:	[CWP 0.857]	**4513.430 m2**
Bulb section area:		**12.670 m2**
Bulb ctr below WL:		**2.000 m**
Bulb nose fwd TR:		**200.000 m**
Imm transom area:	[ATR/AX 0.000]	**0.000 m2**
Transom beam WL:	[BTR/BWL 1.000]	**28.000 m**
Transom immersion:	[TTR/T 0.000]	**0.000 m**
Half entrance angle:		**20.95 deg**
Bow shape factor:	[AVG flow]	**0.0**
Stern shape factor:	[AVG flow]	**0.0**

Planing		
Proj chine length:		*0.000 m*
Proj bottom area:		*0.000 m2*
LCG fwd TR:	*[XCG/LP 0.000]*	*0.000 m*
VCG below WL:		*0.000 m*
Aft station (fwd TR):		*0.000 m*
Deadrise:		*0.00 deg*
Chine beam:		*0.000 m*
Chine ht below WL:		*0.000 m*
Fwd station (fwd TR):		*0.000 m*
Deadrise:		*0.00 deg*
Chine beam:		*0.000 m*
Chine ht below WL:		*0.000 m*
Propulsor type:		*Propeller*
Max prop diameter:		*4750.0 mm*
Shaft angle to WL:		*0.00 deg*
Position fwd TR:		*0.000 m*
Position below WL:		*0.000 m*
Transom lift device:		*Flap*
Device count:		*0*
Span:		*0.000 m*
Chord length:		*0.000 m*
Deflection angle:		*0.00 deg*
Tow point fwd TR:		*0.000 m*
Tow point below WL:		*0.000 m*
Foil assist (planing)		
Foil count:		*0*
Total planform area:		*0.000 m2*
LCE fwd TR:		*0.000 m*
VCE below WL:		*0.000 m*
Lift-drag ratio:		*0.0*
Lift fraction (design):		*0.00*
Design speed:		*0.00 kt*

Propulsor data

Propulsor		
Count:		**2**
Propulsor type:		**Propeller series**
Propeller type:		**FPP**
Propeller series:		**B Series**
Propeller sizing:		**No sizing**
Reference prop:		
Blade count:		**4**
Expanded area ratio:		**0.6500**
Propeller diameter:		**4750.0 mm**
Propeller mean pitch:	[P/D 0.8947]	**4250.0 mm**
Hub immersion:		**4211.0 mm**
Engine/gear		
Drive line:		**Standard**
Gear input:		**Single engine**
Engine data:		
Rated RPM:		**0 RPM**
Rated power:		**0.0 kW**
Primary fuel:		**MDO**
Secondary fuel:		**LNG**
Gear efficiency:		**1.000**
Load correction:		**Off**
Gear ratio:		**1.000**
Shaft efficiency:		**0.980**

Propeller options	
Oblique angle corr:	**Off**
Shaft angle to WL:	**0.00 deg**
Added rise of run:	**0.00 deg**
Propeller cup:	**0.0 mm**
KTKQ corrections:	**Custom**
Scale correction:	**None**
KT multiplier:	**1.000**
KQ multiplier:	**1.000**
Blade T/C [0.7R]:	**0.00**
Roughness:	**0.00 mm**
Cav breakdown:	**Off**
Design condition [No sizing]	
Max prop diam:	
Design speed:	
Reference thrust:	
Design point:	
Reference RPM:	
Design point:	

Propulsion

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Project ID **Atlantic Puffin**
Description
File name **untitled.hcnc**

Symbols and values

SPEED =	Vessel speed
PETOTAL =	Total vessel effective power
WFT =	Taylor wake fraction coefficient
THD =	Thrust deduction coefficient
EFFR =	Relative-rotative efficiency
RPMENG =	Engine RPM
PBENG =	Brake power per engine
VOLRATE =	Volumetric fuel rate total Primary
LOADENG =	Engine load as a percentage of engine rated power
RPMPROP =	Propulsor RPM
QPROP =	Propulsor open water torque
QENG =	Engine torque
PDPROP =	Delivered power per propulsor
PSPROP =	Shaft power per propulsor
PSTOTAL =	Total vessel shaft power
PBTOTAL =	Total vessel brake power
TRANSP =	Transport factor
EFFO =	Propulsor open-water efficiency
EFFG =	Gear efficiency (load corrected)
EFFOA =	Overall propulsion efficiency [=PETOTAL/PSTOTAL]
MERIT =	Propulsor merit coefficient
THRPROP =	Open-water thrust per propulsor
DELTHR =	Total vessel delivered thrust
J =	Propulsor advance coefficient
KT =	Propulsor thrust coefficient [horizontal, if in oblique flow]
KQ =	Propulsor torque coefficient
KT/J2 =	Propulsor thrust loading ratio
KQ/J3 =	Propulsor torque loading ratio
CTH =	Horizontal component of bare-hull resistance coefficient
CP =	Propulsor thrust loading coefficient
RNPROP =	Propeller Reynolds number at 0.7R
SIGMAV =	Cavitation number of propeller by vessel speed
SIGMAN =	Cavitation number of propeller by RPM
SIGMA07R =	Cavitation number of blade section at 0.7R
TIPSPEED =	Propeller circumferential tip speed
MINBAR =	Minimum expanded blade area ratio recommended by selected cavitation criteria
PRESS =	Average propeller loading pressure
CAVAVG =	Average predicted back cavitation percentage
CAVMAX =	Peak predicted back cavitation percentage [if in oblique flow]
PITCHFC =	Minimum recommended pitch to avoid face cavitation
+ =	Design speed indicator
* =	Exceeds recommended parameter limit
! =	Exceeds recommended cavitation criteria [warning]
!! =	Substantially exceeds recommended cavitation criteria [critical]
!!! =	Thrust breakdown is indicated [severe]
--- =	Insignificant or not applicable

Resistance

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Project ID **Atlantic Puffin**
Description
File name **R&P.hcnc**

Analysis parameters

Vessel drag		ITTC-78 (CT)
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Model LWL:		
Expansion:		Custom
Friction line:		ITTC-57
Hull form factor:	[On]	1.181
Speed corr:	[On]	
Spray drag corr:	[Off]	
Corr allowance:		0.000000
Roughness [mm]:	[Off]	

Added drag		
Appendage:	[Calc]	Percentage
Wind:	[Off]	
Seas:	[Off]	
Shallow/channel:	[Off]	
Towed:	[Off]	
Margin:	[Off]	
Water properties		
Water type:		Salt
Density:		1026.00 kg/m3
Viscosity:		1.18920e-6 m2/s

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T	Lambda
Value	0.17	0.70	6.72	4.18	0.81
Range	0.06··0.40	0.55··0.85	3.90··14.90	2.10··4.00	0.01··1.07

Prediction results

	SPEED COEFS		ITTC-78 COEFS						
SPEED [kt]	FN	FV	RN	CF	[CV/CF]	CR	dCF	CA	CT
13.00	0.156	0.398	1.06e9	0.001520	1.179	0.000096	0.000000	0.000000	0.001888
+ 14.00 +	0.168	0.428	1.14e9	0.001506	1.178	0.000139	0.000000	0.000000	0.001913
15.00	0.180	0.459	1.22e9	0.001493	1.176	0.000197	0.000000	0.000000	0.001954
16.00	0.192	0.490	1.30e9	0.001482	1.175	0.000271	0.000000	0.000000	0.002011
17.00	0.204	0.520	1.38e9	0.001471	1.173	0.000361	0.000000	0.000000	0.002085
18.00	0.216	0.551	1.46e9	0.001461	1.170	0.000468	0.000000	0.000000	0.002176
19.00	0.228	0.581	1.55e9	0.001451	1.167	0.000594	0.000000	0.000000	0.002287
20.00	0.240	0.612	1.63e9	0.001442	1.163	0.000725	0.000000	0.000000	0.002402
21.00	0.252	0.643	1.71e9	0.001434	1.159	0.000853	0.000000	0.000000	0.002514
22.00	0.264	0.673	1.79e9	0.001426	1.154	0.001009	0.000000	0.000000	0.002654

	RESISTANCE							
SPEED [kt]	RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RTOWED [kN]	RMARGIN [kN]	RTOTAL [kN]
13.00	263.41	0.00	0.00	0.00	0.00	0.00	0.00	263.41
+ 14.00 +	309.52	0.00	0.00	0.00	0.00	0.00	0.00	309.52
15.00	362.90	0.00	0.00	0.00	0.00	0.00	0.00	362.90
16.00	425.09	0.00	0.00	0.00	0.00	0.00	0.00	425.09
17.00	497.55	0.00	0.00	0.00	0.00	0.00	0.00	497.55
18.00	582.10	0.00	0.00	0.00	0.00	0.00	0.00	582.10
19.00	681.52	0.00	0.00	0.00	0.00	0.00	0.00	681.52
20.00	793.26	0.00	0.00	0.00	0.00	0.00	0.00	793.26
21.00	915.23	0.00	0.00	0.00	0.00	0.00	0.00	915.23
22.00	1060.40	0.00	0.00	0.00	0.00	0.00	0.00	1060.40

	EFFECTIVE POWER		OTHER		
SPEED [kt]	PEBARE [kW]	PETOTAL [kW]	CTLR	CTLT	RBARE/W
13.00	1761.6	1761.6	0.00230	0.04507	0.00109
+ 14.00 +	2229.2	2229.2	0.00332	0.04566	0.00128
15.00	2800.4	2800.4	0.00470	0.04664	0.00151
16.00	3498.9	3498.9	0.00647	0.04802	0.00176
17.00	4351.3	4351.3	0.00862	0.04978	0.00206
18.00	5390.2	5390.2	0.01116	0.05195	0.00242
19.00	6661.5	6661.5	0.01418	0.05459	0.00283
20.00	8161.7	8161.7	0.01731	0.05735	0.00329
21.00	9887.5	9887.5	0.02036	0.06001	0.00380
22.00	12001.4	12001.4	0.02409	0.06335	0.00440

Resistance

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Project ID **Atlantic Puffin**
Description
File name **R&P.hcnc**

Hull data

General		
Configuration:		**Monohull**
Chine type:		**Round/multiple**
Length on WL:		**188.093 m**
Max beam on WL:	[LWL/BWL 6.718]	**28.000 m**
Max molded draft:	[BWL/T 4.179]	**6.700 m**
Displacement:	[CB 0.679]	**24578.14 t**
Wetted surface:	[CS 2.864]	**6080.390 m2**
ITTC-78 (CT)		
LCB fwd TR:	[XCB/LWL 0.516]	**97.051 m**
LCF fwd TR:	[XCF/LWL 0.000]	**0.000 m**
Max section area:	[CX 0.972]	**182.270 m2**
Waterplane area:	[CWP 0.857]	**4513.430 m2**
Bulb section area:		**12.670 m2**
Bulb ctr below WL:		**2.000 m**
Bulb nose fwd TR:		**200.000 m**
Imm transom area:	[ATR/AX 0.000]	**0.000 m2**
Transom beam WL:	[BTR/BWL 1.000]	**28.000 m**
Transom immersion:	[TTR/T 0.000]	**0.000 m**
Half entrance angle:		**20.95 deg**
Bow shape factor:	[AVG flow]	**0.0**
Stern shape factor:	[AVG flow]	**0.0**

Planing		
Proj chine length:		***0.000 m***
Proj bottom area:		***0.000 m2***
LCG fwd TR:	*[XCG/LP 0.000]*	***0.000 m***
VCG below WL:		***0.000 m***
Aft station (fwd TR):		***0.000 m***
Deadrise:		***0.00 deg***
Chine beam:		***0.000 m***
Chine ht below WL:		***0.000 m***
Fwd station (fwd TR):		***0.000 m***
Deadrise:		***0.00 deg***
Chine beam:		***0.000 m***
Chine ht below WL:		***0.000 m***
Propulsor type:		***Propeller***
Max prop diameter:		***4750.0 mm***
Shaft angle to WL:		***0.00 deg***
Position fwd TR:		***0.000 m***
Position below WL:		***0.000 m***
Transom lift device:		***Flap***
Device count:		***0***
Span:		***0.000 m***
Chord length:		***0.000 m***
Deflection angle:		***0.00 deg***
Tow point fwd TR:		***0.000 m***
Tow point below WL:		***0.000 m***
Foil assist (planing)		
Foil count:		***0***
Total planform area:		***0.000 m2***
LCE fwd TR:		***0.000 m***
VCE below WL:		***0.000 m***
Lift-drag ratio:		***0.0***
Lift fraction (design):		***0.00***
Design speed:		***0.00 kt***

Resistance

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HydroComp NavCad 2019 [Premium]

Project ID **Atlantic Puffin**
Description
File name **R&P.hcnc**

Appendage data

General	
Definition:	**Percentage**
Percent of hull drag:	**0.00 %**
Planing influence	
LCE fwd TR:	**0.000 m**
VCE below WL:	**0.000 m**
Shafting	
Count:	**2**
Max prop diameter:	**4750.0 mm**
Shaft angle to WL:	**0.00 deg**
Exposed shaft length:	**0.000 m**
Shaft diameter:	**0.000 m**
Wetted surface:	**0.000 m2**
Strut bossing length:	**0.000 m**
Bossing diameter:	**0.000 m**
Wetted surface:	**0.000 m2**
Hull bossing length:	**0.000 m**
Bossing diameter:	**0.000 m**
Wetted surface:	**0.000 m2**
Strut (per shaft line)	
Count:	**0**
Root chord:	**0.000 m**
Tip chord:	**0.000 mm**
Span:	**0.000 m**
T/C ratio:	**0.000**
Projected area:	**0.000 m2**
Wetted surface:	**0.000 m2**
Exposed palm depth:	**0.000 m**
Exposed palm width:	**0.000 m**
Rudder	
Count:	**0**
Rudder location:	**Behind propeller**
Type:	**Balanced foil**
Root chord:	**0.000 m**
Tip chord:	**0.000 m**
Span:	**0.000 m**
T/C ratio:	**0.000**
LE sweep:	**0.00 deg**
Projected area:	**0.000 m2**
Wetted surface:	**0.000 m2**

Skeg/Keel	
Count:	**0**
Type:	**Skeg**
Mean length:	**0.000 m**
Mean width:	**0.000 m**
Height aft:	**0.000 m**
Height mid:	**0.000 m**
Height fwd:	**0.000 m**
Projected area:	**0.000 m2**
Wetted surface:	**0.000 m2**
Stabilizer	
Count:	**0**
Root chord:	**0.000 m**
Tip chord:	**0.000 m**
Span:	**0.000 m**
T/C ratio:	**0.000**
LE sweep:	**0.00 deg**
Wetted surface:	**0.000 m2**
Projected area:	**0.000 m2**
Dynamic multiplier:	**1.00**
Bilge keel	
Count:	**0**
Mean length:	**0.000 m**
Mean base width:	**0.000 m**
Mean projection:	**0.000 m**
Wetted surface:	**0.000 m2**
Tunnel thruster	
Count:	**0**
Diameter:	**0.000 m**
Sonar dome	
Count:	**0**
Wetted surface:	**0.000 m2**
Miscellaneous	
Count:	**0**
Drag area:	**0.000 m2**
Drag coef:	**0.00**

Environment data

Wind	
Wind speed:	**0.00 kt**
Angle off bow:	**0.00 deg**
Gradient correction:	**Off**
Exposed hull	
Transverse area:	**0.000 m2**
VCE above WL:	**0.000 m**
Profile area:	**0.000 m2**
Superstructure	
Superstructure shape:	**Cargo ship**
Transverse area:	**0.000 m2**
VCE above WL:	**0.000 m**
Profile area:	**0.000 m2**

Seas	
Significant wave ht:	**0.000 m**
Modal wave period:	**0.0 sec**
Shallow/channel	
Water depth:	**0.000 m**
Type:	**Shallow water**
Channel width:	**0.000 m**
Channel side slope:	**0.00 deg**
Hull girth:	**0.000 m**

Resistance

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Project ID **Atlantic Puffin**
Description
File name **R&P.hcnc**

Symbols and values

SPEED = Vessel speed
FN = Froude number [LWL]
FV = Froude number [VOL]

RN = Reynolds number [LWL]
CF = Frictional resistance coefficient
CV/CF = Viscous/frictional resistance coefficient ratio [dynamic form factor]
CR = Residuary resistance coefficient
dCF = Added frictional resistance coefficient for roughness
CA = Correlation allowance [dynamic]
CT = Total bare-hull resistance coefficient

RBARE = Bare-hull resistance
RAPP = Additional appendage resistance
RWIND = Additional wind resistance
RSEAS = Additional sea-state resistance
RCHAN = Additional shallow/channel resistance
RTOWED = Additional towed object resistance
RMARGIN = Resistance margin
RTOTAL = Total vessel resistance

PEBARE = Bare-hull effective power
PETOTAL = Total effective power

CTLR = Telfer residuary resistance coefficient
CTLT = Telfer total bare-hull resistance coefficient
RBARE/W = Bare-hull resistance to weight ratio

+ = Design speed indicator
* = Exceeds parameter limit

APPENDIX I – INTACT STABILITY OUTPUTS

WEIGHT and DISPLACEMENT STATUS
Baseline draft: 5.733
Trim: zero, Heel: zero

Part	SpGr	Weight(MT) / Displ(MT)	LCG / LCB	TCG / TCB	VCG / VCB	RefHt
WEIGHT		20,223.33	98.286f	0.001p	13.340	
HULL	1.025	20,223.34	98.286f	0.001p	3.154	-5.733
Righting Arms:			0.000	0.000		

Distances in METERS.

RIGHTING ARMS vs HEEL ANGLE
LCG = 98.286f TCG = 0.001p VCG = 13.340

Origin Depth	Degrees of Trim	Degrees of Heel	Displacement Weight(MT)	Righting Arms in Trim	Righting Arms in Heel	Area
5.732	0.00	0.00	20,221	0.000	0.000	0.0000
5.638	0.03f	5.00s	20,223	0.000	0.206	0.0090
5.406	0.10f	10.00s	20,224	0.005a	0.423	0.0364
5.071	0.20f	15.00s	20,223	0.000	0.641	0.0828
4.635	0.30f	20.00s	20,223	0.000	0.828	0.1471
4.069	0.42f	25.00s	20,223	0.000	0.926	0.2243
3.882	0.46f	26.42s	20,223	0.003a	0.931	0.2474
3.355	0.56f	30.00s	20,220	0.003f	0.899	0.3049
2.505	0.70f	35.00s	20,223	0.000	0.768	0.3784
1.536	0.85f	40.00s	20,223	0.000	0.577	0.4375
0.470	0.99f	45.00s	20,223	0.004a	0.372	0.4791
-0.678	1.12f	50.00s	20,223	0.002a	0.194	0.5036
-1.892	1.23f	55.00s	20,216	0.002a	0.091	0.5155
-3.148	1.32f	60.00s	20,221	0.000	0.053	0.5213

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

LIM	LIGHTSHIP CRITERION		Min/Max		Attained	
(1)	Area from abs 0.000 deg to 30	>	0.0550	m.-Rad	0.3049	P
(2)	Area from abs 0.000 deg to 40 or Flood	>	0.0900	m.-Rad	0.4375	P
(3)	Area from 30 deg to 40 or Flood	>	0.0300	m.-Rad	0.1327	P
(4)	GM Upright	>	0.150	m.	2.130	P
(5)	Righting Arm at 30 deg or MaxRA	>	0.200	m.	0.899	P
(6)	Absolute Angle at MaxRA	>	25.00	deg	26.42	P

Relative angles measured from 0.000

WEIGHT and DISPLACEMENT STATUS

Baseline draft: 6.428 @ 6.92a, 6.032 @ 100.96a, 5.635 @ 195.00a

Trim: Fwd 0.79/188.08, Heel: Port 0.01 deg.

Part			Weight(MT)	LCG	TCG	VCG	
LIGHT SHIP			20,223.24	125.396f	0.002p	13.340	
Passengers and Effects			170.00	113.300a	0.000	26.875	
Crew and Effects			17.00	119.400a	0.000	32.000	
Passenger Vehicles			400.00	96.000a	0.000	12.500	
Live Units			1,575.00	83.500a	0.000	15.250	
Drop Units			875.00	83.500a	0.000	15.250	
Provisions			22.00	113.300a	0.000	26.875	
Total Fixed--------->			23,282.24	97.463f	0.002p	13.652	
	Load	SpGr	Weight(MT)	LCG	TCG	VCG	RefHt
LNG_P	0.980	0.740	322.97	110.009f	7.250p	5.692	-7.969
LNG_S	0.980	0.740	322.97	110.009f	7.250s	5.692	-7.973
DO_1C	0.980	0.870	56.68	43.751f	0.001	3.470	-4.755
DO_2P	0.980	0.740	64.28	68.501f	2.500p	4.940	-7.591
DO_2S	0.980	0.740	64.28	68.501f	2.500s	4.940	-7.592
TW_C	0.980	1.000	74.88	75.018f	0.000	1.011	-1.645
FW_P	0.980	1.000	185.34	134.589f	9.133p	4.940	-7.311
FW_S	0.980	1.000	185.34	134.589f	9.133s	4.940	-7.315
BW_P	0.100	1.025	20.60	124.863f	10.206p	2.300	-2.072
GW_S	0.100	1.025	20.60	124.863f	10.205s	2.300	-2.077
LO_P	0.980	0.924	20.07	47.503f	3.750p	3.470	-4.739
LO_S	0.980	0.924	20.06	47.503f	3.750s	3.470	-4.741
DIRTY_C	0.100	1.025	3.63	49.005f	0.003p	2.150	-2.093
SL_C	0.100	0.924	4.91	46.511f	0.003p	2.150	-2.104
BT_1C	1.000	1.025	277.12	170.144f	0.000	1.200	
SB_1C	0.980	1.025	86.05	89.001f	0.004s	0.992	-1.585
SB_2C	0.980	1.025	83.13	69.002f	0.001p	1.026	-1.671
SC_1P	0.980	1.025	7.83	89.001f	12.989p	2.986	-3.582
SC_1S	0.980	1.025	7.80	89.000f	12.181s	1.228	-1.601
SC_2P	0.980	1.025	7.83	89.001f	12.989p	2.986	-3.582
SC_2S	0.980	1.025	7.83	89.000f	12.990s	2.986	-3.588
SC_3P	0.980	1.025	7.02	69.006f	12.133p	1.280	-1.681
SC_3S	0.980	1.025	7.02	69.006f	12.133s	1.280	-1.687
SC_4P	0.980	1.025	7.78	69.001f	12.984p	2.991	-3.666
SC_4S	0.980	1.025	7.78	69.001f	12.984s	2.991	-3.673
Total Tanks--------->			1,873.79	112.435f	0.003p	3.904	
Total Weight-------->			25,156.03	98.578f	0.002p	12.926	
			Displ(MT)	LCB	TCB	VCB	
HULL		1.025	25,158.44	98.616f	0.004p	3.773	-6.457
Righting Arms:				0.001	0.001s		

Distances in METERS.

RIGHTING ARMS vs HEEL ANGLE

Fixed CG: LCG = 97.463f TCG = 0.002p VCG = 13.652

Origin Depth	Degrees of Trim	Degrees of Heel	Displacement Weight(MT)	Righting Arms in Trim	Righting Arms in Heel	Area
6.458	0.24f	0.01p	25,158	0.004a	0.001	0.0000
6.458	0.24f	0.00	25,158	0.004a	0.001	0.0000
6.351	0.28f	4.99s	25,156	0.000	0.143	0.0063
6.128	0.34f	9.99s	25,156	0.002a	0.274	0.0245
5.819	0.42f	14.99s	25,156	0.004a	0.415	0.0545
5.423	0.50f	19.99s	25,155	0.002a	0.572	0.0974
4.920	0.59f	24.99s	25,154	0.003a	0.717	0.1537
4.285	0.69f	29.99s	25,152	0.003f	0.806	0.2206
3.758	0.77f	33.49s	25,156	0.000	0.822	0.2706
3.512	0.80f	34.99s	25,156	0.000	0.819	0.2920
2.606	0.91f	39.99s	25,156	0.000	0.778	0.3621
1.585	1.02f	44.99s	25,151	0.003a	0.723	0.4277
0.465	1.11f	49.99s	25,151	0.000	0.694	0.4893
-0.731	1.20f	54.99s	25,155	0.002a	0.693	0.5497
-1.985	1.30f	59.99s	25,156	0.000	0.625	0.6077

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

Note: The Center of Gravity shown above is for the Fixed Weight of 23282.24 MT. As the tank load centers shift with heel and trim, the total Center of Gravity varies. The righting arms shown above include the effect of the C.G. variation.

LIM	FULL LOAD DEPARTURE STABILITY		Min/Max		Attained	
(1)	Area from abs -0.015 deg to 30	>	0.0550	m.-Rad	0.2206	P
(2)	Area from abs -0.015 deg to 40 or Flood	>	0.0900	m.-Rad	0.3621	P
(3)	Area from 30 deg to 40 or Flood	>	0.0300	m.-Rad	0.1415	P
(4)	GM Upright	>	0.150	m.	1.360	P
(5)	Righting Arm at 30 deg or MaxRA	>	0.200	m.	0.822	P
(6)	Absolute Angle at MaxRA	>	25.00	deg	33.49	P

--------------------Relative angles measured from 0.015 --------------------

FULL LOAD - ARRIVAL

WEIGHT and DISPLACEMENT STATUS

Baseline draft: 6.210 @ 6.92a, 5.644 @ 100.96a, 5.078 @ 195.00a

Trim: Fwd 1.13/188.08, Heel: Port 0.02 deg.

Part	Load	SpGr	Weight(MT)	LCG	TCG	VCG	RefHt
LIGHT SHIP			20,223.24	125.396f	0.002p	13.340	
Passengers and Effects			170.00	113.300a	0.000	26.875	
Crew and Effects			17.00	119.400a	0.000	32.000	
Passenger Vehicles			400.00	96.000a	0.000	12.500	
Live Units			1,575.00	83.500a	0.000	15.250	
Drop Units			875.00	83.500a	0.000	15.250	
Provisions			22.00	113.300a	0.000	26.875	
Total Fixed--------->			23,282.24	97.463f	0.002p	13.652	
LNG_P	0.100	0.740	32.98	110.198f	7.251p	3.309	-3.025
LNG_S	0.100	0.740	32.98	110.198f	7.249s	3.309	-3.030
DO_1C	0.980	0.870	56.68	43.751f	0.001	3.470	-4.677
DO_2P	0.100	0.740	6.56	68.508f	2.501p	2.300	-2.187
DO_2S	0.100	0.740	6.56	68.508f	2.499s	2.300	-2.189
TW_C	0.100	1.000	7.64	75.259f	0.002p	0.159	0.196
FW_P	0.100	1.000	18.91	134.665f	9.127p	2.301	-1.788
FW_S	0.100	1.000	18.91	134.666f	9.126s	2.301	-1.794
BW_P	0.980	1.025	201.84	124.813f	10.208p	4.940	-7.126
GW_S	0.980	1.025	201.84	124.813f	10.207s	4.940	-7.133
LO_P	0.100	0.924	2.05	47.542f	3.750p	2.150	-2.013
LO_S	0.100	0.924	2.05	47.542f	3.750s	2.150	-2.015
DIRTY_C	0.980	1.025	35.61	49.001f	0.000	3.470	-4.645
SL_C	0.980	0.924	48.16	46.502f	0.000	3.470	-4.660
BT_1C	0.980	1.025	271.54	170.271f	0.001p	1.184	-0.960
BT_2P	0.980	1.025	253.50	148.998f	3.555p	1.140	-1.078
BT_2S	0.980	1.025	253.45	148.999f	3.553s	1.141	-1.081
SB_1C	0.980	1.025	86.05	89.001f	0.003s	0.992	-1.425
SB_2C	0.980	1.025	83.13	69.002f	0.002p	1.026	-1.547
SC_1P	0.980	1.025	7.83	89.001f	12.989p	2.986	-3.421
SC_1S	0.980	1.025	7.80	89.001f	12.181s	1.228	-1.441
SC_2P	0.980	1.025	7.83	89.001f	12.989p	2.986	-3.421
SC_2S	0.980	1.025	7.83	89.001f	12.990s	2.986	-3.429
SC_3P	0.980	1.025	7.02	69.006f	12.134p	1.280	-1.556
SC_3S	0.980	1.025	7.02	69.006f	12.133s	1.280	-1.564
SC_4P	0.980	1.025	7.78	69.001f	12.984p	2.991	-3.541
SC_4S	0.980	1.025	7.78	69.001f	12.984s	2.991	-3.549
Total Tanks--------->			1,681.34	125.420f	0.005p	2.404	
Total Weight-------->			24,963.58	99.346f	0.002p	12.894	
			Displ(MT)	LCB	TCB	VCB	
HULL		1.025	24,966.10	99.401f	0.006p	3.753	-6.251
Righting Arms:				0.000	-0.001s		

Distances in METERS.

FULL LOAD - ARRIVAL

RIGHTING ARMS vs HEEL ANGLE

Fixed CG: LCG = 97.463f TCG = 0.002p VCG = 13.652

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Righting Arms in Trim	in Heel	Area
6.251	0.35f	0.02p	24,966	0.002f	-0.001	0.0000
6.251	0.34f	0.00	24,966	0.002f	0.001	-0.0000
6.149	0.38f	4.98s	24,964	0.000	0.137	0.0060
5.922	0.45f	9.98s	24,963	0.003a	0.271	0.0238
5.609	0.52f	14.98s	24,963	0.004a	0.416	0.0538
5.209	0.60f	19.98s	24,962	0.002a	0.577	0.0970
4.703	0.70f	24.98s	24,961	0.003a	0.723	0.1538
4.064	0.80f	29.98s	24,960	0.003f	0.810	0.2211
3.567	0.87f	33.28s	24,963	0.003f	0.824	0.2684
3.289	0.91f	34.98s	24,963	0.000	0.820	0.2928
2.383	1.02f	39.98s	24,963	0.000	0.777	0.3629
1.365	1.12f	44.98s	24,958	0.003a	0.720	0.4284
0.253	1.21f	49.98s	24,959	0.002a	0.691	0.4897
-0.936	1.29f	54.98s	24,963	0.002a	0.691	0.5498
-2.189	1.39f	59.98s	24,964	0.000	0.625	0.6077

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

Note: The Center of Gravity shown above is for the Fixed Weight of 23282.24 MT. As the tank load centers shift with heel and trim, the total Center of Gravity varies. The righting arms shown above include the effect of the C.G. variation.

LIM---FULL LOAD DEPARTURE STABILITY		Min/Max		Attained	
(1) Area from abs -0.018 deg to 30	>	0.0550	m.-Rad	0.2211	P
(2) Area from abs -0.018 deg to 40 or Flood	>	0.0900	m.-Rad	0.3629	P
(3) Area from 30 deg to 40 or Flood	>	0.0300	m.-Rad	0.1418	P
(4) GM Upright	>	0.150	m.	1.202	P
(5) Righting Arm at 30 deg or MaxRA	>	0.200	m.	0.824	P
(6) Absolute Angle at MaxRA	>	25.00	deg	33.28	P

--------------------Relative angles measured from 0.018 --------------------

LIGHT OPERATING CONDITION

WEIGHT and DISPLACEMENT STATUS
Baseline draft: 6.332 @ Origin
Trim: Fwd 0.23 deg., Heel: Port 0.01 deg.

Part	Load	SpGr	Weight(MT)	LCG	TCG	VCG	RefHt
LIGHT SHIP			20,223.32	98.690f	0.001p	13.340	
Crew			17.00	119.400a	0.000	32.000	
Provisions			22.00	113.300a	0.000	26.875	
Total Fixed--------->			20,262.32	98.277f	0.001p	13.370	
	Load	SpGr	Weight(MT)	LCG	TCG	VCG	RefHt
LNG_P	0.980	0.740	322.97	110.008f	7.250p	5.692	-7.992
LNG_S	0.980	0.740	322.97	110.008f	7.250s	5.692	-7.994
DO_1C	0.980	0.870	56.68	43.751f	0.000	3.470	-4.764
DO_2P	0.980	0.740	64.28	68.501f	2.500p	4.940	-7.605
DO_2S	0.980	0.740	64.28	68.500f	2.500s	4.940	-7.606
TW_C	0.980	1.000	74.88	75.018f	0.000	1.011	-1.660
FW_P	0.980	1.000	185.34	134.589f	9.133p	4.940	-7.339
FW_S	0.980	1.000	185.34	134.589f	9.133s	4.940	-7.342
BW_P	0.100	1.025	20.60	124.860f	10.206p	2.300	-2.099
GW_S	0.100	1.025	20.60	124.860f	10.205s	2.300	-2.101
LO_P	0.980	0.924	20.07	47.503f	3.750p	3.470	-4.749
LO_S	0.980	0.924	20.07	47.503f	3.750s	3.470	-4.750
DIRTY_C	0.100	1.025	3.63	49.004f	0.001p	2.150	-2.104
SL_C	0.100	0.924	4.91	46.510f	0.001p	2.150	-2.114
BT_1C	0.980	1.025	271.56	170.253f	0.001	1.184	-1.294
BT_2P	0.980	1.025	253.51	148.979f	3.557p	1.140	-1.373
BT_2S	0.980	1.025	253.47	148.980f	3.556s	1.140	-1.374
BT_3P	0.980	1.025	141.35	128.709f	9.142p	1.201	-1.456
BT_3S	0.980	1.025	141.36	128.708f	9.141s	1.201	-1.458
BT_4P	0.980	1.025	212.17	109.779f	9.806p	1.097	-1.526
BT_4S	0.980	1.025	212.14	109.779f	9.805s	1.097	-1.529
BT_5P	0.980	1.025	206.83	79.148f	10.030p	1.086	-1.648
BT_5S	0.980	1.025	206.85	79.148f	10.030s	1.086	-1.651
BT_6P	0.980	1.025	372.96	35.600f	6.304p	3.502	-4.804
BT_6S	0.980	1.025	372.72	35.602f	6.304s	3.503	-4.806
SB_1C	0.980	1.025	86.05	89.001f	0.007s	0.992	-1.604
SB_2C	0.980	1.025	83.13	69.002f	0.002s	1.026	-1.685
SC_1P	0.980	1.025	7.83	89.000f	12.989p	2.986	-3.602
SC_1S	0.980	1.025	7.80	89.000f	12.181s	1.228	-1.617
SC_2P	0.980	1.025	7.83	89.000f	12.989p	2.986	-3.602
SC_2S	0.980	1.025	7.83	89.000f	12.990s	2.986	-3.605
SC_3P	0.980	1.025	7.02	69.006f	12.133p	1.280	-1.697
SC_3S	0.980	1.025	7.02	69.006f	12.133s	1.280	-1.700
SC_4P	0.980	1.025	7.78	69.001f	12.984p	2.991	-3.682
SC_4S	0.980	1.025	7.78	69.001f	12.984s	2.991	-3.685
Total Tanks--------->			4,241.59	100.799f	0.002p	2.770	
Total Weight-------->			24,503.91	98.714f	0.002p	11.535	
			Displ(MT)	LCB	TCB	VCB	
HULL		1.025	24,507.21	98.744f	0.005p	3.693	-6.332
Righting Arms:				0.001a	-0.002s		

Distances in METERS.

LIGHT OPERATING CONDITION

RIGHTING ARMS vs HEEL ANGLE

Fixed CG: LCG = 98.277f TCG = 0.001p VCG = 13.370

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Righting Arms in Trim	in Heel	Area
6.333	0.23f	0.01p	24,507	0.003a	-0.002	0.0000
6.228	0.27f	4.99s	24,504	0.003a	0.264	0.0114
6.000	0.33f	9.99s	24,504	0.003a	0.526	0.0459
5.688	0.41f	14.99s	24,503	0.004a	0.797	0.1036
5.287	0.49f	19.99s	24,502	0.005a	1.079	0.1853
4.776	0.59f	24.99s	24,501	0.003a	1.336	0.2909
4.133	0.70f	29.99s	24,500	0.003a	1.523	0.4161
3.348	0.81f	34.99s	24,498	0.003f	1.625	0.5541
2.437	0.92f	39.99s	24,503	0.000	1.666	0.6981
1.410	1.03f	44.99s	24,503	0.000	1.684	0.8444
0.287	1.13f	49.99s	24,498	0.002a	1.724	0.9930
-0.910	1.22f	54.99s	24,503	0.002a	1.794	1.1463
-1.603	1.27f	57.76s	24,507	0.004f	1.809	1.2334
-2.169	1.32f	59.99s	24,503	0.000	1.799	1.3036

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

Note: The Center of Gravity shown above is for the Fixed Weight of 20262.32 MT. As the tank load centers shift with heel and trim, the total Center of Gravity varies. The righting arms shown above include the effect of the C.G. variation.

LIM---FULL LOAD DEPARTURE STABILITY		Min/Max		Attained	
(1) Area from abs -0.007 deg to 30	>	0.0550	m.-Rad	0.4161	P
(2) Area from abs -0.007 deg to 40 or Flood	>	0.0900	m.-Rad	0.6981	P
(3) Area from 30 deg to 40 or Flood	>	0.0300	m.-Rad	0.2820	P
(4) GM Upright	>	0.150	m.	2.432	P
(5) Righting Arm at 30 deg or MaxRA	>	0.200	m.	1.809	P
(6) Absolute Angle at MaxRA	>	25.00	deg	57.76	P

--------------------Relative angles measured from 0.007 --------------------

WORST CASE OPERATING CONDITION

WEIGHT and DISPLACEMENT STATUS

Baseline draft: 6.531 @ 6.92a, 6.568 @ 100.96a, 6.604 @ 195.00a

Trim: Aft 0.07/188.08, Heel: Port 0.04 deg.

Part	Load	SpGr	Weight(MT)	LCG	TCG	VCG	RefHt
LIGHT SHIP			20,223.24	125.396f	0.002p	13.340	
Passengers and Effects			170.00	113.300a	0.000	26.875	
Crew and Effects			17.00	119.400a	0.000	32.000	
Passenger Vehicles			400.00	96.000a	0.000	14.000	
Live Units			1,575.00	83.500a	0.000	18.000	
Drop Units			875.00	83.500a	0.000	15.500	
Provisions			22.00	113.300a	0.000	26.875	
Total Fixed--------->			23,282.24	97.463f	0.002p	13.873	
LNG_P	0.020	0.740	6.63	109.961f	7.252p	2.939	-3.104
LNG_S	0.020	0.740	6.63	109.961f	7.248s	2.939	-3.113
DO_1C	0.020	0.870	1.16	43.747f	0.077p	2.030	-2.077
DO_2P	0.020	0.740	1.31	68.498f	2.512p	2.060	-2.145
DO_2S	0.020	0.740	1.31	68.498f	2.488s	2.060	-2.148
TW_C	0.020	1.000	1.53	74.916f	0.023p	0.080	-0.129
FW_P	0.020	1.000	3.78	134.553f	9.141p	2.060	-2.166
FW_S	0.020	1.000	3.78	134.561f	9.130s	2.060	-2.179
BW_P	0.020	1.025	4.12	124.775f	10.215p	2.060	-2.162
GW_S	0.020	1.025	4.12	124.779f	10.203s	2.060	-2.176
LO_P	0.980	0.924	20.07	47.500f	3.750p	3.470	-4.956
LO_S	0.980	0.924	20.07	47.500f	3.750s	3.470	-4.961
DIRTY_C	0.100	1.025	3.63	49.000f	0.007p	2.150	-2.319
SL_C	0.100	0.924	4.91	46.499f	0.007p	2.150	-2.318
SB_1C	0.980	1.025	86.05	89.000f	0.005p	0.992	-1.995
SB_2C	0.980	1.025	83.13	69.001f	0.010p	1.026	-1.989
SC_1P	0.980	1.025	7.83	89.000f	12.990p	2.986	-3.986
SC_1S	0.980	1.025	7.80	88.999f	12.181s	1.228	-2.016
SC_2P	0.980	1.025	7.83	89.000f	12.990p	2.986	-3.986
SC_2S	0.980	1.025	7.83	89.000f	12.990s	2.986	-4.004
SC_3P	0.980	1.025	7.02	69.004f	12.134p	1.280	-1.993
SC_3S	0.980	1.025	7.02	69.004f	12.133s	1.280	-2.010
SC_4P	0.980	1.025	7.78	69.000f	12.984p	2.991	-3.979
SC_4S	0.980	1.025	7.78	69.000f	12.984s	2.991	-3.996
Total Tanks--------->			313.13	77.872f	0.026p	1.763	
Total Weight-------->			23,595.37	97.203f	0.002p	13.712	
			Displ(MT)	LCB	TCB	VCB	
HULL		1.025	23,595.56	97.199f	0.009p	3.577	-6.528
Righting Arms:				0.001	0.000		

Distances in METERS.

WORST CASE OPERATING CONDITION

RIGHTING ARMS vs HEEL ANGLE

Fixed CG: LCG = 97.463f TCG = 0.002p VCG = 13.873

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Righting Arms in Trim	in Heel	Area
6.528	0.02a	0.04p	23,595	0.000	0.000	0.0000
6.528	0.02a	0.00	23,595	0.000	0.001	0.0000
6.421	0.02f	4.96s	23,596	0.002a	0.114	0.0050
6.196	0.08f	9.96s	23,596	0.004a	0.213	0.0194
5.882	0.16f	14.96s	23,595	0.000	0.320	0.0426
5.480	0.25f	19.96s	23,595	0.005a	0.435	0.0755
4.963	0.35f	24.96s	23,593	0.004a	0.520	0.1174
4.588	0.42f	27.97s	23,596	0.003a	0.536	0.1452
4.310	0.47f	29.96s	23,595	0.000	0.529	0.1637
3.513	0.59f	34.96s	23,595	0.000	0.453	0.2072
2.583	0.72f	39.96s	23,589	0.004a	0.321	0.2414
1.539	0.84f	44.96s	23,587	0.003a	0.176	0.2632
0.398	0.96f	49.96s	23,588	0.002a	0.060	0.2733
-0.818	1.06f	54.96s	23,593	0.002a	0.002	0.2755
-2.086	1.16f	59.96s	23,593	0.000	-0.079	0.2723

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

Note: The Center of Gravity shown above is for the Fixed Weight of 23282.24 MT. As the tank load centers shift with heel and trim, the total Center of Gravity varies. The righting arms shown above include the effect of the C.G. variation.

LIM	FULL LOAD DEPARTURE STABILITY		Min/Max		Attained	
(1)	Area from abs -0.039 deg to 30	>	0.0550	m.-Rad	0.1637	P
(2)	Area from abs -0.039 deg to 40 or Flood	>	0.0900	m.-Rad	0.2414	P
(3)	Area from 30 deg to 40 or Flood	>	0.0300	m.-Rad	0.0776	P
(4)	GM Upright	>	0.150	m.	1.046	P
(5)	Righting Arm at 30 deg or MaxRA	>	0.200	m.	0.529	P
(6)	Absolute Angle at MaxRA	>	25.00	deg	27.97	P

--------------------Relative angles measured from 0.039 --------------------

APPENDIX J – DAMAGED STABILITY OUTPUTS

RIGHTING ARMS vs HEEL ANGLE with FLOODING
Fixed CG: LCG = 94.740f TCG = 0.001 VCG = 13.778

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Righting Arms in Trim	in Heel	Area	Flood Pt Height
7.462	0.91f	0.00	27,230	0.003a	-0.001	0.0000	11.155(3)
7.422	0.91f	5.00p	27,230	0.003f	0.029	0.0012	9.911(3)
7.275	0.93f	10.00p	27,229	0.000	0.076	0.0056	8.690(3)
7.028	0.94f	15.00p	27,229	0.000	0.242	0.0186	7.442(3)
6.686	0.95f	20.00p	27,229	0.000	0.479	0.0496	6.184(3)
6.523	0.95f	22.00p	27,229	0.003f	0.589	0.0682	5.684(3)
6.251	0.95f	25.00p	27,229	0.000	0.770	0.1037	4.936(3)
5.707	0.96f	30.00p	27,229	0.000	1.093	0.1847	3.730(3)
5.030	0.98f	35.00p	27,229	0.000	1.402	0.2936	2.607(3)
4.204	0.99f	40.00p	27,229	0.000	1.662	0.4276	1.589(3)
4.067	1.00f	40.75p	27,229	0.000	1.695	0.4497	Marg Imm.
3.232	1.01f	45.00p	27,229	0.000	1.871	0.5821	0.687(3)
2.302	1.03f	49.32p	27,229	0.003a	2.020	0.7290	-0.002(3)
2.149	1.04f	50.00p	27,229	0.000	2.036	0.7530	-0.101(3)
1.216	1.07f	54.11p	27,229	0.003a	2.079	0.9007	-0.694(3)
1.013	1.07f	55.00p	27,229	0.000	2.077	0.9328	-0.819(3)
-0.141	1.11f	60.00p	27,229	0.000	2.004	1.1117	-1.733(2)

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

Note: The Center of Gravity shown above is for the Fixed Weight of 23471.15 MT. As the tank load centers shift with heel and trim, the total Center of Gravity varies. The righting arms shown above include the effect of the C.G. variation.

Critical Points		LCP	TCP	VCP
(2) STERN	FLOOD	0.000	14.000	20.500
(3) MIDSHIP	FLOOD	102.000a	14.000	17.000

LIM	DAMAGE STABILITY CRITERION		Min/Max		Attained	
(1)	GM Upright	>	0.100	m.	0.032	F
(2)	Righting Arm at MaxRA	>	0.050	m.	2.079	P
(3)	Absolute Angle at Equilibrium	<	7.00	deg	0.00	P
(4)	Angle from Equilibrium to Dk/margin Immersion	>	0.00	deg	40.75	P
(5)	Area from Equilibrium to abs 22 deg or Flood	>	0.0150	m.-Rad	0.0682	P

RIGHTING ARMS vs HEEL ANGLE with FLOODING
Fixed CG: LCG = 97.730f TCG = 0.002p VCG = 13.873

Origin Depth	Degrees of Trim	Heel	Displacement Weight(MT)	Righting Arms in Trim	in Heel	Area	Flood Pt Height
6.603	1.12f	0.00	25,213	0.002f	-0.001	0.0000	12.396(3)
6.511	1.16f	5.00s	25,212	0.002a	-0.031	-0.0014	11.259(3)
6.305	1.22f	10.00s	25,211	0.000	-0.044	-0.0048	10.175(3)
6.141	1.25f	13.04s	25,215	0.003f	0.000	-0.0061	9.491(3)
6.021	1.27f	15.00s	25,212	0.000	0.053	-0.0052	9.030(3)
5.658	1.29f	20.00s	25,212	0.000	0.241	0.0069	7.829(3)
5.489	1.30f	22.00s	25,212	0.000	0.332	0.0169	7.344(3)
5.206	1.31f	25.00s	25,212	0.000	0.482	0.0381	6.621(3)
4.643	1.33f	30.00s	25,212	0.000	0.737	0.0911	5.454(3)
3.946	1.36f	35.00s	25,212	0.000	0.956	0.1652	4.363(3)
3.106	1.37f	40.00s	25,212	0.000	1.111	0.2558	3.364(3)
2.806	1.38f	41.61s	25,212	0.003a	1.151	0.2877	Marg Imm.
2.133	1.39f	45.00s	25,212	0.000	1.237	0.3583	2.461(3)
1.049	1.41f	50.00s	25,212	0.000	1.353	0.4715	1.403(2)
0.186	1.44f	53.69s	25,212	0.004a	1.381	0.5599	0.669(2)
-0.128	1.46f	55.00s	25,212	0.000	1.378	0.5913	0.418(2)
-0.663	1.48f	57.20s	25,212	0.000	1.356	0.6439	-0.002(2)
-1.343	1.52f	60.00s	25,212	0.000	1.301	0.7087	-0.530(2)

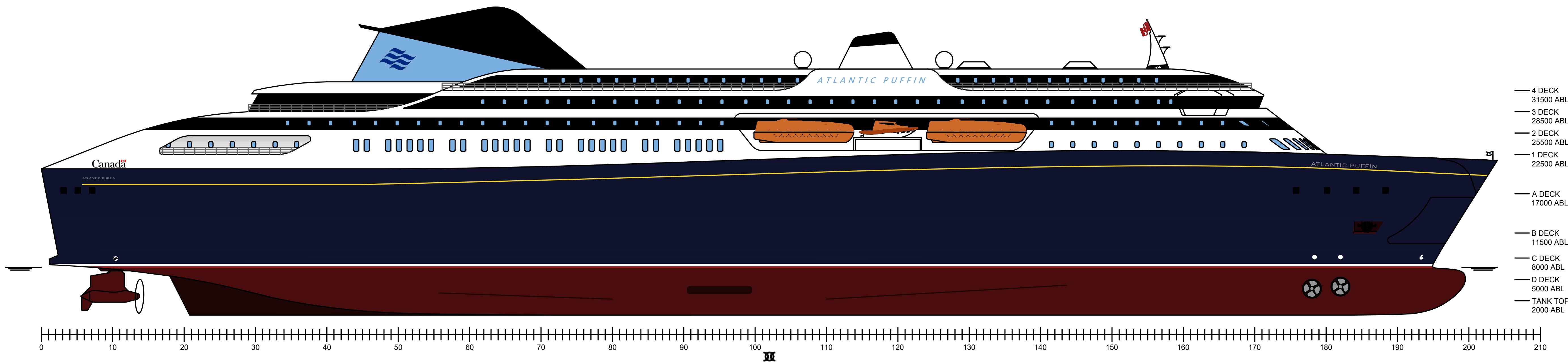
Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

Note: The Center of Gravity shown above is for the Fixed Weight of 22969.19 MT. As the tank load centers shift with heel and trim, the total Center of Gravity varies. The righting arms shown above include the effect of the C.G. variation.

Critical Points		LCP	TCP	VCP
(2) STERN	FLOOD	0.000	14.000	20.500
(3) MIDSHIP	FLOOD	102.000a	14.000	17.000

LIM	DAMAGE STABILITY CRITERION		Min/Max		Attained
(1)	GM Upright	>	0.100	m.	-0.725 F
(2)	Righting Arm at MaxRA	>	0.050	m.	1.381 P
(3)	Absolute Angle at Equilibrium	<	7.00	deg	13.04 F
(4)	Angle from Equilibrium to Dk/margin Immersion	>	0.00	deg	28.57 P
(5)	Area from Equilibrium to abs 22 deg or Flood	>	0.0150	m.-Rad	0.0230 P

APPENDIX K – GENERAL ARRANGEMENT



OUTBOARD PROFILE
STARBOARD

PRINCIPAL PARTICULARS

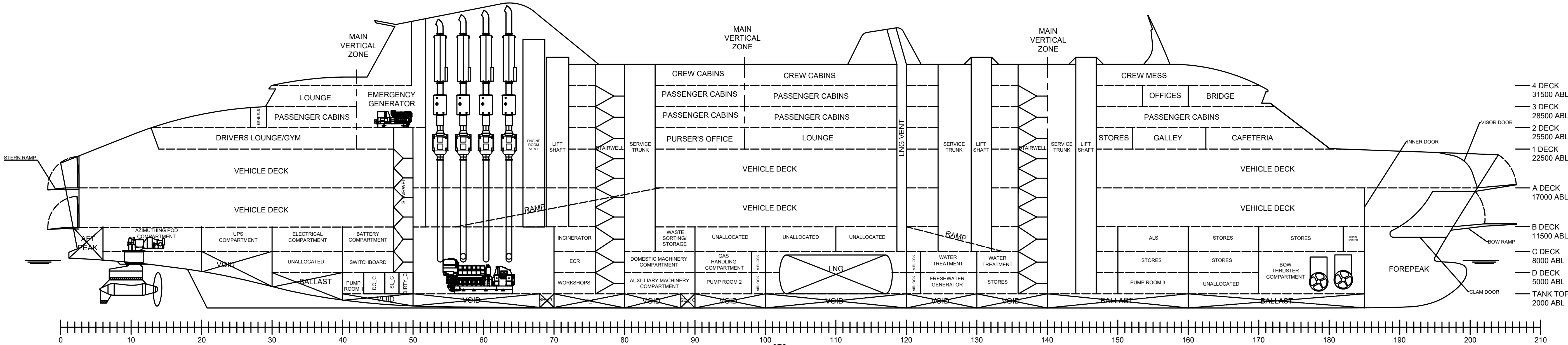
LENGTH OVERALL (m)	204.0
LENGTH BETWEEN PERPENDICULARS (m)	188.0
MOULDED BEAM (m)	28.0
MOULDED DEPTH (m)	17.0
DESIGN DRAFT (m)	6.7
DISPLACEMENT (TONNES)	24,578
COMPLEMENT	100
PASSENGER CAPACITY	1000
VEHICLE CAPACITY (LANE METERS)	3263
ICE CLASS	1A
INSTALLED POWER (kW)	21,600

ABBREVIATIONS

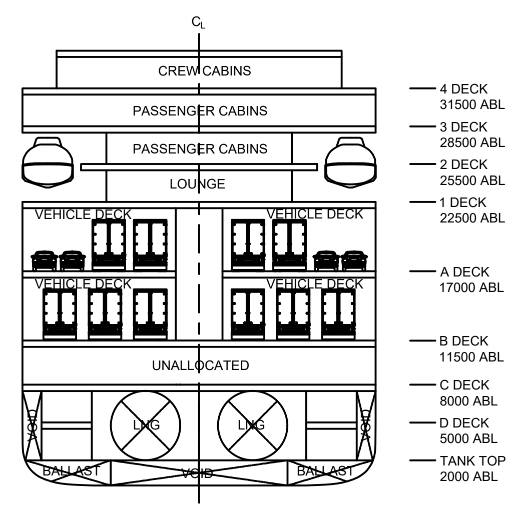
ALS - AIR LUBRICATION SYSTEM
BW - BLACK WATER
ECR - ENGINE CONTROL ROOM
ESC - ESCAPE HATCH
F.O. - FUEL OIL
FW - FRESH WATER
GW - GREY WATER
LM - LANE METERS
LNG - LIQUIFIED NATUAL GAS
L.O. - LUBRICATION OIL
ME - MAIN ENGINE
SB - SEA BAY
SC - SEA CHEST
WC - WATER CLOSET

TRAK

PROJECT TITLE		
MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE		
GENERAL ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 02/03/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/16/2023
DRAWING NO. AP-03	REV. 0	PAGE 1 OF 7



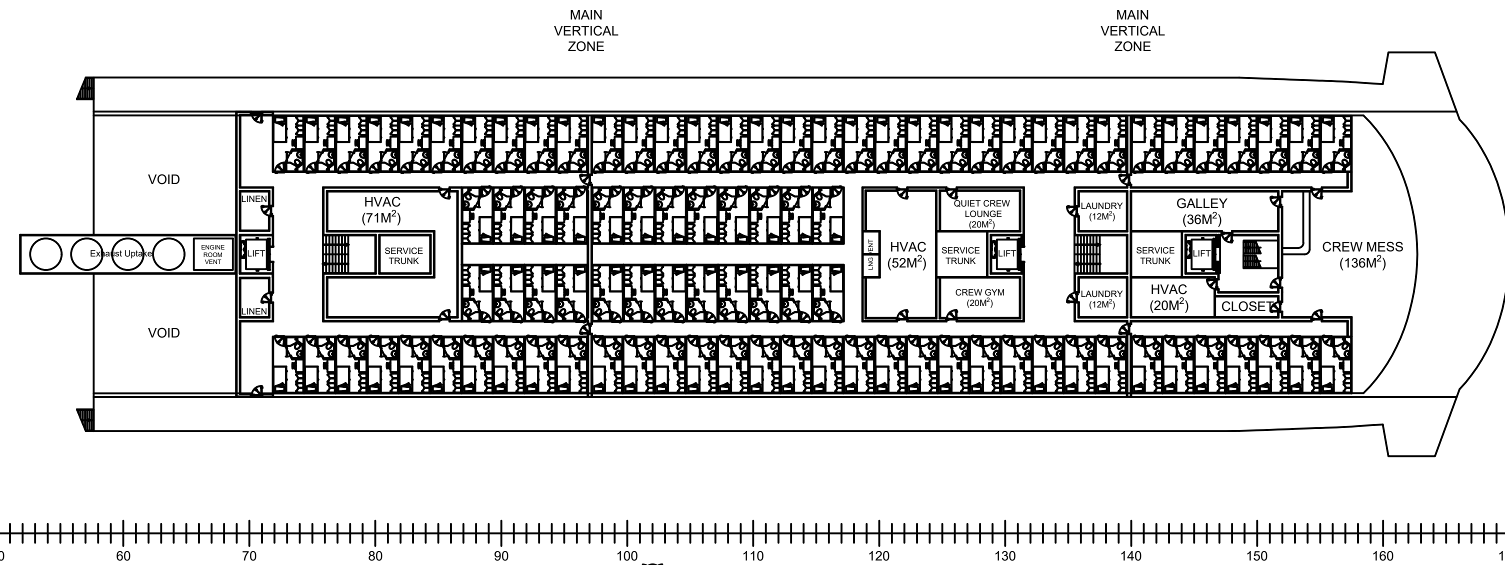
INBOARD PROFILE
STARBOARD



MIDSHIP CROSS-SECTION
LOOKING FORWARD

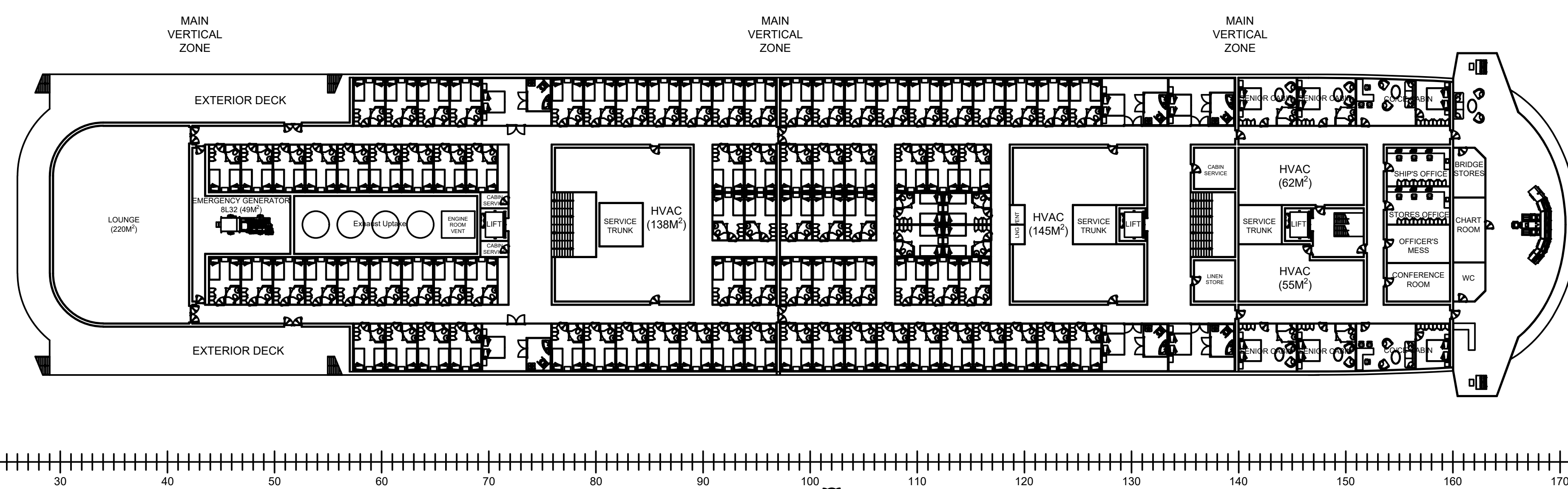
TRAK

PROJECT TITLE		
MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE		
GENERAL ARRANGEMENT		
SHEET SIZE: ANSI B	DRAWN BY: R.C.	DATE: 02/03/2023
SCALE: 1:600	CHECKED BY: A.B.	DATE: 03/16/2023
DRAWING NO.: AP-03	REV.: 0	PAGE: 2 OF 7



PLAN ABOVE 4 DECK

CABINS	
WINDOW	0
INSIDE	0
WHEELCHAIR	0
SUITE	0
CREW	92
TOTAL	92



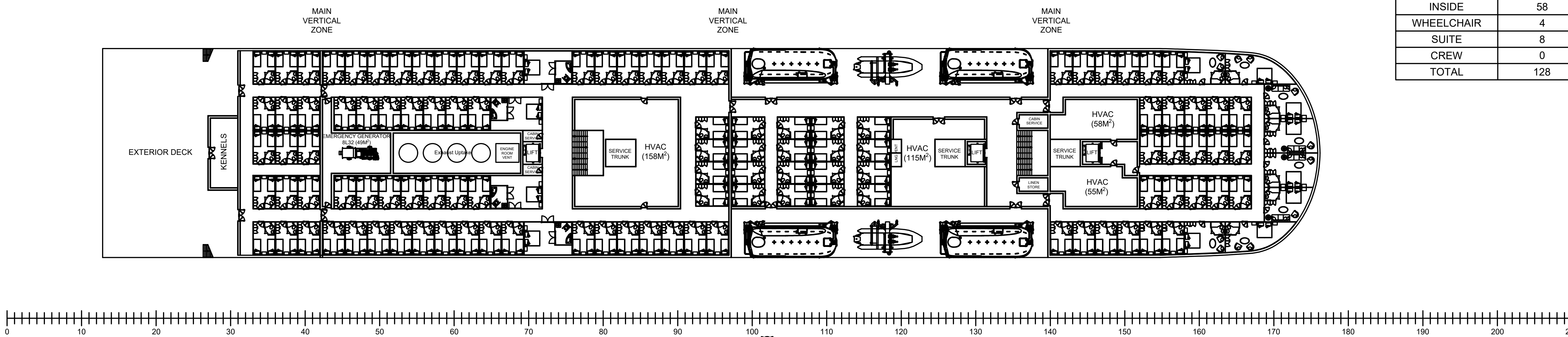
PLAN ABOVE 3 DECK

28500 ABL

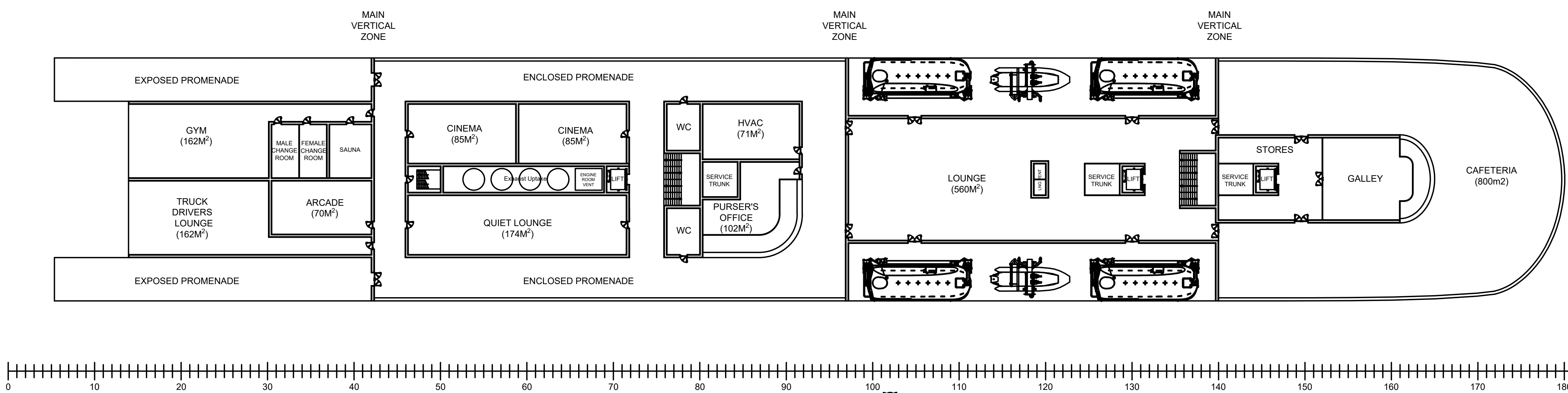
CABINS	
WINDOW	42
INSIDE	43
WHEELCHAIR	6
SUITE	0
CREW	6
TOTAL	97

PROJECT TITLE: MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE: GENERAL ARRANGEMENT		
SHEET SIZE: ANSI B	DRAWN BY: R.C.	DATE: 02/03/2023
SCALE: 1:600	CHECKED BY: A.B.	DATE: 03/16/2023
DRAWING NO.: AP-03	REV.: 0	PAGE: 3 OF 7

CABINS	
WINDOW	58
INSIDE	58
WHEELCHAIR	4
SUITE	8
CREW	0
TOTAL	128



PLAN ABOVE 2 DECK
25500 ABL

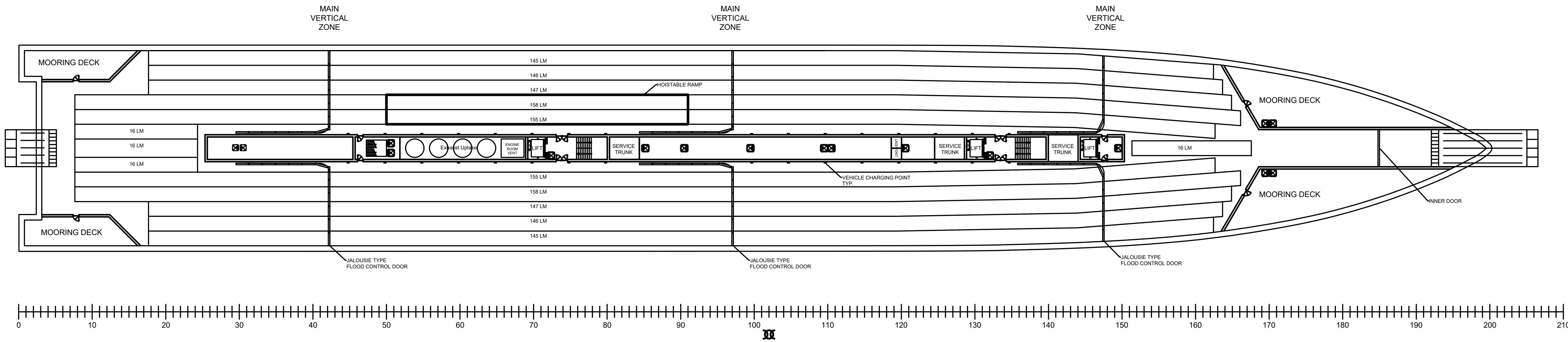


PLAN ABOVE 1 DECK
22500 ABL

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE GENERAL ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 02/03/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/16/2023
DRAWING NO. AP-03	REV. 0	PAGE 4 OF 7

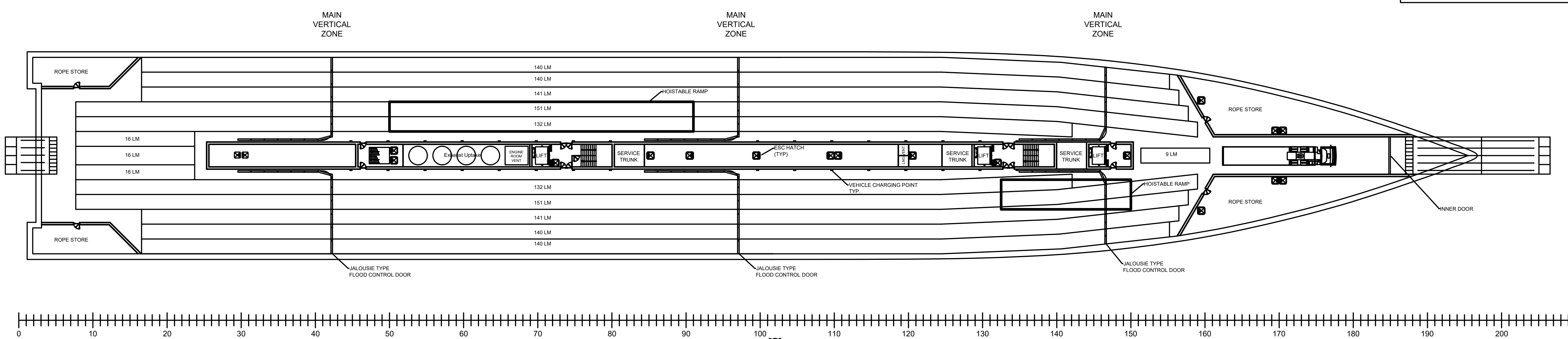
VEHICLE CAPACITY
1566 LM



PLAN ABOVE A DECK

17000 ABL

VEHICLE CAPACITY
1465 LM



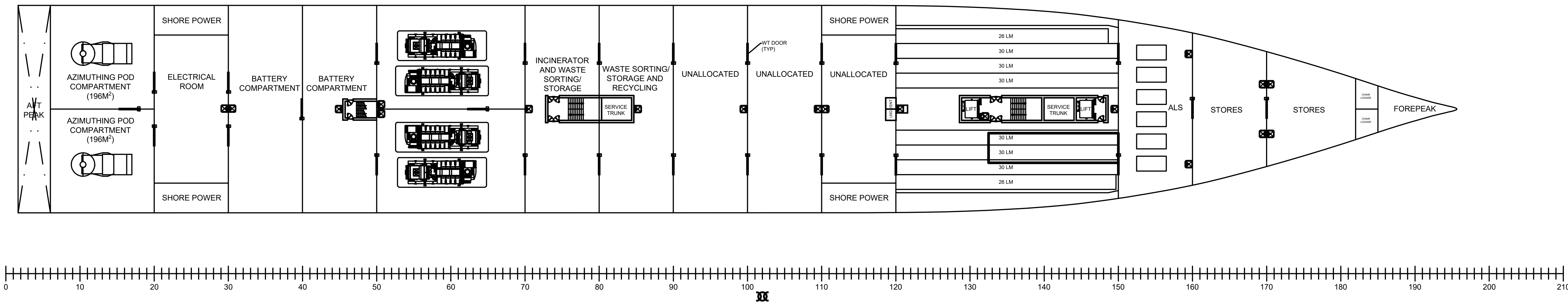
PLAN ABOVE B DECK

11500 ABL

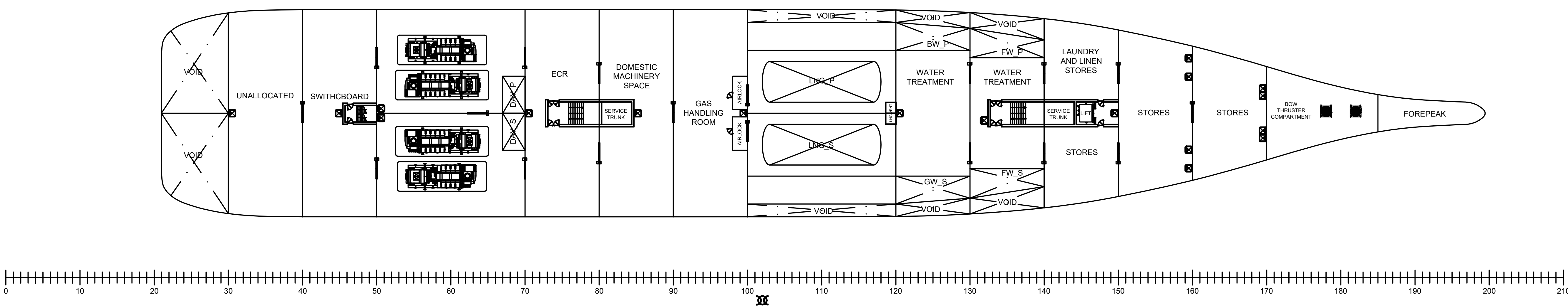
TRAK

PROJECT TITLE		
MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE		
GENERAL ARRANGEMENT		
SHEET SIZE: ANSI B	DRAWN BY: R.C.	DATE: 02/03/2023
SCALE: 1:600	CHECKED BY: A.B.	DATE: 03/16/2023
DRAWING NO.: AP-03	REV.: 0	PAGE: 5 OF 7

VEHICLE CAPACITY
232 LM



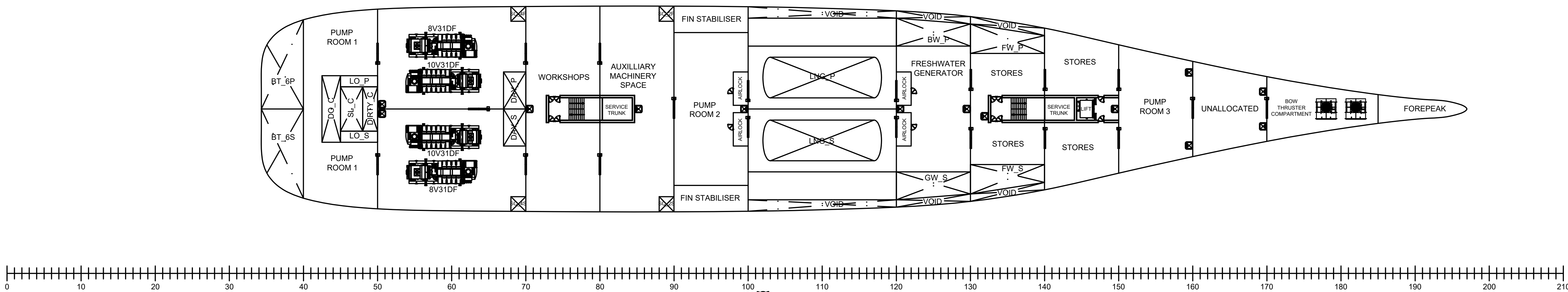
PLAN ABOVE C DECK
8000 ABL



PLAN ABOVE D DECK
5000 ABL

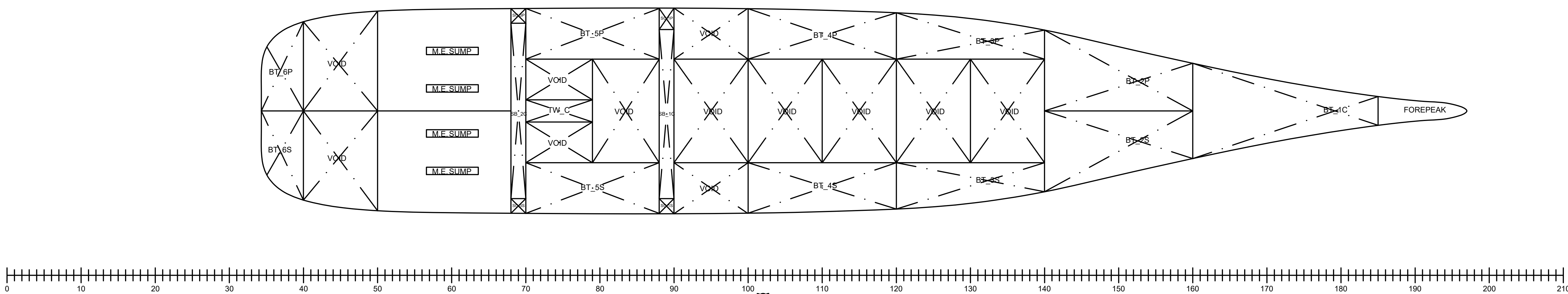
TRAK

PROJECT TITLE		
MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE		
GENERAL ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 02/03/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/16/2023
DRAWING NO. AP-03	REV. 0	PAGE 6 OF 7



PLAN ABOVE TANK TOP

2000 ABL



PLAN BELOW TANK TOP

2000 ABL

TYPE	TANK	VOLUME (M^3)	LCG (FROM 0)	TCG (FROM C_L)	VCG (FROM BL)
LNG	LNG_P	452.0	110.0	7.3	5.75
LNG	LNG_S	452.0	110.0	-7.3	5.75
MDO	DO-C	67.5	43.75	0.0	3.75
MDO	DAY-P	90.0	68.5	2.5	5.0
MDO	DAY-S	90.0	68.5	-2.5	5.0
WATER	TW-C	77.6	76.05	0.0	1.0
WATER	FW-P	192.0	134.6	9.1	5.0
WATER	FW-S	192.0	134.6	-9.1	5.0
WATER	BW-P	204	124.8	10.2	5.0
WATER	GW-S	204	124.8	-10.2	5.0
LUBE OIL	LO-P	22.5	47.5	3.8	3.5
LUBE OIL	LO-S	22.5	47.5	-3.8	3.5

TYPE	TANK	VOLUME (M^3)	LCG (FROM 0)	TCG (FROM C_L)	VCG (FROM BL)
DIRTY OIL	DIRTY_C	36.0	49.0	0.0	3.5
SLUDGE	SL_C	54.0	46.5	0.0	3.5
BALLAST	BT_1C	256.4	170.1	0.0	1.2
BALLAST	BT_2P	274.7	148.9	3.6	1.2
BALLAST	BT_2S	274.7	148.9	-3.6	1.2
BALLAST	BT_3P	143.4	128.6	9.2	1.2
BALLAST	BT_3S	143.4	128.6	-9.2	1.2
BALLAST	BT_4P	215.1	109.7	9.8	1.1
BALLAST	BT_4S	215.1	109.7	-9.8	1.1
BALLAST	BT_5P	209.8	79.0	10.0	1.1
BALLAST	BT_5S	209.8	79.0	-10.0	1.1
BALLAST	BT_6P	378.0	35.6	6.3	3.53

TYPE	TANK	VOLUME (M^3)	LCG (FROM 0)	TCG (FROM C_L)	VCG (FROM BL)
BALLAST	BT_6S	378.0	35.6	-6.3	3.53
SEA BAY	SB_1C	87.5	89.0	0.0	1.0
SEA BAY	SB_2C	84.4	69.0	0.0	1.0
SEA CHEST	SC_1P	8.1	89.0	12.2	1.2
SEA CHEST	SC_1S	8.1	89.0	-12.2	1.2
SEA CHEST	SC_2P	8.1	89.0	13.0	3.0
SEA CHEST	SC_2S	8.1	89.0	-13.0	3.0
SEA CHEST	SC_3P	7.28	69.0	12.2	1.2
SEA CHEST	SC_3S	7.28	69.0	-12.2	1.2
SEA CHEST	SC_4P	8.1	69.0	13.0	3.0
SEA CHEST	SC_4S	8.1	69.0	-13.0	3.0

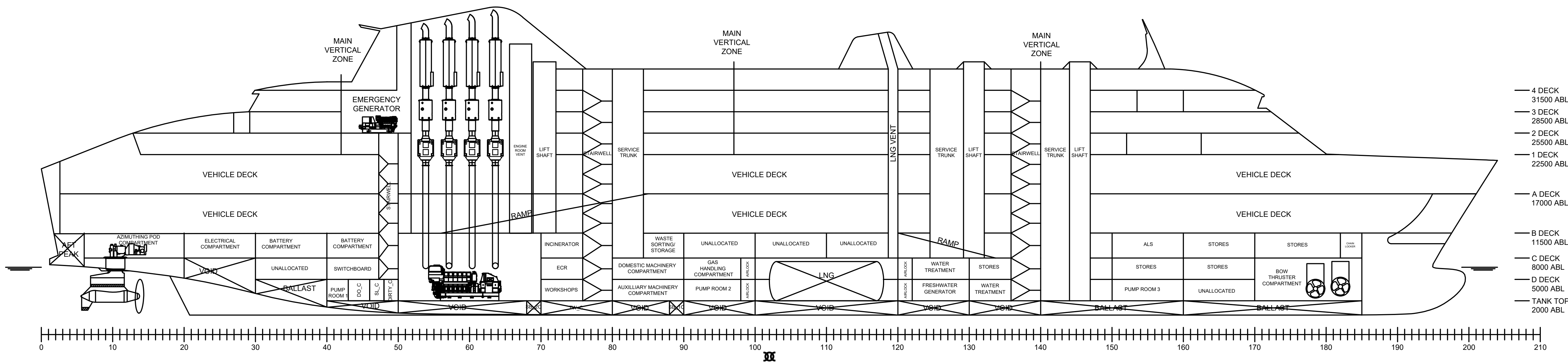
PROJECT TITLE
MARINE ATLANTIC ROPAX FERRY

DRAWING TITLE
GENERAL ARRANGEMENT

SHEET SIZE	DRAWN BY	DATE
ANSI B	R.C.	02/03/2023
SCALE	CHECKED BY	DATE
1:600	A.B.	03/16/2023

DRAWING NO.	REV.	PAGE
AP-03	0	7 OF 7

APPENDIX L – MACHINERY ARRANGEMENTS



INBOARD PROFILE
STARBOARD

PRINCIPAL PARTICULARS

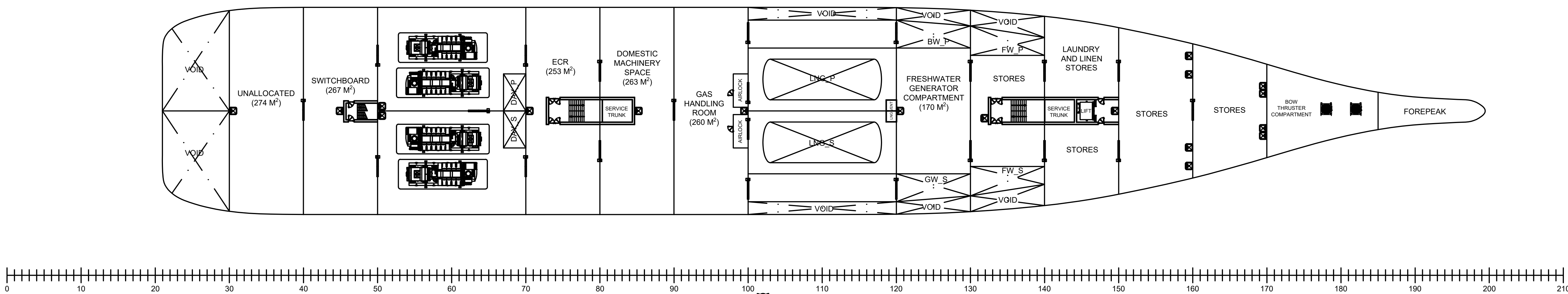
LENGTH OVERALL (m)	204.0
LENGTH BETWEEN PERPENDICULARS (m)	188.0
MOULDED BEAM (m)	28.0
MOULDED DEPTH (m)	17.0
DESIGN DRAFT (m)	6.7
DISPLACEMENT (TONNES)	24,578
COMPLEMENT	100
PASSENGER CAPACITY	1000
VEHICLE CAPACITY (LANE METERS)	3263
ICE CLASS	1A
INSTALLED POWER (kW)	21,600

ABBREVIATIONS

ALS - AIR LUBRICATION SYSTEM
BW - BLACK WATER
ECR - ENGINE CONTROL ROOM
ESC - ESCAPE HATCH
F.O. - FUEL OIL
FW - FRESH WATER
GW - GREY WATER
LNG - LIQUIFIED NATUAL GAS
L.O. - LUBRICATION OIL
SB - SEA BAY
SC - SEA CHEST

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE MACHINERY ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 04/07/2023
SCALE 1:600	CHECKED BY A.B.	DATE 04/15/2023
DRAWING NO. AP-05	REV. 0	PAGE 1 OF 3

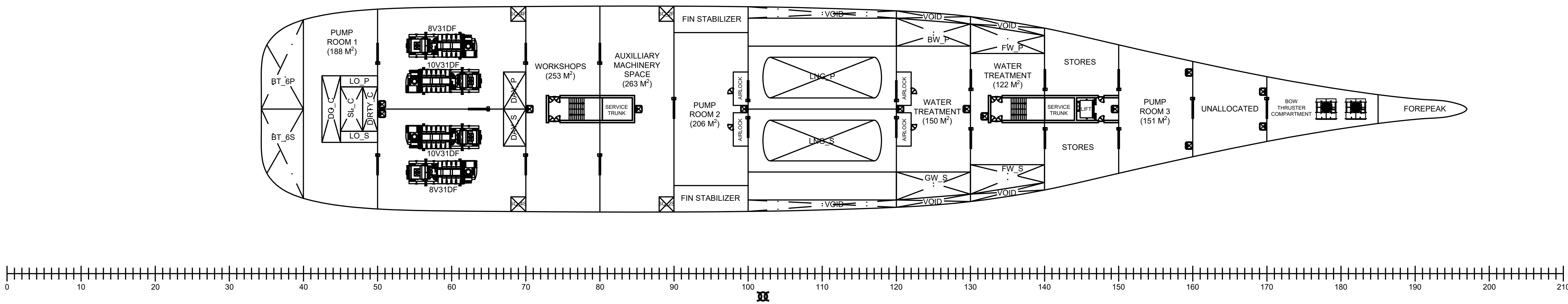


PLAN ABOVE D DECK

5000 ABL

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE MACHINERY ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 04/07/2023
SCALE 1:600	CHECKED BY A.B.	DATE 04/15/2023
DRAWING NO. AP-05	REV. 0	PAGE 2 OF 3



PLAN ABOVE TANK TOP

MAIN ELECTRICAL, PODDED PROPULSORS, AND BOW THRUSTERS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	MAIN GENSET	WARTSILA W10V31DF	6000 kW @ 720 RPM
2	MAIN GENSET	WARTSILA W8V31DF	4800 kW @ 750 RPM
1	EMERGENCY GENERATOR	WARTSILA W8L32	4640 kW @ 750 RPM
TBD	BATTERY	TBD	9.3 MWh
TBD	ELECTRICAL SWITHCBOARD	TBD	TBD
2	PODDED PROPULSOR	ABB AZIPOD VI	7350 kW
2	BOW THRUSTER	WARTSILA WTT-16	1650 kW @ 980 RPM

PURIFIERS AND SEPARATORS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	MAIN ENGINE FO PURIFIER	ALFA LAVAL FM152	$40M^3$/HR
4	MAINE ENGINE LO PURIFIER	ALFA ELIMINATOR 180-14	$30M^3$/HR
1	EMERGENCY GENERATOR FO PURIFIER	ALFA LAVAL FM152	$30M^3$/HR
1	EMERGENCY GENERATOR LO PURIFIER	ALFA ELIMINATOR 180-14	$20M^3$/HR
1	OILY WATER SEPARATOR	ALFA ELIMINATOR PureBilge 5015	5000L/HR, 15 PPM

COOLING WATER PUMPS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
4	SEAWATER PUMP	TBD	TBD
4	FRESHWATER PUMP	TBD	TBD
2	SEAWATER HARBOUR PUMP	TBD	TBD
4	FRESHWATER HARBOUR PUMP	TBD	TBD

BILGE AND BALLAST PUMPS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
6	BILGE PUMP	TBD	TBD
6	BALLAST PUMP	TBD	TBD

FIN STABILISATION

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	ACTIVE FIN STABILISERS	KONGSBERG AQUARIUS A 100	-

AIR LUBRICATION SYSTEM

QTY.	COMPONENT	DESCRIPTION	CAPACITY
TBD	COMPRESSOR	TBD	TBD

PURIFIERS AND SEPARATORS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	MAIN ENGINE FO PURIFIER	ALFA LAVAL FM152	$40M^3$/HR
4	MAINE ENGINE LO PURIFIER	ALFA ELIMINATOR 180-14	$30M^3$/HR
1	EMERGENCY GENERATOR FO PURIFIER	ALFA LAVAL FM152	$30M^3$/HR
1	EMERGENCY GENERATOR LO PURIFIER	ALFA ELIMINATOR 180-14	$20M^3$/HR
1	OILY WATER SEPARATOR	ALFA ELIMINATOR PureBilge 5015	5000L/HR, 15 PPM

POTABLE WATER, BLACK WATER, GREY WATER, AND WASTE DISPOSAL

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	POTABLE WATER PUMP	TBD	TBD
1	GREY WATER PUMP	TBD	TBD
1	BLACK WATER PUMP	TBD	TBD
1	SEWAGE TREATMENT PLANT	WARTSILA STC-60-14	100,800 L/DAY
2	HYDROPHORE	TBD	TBD
1	FRESHWATER GENERATOR	WARTSILA HiTE 120-4	120 TONNES/DAY
1	SHREDDER	TBD	TBD
1	GLASS CRUSHER	TBD	TBD
1	INCINERATOR	TBD	TBD

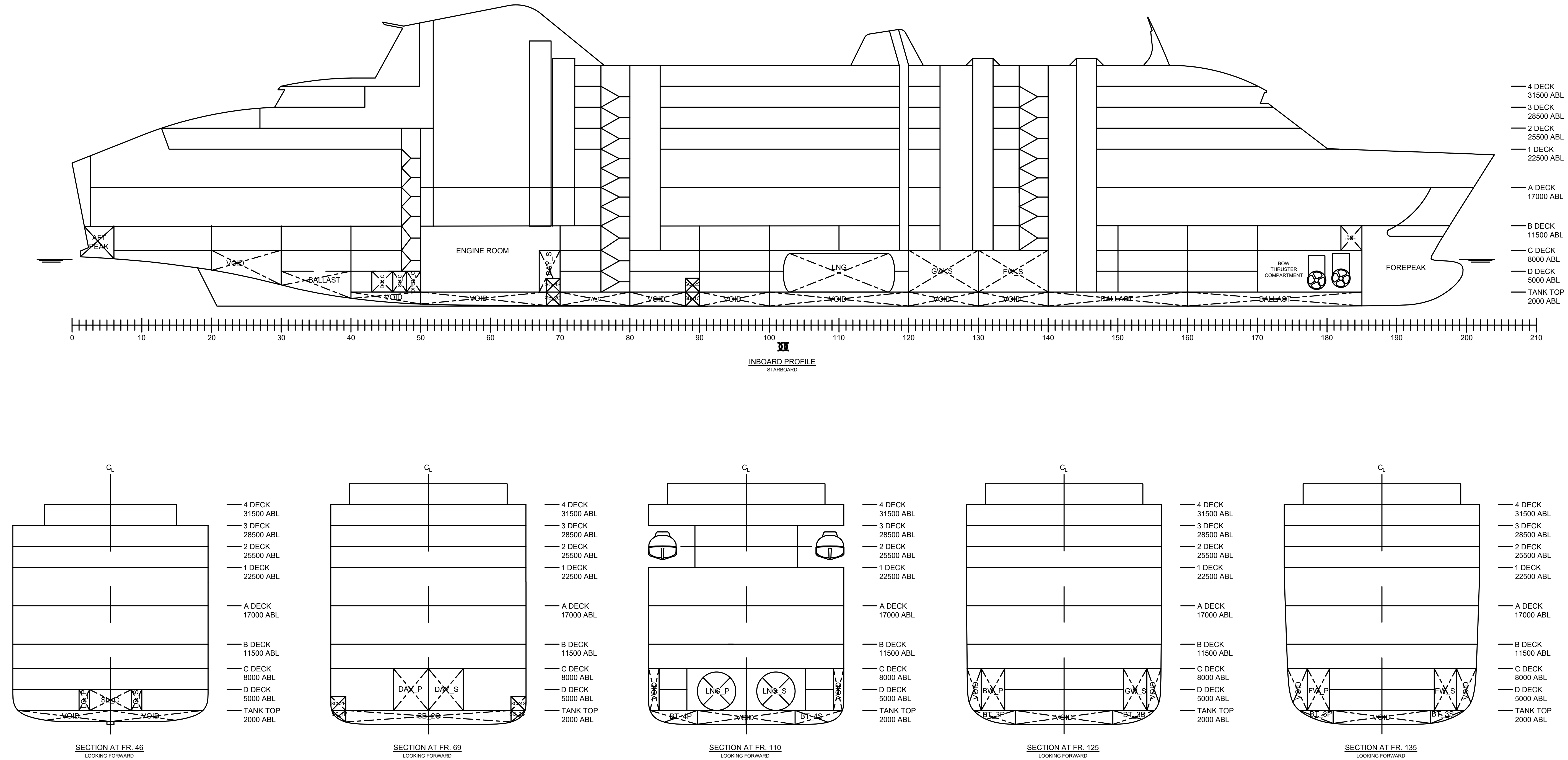
FIRE FIGHTING

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	FIRE PUMPS	TBD	TBD
2	MANUAL FIRE PUMP	TBD	TBD

TRAK

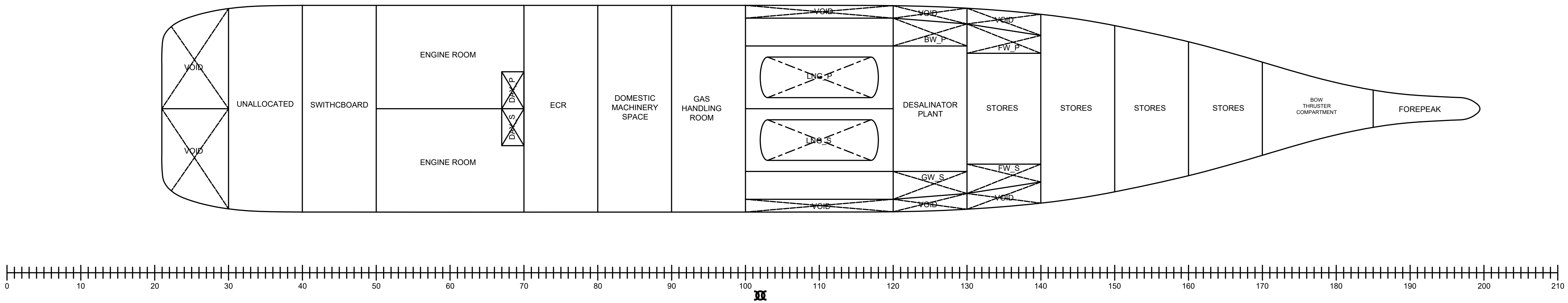
PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE MACHINERY ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 04/07/2023
SCALE 1:600	CHECKED BY A.B.	DATE 04/15/2023
DRAWING NO. AP-05	REV. 0	PAGE 3 OF 3

APPENDIX M – CAPACITY PLAN

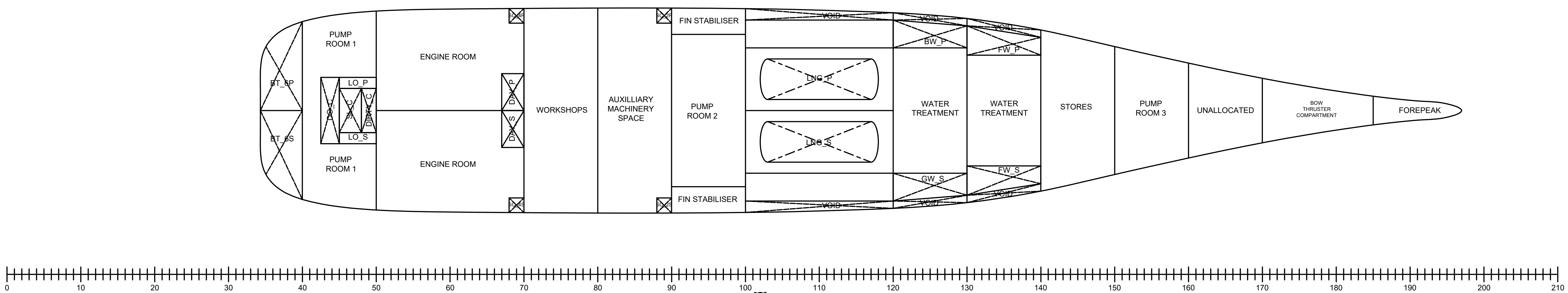


PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE TANK CAPACITY PLAN		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 03/05/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/8/2023
DRAWING NO. AP-04	REV. 0	PAGE 1 OF 3

TRAK



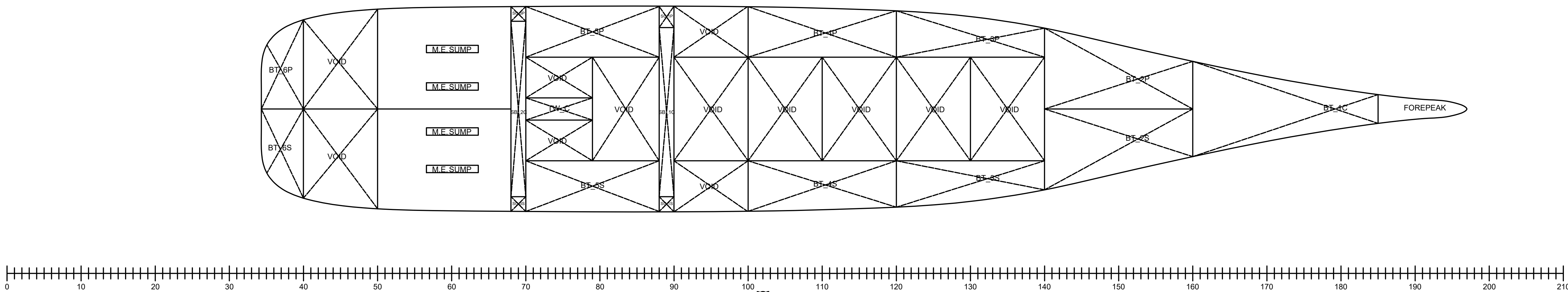
PLAN ABOVE D DECK
5000 ABL



PLAN ABOVE TANK TOP
2000 ABL

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE TANK CAPACITY PLAN		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 03/05/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/8/2023
DRAWING NO. AP-04	REV. 0	PAGE 2 OF 3



PLAN BELOW TANK TOP

2000 ABL

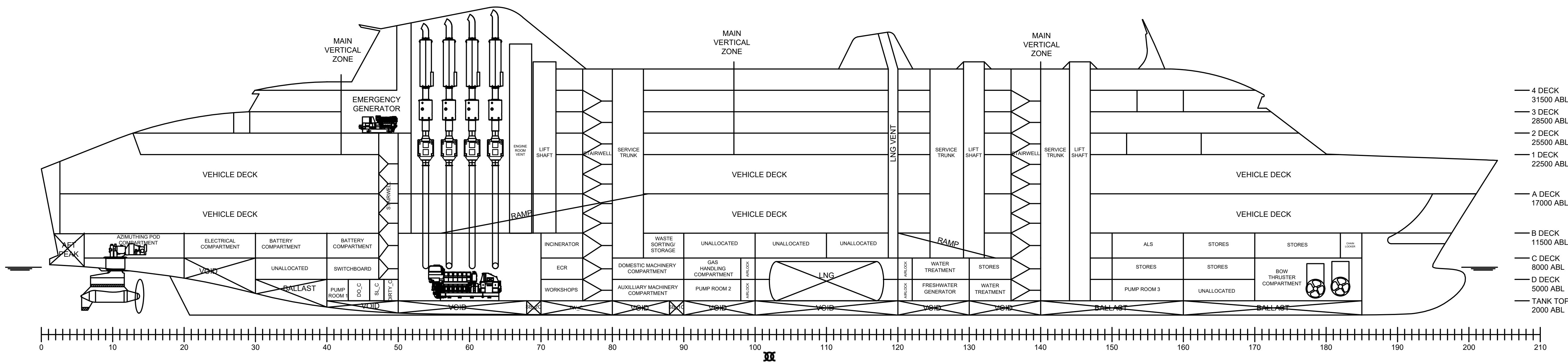
TYPE	TANK	VOLUME (M^3)	DENSITY (TONNES/M^3)	WEIGHT (TONNES)	LCG (FROM 0)	TCG (FROM C_L)	VCG (FROM BL)
LNG	LNG_P	452.0	0.45	203.4	110.0	7.3	5.75
LNG	LNG_S	452.0	0.45	203.4	110.0	-7.3	5.75
MDO	DO-C	67.5	0.85	53.4	43.75	0.0	3.75
MDO	DAY-P	90.0	0.85	76.5	68.5	2.5	5.0
MDO	DAY-S	90.0	0.85	76.5	68.5	-2.5	5.0
WATER	TW-C	77.6	1.00	77.6	76.05	0.0	1.0
WATER	FW-P	192.0	1.00	192.0	134.6	9.1	5.0
WATER	FW-S	192.0	1.00	192.0	134.6	-9.1	5.0
WATER	BW-P	204	1.00	204	124.8	10.2	5.0
WATER	GW-S	204	1.00	204	124.8	-10.2	5.0
LUBE OIL	LO-P	22.5	0.95	21.4	47.5	3.8	3.5
LUBE OIL	LO-S	22.5	0.95	21.4	47.5	-3.8	3.5
DIRTY OIL	DIRTY_C	36.0	0.95	34.2	49.0	0.0	3.5
SLUDGE	SL_C	54.0	0.95	51.3	46.5	0.0	3.5
BALLAST	BT_1C	256.4	1.025	262.8	170.1	0.0	1.2
BALLAST	BT_2P	274.7	1.025	281.6	148.9	3.6	1.2
BALLAST	BT_2S	274.7	1.025	281.6	148.9	-3.6	1.2
BALLAST	BT_3P	143.4	1.025	247.0	128.6	9.2	1.2
BALLAST	BT_3S	143.4	1.025	247.0	128.6	-9.2	1.2
BALLAST	BT_4P	215.1	1.025	220.5	109.7	9.8	1.1
BALLAST	BT_4S	215.1	1.025	220.5	109.7	-9.8	1.1
BALLAST	BT_5P	209.8	1.025	215.0	79.0	10.0	1.1
BALLAST	BT_5S	209.8	1.025	215.0	79.0	-10.0	1.1
BALLAST	BT_6P	378.0	1.025	387.5	35.6	6.3	3.53

TYPE	TANK	VOLUME (M^3)	DENSITY (TONNES/M^3)	WEIGHT (TONNES)	LCG (FROM 0)	TCG (FROM C_L)	VCG (FROM BL)
BALLAST	BT_6S	378.0	1.025	387.5	35.6	-6.3	3.53
SEA BAY	SB_1C	87.5	1.025	89.7	89.0	0.0	1.0
SEA BAY	SB_2C	84.4	1.025	86.5	69.0	0.0	1.0
SEA CHEST	SC_1P	8.1	1.025	8.3	89.0	12.2	1.2
SEA CHEST	SC_1S	8.1	1.025	8.3	89.0	-12.2	1.2
SEA CHEST	SC_2P	8.1	1.025	8.3	89.0	13.0	3.0
SEA CHEST	SC_2S	8.1	1.025	8.3	89.0	-13.0	3.0
SEA CHEST	SC_3P	7.28	1.025	7.5	69.0	12.2	1.2
SEA CHEST	SC_3S	7.28	1.025	7.5	69.0	-12.2	1.2
SEA CHEST	SC_4P	8.1	1.025	8.3	69.0	13.0	3.0
SEA CHEST	SC_4S	8.1	1.025	8.3	69.0	-13.0	3.0

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE TANK CAPACITY PLAN		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 03/05/2023
SCALE 1:600	CHECKED BY A.B.	DATE 03/8/2023
DRAWING NO. AP-04	REV. 0	PAGE 3 OF 3

APPENDIX N – AREA/VOLUMES SUMMARY



INBOARD PROFILE
STARBOARD

PRINCIPAL PARTICULARS

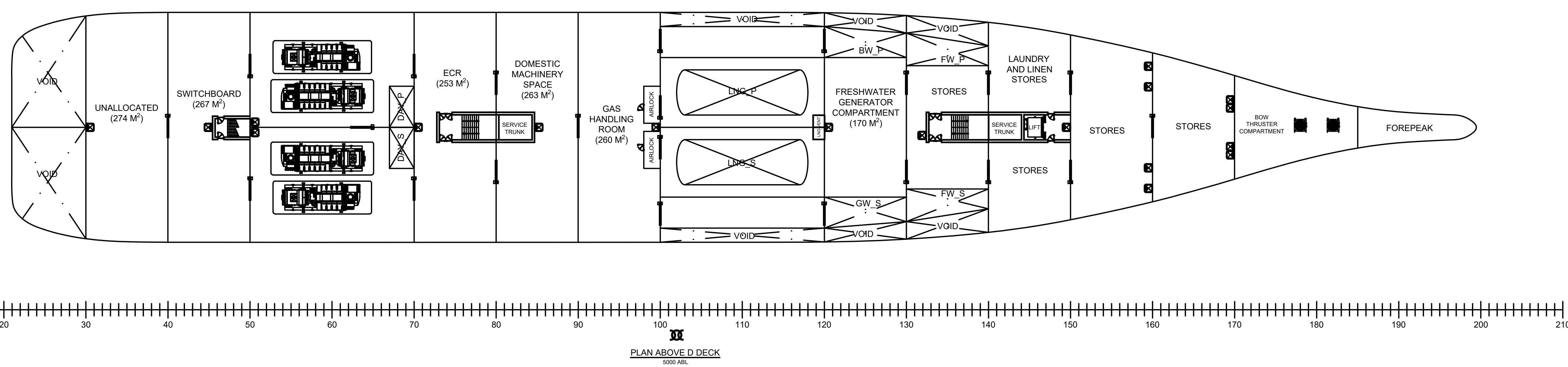
LENGTH OVERALL (m)	204.0
LENGTH BETWEEN PERPENDICULARS (m)	188.0
MOULDED BEAM (m)	28.0
MOULDED DEPTH (m)	17.0
DESIGN DRAFT (m)	6.7
DISPLACEMENT (TONNES)	24,578
COMPLEMENT	100
PASSENGER CAPACITY	1000
VEHICLE CAPACITY (LANE METERS)	3263
ICE CLASS	1A
INSTALLED POWER (kW)	21,600

ABBREVIATIONS

ALS - AIR LUBRICATION SYSTEM
BW - BLACK WATER
ECR - ENGINE CONTROL ROOM
ESC - ESCAPE HATCH
F.O. - FUEL OIL
FW - FRESH WATER
GW - GREY WATER
LNG - LIQUIFIED NATUAL GAS
L.O. - LUBRICATION OIL
SB - SEA BAY
SC - SEA CHEST

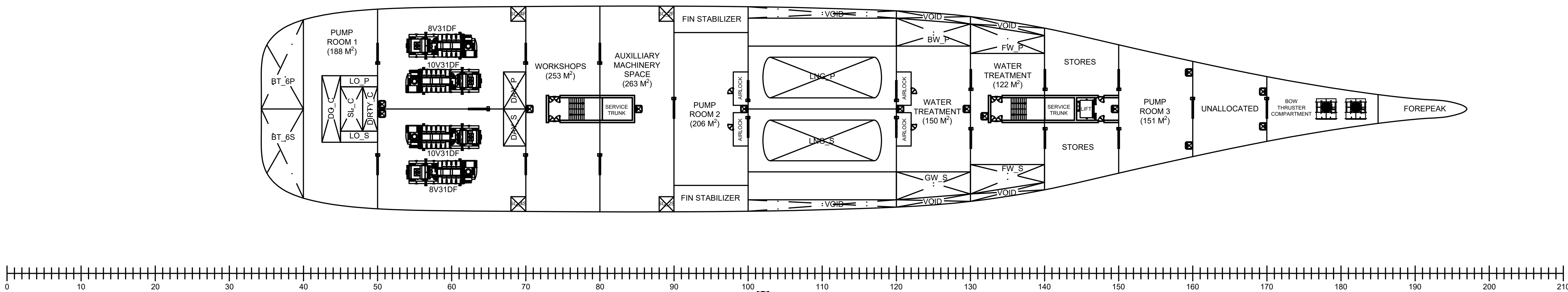
TRAK

PROJECT TITLE: MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE: MACHINERY ARRANGEMENT		
SHEET SIZE: ANSI B	DRAWN BY: R.C.	DATE: 04/07/2023
SCALE: 1:600	CHECKED BY: A.B.	DATE: 04/15/2023
DRAWING NO.: AP-05	REV.: 0	PAGE: 1 OF 3



PROJECT TITLE	MARINE ATLANTIC ROPAX FERRY
DRAWING TITLE	MACHINERY ARRANGEMENT

SHEET SIZE	DRAWN BY	DATE
ANSI B	R.C.	04/07/2023
SCALE	CHECKED BY	DATE
1:600	A.B.	04/15/2023
DRAWING NO.	REV.	PAGE
AP-05	0	2 OF 3



PLAN ABOVE TANK TOP

MAIN ELECTRICAL, PODDED PROPULSORS, AND BOW THRUSTERS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	MAIN GENSET	WARTSILA W10V31DF	6000 kW @ 720 RPM
2	MAIN GENSET	WARTSILA W8V31DF	4800 kW @ 750 RPM
1	EMERGENCY GENERATOR	WARTSILA W8L32	4640 kW @ 750 RPM
TBD	BATTERY	TBD	9.3 MWh
TBD	ELECTRICAL SWITHCBOARD	TBD	TBD
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2	BOW THRUSTER	WARTSILA WTT-16	1650 kW @ 980 RPM

PURIFIERS AND SEPARATORS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	MAIN ENGINE FO PURIFIER	ALFA LAVAL FM152	$40M^3$/HR
4	MAINE ENGINE LO PURIFIER	ALFA ELIMINATOR 180-14	$30M^3$/HR
1	EMERGENCY GENERATOR FO PURIFIER	ALFA LAVAL FM152	$30M^3$/HR
1	EMERGENCY GENERATOR LO PURIFIER	ALFA ELIMINATOR 180-14	$20M^3$/HR
1	OILY WATER SEPARATOR	ALFA ELIMINATOR PureBilge 5015	5000L/HR, 15 PPM

COOLING WATER PUMPS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
4	SEAWATER PUMP	TBD	TBD
4	FRESHWATER PUMP	TBD	TBD
2	SEAWATER HARBOUR PUMP	TBD	TBD
4	FRESHWATER HARBOUR PUMP	TBD	TBD

BILGE AND BALLAST PUMPS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
6	BILGE PUMP	TBD	TBD
6	BALLAST PUMP	TBD	TBD

FIN STABILISATION

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	ACTIVE FIN STABILISERS	KONGSBERG AQUARIUS A 100	-

AIR LUBRICATION SYSTEM

QTY.	COMPONENT	DESCRIPTION	CAPACITY
TBD	COMPRESSOR	TBD	TBD

PURIFIERS AND SEPARATORS

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	MAIN ENGINE FO PURIFIER	ALFA LAVAL FM152	$40M^3$/HR
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POTABLE WATER, BLACK WATER, GREY WATER, AND WASTE DISPOSAL

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	POTABLE WATER PUMP	TBD	TBD
1	GREY WATER PUMP	TBD	TBD
1	BLACK WATER PUMP	TBD	TBD
1	SEWAGE TREATMENT PLANT	WARTSILA STC-60-14	100,800 L/DAY
2	HYDROPHORE	TBD	TBD
1	FRESHWATER GENERATOR	WARTSILA HiTE 120-4	120 TONNES/DAY
1	SHREDDER	TBD	TBD
1	GLASS CRUSHER	TBD	TBD
1	INCINERATOR	TBD	TBD

FIRE FIGHTING

QTY.	COMPONENT	DESCRIPTION	CAPACITY
2	FIRE PUMPS	TBD	TBD
2	MANUAL FIRE PUMP	TBD	TBD

TRAK

PROJECT TITLE MARINE ATLANTIC ROPAX FERRY		
DRAWING TITLE MACHINERY ARRANGEMENT		
SHEET SIZE ANSI B	DRAWN BY R.C.	DATE 04/07/2023
SCALE 1:600	CHECKED BY A.B.	DATE 04/15/2023
DRAWING NO. AP-05	REV. 0	PAGE 3 OF 3