GUEMES ISLAND FERRY REPLACEMENT
Speed and Power

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References

1. *Guemes Island Ferry Replacement, Transportation System Assessment*, Glosten Inc., Report No. 17097-000-02, 14 December 2017.
2. Tsinker, G. P., *Marine Structures Engineering, Specialized Applications*, 1995.
3. Kim, Mingya, et al, *Estimation of added resistance and ship speed loss in a seaway*, 2017.
4. *Guemes Island Ferry Replacement, Lines Plan*, Glosten Inc., Drawing No. 17097.02-070-03.

Summary

Speed and power prediction calculations have been carried out for the Guemes Island ferry replacement vessel in order to establish that the baseline hull form performs adequately.

The calculations show that two (2) 750 kW L-drive propulsion units with a 70/30 thrust split[1] are more than capable of driving the fully loaded vessel in a 20-knot headwind and 2-ft waves at 11.5 knots. This speed allows the ferry to continue to operate at the current scheduled 2-round trips per hour as described in Reference 1. In addition, the vessel is capable of moving transversely at roughly 4.5 knots (required to combat the tidal current) fully loaded in calm seas. The new vessel can produce comparable bollard (zero speed) thrust to the MV *Guemes* using less than half the power.

After these calculations were performed, the hull was refined to reduce navigation draft, improve vessel tracking, and match displacement with the updated weight estimate. The hull will undergo further refinements using a formal computer optimization routine to reduce resistance. Although the newer hull form shown in the lines plan (Reference 4) has different characteristics and includes a fin at each end, the total required thrust at 11.5 knots is comparable to the vessel hull form shown in Figure 1. The hull will be further evaluated after hull optimization to confirm powering needs.

[1] 70% of the total power is applied to the stern thruster, 30% is applied to the bow thruster

Hull form and Load Conditions

The preliminary hull form (with originally proposed skegs and no fins) is shown in Figure 1 below.

Two loading conditions and assumed draft, T, were evaluated as follows.

1. Most probable: 15 walk-on passengers, 24 passenger vehicles, and 1 truck; draft = 7.37'
2. Full operating: 106 walk-on passengers, 25 passenger vehicles, and 1 truck; draft = 7.50'

The hull particulars for these loading conditions for the purposes of hull resistance calculations are summarized in Table 1. Note that these values do not include the skeg or propulsor well.

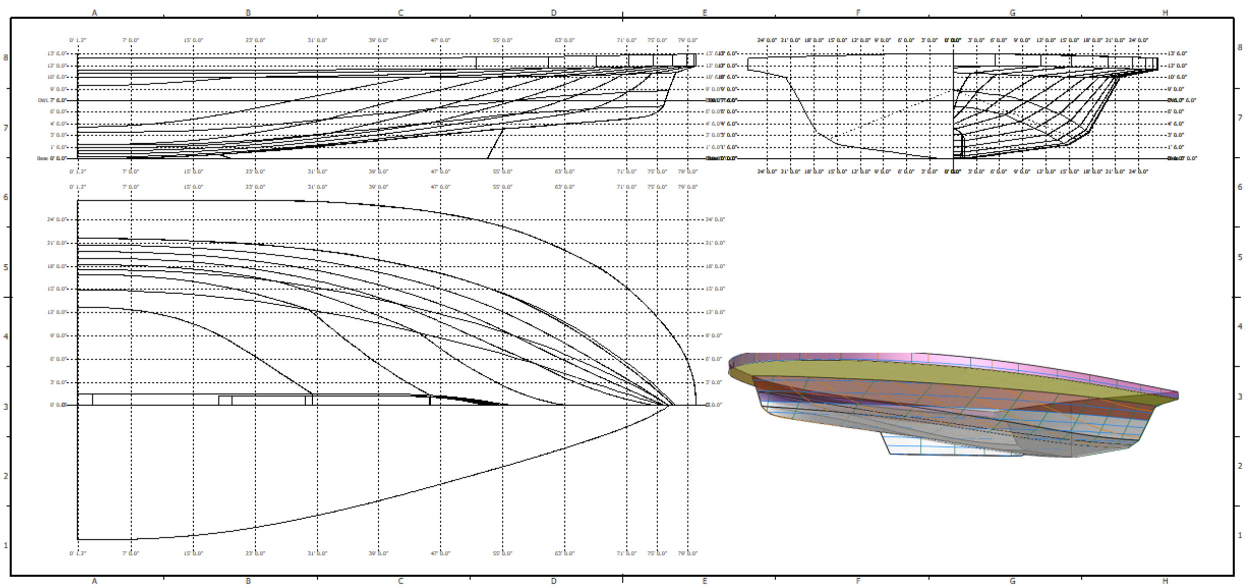

Figure 1 Hull lines used in this speed and power evaluation

Table 1 Hull particulars without skegs

	Most probable load	Full load
LWL (ft)	152	152
BWL (ft)	39.7	39.8
Depth D at side (ft)	13.0	13.0
Draft T (ft)	7.38	7.50
Displ. molded (LT)	521.4	536.2
C_b	0.410	0.413
C_m	0.787	0.788
C_p	0.521	0.524

Resistance Calculations and CFD Verification

Standard and transverse vessel resistance were calculated for the loading conditions above using the hull conditions and climatology (as per Reference 1 and outlined in Table 2 below) summarized below:

1. Most probable load: hull coated with heavy slime; average run (standard only)
2. Full load: hull coated with light calcareous fouling/weed growth; 1) above average run, 2) generator starts, and 3) schedule slip (standard and transverse)

Table 2 Climatology

Description	Approx. Percentile	Wind Speed (knots)	Current (knots)	H_s (ft)	T_p (s)	Remarks
Average Run	50%	6	1.0	-	-	
Above Average Run	80%	10	2.0	-	-	Winds from south, little wave interaction
Generator Starts	95%	10	3.0	1.0	2.0	Winds from west
Schedule Slip	99.7%	20	3.0	2.0	2.8	

Standard resistance calculations were developed based on the 1978 ITTC Performance Prediction Method. Transverse resistance was developed based on methods outlined in Reference 2.

Standard Resistance (1978 ITTC Method)

The frictional resistance coefficient for the vessel was determined using the ITTC-1957 model-ship correlation line. The residual resistance coefficient was developed by regression of empirical resistance data of similar vessels. The roughness allowance was calculated by summating the roughness and correlation allowances defined the 19th ITTC proposal, which approximates the roughness allowance of the original 1978 ITTC method. Air drag was calculated assuming a drag coefficient of 1.

Residual Resistance

It was found that the natural log of residual resistance (Rr) normalized with respect to displacement was linear with respect to Froude number (Fn) for Fn between 0.2 and 0.3. The design speed is 11.5 kts with Fn=0.278. Furthermore, the magnitude of that slope, m_1, was directly proportional to the block coefficient (m_2 and b_2) and the resulting intercept, b_1, was found to be roughly constant. The following equation was derived based on these relationships:

$Rr = \Delta * \exp(-b_1 + m_1 * Fn)$, where $m_1 = m_2 * C_b + b_2$

The skegs were not included in this calculation in order to better represent the hull coefficient of the bare hull.

Transverse Resistance

Transverse resistance was deemed an important design criterion given that during normal operation of the current ferry the propulsors are used to remain stationary against a side current. The design requirement for the hull/propulsor was to develop enough power to keep the hull from moving in 4.5 knots of current, or to move the vessel 4.5 knots sideways through still water. This speed is roughly 5% greater than what the current vessel can accomplish to provide conservatism.

When the resistance of the hull is determined from the methods outlined in Reference 2 and the drag due to skegs (appendages) is added separately assuming basic flat plate drag coefficient, the results show good correlation with the current vessel.

CFD Verification

CFD calculations were carried out in full scale using FINE/Marine version 8.1 by Numeca to verify the resistance prediction methods outlined above. The computational domain consisted of a half hull and a symmetry plane at the vessel centerline for standard resistance and vessel amidships for transverse resistance. The models were free to heave for both cases and free to trim for the standard case. The models were towed in line with the propeller shaft at the respective design speeds.

Standard

CFD predictions of hull with the skegs showed good correlation with the standard case regression-based calculation (without the skegs) assuming the same draft. Therefore, the regression model was assumed satisfactory for the purposes of preliminary design and was used for powering calculations.

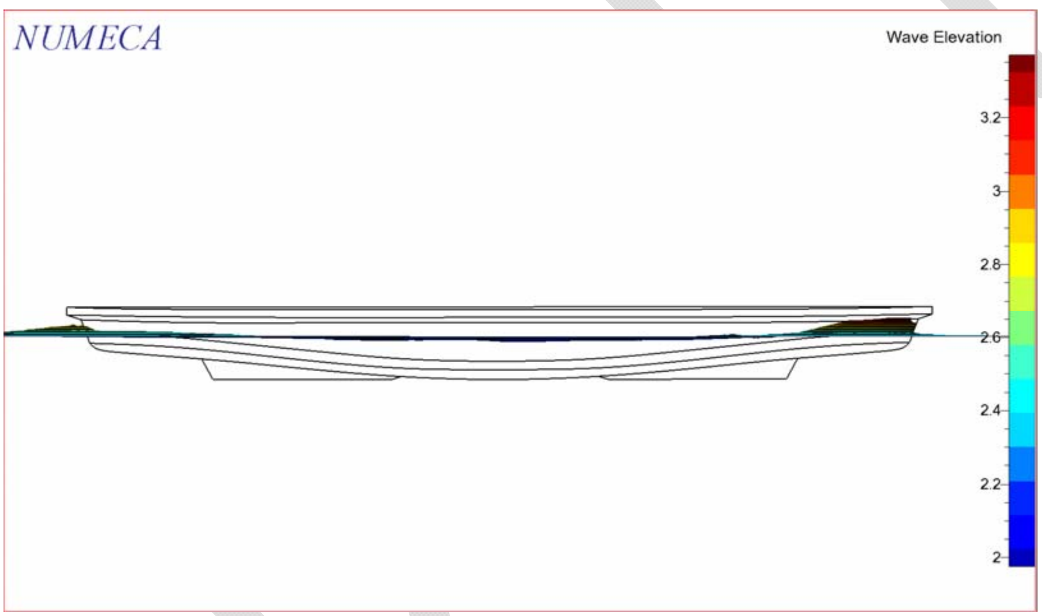

Figure 2 Side view of wave elevation at a forward speed of 11.5 knots (in meters relative to vessel baseline)

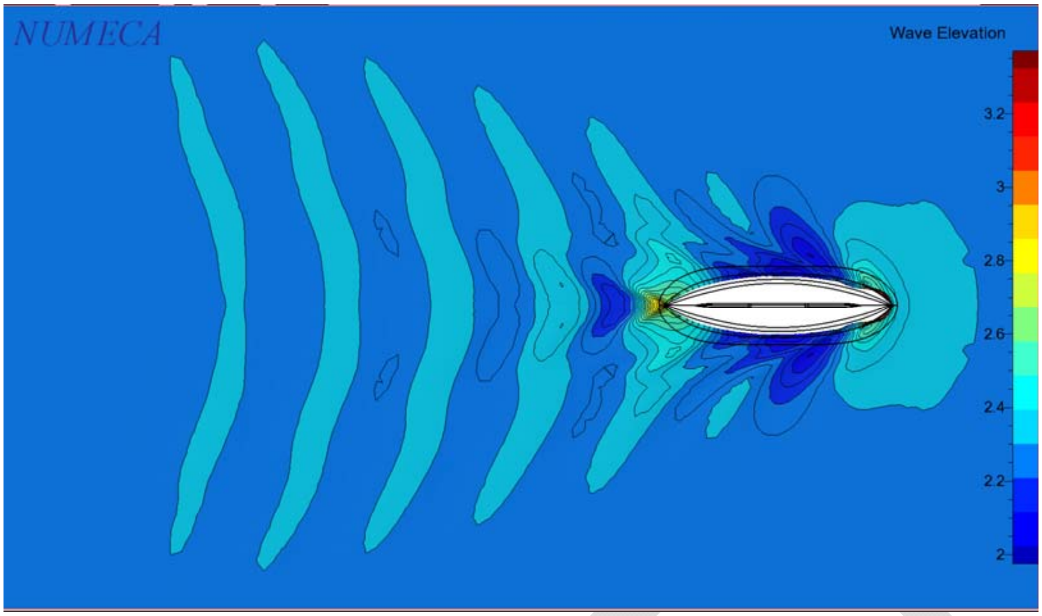

Figure 3 Top view of wave elevation at a forward speed of 11.5 knots (in meters relative to vessel baseline)

Transverse (Side Current)

CFD predicted a resistance 3% greater than the transverse case calculation. The CFD result was used for powering calculations with the assumption that resistance is a quadratic function of vessel speed with intercept of 0.

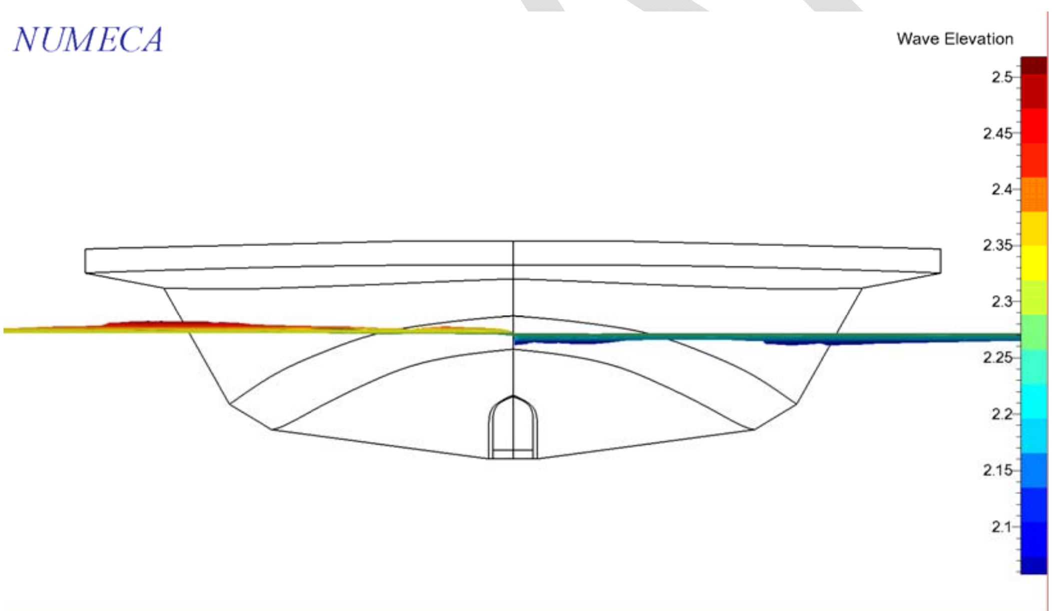

Figure 4 Front view of wave elevation at a sideways speed of 4.5 knots (in meters relative to vessel baseline)

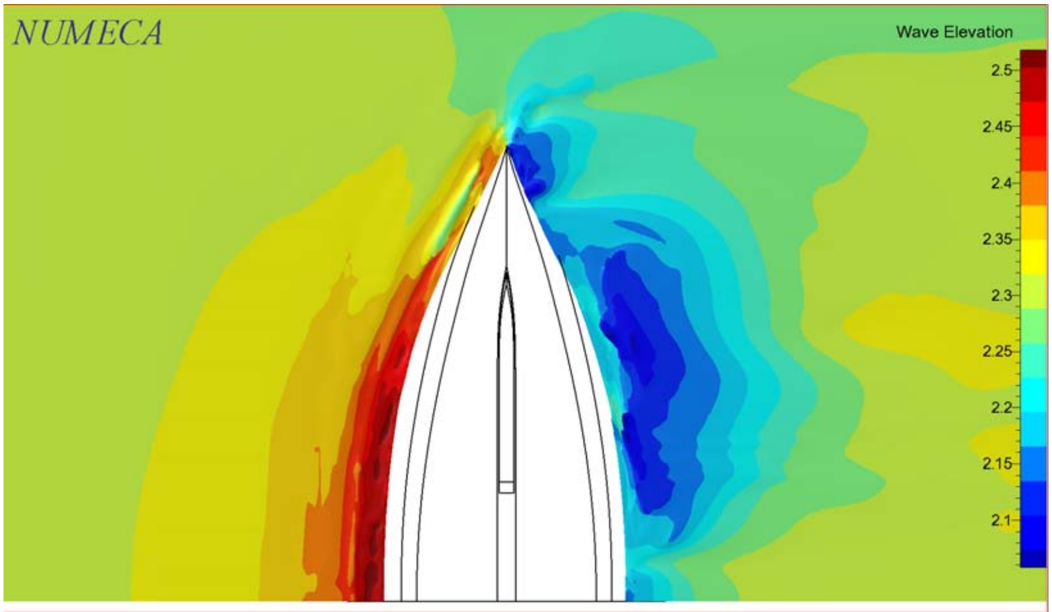

Figure 5 Top view of wave elevation at a sideways speed of 4.5 knots (in meters relative to vessel baseline)

Wave Margin

Initial resistance calculations and CFD simulations assume still water conditions. In order to account for added resistance (and added required power) due to waves, a wave margin applied to standard resistance for head seas was developed based on the research presented in Reference 3. The resulting wave margin was negligible for average climatology and was 3% for a 2-ft wave corresponding to the schedule slip event. Although wave margin is generally considered to be inversely proportional to vessel speed, it was assumed to be a constant for simplicity.

Powering Calculations

The resistance curves were used as inputs to the powering calculations spreadsheet.

The following propulsive coefficients were treated as constants for all conditions and speeds. The wake fraction and thrust deduction factor for standard power were developed from the CFD results. The relative rotative and mechanical efficiencies are estimated from experience.

- Wake fraction, w
  - Standard
    - Aft: -0.046
    - Fwd: 0.055
  - Transverse
    - Aft/Fwd: 0.030
- Thrust deduction, t
  - Standard
    - Aft: 0.033
    - Fwd: 0.125
  - Transverse
    - Aft/Fwd: 0.030
- Relative rotative efficiency $\eta_{RR} = 1$
- Mechanical efficiency $\eta_m = 0.97$

In addition, a sensitivity study with respect to wake fraction was performed for the transverse case assuming w=0.

The assumed propeller and motor performance and characteristics are derived from vendor info received in response to the RFIs submitted last year. The assumed propeller characteristics are listed in Table 3 and the open water curves are presented in Figure 6. The powering calculation solves for the propeller advance ratio J corresponding to the required thrust using the equation $CT*J^2 = KT$ (independent of RPM).

The typical motor performance is shown in Figure 7. The results of the powering calculations are presented in Figures 8-10.

Table 3 Typical propeller characteristics

Type:	Nozzled	
Diameter:	1.65 m	65 in
Pitch:	1.70 m	67 in
P/D:	1.03	
EAR:	0.7	
Z:	4	
Rdgr Ratio:	0.326	

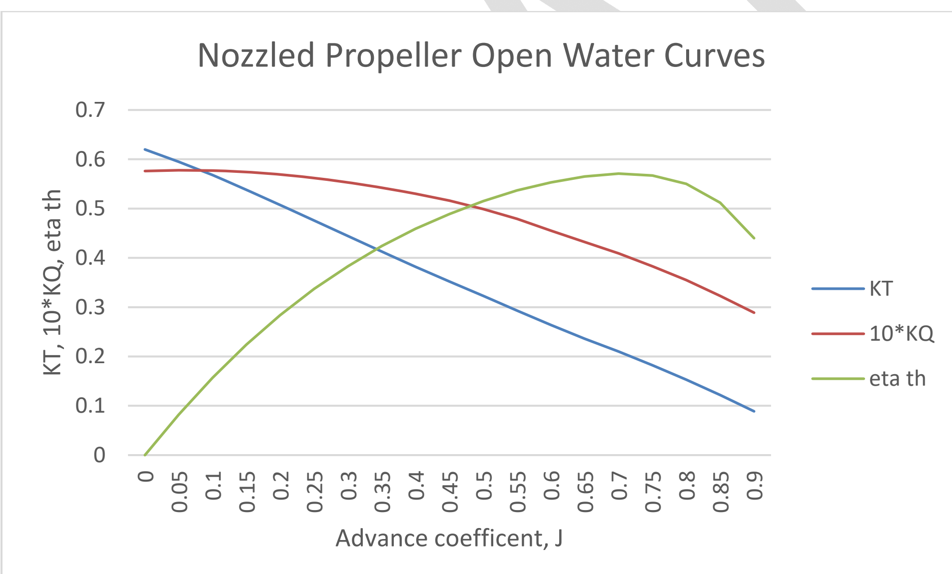

Figure 6 Assumed nozzled propeller open water curves

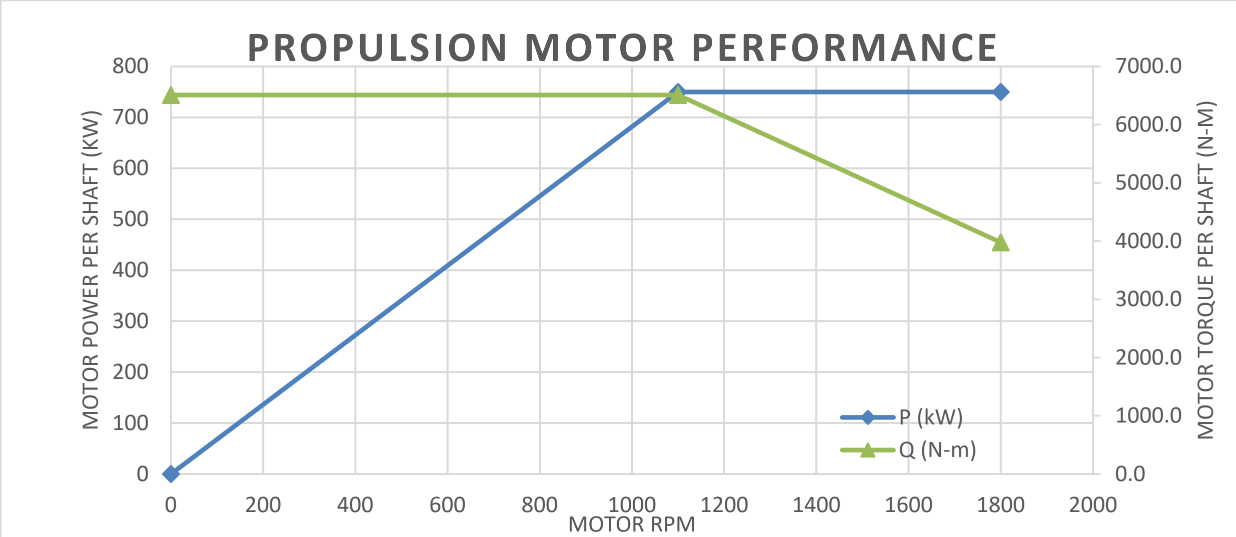

Figure 7 Assumed motor performance

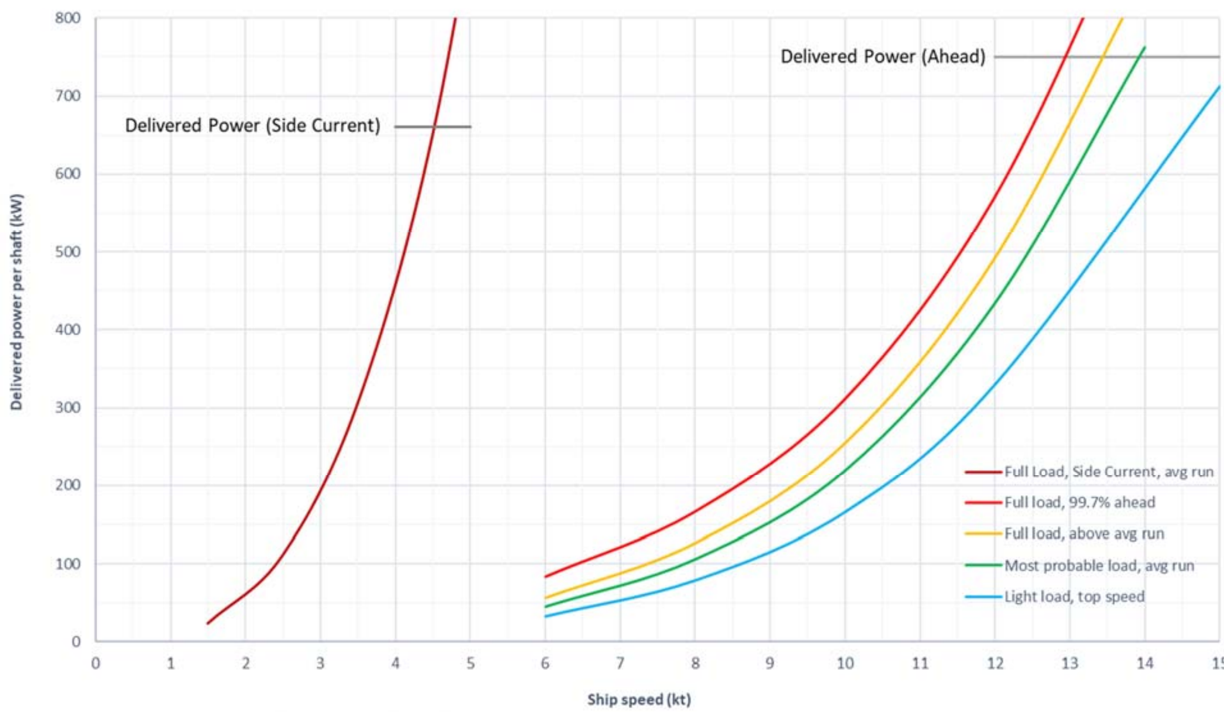

Figure 8 Required and delivered power versus ship speed

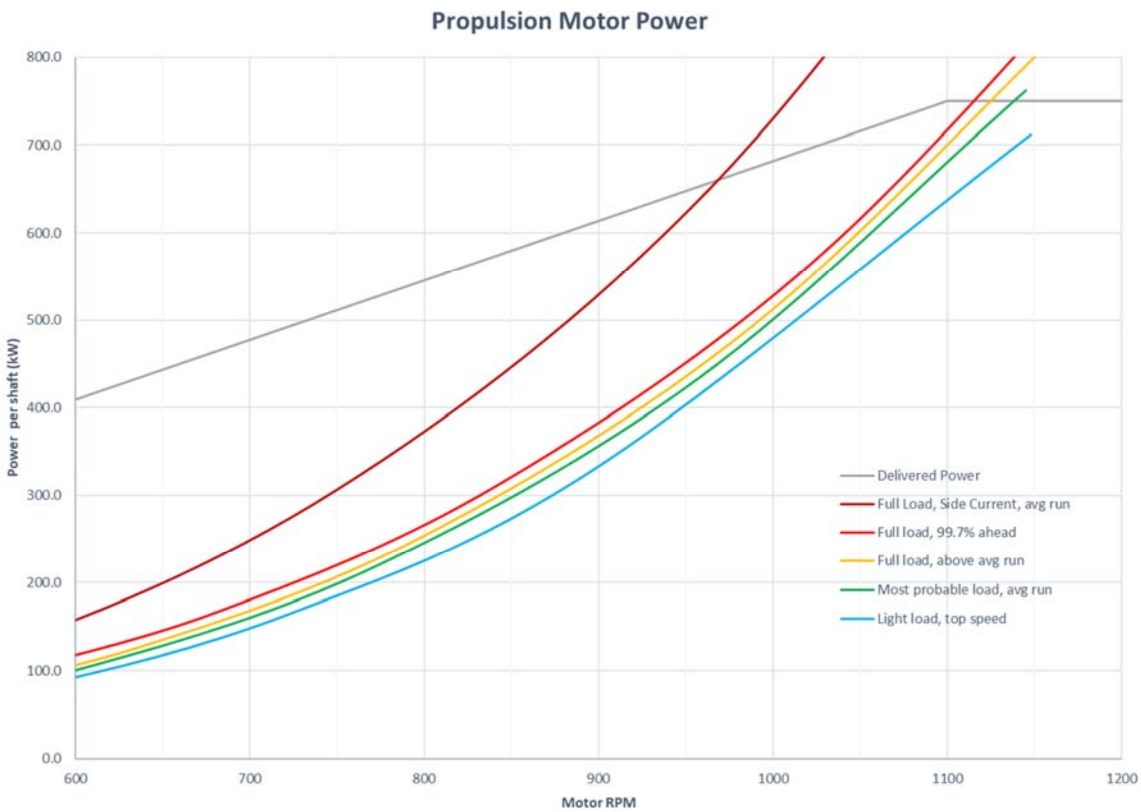

Figure 9 Required and delivered power versus motor RPM

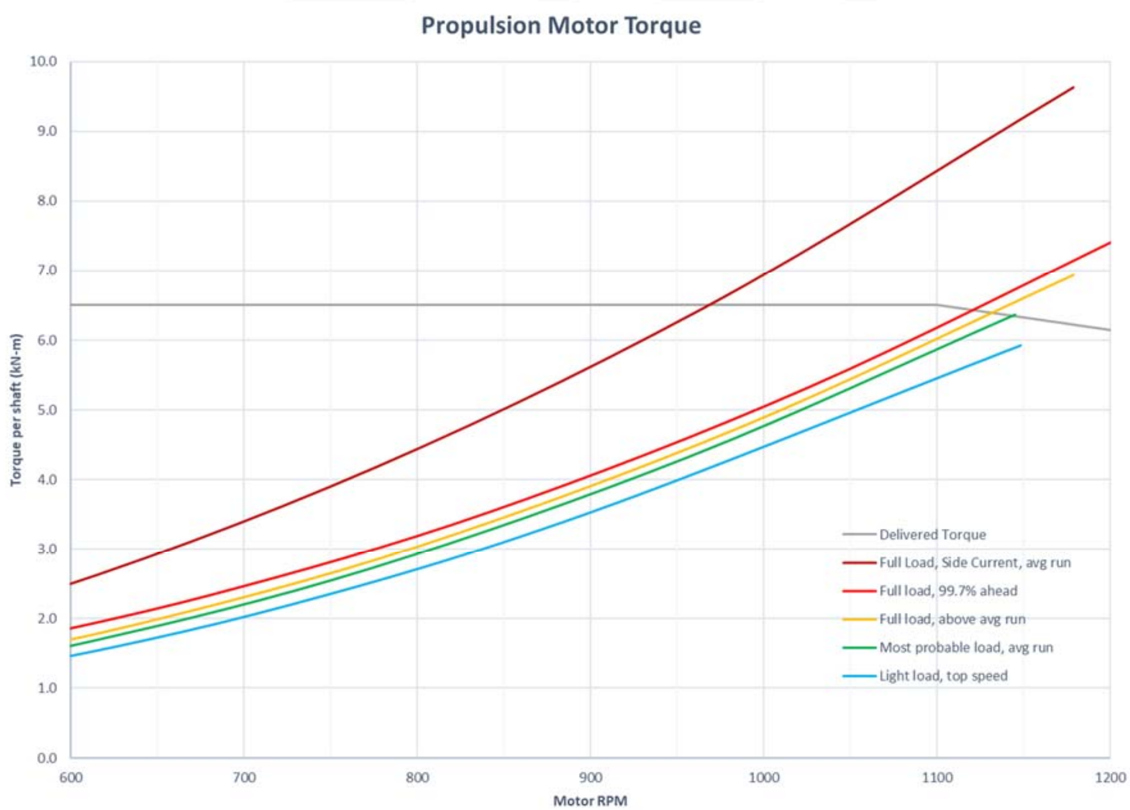

Figure 10 Required and delivered torque versus motor RPM

Summary of Power Results

The results indicate that the driving design case is that for the side current where the motor is limited by power and torque at 960 RPM at just over 4.5 knots. There is ample margin for the vessel to maintain the design speed of 11.5 knots even for the worst case loading and weather conditions.

Bollard Thrust Calculations

The MV *Guemes* bollard thrust was considered as the baseline value, i.e. the replacement vessel needs to generate at least as much thrust as this value. The required bollard thrust for normal operations of the existing vessel was found to correspond to ~150 KW per thruster. The design rationale is that the bollard thrust pins the vessel's bow against the terminal fender wall to resist heave motions during loading. The forces imparted on the vessel and the frictional forces required to resist vessel heave are assumed to be comparable for a given sea since the energy from the sea is the same. The new vessel should exhibit less motion and lower accelerations in a given sea state since it is more massive and stiffer. However, since the increase in the mass is offset by the decrease in acceleration the resulting forces will be comparable.

The propeller open water curves for the MV *Guemes* were estimated assuming a 4-blade Wageningen B-series propeller with an area ratio of 0.7. The bollard thrust predictions are presented in Table 4.

Table 4 Bollard Thrust at RPM with corresponding Power and Torque

		n_{input} (rpm)	P_{input} (kW)	M_{input} (kNm)	Thrust (kN)
GUEMES	Limit*	1800.0*	380.2	2.0	54.6
	Normal Op	1320.2	150.0	1.1	29.4
Replacement Ferry	Limit*	954.6	650.8	6.5*	126.5
	Match MV *Guemes* Limit	627.1	184.5	2.8	54.6
	Match MV *Guemes* Normal Ops	460.1	72.9	1.5	29.4

The results show that the new vessel has the capability to produce over twice as much bollard thrust. More importantly, it shows that the new vessel can produce a thrust comparable to the MV *Guemes* for normal operations at half the power. This result is of paramount importance as more than half of a round trip time is dedicated to loading/unloading. Therefore, lowering the power demand at loading/unloading will help to reduce the size of the battery bank.