Tustumena Replacement Vessel

Design Study Report

Prepared for
Alaska Marine Highway System
Ketchikan, Alaska

File No. 13105.05
21 November 2014
Rev. A

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Section	Rev	Description	Date	Approved
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All	–	Final Submittal	10/22/2014	DWL
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Executive Summary

The *M/V Tustumena* entered service in 1964 and is near the end of its design service life. Together with the *M/V Kennicott*, these two ferries are the only ferries capable of serving the Alaska Marine Highway routes between Homer, Kodiak, and the Aleutian Chain. Alaska Marine Highway System (AMHS) has begun a design project to replace the existing *Tustumena* with a new ferry, hereafter referred to as the *Tustumena Replacement Vessel*.

These ferries are set apart by not only their unique service route, but also their onboard systems; no other vessel in the world shares the unique vehicle handling systems of these two ferries. The *Tustumena Replacement Vessel* will require a vehicle handling system with similar capabilities. This handling system is the key driver of the new vessel design.

This report presents the findings from the preliminary design cycle and builds on the previous work developed during the March 2014 Recon Study. A complete preliminary design for the replacement vessel has been developed addressing the key design and regulatory requirements identified during the Recon Study. The appendices to this report contain drawings and renderings of the *Tustumena Replacement Vessel* preliminary design.

The purpose of this report is to provide feedback on the validity of the results developed during the Recon Study and report on the progress of the vessel design. As part of that effort, this report builds on key vessel design drivers, regulatory requirements and cost drivers of the new vessel design identified during the March 2014 Recon Study.

The *Tustumena Replacement Vessel* design is driven by several competing design and regulatory requirements:

- Handle vehicles, heavy construction equipment, and trailers (vans) through the vessel side at docks which do not have dedicated ferry ramps or other standard loading facilities.
- Interface with the standard AMHS docks in Prince William Sound and Southeast Alaska.
- Serve southwest Alaska routes and docks with design challenges due to the draft limits while maneuvering at low tide and small dock sizes.
- Sail in unprotected north Pacific waters and meet current American Bureau of Shipping and United States Coast Guard regulations for oceans certification.
- Meet Americans with Disabilities Act requirements.
- Meet new Environmental Protection Agency air emission and water emission standards.

An initial design for a *Tustumena Replacement Vessel* is presented in this report and reflects an ongoing and collaborative effort with AMHS vessel engineering and the AMHS Steering Committee. This design seeks to balance the design requirements with operator and real world experience.

This preliminary design principle dimensions and capabilities are presented in Table 1. Comparisons to the data presented with the concept design during the Recon Study are included. The vessel size has increased by 5 feet in length, 2 feet in beam and 1.5 feet in depth, while the passenger and vehicle capacity remain the same. This increase in size allows for a longer vehicle elevator to decrease the "double shuffle" requirements during loading/unloading operations, speeding up vessel loading/unloading times.

Table 1 Recon Study and preliminary design principal characteristics

Dimension/Capability	Preliminary Design Characteristics (Current)	Recon Study Characteristics (Superseded)
Length Over All (LOA)	330'	325'
Length Water Line (LWL)	314'-0"	309'-6"
Depth	24'-6"	23'
Breadth Over All (BOA)	70'	68'
BOA (Over Guards)	72'	70'
Design Draft	15'-10"	14'-10"
Draft at End of Service Life	16'-6"	15'-6"
Air Draft	77'	81'
Vans & Cars	12 & 27	12 & 27
Cars Only	52	52
Vehicle Lane Length	1135'	1135'
Passengers	250	250

A Value Engineering (VE) Study was completed between the 95% draft Design Study Report and this final Design Study Report. The VE Study identified 27 items to be considered during the PS&E phase of the project. Of those 27 recommendations, AMHS has approved 19 of the recommendations for incorporation into the vessel design during PS&E. Design areas where the VE Study recommendations differ from the present design are identified in this report.

Cost estimates place the project budget for the new vessel at up to $237 million in 2014 dollars. However, it should be noted that until the design is sufficiently mature and the procurement methodology finalized these numbers are preliminary.

Section 1 Mission Requirements and New Vessel Capabilities

1.1 Introduction

This report presents the preliminary design for the *Tustumena Replacement Vessel*, expanding upon the concept design presented in the Recon Report, Reference 1. The *M/V Tustumena* entered service in 1964 and is nearing the end of its design service life. Together with the *M/V Kennicott*, these two ferries are the only vessels capable of serving the Alaska Marine Highway System routes between Homer, Kodiak, and the Aleutian Chain.

This report represents the findings from additional design development, full-scale vehicle testing, seakeeping analysis, detailed structural and system calculations, vendor discussions, interviews with AMHS personnel, and discussions with regulatory authorities.

1.2 Service Area

The service area of the *Tustumena Replacement Vessel* will be primarily Southwest Alaska. Figure 1 shows the vessel's anticipated service area.

Figure 1 *Tustumena Replacement Vessel*'s anticipated service area

The docks in the service area for the *Tustumena Replacement Vessel* play a large role in the vessel's design. This vessel will operate in the AMHS fleet and will be designed to service the docks in Southwest Alaska. These docks do not have dedicated ferry ramps or other standard loading facilities found in Prince William Sound and Southeast Alaska. The docks of Southwest Alaska experience high tidal ranges, exposed locations, and severe weather conditions which the vessel will be required to overcome on a regular basis. In Southwest Alaska, all vehicle loading will be through the vessel side using a newer variation of the proven vehicle elevator/turntable design of the *M/V Tustumena*. The vessel will also be designed to interface with the docks in Prince William Sound and Southeast Alaska, which implies a stern door and clear decks in way of the port and starboard side doors.

The Southwest Alaska routes and docks present vessel design challenges due to the small dock sizes and draft limits while maneuvering at low tide. AMHS decided the overall length and draft of the vessel will be designed to meet all requirements without modifying the ports or docks on the Southwest routes. Therefore, the principle dimensions of the new vessel were determined based on these limitations set by AMHS.

Vessel speed and route will be evaluated to see if stops at both Chignik and Old Harbor in at least one direction will be possible within the expected standard vessel schedule.

1.3 New Vessel Capabilities/Mission Requirements

Table 2 Mission requirements

Mission Requirements	*Tustumena*	*Kennicott*	*Tustumena Replacement Vessel*	Notes
Overall Vessel				
Length	296'	382'	330'	
Beam	59'	85'	70'	72' over the guards
Draft	14'5"	17'6"	15'-10" as built and 16'-6" keel draft at end of service life	Includes an allowance for service life weight growth.
Air Draft	77'	92'-3"	77'	Set a maximum design criteria of 90'
Speed (cruising speed in weather)	13.8 kts	16.75 kts	15-16 kts at Sea State 4, 85% MCR	Increasing speed to better maintain sailing schedule and/or increase frequency of service.
Range	3300 nm	4500 nm	4000 nm	
Deadweight Capability	900 LT	1219 LT	1595 LT	Based on estimated lightship
Displacement	3067 LT	7503 LT	5595 LT	

Mission Requirements	*Tustumena*	*Kennicott*	*Tustumena Replacement Vessel*	Notes
Implement “water on deck” stability criteria	No	Yes	No	Selected parts of SOLAS apply due to ABS Class
Vehicles				
No. of vehicles or lane feet of vehicles	852' (42 cars)	1600' (80 cars)	1135' (52 cars)	Incorporating a VE recommended Mezzanine Deck vehicle deck will increase the capacity up to 6 vehicles. Incorporating the VE recommended turntable vehicle stowage will increase capacity by 2 additional vehicles.
No. of trailers or lane feet	12 (6 due to maneuverability, may carry up to 9)	20	12 – 40' containers	
Vehicle lane width	25'3" structure to structure / 3 lanes	33' between curbs / 3 lanes or 4 lanes	9' center lanes and 10'-10" on sides	
Additional width for access on Main Deck	No	Yes	Yes	3' for fire lane
Minimum vehicle space vertical clearance	14.5'	14.5'	15'-6" center lanes and 9'-6" for side lanes	
Vehicle turnaround capability forward of casing	No	Yes	Yes	Optional
Vehicle elevator capacity	60,000 lbs.	80,000 lbs.	80,000 lbs.	Vehicle elevator same capacity as *Kennicott*
Vehicle elevator size/length (clear inside)	41'6" LOA x 12' Wide	53' LOA (52' curb) x 17' Wide	52' LOA x 17' Wide	
Stern doors	No	Yes	Yes	Ship needs to be SE Alaska capable.
Side doors suitable for SE AK	No	Yes	Yes	Doors shall be capable of opening while moored to the dock.

Mission Requirements	*Tustumena*	*Kennicott*	*Tustumena Replacement Vessel*	Notes
Passengers				
Number of passengers	174	499	250	Maximize to suit lifesaving and lifeboat capacities
2 person staterooms	17 (19.5% of passenger total)	32 (12.8% of passenger total)	16 (12.8% of passenger total)	Includes Toilets and Showers, does not include ADA
4 person staterooms	8 (18.4% of passenger total)	48 (38.5% of passenger total)	7 (11.2% of passenger total)	Includes Toilets and Showers, does not include ADA
2 person roomettes	No	24 (9.6% of passenger total)	17 (13.6% of passenger total)	Does not Include Toilets and Showers
2 person ADA staterooms	1	5	2	Maintain ratio of *Taku* and ADA recommendations
4 person ADA stateroom	0	0	1	
Total number of berths	68 (39%)	320 (64%)	102 (41%)	
Passenger food service preferences	Sit down	Cafeteria	Cafeteria	
Accommodation decks	2	3	2.5	Allow stability to determine
Crew				
No. of total crew	38 summer 35 winter	56 summer 52 winter	38 summer 34 winter	Detailed in the manning study
Crew below Main Deck	No	Yes	No	
Crew on Main Deck	Yes	No	No	
Crew on Mezzanine forward	Yes	No	Yes	
Structure				
Steel hull	Steel	Steel	Steel	Ice belt currently in the design
Bulbous bow	No	Yes	Yes	
Helo deck	No	Yes	Helo pickup area only	
Parallel midbody	No	No	Yes	
1 or 2 casings	1	1	1	
Centerline or offset casing	Centerline	Centerline	Offset	
Propulsion system				

Mission Requirements	***Tustumena***	***Kennicott***	***Tustumena Replacement Vessel***	**Notes**
Twin Screw - CPP or FPP	FPP	CPP	CPP	
Geared Diesel or Diesel Electric	Geared Diesel	Geared Diesel	Geared Diesel	2 x 4000 BHP - 5000 BHP
Bow thruster type - tunnel or azimuthing	Tunnel	Azimuthing	Tunnel	Azimuthing thrusters are less efficient than tunnel thrusters.
Bow Thruster - electric or diesel?	Electric	Electric	Electric	
Bow Thruster - size	600 HP	2200 HP	1500 HP (1150kW)	Apply *Kennicott* design criteria (30 kts), but also evaluate for higher wind speeds.
Electrical System				
Clean power system	None	Distributed UPS	Distributed UPS	Needed for more advanced electronics
Shaft generators	No	Yes	Yes	
SSDG's	Yes	Yes	Yes	Investigate dual-fuel engines
Number of SSDG's	2	2	2	
Total Number of Generator Sets	2	4	4	2 x 550 ekW (Cat C18 or equal) & 2x 1000 ekW shaft gen.
Auxiliary Systems				
Shipwide Air Conditioning	No	Yes	Yes	Take into consideration solar loads that tend to heat up the interior spaces.
Heating - steam or hot water	Steam	Steam	Steam	
Waste Heat, Exhaust gas or jacket water or both	No	Yes - exhaust gas	Yes – exhaust gas	
Engine cooling - heat exchanger, keel cooler or channel cooler	Heat exchanger	Heat exchanger	Heat exchanger	

Mission Requirements	*Tustumena*	*Kennicott*	*Tustumena Replacement Vessel*	Notes
High performance rudders/steering	No	Yes	Maybe	The VE Study recommended high performance rudders and steering systems.
Retractable fin stabilizers	Yes	Yes	Yes	
Accommodations/Outfit				
Passenger Lounge aft of Vehicle Elevator	No	Yes	No	Not widely used on *Kennicott*
Standard AMHS passenger arrangements? i.e. Lounge Forward, Solarium, Side Lounge, etc.	Yes	Yes	Yes	
Special rooms or areas- Theater, etc.	Yes	Yes	Yes	
Lifesaving - boats/rafts/slides	LSA	LSA	LSA	Fleet Standardization using Lifesaving Systems of Australia (LSA)
Miscellaneous				
SOLAS	No	Yes	No	Selected safety systems will be added to the design. Evaluate impact and cost tradeoffs of designing to SOLAS even if not certified.

Section 2 Ferry System Operational Requirements

2.1 Terminal Compatibility

The *Tustumena Replacement Vessel* is intended to operate in conjunction with a unique combination of ports and terminals currently served by the *M/V Tustumena*. Terminal compatibility determined several important characteristics of the vessel design including: overall length and depth. The majority of ports in the *Tustumena*'s area of operation are unimproved piers, characterized by tall vertical faces and fixed height pier decks. However, the *Tustumena Replacement Vessel* is also intended to operate in conjunction with terminals specially designed for vehicle loading which is characterized by floating or adjustable loading interfaces. Each of these different types of loading facilities has different operating conditions and limitations and a unique spatial arrangement. The terminal compatibility study, Appendix C, shows the operating limitations associated with each terminal interface and representative diagrams of each terminal with the *Tustumena Replacement Vessel* shown moored in place.

The preliminary vessel design was used to analyze and evaluate several terminal elements, including fixed height vehicle loading, vehicle loading at adjustable height terminals, passenger loading through the boarding ladder, and the vessel mooring arrangement.

2.1.1 Fixed Height Vehicle Loading

The calculation of the elevator operating range is dependent on pier geometry at each port, design tide heights (high and low) at each port, and the vehicle elevator and vessel geometry. Figure 2 shows the basic ship/terminal configuration. Due to the variability in both pier heights and tidal variations, each fixed pier was defined and analyzed.

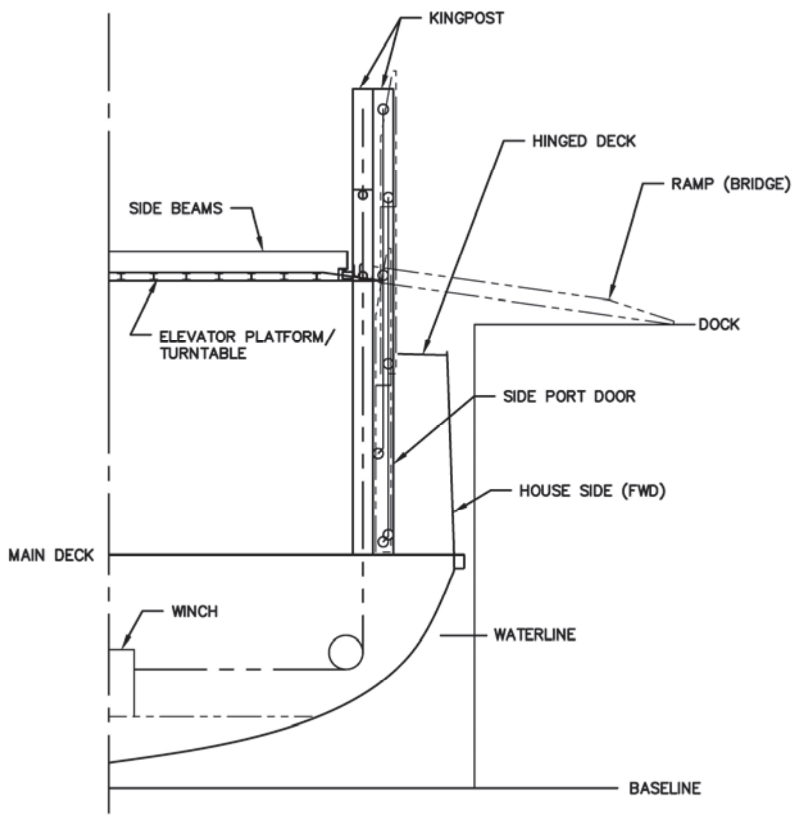

Figure 2 Configuration of vehicle elevator at terminal

The maximum vehicle elevator height is determined by a tide change of approximately 30 feet in Homer and Seldovia. All the remaining terminals have tide swings of closer to 15 feet. The vehicle elevator height could be substantially reduced by making the Homer and Seldovia terminals adjustable height docks. This effort would provide a cost savings of up to $3 million in vehicle elevator construction and maintenance cost. The issue of modifying the Homer and Seldovia terminals should continue to be monitored throughout the vessel design as a major design and cost constraint.

2.1.2 Vehicle Loading at Adjustable Height Terminals

Most of the AMHS vessel terminals owned by the State of Alaska have a vehicle loading system that adjusts for tide height. These adjustable systems are designed for standard AMHS vessel freeboards, which can vary by three or four feet. The *Tustumena Replacement Vessel*'s aft side doors and aft stern door are currently designed to fit into the terminals that require use of each door. Loading vehicles is a simple matter of driving them onto the vessel over the terminal transfer ramps.

Although mooring at adjustable side terminals is not a primary mission, the vessel's freeboard and ability to side load during light operating conditions will continue to be monitored during the design process.

2.1.3 Passenger Loading via the Boarding Ladder

As a design requirement, the *Tustumena Replacement Vessel* needs to provide passenger loading separate from the vehicle elevator. The terminal compatibility study assumes that walk on passengers will generally desire to be loaded onto the vessel using accommodation ladders and/or gangways.

The AMHS standard for this type of loading has not been fully defined. The study assumes that accommodation ladders are required and that maximum operation angle is 45 degrees to horizon, based on historical *Tustumena* documentation.

Unfortunately, passenger loading suffers from extreme tidal range problems similar to the vehicle elevator. For this study, the 10 year maximum and minimum tidal ranges and pier heights developed for the vehicle elevator are assumed applicable to passenger boarding. Similar to the vehicle elevator, the limiting high tide condition is assumed to be when the main deck is level with the pier.

The majority of the adjustable height terminals are owned and operated by the AMHS. The current practice at these terminals is to have passengers board the vessel using the terminal transfer ramps.

2.1.4 Mooring Arrangement

The vessel-to-pier interface was evaluated to verify that the *Tustumena Replacement Vessel* will fit at each pier. The depth sounding, fender contact, and mooring line arrangements were examined for each location.

Some piers have marginal fender spacing that is not reachable by the *Tustumena Replacement Vessel* at its currently designed length and these piers are not a good fit for this vessel. Oddly enough this occurs at State owned terminals like Auke Bay, Ketchikan, and Valdez, where the vessel can only contact two fenders about 90 feet apart. At these terminals, vehicle elevator operation is not required.

While all the focus of the fender contact is primarily forward of the vehicle elevator, one interesting aspect of this analysis is that the new vessel fit in all terminals could be further improved by increasing the length of the *Tustumena Replacement Vessel* aft of the vehicle elevator.

In general, most of the piers provide good mooring arrangements and three piers provide acceptable mooring. Only one dock was rated marginal and that is the Chignik terminal, which also has fender contact limitations. The Chignik terminal is intended to be replaced in the near future.

For terminals with extreme tidal ranges (like Homer) additional analysis is needed to examine the fleet angle of mooring lines in relation to the relative heights of mooring equipment.

2.1.5 Kodiak Pier 1 Access and Right of Way

A maritime access concern was raised by neighboring facilities to the Kodiak Pier I. To address this concern, additional research was completed on the Kodiak Pier I.

Figure 3 shows the existing mooring arrangement and the future mooring arrangements (*Tustumena* at new pier and *Tustumena Replacement Vessel* at new pier). This figure indicates that the proximity of the replacement vessel's bow to the adjacent dock in the future configuration is essentially unchanged when compared to the existing arrangement. However the proximity of the stern is approximately 35 feet closer to the adjacent float.

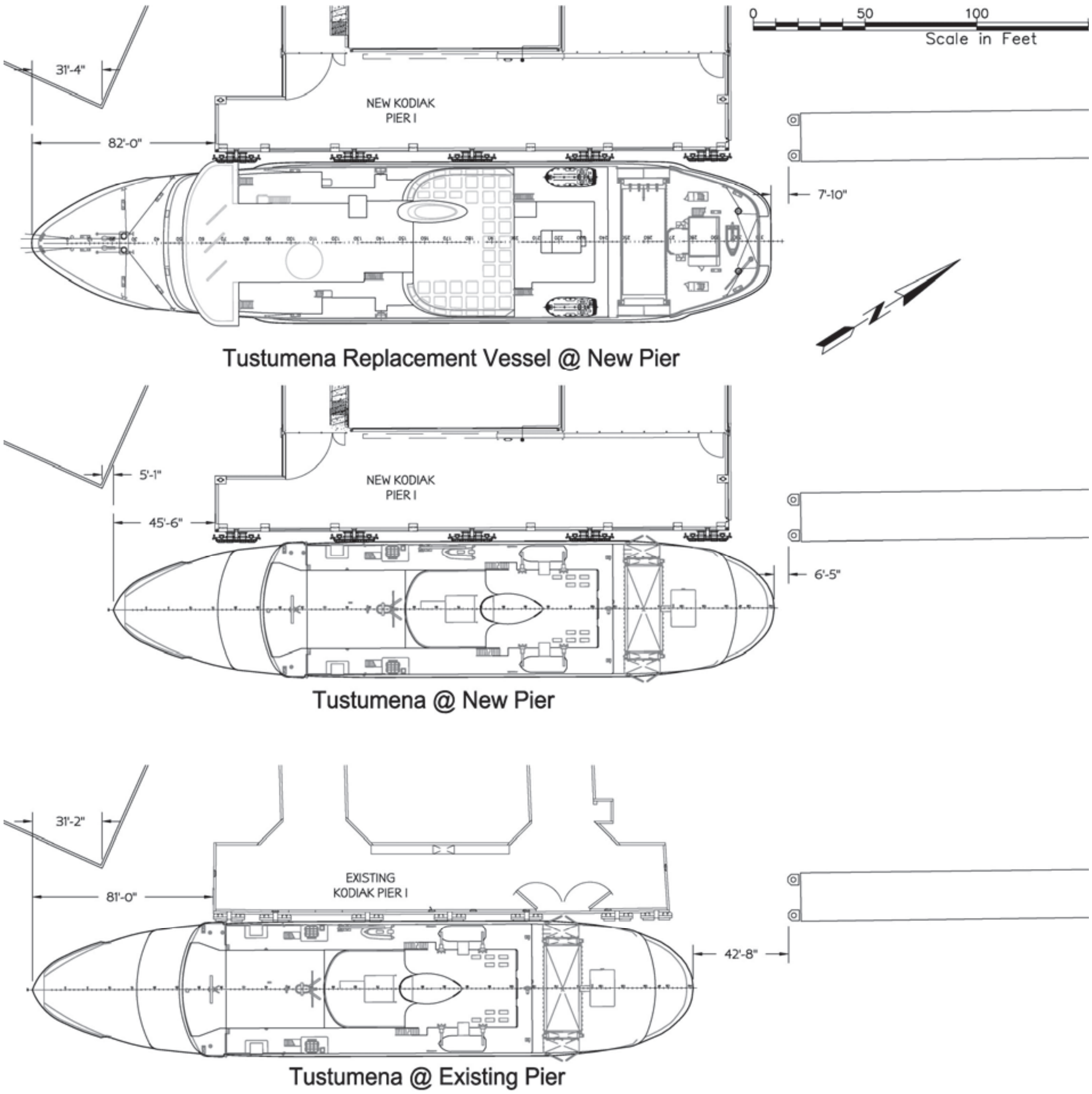

Figure 3 Kodiak Pier I mooring comparison

Based on a search of public records (Reference 11 and Reference 12) the property boundaries are as shown in Figure 4. All the lots associated with the Kodiak Pier I and adjacent properties are within Block 18 of the New Kodiak Subdivision.

- Lots 1 and 2 are owned by Harbor Marine.
- Lots 3, 4A, and 5 are owned by the City of Kodiak.
- Lot 6 is owned by Trident Seafoods.

It is interesting to note that, as shown in Figure 4, development in Lot 5 (owned by the City of Kodiak) could block any marine access to Lots 2 and 3 as well as partial access to Lot 4A. Based on discussions with the Kodiak Borough, all waters beyond the lot lines shown are the jurisdiction of the State of Alaska Department of Natural Resources (DNR). We are awaiting a response from DNR regarding regulations for marine access to these lots.

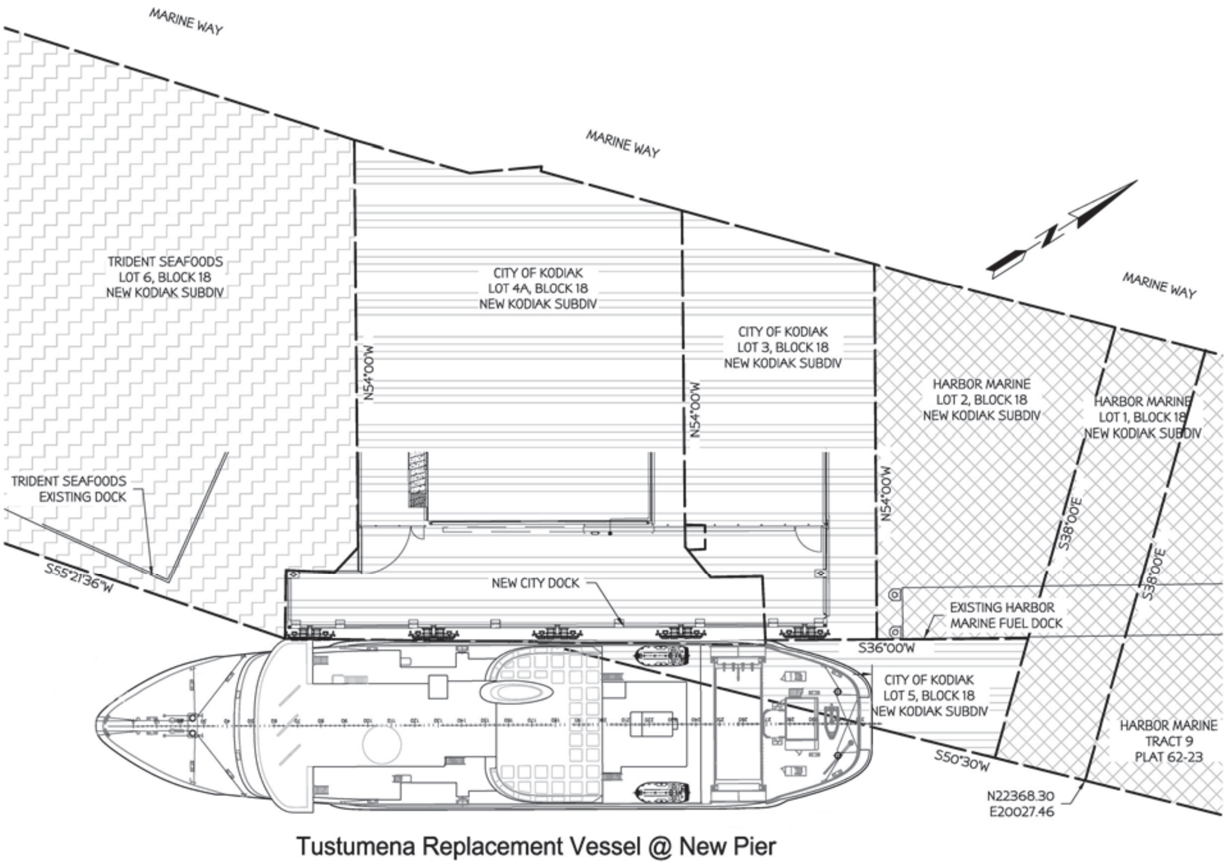

Figure 4 Property lines and lot ownership

As shown in Figure 4, the new Pier I is being built with the seaward face of the pier on the boundary of both Lot 3 and 4A. As the new pier is on the lot line, all the water beyond the new pier is either state navigable waters, or Lot 5 (owned by the City of Kodiak). This information indicates that neither the existing mooring arrangement or the future mooring arrangement will result in a vessel encroaching on private property while moored at the Kodiak Pier 1 terminal. However, the issue of marine access from navigable waters to private land may still be an issue and is a complicated subject. Since access to navigable waters from Lot 2 (privately owned) is blocked by Lot 5 (city owned), it is unlikely the owners of Lot 2 can pursue an access complaint. The only issue in this regard may be the navigable water access to Lot 6 (privately owned.) which is currently partially impeded by the bow of the vessel when moored. This topic is currently being further researched.

2.2 Passenger and Vehicle Traffic Demand

A key part of a vessel design process is the analysis of the payload capacity of the vessel. In a ferry design, the results of a traffic study are normally used to determine the capacity of the new vessel and subsequently its overall size. However, many of the ports that must be served by the *Tustumena Replacement Vessel* limit maximum vessel size and therefore limit the capacity of this vessel. In this case, the need to access ports supersedes the need to provide maximum carrying capacity. A complete traffic study was conducted and is provided in Appendix D.

In Appendix D, the vehicle capacity, passenger capacity, and quantity of staterooms were analyzed to determine the transportation effectiveness of the *Tustumena Replacement Vessel*. In general, this study is based on historic *M/V Tustumena* traffic data and a very rough approximation of latent demand. It is intended to forecast the traffic only in the near future, around the time of vessel delivery. An analysis of traffic over the life of the new vessel will require a more sophisticated analysis based on market surveys.

Due to the small number of vessels providing service, long travel distances, and remote locations, there are several transportation issues that are unique to Southwest Alaska. These issues must be considered when conducting an analysis of AMHS transportation in this region.

1. Service to the Kenai Peninsula, Kodiak Island, and the Aleutian Islands is almost solely provided by the *Tustumena*, resulting in essentially a one-vessel system.
2. Frequency of service is lower in Southwest Alaska than that provided in Southeast Alaska due to the fact that there is generally only one vessel operating on fairly long routes.
3. The amount of winter traffic in the Southwest system is significantly less than the amount of summer traffic, but winter traffic in the Southwest system (as a percentage of summer traffic) is generally greater than in Southeast.
4. The schedule of the *Tustumena* can impact the payload that is willing or able to purchase fares.
5. The service provided by the *Kennicott* between the Kenai Peninsula and Kodiak Island reduces the amount of traffic carried by the *Tustumena*.

2.2.1 Vehicle Capacity

2.2.1.1 Homer-Seldovia

The *Tustumena* currently has relatively low vehicle capacity utilization in the Homer-Seldovia service area. Due to the current lower utilization of vehicle capacity on the *Tustumena* in the Homer-Seldovia service area, vehicle traffic in this area is not expected to increase due to unforeseen latent demand. However, this analysis assumed that the *Tustumena Replacement Vessel* will carry four additional 40 foot vans on this route, which is equivalent to eight ASVs.

With the increase in traffic due to the four 40 foot vans, the *Tustumena Replacement Vessel* will likely have sufficient vehicle capacity to accommodate the vehicle traffic in the Homer-Seldovia service area.

2.2.1.2 Homer-Kodiak Island

The *Tustumena* currently has very high vehicle capacity utilization in the Homer-Kodiak Island service area, particularly in the summer. The vehicle traffic in this service area is greater than the capacity of the *Tustumena*.

Due to the high vehicle capacity utilization in the Homer-Kodiak Island service area during the summer, vehicle traffic in this area was increased due to likely latent demand. In addition, this analysis assumed that the *Tustumena Replacement Vessel* will carry four additional 40 foot vans on this route.

If the increase in traffic occurs as forecast, the *Tustumena Replacement Vessel* will likely be operating near capacity in summer service on the Homer-Kodiak route when it begins service. This analysis did not attempt to calculate the growth of traffic over the life of the vessel.

2.2.2 Passenger Capacity

As mentioned earlier, passenger capacity utilization in the Homer-Kodiak service area is greater than in all other Southwest Alaska service areas. Therefore, this study only analyzed passenger capacity utilization in the Homer-Kodiak Island service area. The *Tustumena* currently has sufficient passenger capacity for this service, although utilization is relatively high in the summer.

As the *Tustumena* currently has sufficient passenger capacity, it is assumed that there is no latent demand for passenger traffic. Since there will likely not be a significant increase in passenger traffic, the *Tustumena Replacement Vessel* has sufficient passenger capacity for service in Southwest Alaska.

2.2.3 Stateroom Capacity

Stateroom utilization was evaluated for the various routes, and with the increased stateroom capacity on the *Tustumena Replacement Vessel* results indicate that sufficient stateroom capacity will be available for the various service areas.

2.2.4 Mitigation of Future Traffic Growth

The traffic study results show that the *Tustumena Replacement Vessel* will likely be at or near full vehicle capacity utilization in some summer service areas at start of service, which suggests the need for a larger vehicle payload capacity. However, the size of the *Tustumena Replacement Vessel* is constrained by the ports in the Southwest Alaska service area, and cannot be significantly increased.

The Value Engineering review of the proposed new design suggested converting part of the Mezzanine Deck to vehicle stowage as well as stowing vehicles on the vehicle elevator platform during transit. Both of these options will increase vehicle capacity and will be designed into the new vessel during the next phase of the design.

Alternatively, in order to meet future vehicle traffic demand in the Southwest Alaska service area, the AMHS may need to use alternate methods to provide additional vehicle capacity. Possible methods of increasing vehicle transportation capacity are the increased use of small day-boats, or increased use of the *Kennicott* in Southwest Alaska.

2.2.4.1 Increased Use of Small Day-Boats

Currently, the AMHS relies on the *Tustumena* and *Kennicott* to provide service on short, low utilization routes such as Homer-Seldovia, and intra-Kodiak Island. This means that these vessels are not able to provide service on longer, high utilization routes, such as Homer-Kodiak and Kodiak-Dutch Harbor, with the necessary frequency to meet the traffic demand.

Using small day-boats on short, low utilization routes would allow the AMHS to no longer use the *Tustumena* or *Tustumena Replacement Vessel* and *Kennicott* for this service. These vessels could then be used to provide more service on longer, high utilization routes to meet the transportation capacity demand. The use of small day-boats for Homer-Seldovia service was previously studied by Seldovia Native Association. Small-day boats for Ouzinkie-Port Lions-Kodiak service was previously studied by McDowell Group and Coastwise Corporation.

2.2.4.2 Increased Utilization of *Kennicott* in Southwest Alaska

Use of the *Kennicott* in Southwest Alaska is not historically consistent. Although this service does increase the AMHS's transportation capacity in this region, the overall effect is likely reduced due to these inconsistencies. Increased, regular usage of the *Kennicott* in the Southwest Alaska transportation region, particularly on Homer-Kodiak service would decrease the amount of traffic required to be carried on the *Tustumena*, and would likely meet the traffic demand in the region. However, this change in service may have negative effects on the transportation capacity in the other AMHS service regions.

2.3 Manning Requirements

Minimum crew requirements are based on a combination of flag state requirements and AMHS standard practices relative to normal vessel operation, emergency response, and regular maintenance of the vessel. Two recommended manning levels were developed: one suited to selection of an ACC (automatic control certified) propulsion and machinery plant; and another suited to selection of an ACCU (automatic control certified *unattended*) propulsion and machinery plant.

A cost comparison was developed to calculate the increased construction cost of ACCU over ACC. It was estimated that an ACCU plant would cost in excess of $1.2 million more than an ACC plant, as shown in the table below.

Table 3 Construction cost comparison of ACC vs. ACCU

DESCRIPTION	LABOR (HOURS)	MATERIALS ($)	SUB-TOTAL ($)	MATERIAL MARK-UP	ESTIMATE CONTINGENCY	TOTAL
ACC vs. ACCU Cost Differential						
Additional Call Alarms/Monitors	200	$25,000	$40,000	$3,750	$8,000	$51,750
Additional AMS Points to Monitor (Sensors, etc.)	400	$50,000	$80,000	$7,500	$16,000	$103,500
Additional Cabling for AMS Components	2,000	$125,000	$275,000	$18,750	$55,000	$348,750
Additional Motor Operated Valves	600	$150,000	$195,000	$22,500	$39,000	$256,500
Additional Auto Pump Start/Stop Controls	400	$100,000	$130,000	$15,000	$26,000	$171,000
Additional Test/Trials	600	$25,000	$70,000	$3,750	$14,000	$87,750
Additional Shipyard Engineering		$100,000	$100,000	$15,000	$20,000	$135,000
Additional Regulatory Costs		$50,000	$50,000	$7,500	$10,000	$67,500
SUB-TOTAL	4,200	$625,000	$940,000	$93,750	$188,000	$1,221,750
LABOR RATE	$75	PER HOUR				
MATERIAL MARKUP	15%					
ESTIMATE CONTINGENCY	20%					

AMHS indicated that many aspects of the machinery plant will have ACCU-compliant elements, but the vessel will be operated with manning as an ACC vessel due to the operational demands of operating the vessel on remote routes with unique vehicle elevator operating procedures.

USCG 46 CFR 12 and 15 provide requirements for minimum manning levels. A manning spreadsheet, Appendix F, was developed with deck, engine, steward, and purser personnel categories. The specific regulatory references, interpretations/assumptions, and station bill duties are identified.

The minimum regulatory manning levels, recommended levels, and current *M/V Tustumena* levels are summarized in Table 4.

Table 4 Manning requirements ACC vs. ACCU

POSITION	CURRENT TUSTUMENA MANNING		TUSTUMENA REPLACEMENT VESSEL					
			ACC Notation	ACCU Notation	RECOMMENDED			
					ACCU		ACC	
	Summer	Winter	Summer	Summer	Summer	Winter	Summer	Winter
Master/Pilot	1	1	1	1	1	1	1	1
Chief Mate	1	1	1	1	1	1	1	1
Second Mate	1	1	1	1	1	1	1	1
Third Mate	2	2	1	1	2	2	2	2
Bosun Mate (AB)	1	1	1	1	1	1	1	1
Able Seaman	6	6	3	3	6	6	6	6
Ordinary Seaman	4	4	2	2	4	4	4	4
Patrolmen/Watchman	1	1			1	1	1	1
DECK	**17**	**17**	**10**	**10**	**17**	**17**	**17**	**17**
Chief Engineer	1	1	1	1	1	1	1	1
1st Assistant Engineer	1	1	1	1	1	1	1	1
2nd Assistant Engineer	1	1	1	1	1	1	1	1
3rd Assistant Engineer	2	2	1	0	0	0	2	2
Oilers / Juniors	4	4	3	0	0	0	4	4
Wiper	1	1	0	0	0	0	1	0
ENGINE	**10**	**10**	**7**	**3**	**3**	**3**	**10**	**9**
Chief Steward	1	1	1	1	1	1	1	1
Chief Cook	1	1	1	1	1	1	1	1
Second Cook	1	1	1	1	1	1	1	1
A/2nd Cook	1		1	1	1		1	
Head B/R Steward	1	1	1	1	1	1	1	1
Head Waiter	1	1	1	1	1	1	1	1
Other Stewards	4	2	4	4	4	2	4	2
STEWARDS	**10**	**7**	**10**	**10**	**10**	**7**	**10**	**7**
Chief Purser	1	1	1	1	1	1	1	1
Other Pursers	0	0	0	0	0	0	0	0
PURSERS	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
TOTAL CREW	**38**	**35**	**28**	**24**	**31**	**28**	**38**	**34**

The minimum regulatory manning level for an ACC vessel is 28, however, several additional factors need to be considered to determine the recommended manning levels. This considerations include:

- USCG mandated work/rest rules in concert with the crew callouts for vessel docking/undocking and loading/unloading operations.
- Numbers of Pursers and Stewards required to serve the crew and passengers.
- Collective bargaining agreements with vessel crew unions.
- Ability of the crew to perform on-the-run maintenance and incidental repairs.

The resulting recommended manning level meeting both ACC requirements and a minimum level of safe operation on the *Tustumena Replacement Vessel*, as defined by the Steering Committee and demonstrated by the *M/V Tustumena*, is 34 crew members in winter and 38 crew members in summer. The recommended crew breakdown is given in Table 4.

Section 3 Concept Vessel Design

3.1 Arrangement Concepts

3.1.1 General Configuration

This section reviews the major design concepts for the arrangements of the overall vessel, as well as its main deck, passenger accommodations, officer/crew accommodations, food service areas, and ADA accessibility.

Among the design goals for the vessel configuration were maximize vehicle and passenger capacity while separating functions and meeting the new Maritime Labour Convention (MLC) manning standards. Drawing No. 13105.05-070-01 in Appendix A shows the proposed vessel general arrangements.

Maximizing vehicle capacity requires using the entire main deck for vehicles. The vehicle area extends from the collision bulkhead to the transom with room only for a minimal casing and the vehicle elevator. The beam of the new vessel is too narrow for six lanes of traffic with a fire lane and a casing; therefore, a five-lane arrangement was adopted.

The desire to maximize vehicle capacity precludes having crew staterooms on the Main Deck. Spaces below the Main Deck would have limited access and the MLC requirement to have windows in all crew state rooms severely limits the quantity and location options. Creating the space needed for crew accommodations required either the adoption of mezzanine decks at the sides of the vehicle space or another deck above the vehicle space. The mezzanines work well with the five-lane arrangement and are supported structurally by an off-center casing to starboard and a line of stanchions to port. The alternative of adding another deck above the Main Deck would present serious challenges for stability and was not considered feasible within the overall size constraints of the vessel.

With the crew spaces on the Mezzanine Deck it was decided to place all passenger cabins on the Cabin Deck, and dining and lounge spaces above on the Boat Deck, similar to how the SE Alaska mainline AMHS vessels are arranged. The passenger staterooms are arranged in four person and two person configurations with private toilets and showers, and two person roomettes without private restroom facilities. Public toilets and showers are provided near the roomettes.

The passenger lounges are located forward in the traditional AMHS arrangement and are high enough to see over the bulwarks. The Galley serves both the crew and the passengers while also separating the two groups.

The top deck (Solarium Deck) has space for the officer staterooms forward and the Solarium aft. Security fences (exterior) and doors (interior) are provided so that the passengers cannot access the officer stateroom area from the interior or exterior of the vessel. The officer staterooms can be accessed by stairways separate from the main passenger stairs. The Pilot House is raised up from the Solarium Deck for improved visibility, with access provided from the officer stateroom area.

The Value Engineering review of the proposed new design suggested converting part of the Mezzanine Deck to vehicle stowage. Mezzanine Deck vehicle stowage will be designed into the new vessel during the next phase of the design.

3.1.2 Main Deck Arrangement Concepts

3.1.2.1 Interface with Docks

The new vessel is expected to interface with all docks served by the existing *M/V Tustumena* and the *M/V Kennicott*, including docks that may only be visited occasionally. The new vessel will therefore require a vehicle elevator capable of meeting the tidal range height with port and starboard side doors and a stern door. The vessel needs to carry ramps for interfacing the vehicle elevator with the piers of Southwest Alaska, while allowing shoreside ramps to be used at other AMHS facilities in Alaska. To the maximum extent practicable, shoreside facility modifications cannot be dictated by the vessel design and the vessel is required to interface with all loading configurations at each dock.

The Main Deck arrangement gathered elements from the current *M/V Tustumena* and *M/V Kennicott* to accomplish dock interfaces. A stern loading door will allow two lanes of cars to enter/exit through the aft of the vessel using existing shore ramps. The stern is a very specific shape to accommodate the stern door and fit all existing piling configurations. The hull in way of the elevator needs to be the full width so the stern expands abruptly to accommodate this. The expansion is at or above the guard while the hull below the guard remains fair.

The vehicle elevator will fit 53-foot vehicles, similar to the *M/V Kennicott*. This is equivalent to a 40-foot trailer with a small yard tractor. Larger trailers or tractors will have to load separately as on the current vessels. The vehicle elevator will also be capable of loading two lanes of cars, making it slightly wider than the current design. This will encroach on deck area of the vessel but will make loading cars significantly faster.

3.1.2.2 Vehicle Deck Capacity

One of the goals of the new design is to maximize the number of cars held on the Main Deck. The minimum design requirements are to maintain the same number of lane feet as the current *M/V Tustumena* (852') and the capability of loading twelve 40 foot vans.

Vans require significant overhead height to detach from the tractors. Structural members are often large to compensate for the long spans in the overhead of the vehicle deck. These requirements pushed the height from the Main Deck to the Cabin Deck to about 19 feet.

A centerline casing was originally discussed as a majority of AMHS vessels are designed in this manner. The large height requirement for the vehicle space created excessive void space with this centerline casing configuration as the entire deck would need to be full height. It was decided to pursue an offset casing to create a Mezzanine Deck, which would fulfill the van capacity requirement while allowing more deck area for other vessel requirements and satisfying the need for crew member accommodations above the Main Deck. See Section 3.1.4 for further discussion on the need for a Mezzanine Deck.

A single 36-inch fire lane is required to run the length of the deck. This is not found on the current vessel, but was requested by AMHS and satisfies ADA requirements. Based on optimizing the lane configuration, a minimum of 9-foot lane widths were utilized in the full height area for vans and large vehicles. Lane widths of near 10 feet for outboard lanes under the mezzanines were specified to allow more room for access. The design of the outboard lanes is similar to, but much roomier than, the area under the *M/V LeConte* and *Aurora*.

The design characteristics of the Main Deck were examined on scale arrangement drawings using vehicle maneuvering software. However, the accuracy of the vehicle maneuvering software is limited, particularly with regard to extreme angle maneuvers (such as a jackknife turn) of large semi-tractor trailer rigs. Therefore full scale testing was conducted at the AMHS facility in Ketchikan, Alaska, with results showing a typical passenger vehicle, tour bus, and tractor trailer will be able to load, offload, and maneuver on the *Tustumena Replacement Vessel*. The detailed test report is contained in Appendix G.

The Value Engineering review of the proposed new design suggested converting part of the Mezzanine Deck to vehicle stowage. Furthermore, the Value Engineering review also suggested stowing vehicles on the vehicle elevator platform while underway. These two recommendations will be incorporated during the next design cycle and will increase vehicle capacity from 52 vehicles up to at least 60 vehicles.

3.1.3 Passenger and Crew Spaces

3.1.3.1 Public-Workspace Matrix

A matrix of all spaces in the vessel was developed to compare the proposed replacement with the original *M/V Tustumena* design. Please see Appendix S.

3.1.3.2 Boarding and Disembarking

The arrangements have been designed so that any person entering shall have an obvious path through the common areas of the vessel, including the Foyer, Galley, various lounges, and restrooms.

The forward elevator and stair tower are the primary means of passenger flow between various decks. The main stair tower leads up from the Main Deck and opens into the Cabin Deck near the Foyer and Purser's Office. Passengers boarding in cars will be directed to the forward part of the casing while passengers on foot will be directed to the boarding ladder which leads directly to the Foyer on the Cabin Deck. This allows the Purser's Office to be the main point of entry for everyone. Cabins can then be purchased and found on the same deck. Those passengers not purchasing cabins will continue up to the Boat Deck or Solarium where the remainder of public spaces are located.

In low tide, high pier situations, the Cabin Deck will be below the level of the pier and inaccessible to direct access from the boarding ladder. The boarding ladder will slide up to either the Boat Deck or the Solarium Deck allowing passengers on foot to continue to board. Foyers are located on these upper three levels to receive passengers from the boarding ramp. If the Cabin Deck is not the boarding location, passengers will be directed to the Purser's Office by utilizing the main forward stair tower or elevator.

The solution of using two elevators complicates arrangements, but segregates passengers and crew, and is thus an ideal solution. The arrangement of having the passenger elevator forward and service elevator aft was dictated by practicality. The service elevator was required to access the store rooms below the Main Deck and the Galley on the Boat Deck directly. Placing the service elevator forward would require moving the Galley as well as stores forward of the machinery spaces, which was briefly discussed but deemed a less advantageous arrangement.

3.1.3.3 Emergency Equipment

Based on an operational limit of 50 nautical miles from shore, the lifeboats are allowed to have a capacity of 48 persons on each side. Additional life rafts will be carried in place of larger boats for the remainder of the required complement. The lifeboats will be stored aft of the Solarium in order to not disrupt the view for passengers or line of sight from the Pilot House.

The lifeboats will be registered as rescue boats. This will provide more flexibility while eliminating the requirement for an additional rescue boat on each side of the vessel. A single service work boat handled by a davit will be stowed aft of the Elevator Control Room.

Lifeboats will be boarded on the Boat Deck in order to allow mustering in public spaces such as the Dining Area and forward lounges. The two main stair towers will be sized appropriately on each side of the Main Vertical Zone (MVZ) to allow passenger embarkation.

Evacuation slides will be used for boarding the life rafts from the Boat Deck. Liferaft Systems Australia (LSA) evacuation slides contain a single 100-person raft in each deployment container. Additional rafts will be placed to the side of the slides for deployment in case of emergency. The evacuation slide system has a maximum height above waterline of 44.6 feet. This height requirement must be maintained in the lightest undamaged sea-going condition and take into account unfavorable conditions of list and trim. The Boat Deck meets the requirements of the slide while allowing easy access from mustering stations.

3.1.3.4 Public Spaces

The arrangements were developed to segregate the public areas from the passenger cabins as well as the crew spaces. This was accomplished by having a dedicated Cabin Deck and placing most public spaces on the deck above. The Galley on the Boat Deck segregates public spaces forward and all crew/officer spaces aft. This also allows the Forward Observation Lounge to be above the Cabin Deck in order to see over the bulwarks and provide optimal viewing areas for the passengers.

Public space areas were scaled from the current *M/V Tustumena* arrangements based on increased passenger capacity. The initial intention was to start with the same spaces as the current vessel and add any necessary spaces based on AMHS input. It was indicated public spaces aft of the vehicle elevator on other vessels were not utilized and these should be reserved for crew or machinery areas.

The Forward Observation Lounge extends across the entire width of the Boat Deck at the forward end of the house. No railings or bulwarks are placed in front of the windows which are located low enough to provide a good view while seated. Booths are located at the back of the space while the majority of the lounge is dedicated to aircraft type seats.

Side lounges are located port and starboard aft of the main lounge. They are physically all in the same space but are divided by glass partitions and arranged with half height walls to provide a degree of separation. The starboard side lounge has an area designated as a children's play area with the remainder taken up with tables, chairs, and booths. The port side lounge has booths inboard along the half height wall and aircraft seating outboard. A small theater is located between the two side lounges. Both the theater and the port side lounge may be used for special events for limited groups without disturbing passengers in the main lounge.

The Galley/Dining facility will be cafeteria style, very similar to the arrangement on the *M/V Columbia*. This style dictated arrangements with the dining area just forward of the Galley for easy access from the lobby. A single serving line will provide hot food on one side and cold beverages on the other. The cashier will be placed at the end before entering the Dining Area. The serving line will be able to be secured after dining hours while still providing access to the Dining Area for passenger use at all times.

Beer and wine sales are being considered for the Galley/Dining facility during meal times only. It will be necessary to restrict beer and wine consumption to a location in the dining area where consumption is able to be monitored by the galley crew.

The Dining Area is separated into two parts by the offset casing. Both contain tables and chairs, including ADA-accessible locations. In addition, the port side has six person booths and the starboard side has benches along the windows. The outboard bulkheads are lined with windows for good lighting and views. The connecting door may be closed for special events.

The Solarium and the adjacent deck space constitute the primary area for the passengers to be outside while still somewhat sheltered. The Solarium is large and split in two parts, port and starboard, by the public restrooms and stack. The Solarium is cantilevered out to the vessel sides to provide an improved view forward. It has aft wind break bulkheads and the window area in both the sides and top is maximized.

3.1.3.5 Passenger Staterooms

The new vessel carries a mix of four- and two-passenger staterooms. The quantities were proportioned from the existing *M/V Tustumena* based on passenger complement and then adjusted to have a greater proportion of two person staterooms. The four-person staterooms all have private toilet and shower facilities incorporated into the rooms, while the two-person staterooms are split between those that have private restroom facilities, and roomettes, which do not. Roomettes are expected to be a popular choice for the short overnight Southwest Alaska runs. For ease of cleaning, the roomettes will not contain lavatories or trash cans.

The size of the four person staterooms was taken from the *M/V Tustumena.* This is a minimal size but fits the arrangements well. The two person staterooms are proportionally larger. The roomettes are sized similarly to the *M/V Kennicott.* Public toilet and shower facilities are located adjacent to the roomettes.

3.1.3.6 Access

Original concepts split the Main Vertical Zone (MVZ) bulkhead (i.e. fire boundary) down the middle of the vessel. Originally, a single stair tower was positioned to serve both sides of the MVZ. This stair tower would be required to meet special regulations for width based on passenger egress and fire protection. Boarding of passengers into the main foyer on the Cabin Deck was required to spread the breadth of the vessel. Due to the casing and foyer requirements, arrangements became too complicated to support a single stair tower approach.

The original stair tower was split into two smaller stair towers on each side of the MVZ. These will be sized for the appropriate number of people required to utilize them for embarkation of lifeboats in an emergency.

American Bureau of Shipping (ABS) requires SOLAS calculations for landing area requirements of the stair towers. This requirement will drive the area of the stair towers to be quite large, but was considered in the design.

3.1.4 Officer/Crew Accommodation Concepts

MLC standards require crew to be placed on the Main Deck or above. While the US has not yet ratified or implemented the Convention, the USCG issued Navigation and Vessel Inspection (NVIC) 02-13 that provides compliance guidance for vessel owners (Reference 4). While MLC requirements are not yet mandatory, it is prudent to design the vessel to be compliant since the USCG may deny acceptance of the arrangements if the Convention enters into force prior to vessel construction.

In order to maximize vehicle capacity, crew staterooms were not placed on the Main Deck. In order to accommodate the number of crew, a mezzanine level was required to provide maximum deck area for vehicles while preventing the need for another full deck above the Main Deck for crew accommodations. The crew staterooms are arranged with pairs of mostly two person (double) staterooms sharing a toilet/shower space. Lavatories are in the staterooms. While most of the crew staterooms are arranged as doubles, the number of crew staterooms was maximized in order to allow as many staterooms as possible to be used as single staterooms.

The officer staterooms are similar to those on the *M/V Tustumena*. Four crew are required to have separate offices and the arrangements have been expanded in area to accommodate them. The officer staterooms are located on the Solarium Deck aft of the Pilot House, with the exception of the Purser and Steward staterooms located on the Cabin Deck. All officer staterooms have individual toilet and shower facilities.

In addition to the staterooms there are laundry and training rooms provided for the crew on the Mezzanine Deck.

3.1.5 Americans with Disabilities Act (ADA)

3.1.5.1 Access

The intent of the vessel design is to meet the ADA requirements and provide the same experience for disabled persons on the vessel to the extent possible within the limitations imposed by the marine environment. A portion of staterooms and heads will be configured for ADA passengers according to the regulations.

The forward passenger elevator was carried from the Main Deck all the way to the Solarium Deck in order to allow access for everybody. This altered the original arrangements for officer cabins and access to the Solarium Deck as the offset casing puts the elevator near the edge of the deck. It was important to incorporate this capability in the design and some side effects were inevitable.

3.1.5.2 ADA Compliance – Regulatory Overview

A summary table outlining the accessibility of the current vessel general arrangements is included in Appendix S. A full report addressing the ADA regulations is included in Appendix M.

The accessibility guidelines for passenger vessels covered by the Americans with Disabilities Act (ADA) will, in the future, be set forth in an appendix to the *Passenger Vessels Accessibility Guidelines*, US Code of Federal Regulations, Title 36, Part 1196 (Reference 5). Currently however, Part 1196 of CFR Title 36 is "reserved." Once these guidelines are established, the U.S. Department of Transportation (DOT) and U.S. Department of Justice (DOJ) are then required to issue accessibility standards for the construction of passenger vessels covered by the ADA that are consistent with the Part 1196 guidelines. We note here that the DOT regulations applicable to passenger vessels, addressed in 49 CFR 39 (Reference 6), discuss requirements for providing assistance to passengers with disabilities, but the subpart intended to deal with actual accessibility design standards for vessels (Subpart E - Accessibility of Vessels) is currently "reserved". Nonetheless, passenger vessel owners and operators will be required to comply with the published standards, once they are promulgated.

The Passenger Vessel Association is presently developing a proposed comprehensive set of guidelines that contain scoping and technical requirements for accessibility to passenger vessels by individuals with disabilities. For now, the proposed Passenger Vessel Association Accessibility Guidelines (hereafter referred to as "AGs," Reference 7) is the primary useful source for detailed ADA compliance guidelines for passenger vessel design. Presumably, these guidelines will form the basis for the Part 1196 guidelines and related DOT and DOJ standards for passenger vessels to be included in the CFR in the future.

At 237 pages, the AGs are extensive and cover the gamut of accessibility issues in great detail. While our design team will be monitoring design carefully to ensure compliance with all applicable provisions of the AGs, the following are considered the most germane accessibility guidelines pertaining to the preliminary design of the *Tustumena Replacement Vessel*:

- Boarding System - The vessel will be required to have a boarding system and onboard accessible routes that ensure that each passenger deck and passenger amenities (e.g., staterooms/roomettes, solarium, dining room, child play area, public restrooms, etc.) within each deck are ADA accessible. As a practical matter, the only means by which each passenger deck can be connected for ADA accessibility is through use of a passenger elevator system. Only one accessible route is required between decks however, meaning that only one elevator system would be required for passenger use.
- Stateroom Features - The *Tustumena Replacement Vessel* design currently provides for 43 passenger staterooms, including roomettes. Based on this total number of staterooms, two (2) staterooms with mobility features and four (4) with communication features[1] will have to be provided. The current design has two (2) 2- person ADA-compliant staterooms and one (1) 4-person stateroom so meets the mobility features requirement. At least one of the

[1] Communication features include separate audible notification appliances to alert stateroom occupants of general emergency and smoke alarm activation, visible devices to alert occupants of a phone call (if phones are provided in staterooms), and a visible device to alert an occupant to a knock on the door or the ringing of a door bell.

staterooms has to have both types of features. Moreover, each stateroom with mobility features must be equipped with a tub or shower, but showers need not be roll-in type. There are related requirements governing access to the sides of stateroom berths - either to one or both sides pending on berth arrangements - which will need to be considered as design of each ADA stateroom or roomette proceeds. Similar issues apply to details of facilities within the rooms.

- Stateroom Dispersion - Notwithstanding that only two passenger staterooms with ADA mobility features are required based on total passenger stateroom/roomette count, there is a separate expectation in the AGs that ADA features be "dispersed," such that individuals requiring ADA services are given choices comparable to the choices provided to other guests. Priority is given to ensuring that comparable choice be provided relative to guest room type, number of beds, and amenities, in that order. Because the *Tustumena Replacement Vessel* is intended to have three types of guest rooms (four person, two person, and roomette), this hierarchy requirement with respect to dispersion suggests that:
  - It may be desirable, although not required, to have at least one roomette configured as an ADA-compliant space incorporating both mobility and communications features. In any case, at least one roomette should have the required communications features.
  - Of the two ADA-compliant staterooms required to be equipped with a shower or tub, one could be a four person unit and one could be a two person unit, or alternatively, both could be four person units. In either case, at least one unit must incorporate both mobility and communication features.
- Stateroom Selection - Providing a disabled person with an ADA 4-person or ADA 2-person stateroom in place of an ADA roomette, or providing an ADA 4-person stateroom in place of an ADA 2-person stateroom, does not provide the disabled passenger with the same choice and equivalent experience available to other guests. However, the offered alternative could be considered an "upgrade" in experience that would be welcomed, assuming it was provided at no additional cost. As such, supplying only two ADA staterooms, each being of 4-person type, would be an acceptable means of achieving ADA intent through use of only the minimum required number of ADA staterooms that incorporate mobility features. Configuring for two 4-person ADA staterooms also affords the opportunity to meet the needs of two families that may require sleeping accommodations for 3 or 4 persons in an ADA mobility-compliant environment - an option that is not afforded by roomettes or 2-person staterooms. On the other hand, where a disabled person does not require or possibly even want toilet/shower facilities or extra berths in his/her stateroom, then having only 4-person ADA mobility-compliant staterooms available is wasteful in terms of both lost capacity and under-utilizing available sleeping accommodations; and, again, it would not tacitly comply with the AGs guidelines for "disbursement" with respect to guest room types, number of beds, and amenities.
- Public Spaces - Public spaces and amenities available to the general public must also be available and provide the same general level of experience for persons with disabilities. These public spaces and amenities include: lounges, bars, dining areas and condiment stations, public restrooms, Purser's service counter, theater, solarium, and first aid room. Entertainment systems including audio components, such as the theater movie system and televisions distributed throughout public areas, should incorporate features for the hearing-

impaired to the extent that audio is available to the general public at such locations. Viewing options for mobility-impaired passengers should be comparable to that available to the general public.

- Emergencies - Methods for disembarking persons with disabilities in case of an emergency, using the available lifesaving appliances, will need to be given thoughtful consideration. Requirements will apply with respect to providing routing for stretchers and stretcher bearers to the lifeboat/rescue boats and the marine evacuation slide systems. Note that requirements pertaining to this topic are not included in the AGs but rather are found in the CFR and related IMO regulations covering lifesaving appliance installations.

As alluded to previously, there are also myriad guidelines in the AGs pertaining to the design of vessel. Such requirements address appurtenances such as showers, sinks, drinking fountains, and handrails; passenger facilities and spaces such first aid/medical rooms, laundry rooms, toilet and bathing facilities, arcade game areas, and child play areas; and details of vessel arrangement and construction, such as requirements for walking surfaces, clear deck space, turning space, changes in level, knee and toe clearance, doorway clearance, restrictions on protruding objects, signage, and requirements to ensure that thermostats, light switches, door operators, and other passenger-operable parts can be reached and operated by passengers with disabilities. These are second-order design considerations that will be addressed more fully as design proceeds beyond the preliminary stage.

The current arrangements have two (2) 2-person ADA staterooms with ADA toilet and shower and one (1) 4-person stateroom with toilet and shower. Wheel chair spaces are provided throughout the vessel. The Forward Observation Lounge has spaces for three wheel chairs. Each side lounge has a space, one with a table. The Dining area has three spots for wheel chairs.

3.2 Hull Form

3.2.1 General Configuration

The hull form is designed to meet a complex and conflicting set of requirements. It needs to provide enough buoyancy to support the weight of the vessel while providing enough space for the interior arrangements. It must fit into all proposed ports-of-call with a maximum allowed length and draft and a very constrained freeboard. It must have enough stability to meet all regulations and good seakeeping for all weather conditions. It must do all of the above while having the least possible resistance for maximum speed at minimum power. Application of these complex requirements to the vessel design is discussed in the following sections.

3.2.1.1 Length

Initially AMHS prescribed a maximum length of 325 feet as this length is believed to fit at all the piers and will also be able to maneuver in all the ports. Since increased length will always lower resistance and provide the maximum amount of capacity, 325 feet was chosen as the design length.

Waterline length was maximized within this length by selecting short overhangs relative to other vessels in the AMHS fleet. The initial recon phase arrangements were done at this length and had most of the desired features, but used a 48 foot long elevator. When the elevator was changed to 52 feet for better vehicle handling, five feet was added to the length of the vessel to accommodate it without reducing vehicle storage capacity.

It was felt the final length of 330 feet would still be maneuverable enough while the piers could still accommodate this longer vessel. Because the length of the bow was more of a problem than the stern, the extra length was added aft of the elevator so the bow did not extend past the end of the dock any more than on the initial concept design described in the Recon Report, Reference 1.

3.2.1.2 Draft and Freeboard

The initial draft requirement of 15'-6" was driven by the depth at the entrance to Seldovia. The maximum freeboard in a light condition to use the side ramps in Southeast Alaska is 10'-6". The sum of the max freeboard, the max draft, and the difference between full load and light conditions gave a hull depth of 23 feet.

As the design progressed and the displacement grew along with the design margin, it became apparent that a draft of 15'-6" could not provide enough buoyancy with a reasonable hull shape. A decision was made, in concurrence with the AMHS Steering Committee, to allow a draft of 16'-6" and work within the operational constraints that this would impose. With the additional draft, the hull depth was increased to 24'-6". The extra 6 inches was obtained by having a stricter limit on the fuel loadings. The extra depth allowed the arrangement of two deck levels in the engine rooms, greatly increasing their effective size. The vessel may have to carry additional ballast or fuel in its light condition to meet the freeboard requirements of some facilities in Southeast Alaska.

3.2.1.3 Weight and Longitudinal Center of Gravity

The weight and LCG are ever changing as the design progresses. Design margins effectively manage the weight changes as experience shows that the weight on average always increases. The LCG shifts are more difficult to predict and neither direction, aft or forward, is better than the other. As a result, the hull design has the LCB aligned with the latest LCG estimate in order to produce small trims. It is expected that future LCG shifts will increase the design trim and therefore the need for trim ballast.

3.2.1.4 Beam

Greater beam results in increased stability and increased area for arrangement changes. Both are very important, but more beam also results in a reduction in seakeeping, higher accelerations, and an increase in resistance. The optimum solution is to have the least beam that has adequate stability while allowing a workable arrangement.

The initial design beam of 68 feet seemed to meet all these requirements, however a closer look at stability and weight margins prompted an increase to 70 feet. This was accomplished by increasing the beam at the vehicle deck through increased hull flare and tumblehome.

3.2.1.5 Vehicle Deck Arrangement

The Main Deck is designed to carry the maximum number of vehicles while incorporating the vehicle elevator and having enough space left over for an adequate casing. The five lane arrangement with an offset casing worked well and was chosen for this design. This produced a minimum workable beam and also required enough beam forward and aft to allow vehicles to maneuver around the casing and provide adequate room to install and operate the vehicle elevator with loading ramps.

The vessel interface with the various piers also produced a hull form with extended parallel sides to allow adequate fender contact in all locations. The requirement to dock at piers with stern loading arrangements produced a very specific stern shape to fit in all the piers with good fender contact. The resulting main deck plan shape was fixed at this point and all hull shape changes were made to lower parts of the hull.

3.2.1.6 Prismatic Coefficient

The prismatic coefficient is based on the speed of the vessel compared to its length, the Froude number, and also varies a small amount based on the style of hull form. Given all the constraints above, the prismatic coefficient was adjusted to produce optimum values for reduced resistance. The prismatic coefficient is changed by making the bow and stern fuller or finer compared to the midships section.

3.2.1.7 Resistance and Powering

In addition to varying the prismatic coefficient, a bulb was added to the design. The length and diameter were determined based on empirical studies of bulbs on other vessels. It was then blended into the hull lines. It is not expected that the initial bulb will be the final design. The bow shape and bulb will get considerable attention during the hull optimization phase.

The lines at the stern were specifically drawn to provide the maximum space for the propeller consistent with adequate blade immersion and minimum baseline clearance. The largest propeller maximizes efficiency.

3.2.2 Hull Optimization

The hull form defined above was used for all aspects of this preliminary design iteration and is presented as the Hull Lines and Appendages Drawing (No. 13105.05-070-02) in Appendix A.

Towards the end of this project phase, the hull form was sent to FutureShip for optimization. The optimization takes the starting hull as a baseline and uses a computer to vary the shape within bounds provided by all the constraints detailed earlier in this section. The computer uses advanced algorithms to produce faired hulls which have buildable shapes so that the results are usable in a practical manner. The computer is able to produce a multitude of variations, each with a small change in shape, and then predict the resistance. Using the results of each shape change the computer can recognize trends and explore promising modifications. The resulting hull forms are presented to the naval architect for final selection.

The hull forms were evaluated at two displacements and two speeds. A weighted average of the four conditions was made to compare the various hulls. The displacements and speeds are shown below in Table 5. The different displacements represent light and full load conditions and the speeds represent a typical cruising speed and a top speed. It was important to select a range of speeds to ensure a hull that will operate well in a variety of conditions.

Table 5 Optimization conditions and weighting

Speed (kt)	Displacement (LT)	Weighting
15.0	4620	35% (each displacement)
16.5	5460	15% (each displacement)

The initial optimized hull form presented had an average resistance reduction of 17%. It achieved this with a reduction in prismatic coefficient and a very narrow bow. This bow had inadequate parking area forward resulting in a loss of vehicles. Attempts to widen the bow produced large flare angles and a concern about bow accelerations and slamming. The optimization was partially re-run with additional constraints on the flare angle and the main deck widths. The flare angle limit chosen was 40 degrees, similar to that on the Kennecott.

A new optimized hull form was produced with a bow area between the sizes of the original hull and the first optimized hull, Figure 5. This bow can be arranged with the same 52 vehicles but retains most of the resistance benefits. The weighted average resistance reduction is 14% from the original hull form. Appendix V contains the final report from FutureShip describing the hull optimization methodology and results.

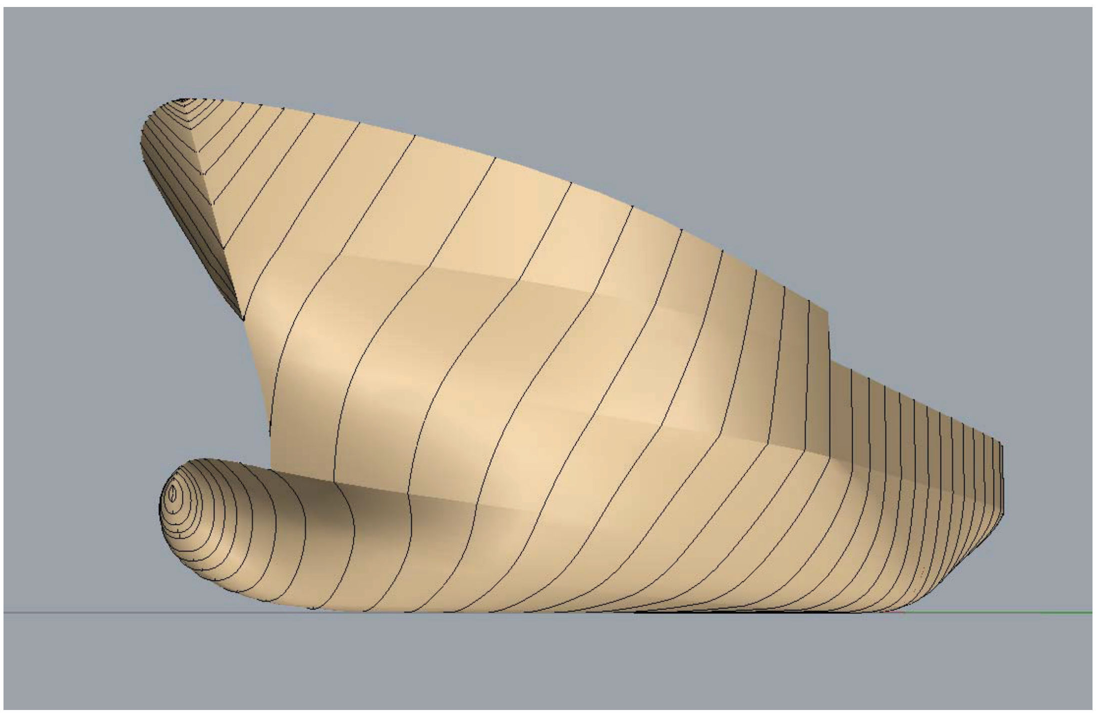

Figure 5 Optimized hull form

In addition to checking the main deck parking capacity and flare angles, a check of parametric rolling and floodable length were performed. The parametric rolling criteria used was the proposed IMO 2nd generation intact stability rules (Reference 14). These rules are not yet final and will not apply to this vessel by regulation but provide a method of performance comparison to other vessels. The floodable length calculation showed no required changes in bulkhead positions.

The resistance reduction of the selected hull form will be confirmed by CFD calculations in the next phase of the design.

3.2.3 Resistance

3.2.3.1 Resistance

The base, non-optimized hull form was used to estimate speed and power requirements. Parametric calculations were used for both resistance and propeller design. Navcad was used to implement the various parametric estimating methods.

3.2.3.2 Residuary Resistance

There are scores of parametric resistance methods which are based on series of model tests. Some series use a wide range of hull shapes while most are very specific to a certain type of hull form. It is essential to use a model series that resembles the desired hull. The general series tend to be applicable to a wide range of hull shapes but do that at the expense of accuracy. Specific model series can be very accurate but only when used for hulls of the correct shape. The applicable series is typically selected based on the ranges of parameter values that the series author reports as being appropriate to his regression analysis. Every series has a different set of parameters.

There were four series applicable to this design. The Holtrop series uses a wide range of hull type and the rest are very specific to type. All four were tried and the worst case selected. The Holtrop prediction was 75% of the drag predicted by the Fung CRTS, Reference 8, which was selected. All the series had some parameter out of range. The CRTS, originally intended to cover round-bilged transom-sterned naval vessels, is set up for sharper entry angles, less than 20 degrees rather than the 23 degrees in our case, and smaller bulbs. There is a lot of room for improvement in the resistance prediction which will be addressed with a CFD analysis of the optimized hullform.

3.2.3.3 Friction Resistance

The standard ITTC friction curve was used to calculate the frictional resistance based on Reynolds number. The method used the standard correlation allowance of 0.0004.

3.2.3.4 Appendage Resistance

The Holtrop method of appendage drag prediction was used, Reference 9. This method calculates the actual wetted surface of each component compared to the hull wetted surface, and scales the hull drag based on Froude number.

3.2.3.5 Wind Resistance

The Taylor method of wind drag prediction was used, Reference 10. This method calculates the projected area for head winds and applies a flat plate drag coefficient. Table 6 shows the weather conditions used for this analysis.

Table 6 Weather conditions

	Wind (kt)	**Wave Height** (ft)	**Wave Modal Period** (s)
Calm	0	0	0
Sea State 4	19.0	6.2	8.8
Sea State 5	24.5	10.7	9.7

3.2.3.6 Wave Resistance

The Small Naval Series wave resistance model was used, Reference 13. The hull parameters met the required ranges and this method gave the highest resistance of all the available methods.

3.2.3.7 Total Resistance

The various resistance components are added together to get the total resistance. Figure 6 shows the total resistance curve in blue along with its major components, hull resistance in green, and appendage resistance in red.

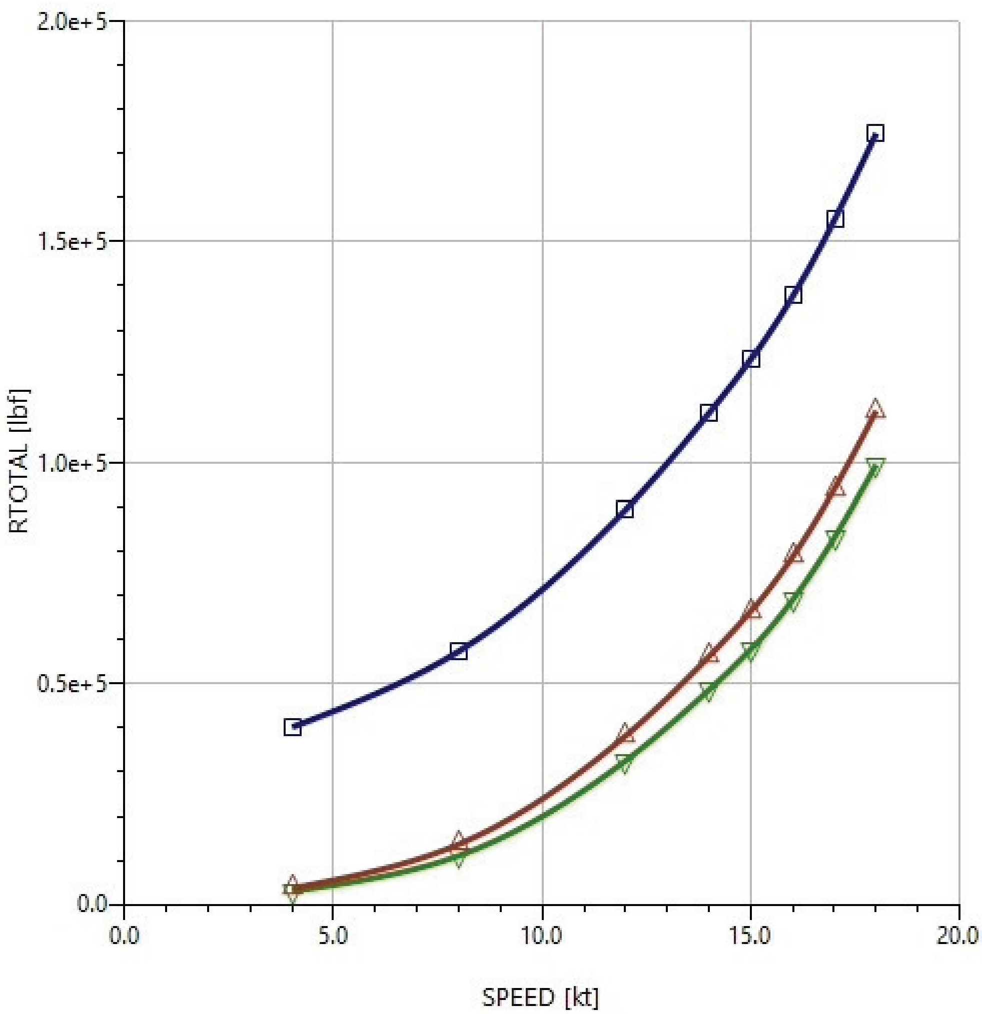

Figure 6 Resistance curves

3.2.4 Speed and Power

To predict the speed based on the resistance it is first converted into a power, EHP. The propeller is selected based on the allowable diameter and a balance of speed, RPM, and pitch. The power delivered by the propeller is increased to account for the gear and shafting losses to give the engine power per shaft, BHP.

The maximum propeller diameter that would fit with adequate tip clearances was used. A tip clearance of 20% was used. A reduction gear ratio of 4:1 was selected to achieve reasonable tip speeds for the diameter of propeller selected at the main engine RPM. As a CPP propeller was requested for maneuverability, the pitch was allowed to vary for the different weather conditions. The pitch selected was sized to produce 3800HP. This allows the main engines to run at 92%MCR with an allowance of 500BHP for the PTO generator on each engine. Other pitches could be selected with a resulting change in vessel speed.

Table 7 Propeller

	Reduction	Diameter ft	Pitch ft	Area Ratio	Speed kt
Calm	4:1	10	0	0.589	17
Sea State 4	4:1	10	8.8	0.623	15
Sea State 5	4:1	10	9.7	0.664	13

The propeller blade-area ratio is calculated to produce an acceptable level of cavitation. The cavitation is estimated at 5%. As it cannot be changed with the pitch, the largest blade area will be selected.

The power needed for propulsion was calculated for different engine RPMs and plotted with the engine power curve for comparison. A curve was generated for each weather condition, see Figure 7 through Figure 9.

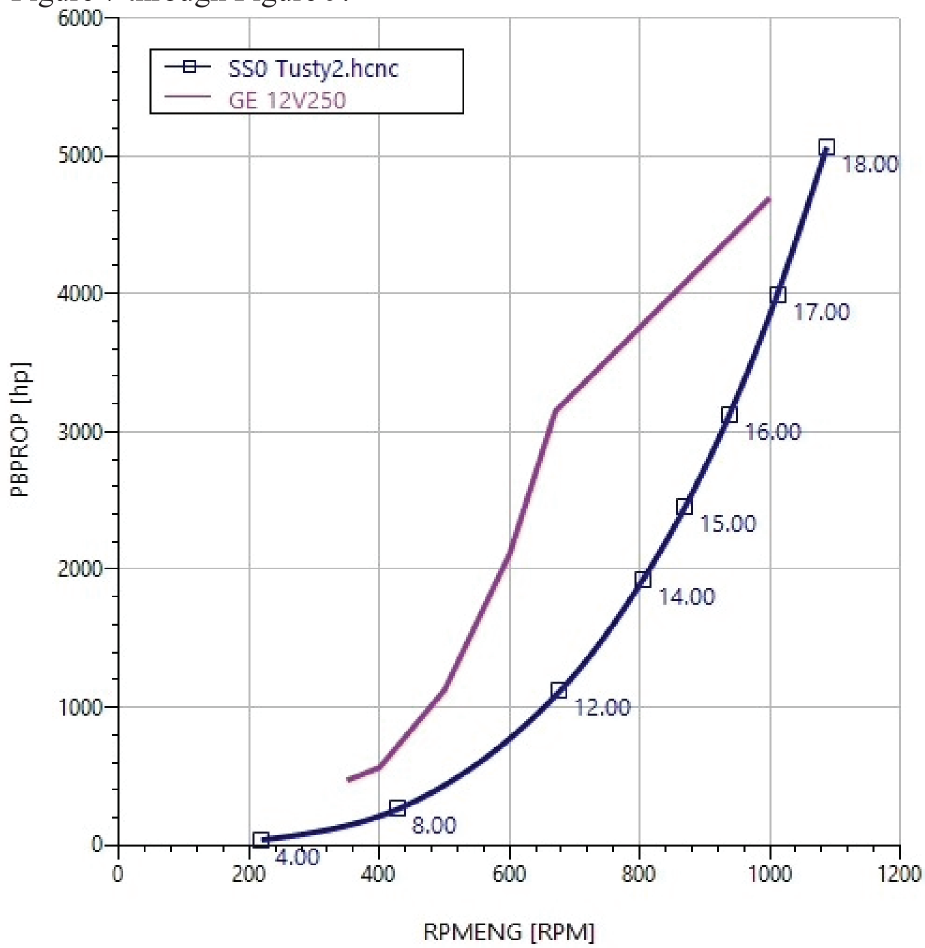

Figure 7 Speed-Power – Sea State 0

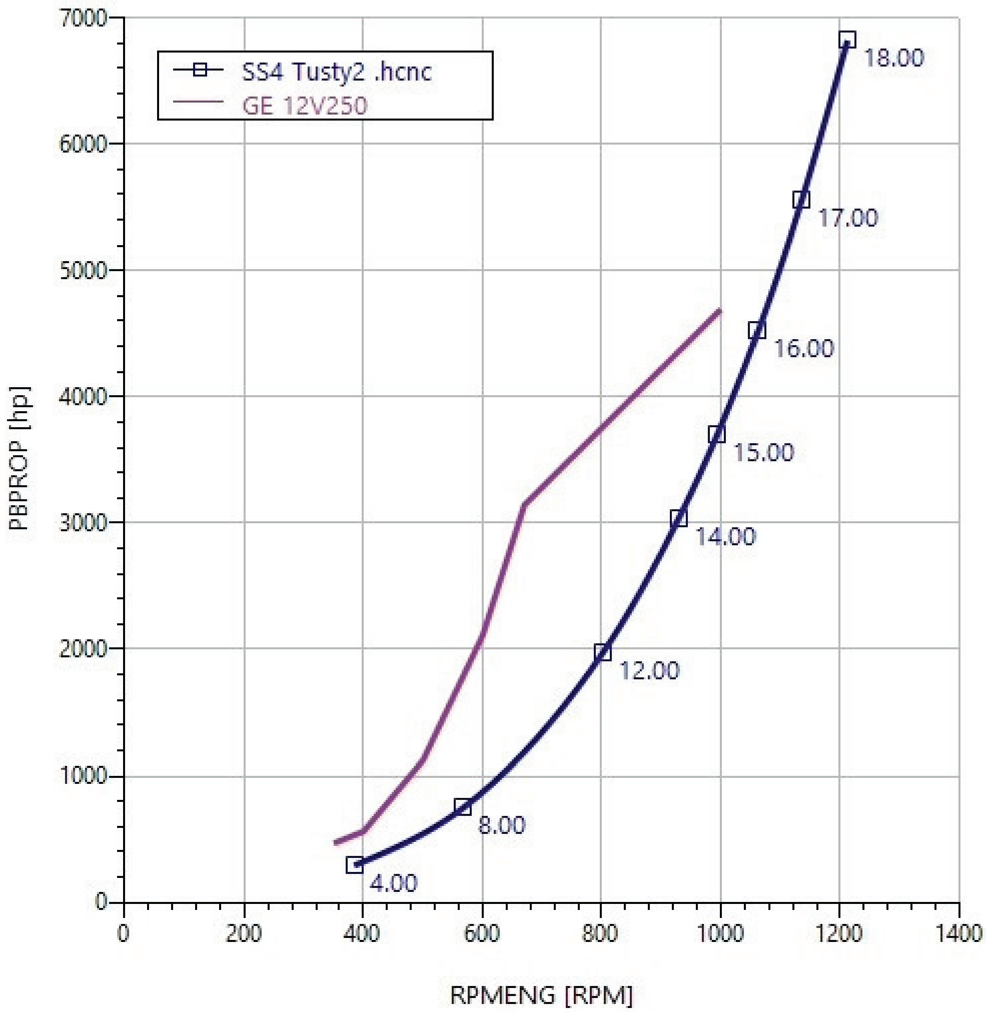

Figure 8 Speed-Power – Sea State 4

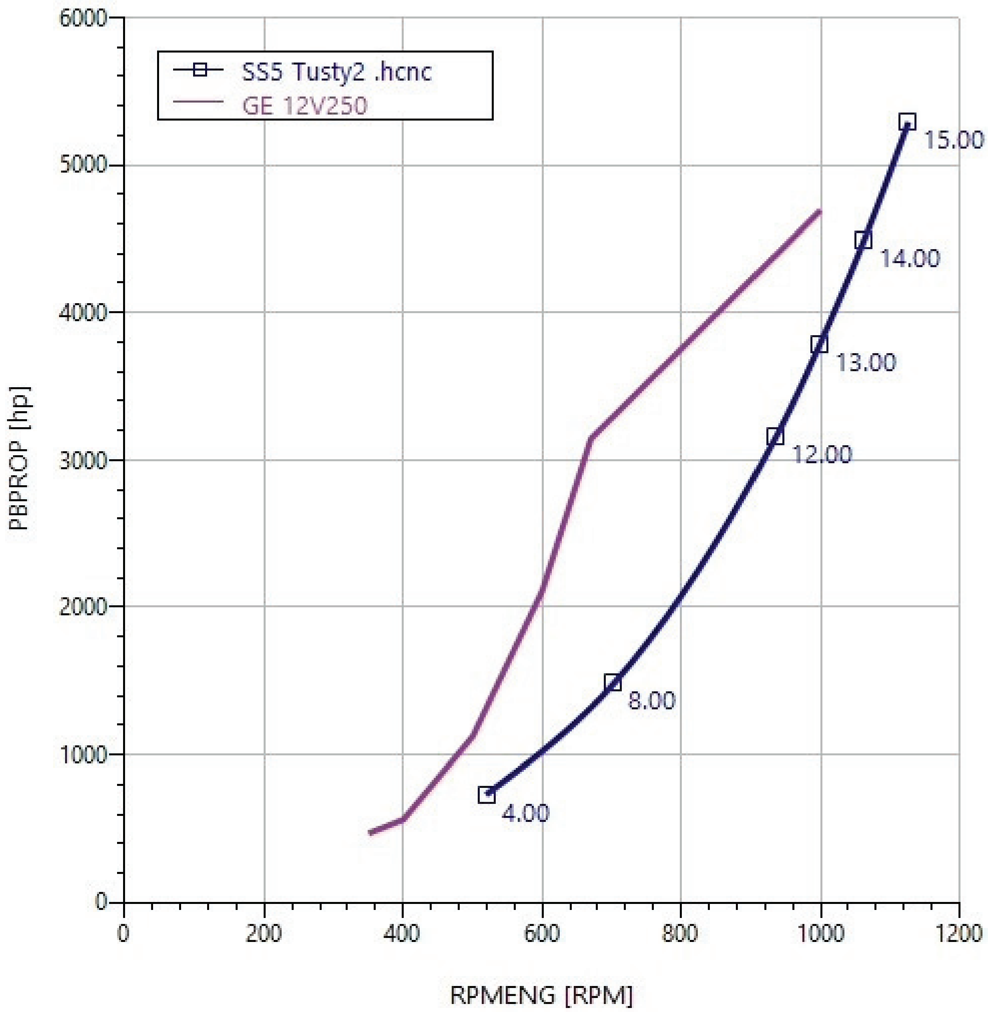

Figure 9 Speed-Power – Sea State 5

3.3 Vehicle Elevator Design

3.3.1 Summary

The vehicle elevator for the *Tustumena Replacement Vessel* moves vehicles ranging from heavy trucks and construction equipment to small cars and motorcycles between the Main Deck and a pier level different from the Main Deck. At the Main Deck level the vehicle elevator platform rotates to align with the vehicle lanes because there is insufficient room for vehicles to maneuver on and off the platform if it does not rotate. At pier level the elevator platform is oriented transverse to the ship's centerline for vehicles to drive on and off. The large watertight side doors to the vehicle deck act as transfer ramps to span between the elevator and pier. The door/ramps are moved vertically by the elevator and are folded out by their own winches. The vehicle elevator configuration is depicted in Figure 10.

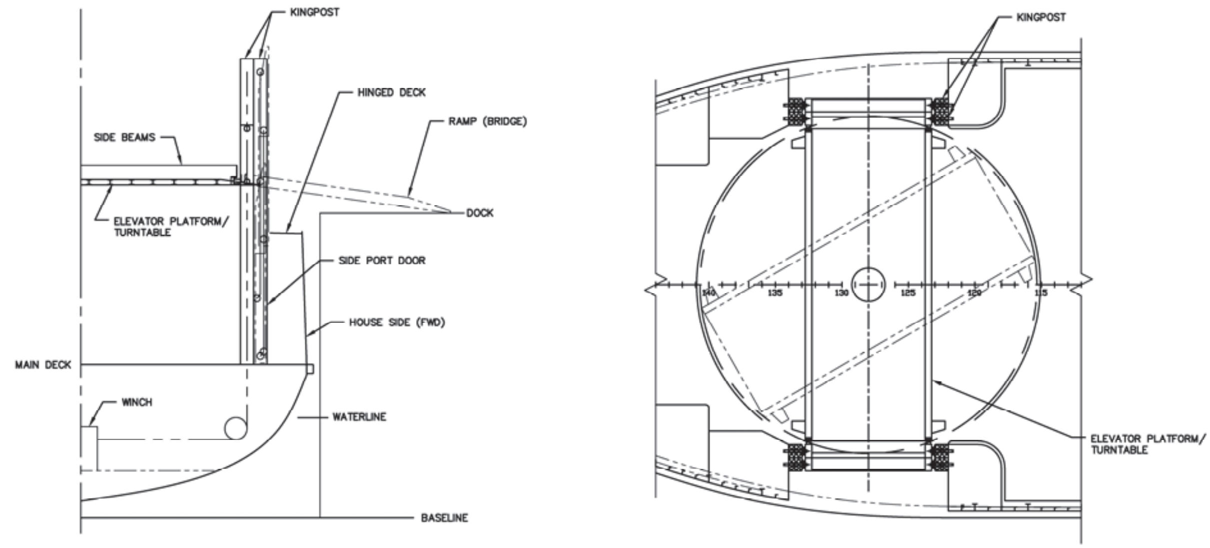

Figure 10 Vehicle elevator configuration

Any vehicle that can travel Alaska's highways without special weight permits can use the elevator (Reference 15). However, the size of the ship limits the size (length) of the vehicle elevator, which limits the length of vehicles that use it. The selected configuration limits vehicle length to 46.5 feet maximum over the axles with 3.25 feet maximum overhang at the front and back. A 53 foot trailer can be accommodated without a tractor.

Pedestrians will be able to ride the elevator when necessary. The *Tustumena Replacement Vessel* is designed with a movable passenger boarding ladder separate from the vehicle elevator so that passengers may board the vessel directly to one of three decks. On the current *M/V Tustumena* the primary passenger boarding ladder is on the Cabin Deck with alternative means of access provided through other gangways positioned aft or through the use of the vehicle elevator. The new passenger boarding ladder design should eliminate the need for passengers to use the vehicle elevator, but there may be times when passengers will ride the vehicle elevator. Consequently, the selected vehicle elevator configuration provides an equivalent level of safety for a passenger elevator built in accordance with the Safety Code for Elevators (Reference 16).

Vessel terminal time is influenced by elevator speed as all vehicles must ride it. The selected configuration uses screw column hoists that have higher allowable hoisting speeds by code than winding drum winches as used on *M/V Tustumena* and *M/V Kennicott.* However, screw dynamics and available electric power limit hoisting speed to the same 50 feet per minute. The elevator cycle time is included in the voyage scheduling spreadsheet, Appendix E.

3.3.2 Regulatory Compliance

Section 1.1.2 of the Safety Code for Elevators (Reference 16) states: "Equipment not covered by this Code includes, but is not limited to, the following: ... *(u)* platform elevators installed in a ship or offshore drilling rig and used for the purpose of loading and unloading cargo, equipment, and personnel." As a result, the Safety Code for Elevators can be used only as guidance for the design and construction of the vehicle elevator to achieve a level of safety equivalent to a fully compliant elevator for carrying passengers and freight.

For the *Tustumena Replacement Vessel* vehicle elevator, fundamental design elements such as stress levels and factors of safety for structure and machinery meet the Safety Code for Elevators. Door, car enclosure, pit, and hoistway configurations cannot meet the prescriptions of the Safety Code for Elevators so equivalencies have been established to address the following issues:

1. Preventing passengers and freight from falling from the elevator.
2. Preventing passengers from leaving the elevator between stops.
3. Preventing passengers from entering the hoistway from any stop when the elevator is not at the stop.
4. Preventing passengers and freight from coming into contact with things that are not moving at the same speed as the elevator.
5. Providing safe access and working areas for maintenance workers above, around, and below the elevator and its associated machinery during all conditions of proper and improper elevator operation.
6. Excluding unauthorized people from areas where they do not belong above, around, and below the elevator and its associated machinery.
7. Preventing the elevator from descending or ascending too fast.
8. Preventing the elevator from descending or ascending uncontrollably if any single part breaks.
9. Preventing untrained people from having unsupervised control of the elevator.
10. Providing a means for extracting passengers from the elevator in the event it becomes stopped between landings.

For issues 1 through 4, the structural side girders on the platform provide inherent containment for passengers and freight to keep them from falling off. Handrails and gates on the platform and ramps, in conjunction with crew vigilance, confine passengers to safe walking and riding areas that are away from platform and ramp edges. A reach barrier on the platform makes non-moving parts of the hoistway inaccessible to passengers riding the platform when they are in the passenger holding area.

For issues 5 and 6, crew vigilance, light barriers on the Main Deck and a secure machinery room provide safe maintenance access while excluding unauthorized people from critical areas around the vehicle elevator and its machinery.

For issues 7 and 8, the selected configuration has four screw columns tied together with a timing drive fitted with over speed brakes such that the platform cannot move too fast in either direction and will not fall if one column fails.

For issue 9, the vehicle elevator will only be operated by a trained hoist operator located in a cab high in the hoistway and a trained turntable operator located at a control station on the Main Deck.

For issue 10, the platform can always be lowered by gravity to the Main Deck in a controlled manner by slowly releasing parking brakes. If it is stuck in a raised position, it can always be reached by ladder from the Main Deck or the Cabin Deck. Procedures for extracting passengers will be developed and crew training will be necessary to execute those procedures properly.

3.3.3 Design Basis

The vehicle elevator consists of a hoistable platform that forms a turntable when at Main Deck level. The turntable can align with vehicle lanes on the Main Deck for loading and discharging. When oriented transversely, the platform can be hoisted vertically to align with a shore side pier. A transfer ramp between the platform and the pier completes a path for moving vehicles between the Main Deck and the pier. The arrangement of the ship constrains the platform to be lifted from its corners by hoisting gear located at vertical columns (king posts) near the sides of the ship on either side of doors in the Main Deck side shell (curtain plate).

The load on the platform will be mostly semi-trailers (with or without tractors, depending on length), box trucks, pickup trucks, and automobiles. Occasionally there will be construction equipment of unusual form that will tax the capability of the elevator by having a center of gravity far from the center of its footprint, loading the hoists unevenly. Consequently, the design limit for the hoists will be 25% greater than the maximum cargo weight. The design criteria for the vehicle elevator are included in Table 8 below.

Table 8 Elevator design criteria

Maximum weight of cargo:	80,000	pounds	
Maximum live load at platform corner:	30,000	pounds	
Clear width of roadway:	17.0	feet	
Minimum length of roadway:	46.5	feet	
Platform clearance circle diameter:	55.0	feet	
Maximum length bumper to bumper:	53.0	feet	
Maximum width for maximum length:	8.5	feet	
Truck wheel track:	6.0	feet	
Maximum truck axle load, dual wheels:	20,000	pounds	
Maximum truck axle load, single wheels:	12,000	pounds	
Minimum tandem axle spacing:	4.0	feet	
Minimum distance, axle to bumper:	3.25	feet	for 53 foot length
Maximum load on landing gear, per pad:	20,000	pounds	
Landing gear pad size:	10 long x 10.5 wide	inches	
Truck tire ground pressure, maximum:	100	psi	
Platform and carrier design dead weight:	100,000	pounds	

The vehicle elevator design was selected from several different potential configurations (see Appendix H). The following sections detail the selected configuration for the platform, turntable, hoistway, hoists, shore ramp, ramp handling gear, and controls. The vehicle elevator nomenclature is depicted above in Figure 10.

3.3.4 Elevator Platform

The elevator platform consists of a roadway between side beams that spans between the lifting points. The roadway has a clear width of 17 feet to accommodate up to two lanes of vehicles. The length of the roadway surface is approximately 49 feet. Additional vehicle length is accommodated by overhanging the platform. The platform is designed to accommodate 53-foot trailers.

The roadway structure is 11 ⅜ inches thick and the side beams extend 42 ⅝ inches above the driving surface to allow 42-inch high gates to fold below the top flange of the side beams. Total structural depth is 52 inches. The hoistway hatch is elevated above the cabin deck so 15 feet of headroom can be maintained below the platform when it is stowed in a raised position.

The roadway structure is a stiffened steel plate panel with 10-inch stiffener spacing in the truck wheel tracks and 12-inch stiffener spacing elsewhere. Roadway plate thickness is ⅜ inch in the horizontal portion and ½ inch in the fixed taper portion. Some plastic deformation of the deck due to truck wheel loads is expected and is acceptable based on car deck performance on Washington State Ferries. The use of cribbing under trailer landing gear pads will be required.

The ends of the roadway have a double taper so that vehicles can transition to and from the vessel's main deck or to and from the platform carrier. The first part of the taper is fixed down at 6°. The second part of the taper is hinged down at 12.5° when it rests on the main deck and 0° when it rests on the platform carrier. The thickness at the narrow end of the taper is 1 inch.

Swinging gates provide a triangular area in the middle of the platform for containing passengers in a safe location when the platform is being hoisted and rotated. The crew manually operates the gate. One side of the triangular area is against a platform side beam and close to the hoistway structure that passengers could touch if not prevented from doing so. A telescoping, solid barrier is located on this side of the platform to act as a reach barrier. The top of the barrier is seven feet above the platform driving surface when it is raised and it can be lowered below the highest part of the platform for stowage.

3.3.5 Turntable

The elevator platform descends to the Main Deck to form a turntable. When on the deck and acting as a turntable, the platform is supported by four 4-wheel trucks that run on a 2-inch thick circular insert plate in the main deck. Turntable power considerations require the wheels to be steel riding on a steel surface. Rolling contact stress levels require the deck insert to be high strength steel. Trucks have flexible axle support so all wheels share the load equally. Ring spring buffers in the trucks are sized to dissipate all of the kinetic energy of the platform when stopping from the full load descent speed controlled by the overspeed brakes. The movement of the wheels as the buffers compress meets the Safety Code for Elevators requirements for buffer stroke.

When the carrier lifting lugs disengage the platform, the turntable rotation is controlled by the turntable drive system. The turntable drive speed is 1.5 RPM to produce 3 MPH peripheral speed at the platform hoist points. The drive is the friction type driving against a medium diameter ring under the platform. It consists of four 10.00R15 truck tires with 34.83 inch effective diameter bearing against a circular plate with 14'-10" track diameter. Four tires are required to obtain adequate traction without exceeding their load rating. Each tire is driven by a 15 HP variable speed AC motor through a two stage worm drive with a reduction ratio of 225:1. The worm drive is capable of overhauling so that abruptly removing power from the motor will not cause the drive to lock up.

Each drive is also fitted with a spring set, electric release brake to hold the platform position when it is not being driven. All of the motors are powered by coordinated variable frequency drives with ramped start and stop. Total power of 60 HP produces 3.6 second acceleration time from zero to 1.5 RPM as a platform end moves through about 8 feet of arc. The drive is stiff and torsional vibration in the operating speed range is unlikely.

Drive tires project above the main deck by 2 inches when the platform is hoisted out of the way. Access for tire maintenance is through lift-off plates in the deck. The tires themselves are housed in recesses in the main deck. Motors, worm gears, and brakes are located in the elevator machinery room below the deck with drive shafts projecting through sealed bulkhead bearings into the tire recesses. Tire recesses require drains to the oily bilge tank.

The center pivot is a 3 inch diameter pin projecting from the bottom of the platform into a socket in the main deck. The socket is fitted with an oil-impregnated bronze bushing for the pin and a spring-loaded plug that fills the hole in the deck when the pin is removed.

3.3.6 Hoistway

The hoistway is partially enclosed on the Main Deck by watertight doors on the side and a weathertight hatch in the Cabin Deck. It is open fore and aft to the vehicle storage areas of the Main Deck. Hinged sections of the Cabin Deck, outboard of the hatch, swing up to allow unrestricted positioning of the shore ramp between the elevator platform and the pier at any height from main deck level to 34 feet above. The watertight doors also serve as shore ramps. Normal use is with one watertight door closed and the hinged deck above in the lowered position to provide access to the stern portion of the Cabin Deck. The interface between the hinged deck sections and the top edges of the watertight doors is only weathertight while the interface between the watertight doors, the Main Deck and the side shell above the Main Deck is watertight as required by Class rules. The interfaces between the Cabin Deck hatch, the hinged deck sections, and the king posts are made weathertight by rubber seal strips. Where the Cabin Deck hatch and the hinged deck sections are adjacent to the king posts, the joint is also weathertight.

Fixed king posts in the four corners of the hoistway extend 56 feet above the Main Deck. The height is governed by the height of door carriers that are 19 feet tall and extend above the hinge line of the door, which can be 34 feet above the Main Deck in its highest position. Cross beams connect the top of the forward and aft kingposts on each side of the vessel. The cross beams ensure adequate stiffness of the king posts is provided to maintain clearances of the hoist system.

Openings in the king posts above the Cabin Deck for platform and door/ramp carriers are fitted with hinged, weathertight covers to keep rain and spray from blowing in and working its way to the vehicle deck or freezing on ball screws and guide rails. A means for de-icing king posts by circulating hot air inside is being considered. Waste heat from engine cooling would work well in this application.

3.3.7 Hoist System

NOTE: The following section describes an innovative new ball screw type hoist system initially proposed for the new vessel. During the Value Engineering Study, it was recommended that the hoist system revert back to the proven cable system similar to the vehicle elevators on the *M/V Tustumena* and *M/V Kennicott*. During the next phase of the design, the vehicle elevator hoist system will be changed to a cable system as recommended by the VE Study.

The platform is hoisted by detachable carriers at each end (or side in ship coordinates). The carrier hoists are screw columns with an interconnected drive that rotates all screws simultaneously so that all corners rise evenly and keep the platform level. The carriers have flanged rollers that mate with guide rails on the king posts to resist transverse loads due to roll, pitch, trim, and heel. When the platform is on the Main Deck, the carriers drop below the platform side beams by at least one inch and disengage from the platform so it can be rotated. When the platform is rotated out of the way, the carriers can be raised so as not to obstruct the Main Deck in way of the side port doors. About one inch of overrun distance is available between the platform carriers and the Main Deck when the carriers are at the normal disengaged height.

King post height is governed by door/ramp carrier considerations and is more than sufficient to guide the platform for its full 34-foot rise plus an additional three inches for carrier disengagement. The king posts are tied together by longitudinal structure at their tops to maintain guide rail fore and aft spacing when the hull deflects.

The screw column hoists utilize ball screws with three nuts on each screw to provide a predicted life in excess of 25 years before replacement. The nuts are connected to the carrier through a load sharing linkage so that all nuts are loaded evenly regardless of lead errors in the screw. Although the Safety Code for Elevators allows greater hoisting speeds, ball dynamics combined with stock gear ratios limit hoisting to 50 feet per minute. The ball screws have 4-inch pitch diameter with one inch lead and turn at 600 RPM. Each screw is fitted with a spring set, pressure release brake for load holding. Brake actuators are pressurized when a drive motor is energized and can be manually released for emergency lowering. The screws are suspended from the top ends by spherical roller thrust bearings and guided at the Main Deck by spherical roller bearings. At three points along the screw length, above and below the nuts, there are sliding plain bearings to prevent whipping.

The screw column drive consists of six bevel gear boxes, two electric motors, and two centrifugal brakes with shafting arranged in an “H” pattern. Four bevel gear boxes with 3:1 reduction ratios are at the ends of the “uprights” and drive the ball screws. Two bevel gear boxes with 1:1 ratios are at the connection of the “crossbar” to the “uprights” to tie all of the parts together. A variable speed AC motor drives into each end of the “crossbar”. A centrifugal brake with an activation speed of 1850 RPM is mounted at each end of the “crossbar” to prevent platform overspeed in the event of motor failure. One motor is capable of raising an empty platform should the other motor fail. The centrifugal brakes can lower a fully loaded platform at about 70 feet per minute should both motors fail. All shafts are rated to carry the full power from one motor even though the cross shaft normally carries no load and the input shaft to each screw normally carries only half the power from one motor. Both motors have ramped acceleration for start and stop plus dynamic braking. Future addition of energy recovery devices such as flywheel storage is possible. Torsional dampers may be required.

No safety devices other than the brakes described above are required by the Elevator Code. There are no governors or track brakes as required with winding drum winches. The three nut per screw arrangement fulfills the code requirement for a safety nut because any one of the three nuts can carry the full load.

3.3.8 Hoist Capacity

The static capacity of each screw and its nuts is far in excess of the required rated load because fatigue life governs their sizing. Other components of the hoists are designed for one quarter of the platform dead load or 25,000 pounds plus 30,000 pound live load for a total design load of 55,000 pounds. Hoist motor size is based on two motors sharing the load evenly and 100,000 pound dead load for platform and carriers plus 80,000 pound live load with 90% screw efficiency and two sets of bevel gears with 98% efficiency each. Total power required per motor for 50 feet per minute speed is 158 HP. Two 200 HP motors are used to provide margin for acceleration and so that one can lift an empty platform.

3.3.9 Side Doors and Shore Ramps

The vessel side doors are designed to also serve as shore ramps to span from the end of the platform to the pier. There are two combination door/ramps, one on each side of the vessel. The outboard end of the ramp rests on the pier deck and the inboard end is supported directly by the king posts by way of sliding carriers, separate from the platform carrier.

The ramps are 18½ feet long to fit beneath the Cabin Deck when closed in the door position. Folding deck sections cover the door/ramps when stowed to permit clear access to the aft deck. A ramp length of 18½ feet provides a minimum of 4 feet of overlap at the pier with the largest known fender depth (Port of Ouzinkie).

Hinged dock flaps fold out from the outer end of the door/ramp to provide a transition from the structurally thick ramp to the dock. The dock flaps are designed to allow vehicles with low ground clearance (e.g. Honda Prius) to transition to and from the ramp without scraping their undercarriage. Operation of dock flaps is automatic with a combination of gravity and wheels against the pier unfolding or folding as the ramp is lowered or raised.

The door/ramps are about 23 feet wide to provide space for hinges and closing tackle plus watertight edge seals. Folding handrails limit the useable width of the ramps to 17 feet. The dock flap is 17 feet wide to match the width of the driving surface on the elevator platform. The dock flaps are constructed of aluminum to save weight.

The bottom edge of each ramp has a hinged filler plate that spans the clearance between the driving surface on the ramp and platform carrier. Operation of this filler plate is automatic by gravity when opening the door and by contact with the main deck when the door closes.

3.3.10 Ramp Handling Gear

The fixed king posts support sliding ramp carriers which move vertically from the Main Deck to the to the uppermost platform position. The ramp carriers provide hinges for the ramp and sheaves for the wire rope used to control the angle of the ramp.

The angle of the ramp is operated by a grooved, double drum hoist located below the Main Deck with wire rope led to the top of each king post. One hoist serves the port ramp and another serves the starboard ramp. The rigging arrangement ensures the angle of the ramp does not change as the ramp moves up and down the king posts.

The ramps are lifted and lowered by manually retractable lugs on the platform carriers. These lugs engage hooks on the ramp. Lifting or lowering a platform carrier takes the ramp along with it. Lifting and lowering a ramp can take place at any angle of ramp deployment. Spring-loaded, retractable pawls in the king posts hold the hinged edge above the main deck at 6-inch increments of elevation. Lowering requires the pawls to be positively retracted.

When lowered to the Main Deck, pins on the ramp engage sockets in the deck. The ramp retracts against sealing surfaces and hydraulic dogs engage the ramp to form a watertight door. Because the ramps open outward, hydrostatic pressure will tend to keep them closed in a casualty situation. The folding deck sections lower to form a weathertight seal at the top of the ramp and restrain the dock flaps in place.

Folding out the ramp from the door position is not possible until the ramp is about one foot off the Main Deck due to the seal geometry. Conversely, seating the ramp on the Main Deck is not possible until the ramp is folded nearly closed to the door position.

Handrails on the ramp are raised and lowered by hand. If the ramp is closed or nearly so, the effort to overcome gravity and move the handrails is small. Care is required to assure the handrails on the ramp, in the door position, are folded clear of moving platform carriers.

3.3.11 Controls

AC motors with variable frequency drives are used for platform hoisting, platform rotation, and door/ramp folding. No constant speed motors are used. Motor controls have programmable start and stop ramps that are initiated by limit switches or operator controls as appropriate. Acceleration during normal and emergency stops will not exceed the limits in the Elevator Code.

All controls are arranged for manual start by a trained operator. Depending on function, stop controls are manual by a trained operator or automatic by limit switch. All movement functions have a normal speed and a creep speed that is approximately $\frac{1}{10}$ of normal speed. In general, creep speeds are initiated by manual jog control requiring maintained actuation of a pushbutton by the operator.

Emergency stop and overrun limit switches are located in the king posts to operate directly on the platform carriers. Normal stop limit switches are actuated by a mimic screw that is driven by one of the screw columns and has a lead of $\frac{1}{10}$ that of the ball screw.

Parking brakes as described above will be activated by the controls when the platform is stopped.

Hoist controls are located in a cab above the Cabin Deck from which the whole operation of loading and hoisting can be observed. An emergency stop and rotation controls are located in a station on the Main Deck in the fore port corner of the hoistway to match the *M/V Kennicott* arrangement.

Controls are configured to match those on *M/V Kennicott* for fleet commonality. In addition to manual jog control for hoisting, there is “2 floor” semi-automatic control where one button in the control cab sends the platform to the main deck at full speed and another button sends the platform to an upper “floor” that is programmable in 6 inch increments above the Main Deck. In addition to manual jog control for rotation, there is variable rate joystick control for rotation and a “home” function that returns the platform automatically to transverse orientation aligned with the carriers for hoisting.

A summary of the elevator controls and operating procedures for different service areas is included in Appendix I.

3.3.12 Fabrication

The vehicle elevator for the *Tustumena Replacement Vessel* has a design capacity that is second only to a *Nimitz* Class deck edge aircraft elevator and it has a turntable function. Fabricators for such unique equipment are few. Three fabricators have been contacted to determine interest. Jesse Engineering and PaR Marine Services have returned positive initial responses. A response from MacGregor’sEuropean division has not yet been received.

Sources of long ball screws are also limited. Two ball screw manufacturers have been contacted to determine their capability to make one piece, 40 foot long, 4 inch diameter screws. A&A Manufacturing – Lead Screws International responded positively and has material in stock. SKF –TCM has the capability but was not able to confirm material availability. Barnes Industries, Inc. advertises the capability so they were not contacted.

3.3.13 Pier Compatibility

The ramp design is intended to be compatible with the piers at all anticipated ports of call. The pier geometry for each terminal is included in the Terminal Compatibility Study, Appendix C.

The Pier at Yakutat has a non-removable bull rail with a cleat on top of the bull rail as shown in Figure 11 below. The ramp on *M/V Kennicott* is long enough to span over the cleat. The *Tustumena Replacement Vessel* ramp is not long enough to clear the cleat. The cleat must be relocated to remove the interference with the ramp. A longer ramp would require stairs on the Cabin Deck level to transit up and over the longer ramp since the ramps serve as the side doors.

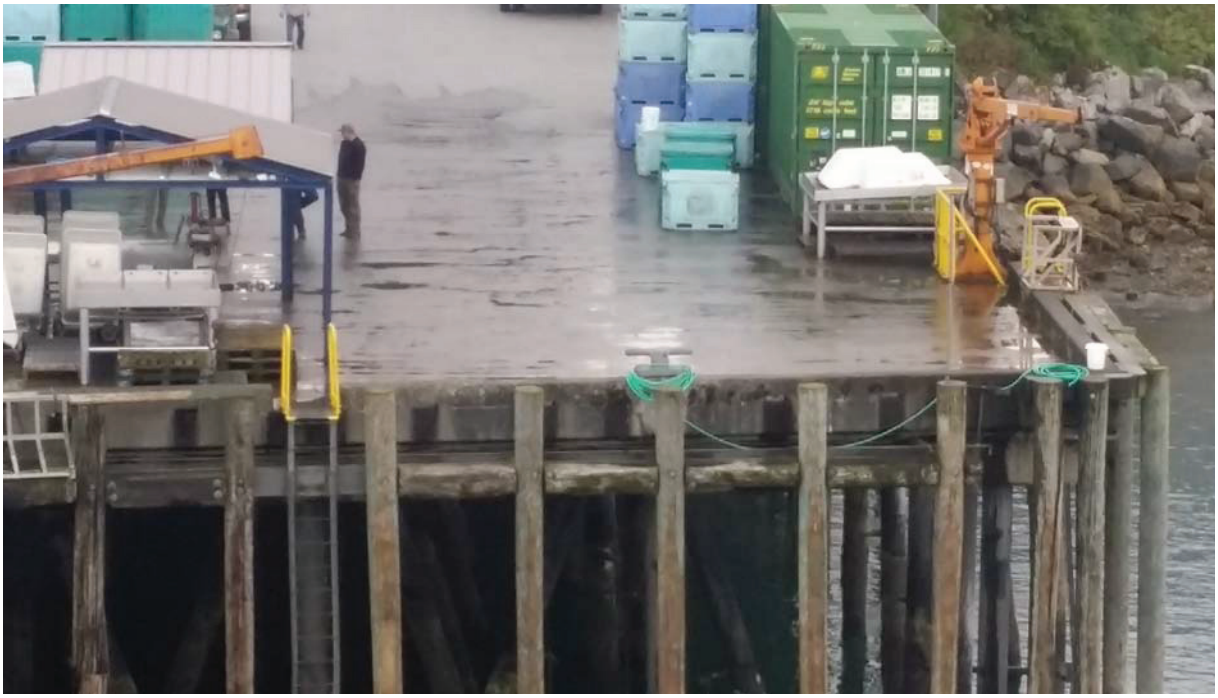

Figure 11 Yakutat

The dock flap at the end of the ramp relies on wheels to rotate the flap into position on the pier. This arrangement allows the ramp to be deployed without crew involvement. The wheels will be effective when in contact with hard flat surfaces. Gravel, mud and snow may limit the ability of the wheels to deploy the dock flap. Flat, compacted gravel, as shown in Figure 12 below at Ouzinkie, should allow the flap to deploy freely. Steel or timber matts may be required in adverse conditions.

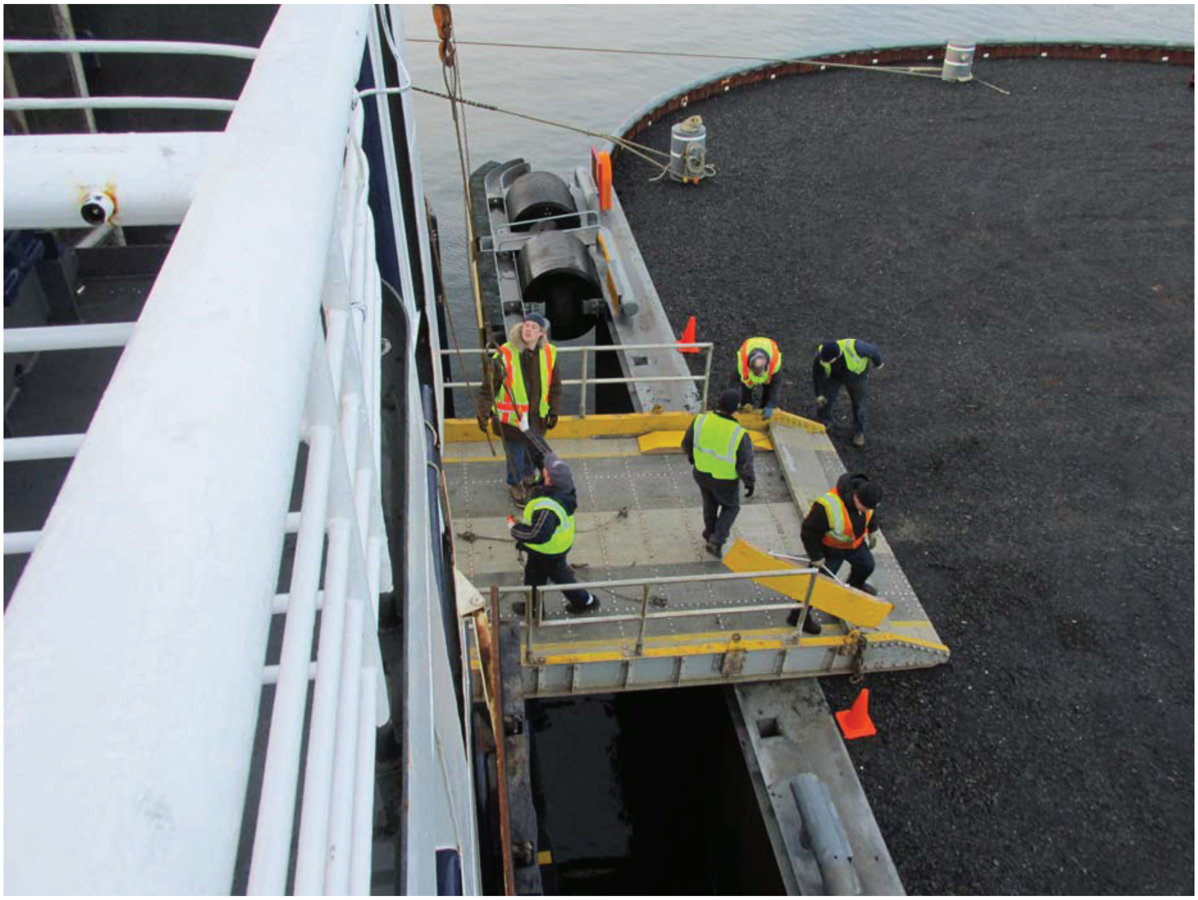

Figure 12 Ouzinkie

3.3.14 Future Work

Each carrier uses three ball screw nuts to hoist each corner of the platform. Multiple nuts are required to achieve the desired design life rather than the rated hoist capacity. The load to each nut must be equalized to maximize the life of the ball screw assembly. The load sharing concept needs to be finalized and gain manufacturer approval prior to moving forward with the ball screws hoist system.

3.4 Structural Design

3.4.1 Preliminary Structural Design

3.4.1.1 Summary

The structure for the *Tustumena Replacement Vessel* was designed reflecting the current general arrangement (Appendix A Drawing No. 13105.05-070-01) and the pre-optimized hull form. The American Bureau of Shipping (ABS) *Rules for Building and Classing Steel Vessels* (Reference 17) were used to size the vessel's scantlings. Constructability and maintenance issues were considered when choosing structural members, and the design also considered operational needs such as ice strengthening and a strengthened main deck for heavy vehicles. Structure drawings are provided in Appendix A (Drawing No. 13105.05-100-01).

3.4.2 Governing Design Requirements

3.4.2.1 Class and Federal Requirements

The American Bureau of Shipping *Rules for Building and Classing Steel Vessels* (Reference 17) were used to size the vessel's scantlings. As the vessel is designed to carry passengers and vehicles, the scantlings were sized per Part 3 *Hull Construction and Equipment*; Chapter 2 *Hull Structures and Arrangements*. Further care was made to ensure that the scantlings also met all of the applicable criteria in Part 5C *Specific Vessel Types*; Chapters 7 and 10 *Vessels Intended to Carry Passengers/Vehicles*. Along with containing variations to some of the scantling rules in Part 3, these two chapters in Part 5C also require additional analyses to be performed to verify that the structure is sound. Global and local Finite Element Analysis (FEA) models are required to be built and used to evaluate the longitudinal and transverse strength. This work is proposed for the next phase of the design.

Additionally, applicable criteria in the Code of Federal Regulations *Title 46: Shipping* (Reference 2) were applied.

3.4.3 Structural Overview

3.4.3.1 Framing Scheme

After evaluating both longitudinal and transverse framing schemes, it was found that a hybrid scheme was the most efficient method to frame the vessel. The hull structure is depicted in Figure 13. The bottom shell and decks are all longitudinally framed on 24-inch centers in conjunction with inner bottom floors and girders spaced every 6 feet. The side shell below Main Deck is transversely framed with deep web frames and ordinary frames alternating every 3 feet. The scantling length of 305 feet resulted in a minimum side shell plate thickness of ⅜ inch, which allowed for the 36-inch frame spacing on the side shell instead of the smaller 24-inch spacing elsewhere. The wider frame spacing allows for fewer parts which will help reduce both construction cost and maintenance cost. Above the Main Deck the side shell reverts to longitudinal framing in conjunction with deep web frames spaced every 12 feet. A 12-foot web frame spacing was used to better align the structure with the crew cabins on the Mezzanine Deck. The deckhouse and all internal bulkheads are framed vertically with stiffeners on 24-inch centers.

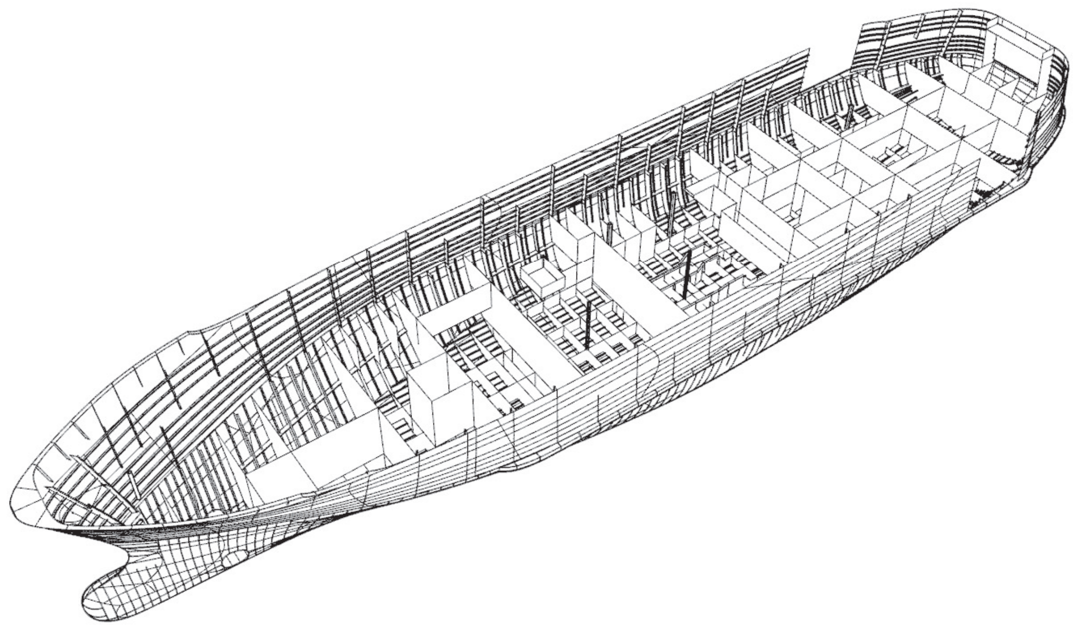

Figure 13 Hull shell structure with below deck bulkheads shown

3.4.3.2 High Strength Steel

A significant portion of the steel weight in the vessel can be attributed to the Main Deck which must be built with heavy plate and a tight stiffener spacing to withstand heavy 40 foot vans and construction equipment. To save weight, the decision was made to use ABS Grade A36 high strength steel on the Main Deck so that the deck plate thickness could be reduced. Based upon the weight savings on the Main Deck, the decision was made to use A36 steel throughout the hull and superstructure to achieve further weight savings. Higher strength steel was not selected for the deckhouse, however. The deckhouse scantlings were calculated to already be at their ABS minimums using ABS Grade A mild steel, meaning higher strength steel would not provide any additional weight savings.

3.4.3.3 Longitudinal and Transverse Strength

The vessel has more than sufficient longitudinal structure through the midship 0.5L to meet ABS longitudinal strength requirements. However, it is less clear if there is sufficient longitudinal structure through the hull where the superstructure is discontinuous in way of the vehicle elevator and turntable. In lieu of a complete longitudinal strength analysis, two non-tight bulkheads were placed in the hull in way of the elevator to provide additional longitudinal strength.

The transverse racking strength of the vessel is compromised by the lack of full breadth bulkheads on the Main Deck and Mezzanine Deck. To partially remedy this deficiency, racking bulkheads were placed in the Mezzanine Deck and connected by deep transverse structure running across the overhead of the vehicle space. Additionally, transverse bulkheads in the deckhouse were aligned, where possible, with these racking frames to further improve the racking strength. See Sheet 13 of Drawing No. 13105.05-100-01 in Appendix A for a section view of Frame 182, which includes the aforementioned racking bulkheads.

3.4.3.4 Constructability and Maintenance Considerations

Constructability and maintenance issues were considered during the preliminary structure design to attempt to minimize both construction and maintenance costs. The ordinary side frames were originally sized as rolled angles. This is the lightweight solution for the frames; however, rolling stiffeners is time intensive and expensive. To save on labor costs, the side frames will instead be made from flanged plates, which weigh more but will cost less to install.

On centerline, the vessel is designed to have a minimum 4 foot double bottom height. Outboard, deadrise and the turn of the bilge reduce the double bottom height significantly. To maintain a reasonable depth in the double bottom for construction and inspections the double bottom is stepped in a number of locations. In the Auxiliary Machinery Room (AMR), the double bottom is located at 5 feet above base line. In both the Main Machinery Room (MMR) and the AMR, the double bottom is raised to 7 feet outboard of 21 feet off center line. Additionally, the double bottom of the Marine Sanitation Device (MSD) Room is located at 7 feet above base line. The increased double bottom tank top level at the turn of the bilge follows previous AMHS design practice and increases the vessel's ability to survive side damage from groundings, which has happened to previous AMHS vessels.

To improve paint retention and simplify maintenance external stiffeners on deckhouse decks were designed to be flatbars instead of angles.

In the deckhouse, compromises were made to ensure that the structure was sufficient to support the decks while providing enough room to run HVAC ductwork, piping, electrical cabling and other systems through the overheads. In the Forward Observation Lounge, the deck transverses were increased in depth so that HVAC could be run through holes cut in the webs of the transverses. In the aft portion of the Cabin Deck, additional girders and stanchions were added so that the required depths of the deck girders and transverses could be reduced enough to allow clearance for HVAC ductwork to be run between the ceiling panels and the structure.

3.4.3.5 Operational Considerations

As mentioned above, the Vehicle Deck (Main Deck) is designed with high strength steel to reduce weight. Even with high strength steel the deck must be specially strengthened to withstand the weight of 40 foot vans and construction equipment. The center three lanes, which have the overhead clearance for the 40 foot vans, are longitudinally stiffened on 12 inch centers and the deck plate is ⅜ inches thick. The outboard tunnels, which will only store passenger vehicles, are longitudinally stiffened every 24 inches and the deck plate is 5⁄16 inch plate.

As there is a good chance that the vessel will encounter ice and bergy bits while navigating in the North Pacific the decision was made to increase the sideshell plating forward of Frame 92 by one plate size. The forward bow plating along the waterline will be ½ inch thick while the plating aft of Frame 50 will be 7⁄16 inch thick. This design improvement does not follow any specific ice class rules and should not be considered an ice belt. It merely provides additional impact resistance without additional engineering.

3.4.4 Future Work

Although the preliminary structure has been designed, additional analysis is needed to verify that the structure meets all of the ABS Rules. In the next phase of design, longitudinal strength, transverse strength, and buckling requirements will be checked. Additionally, a global FEA model will be built and analyzed for global loads. Based upon the results of the global FEA model, refined local models will also be constructed and analyzed. Of particular concern is the section of the hull in way of the vehicle elevator. The models representing this portion of the hull will be thoroughly scrutinized to ensure that there are no critical stress concentrations around the discontinuity in the hull.

Lashing loads were not considered during this stage of the design. They should be evaluated in the next phase to ensure that the vehicle deck and curbing have sufficient capacity to withstand the lashing loads.

3.5 Weight Estimate and Margins

3.5.1 Summary

The arrangements have been through several phases of review by the AMHS Steering Committee during the DSR phase and are well defined. The structure has been developed based on these arrangements and a detailed steel weight estimate has been created. System design continues to evolve as the design progresses with weights for most systems based on parametric estimates. Actual weights for defined systems are included where the information is available.

3.5.2 Parametric Lightship

A regression analysis of lightship weight versus cubic number was developed using the latest lightship weights of the eight (8) existing similar AMHS vessels: *Aurora*, *Columbia*, *Kennicott*, *LeConte*, *Malaspina*, *Matanuska*, *Taku*, and *Tustumena*. This plot excluded the "non-similar" *Fairweather*, *Chenega*, and *Lituya*. Figure 14 shows the vessel data used in the analysis and the regression line utilized to estimate the lightship weight of the *Tustumena Replacement Vessel*.

The vessel has increased in size since the Recon phase due to an increase in allowable draft and extension of the vehicle elevator length. The new cubic number is based upon length at the water line of 319.0 feet, beam at the waterline of 67.5 feet, and depth of 24.5 feet.

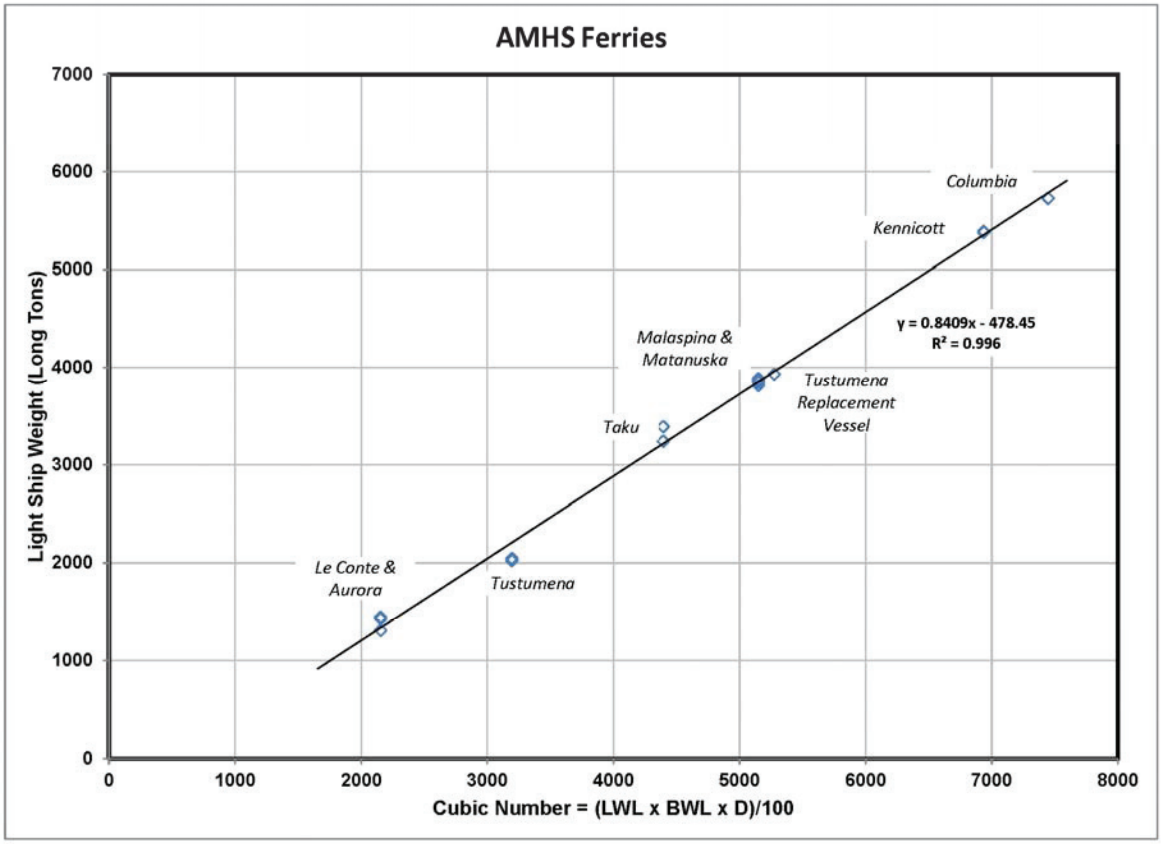

Figure 14 Lightship weight regression

The cubic number of the *Tustumena Replacement Vessel* is CN=5,275. The mean lightship weight corresponding to this cubic number is 3,928.9 long tons. The design margin is based on a normal distribution with a 0.98 confidence interval (i.e. 98% probability that the actual lightship weight does not exceed the estimation). It was felt that the confidence interval used during the Recon phase, 0.95, was not conservative enough so it was increased for this phase. The parametric lightship weight inclusive of design margin for the *Tustumena Replacement Vessel* is 4,240 long tons.

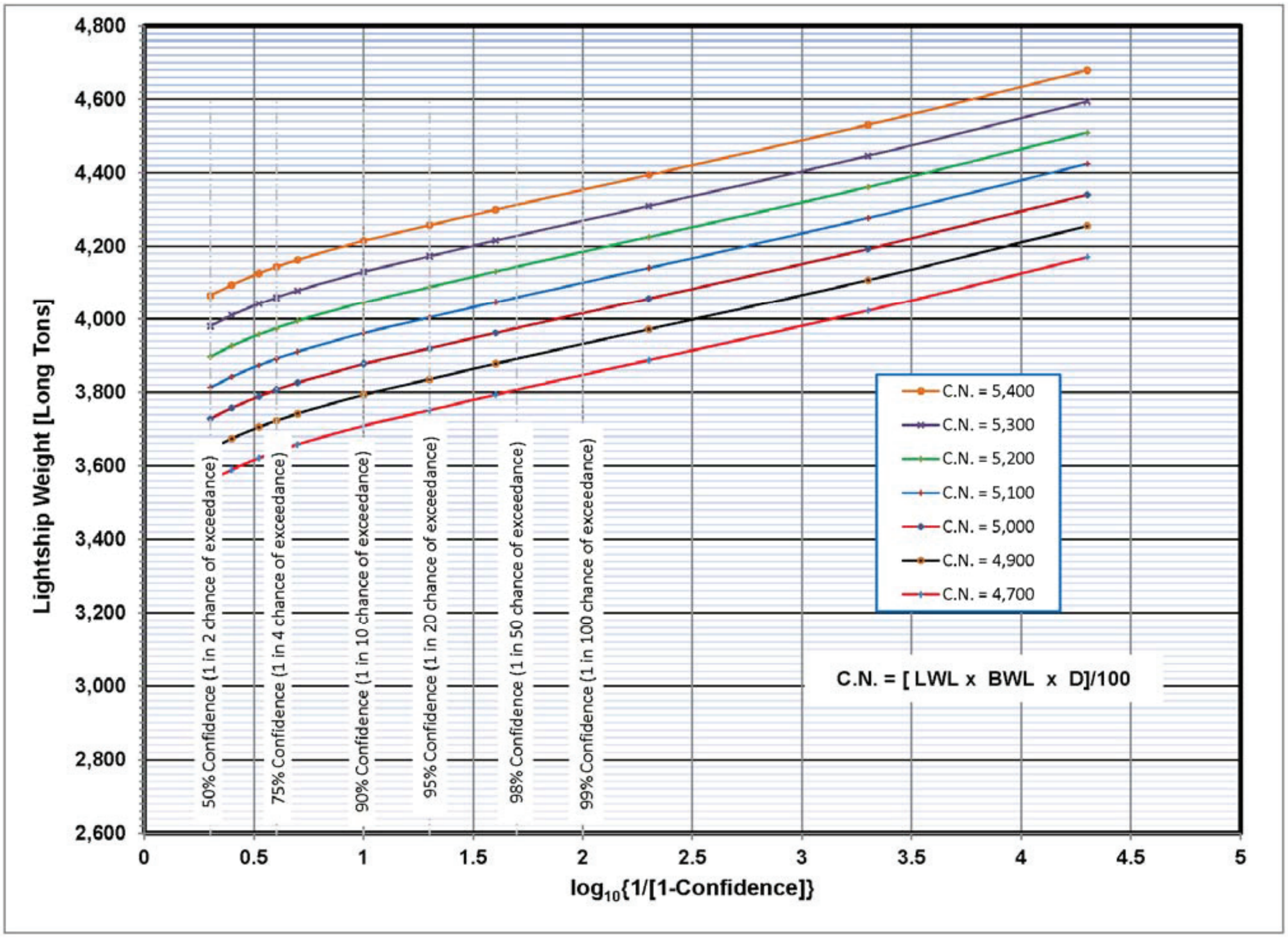

Figure 15 Lightship weight with confidence intervals

3.5.3 Parametric VCG

Similarly, a regression analysis of the above eight existing AMHS vessels' lightship vertical center of gravity, VCG, versus depth was developed using the latest VCGs. In order to capture the VCG differences of different numbers of decks as well as differing deck heights, VCG was scaled by several depths. Depths to the main deck, the weather deck, and the cabin top were plotted. The curve using the cabin top depth had the best fit and was used in this analysis. Figure 16 shows the vessel data used in the analysis and the regression line utilized to estimate the lightship weight of the *Tustumena Replacement Vessel*. Using this line, the VCG at 4,240LT is 32.12 feet above base line.

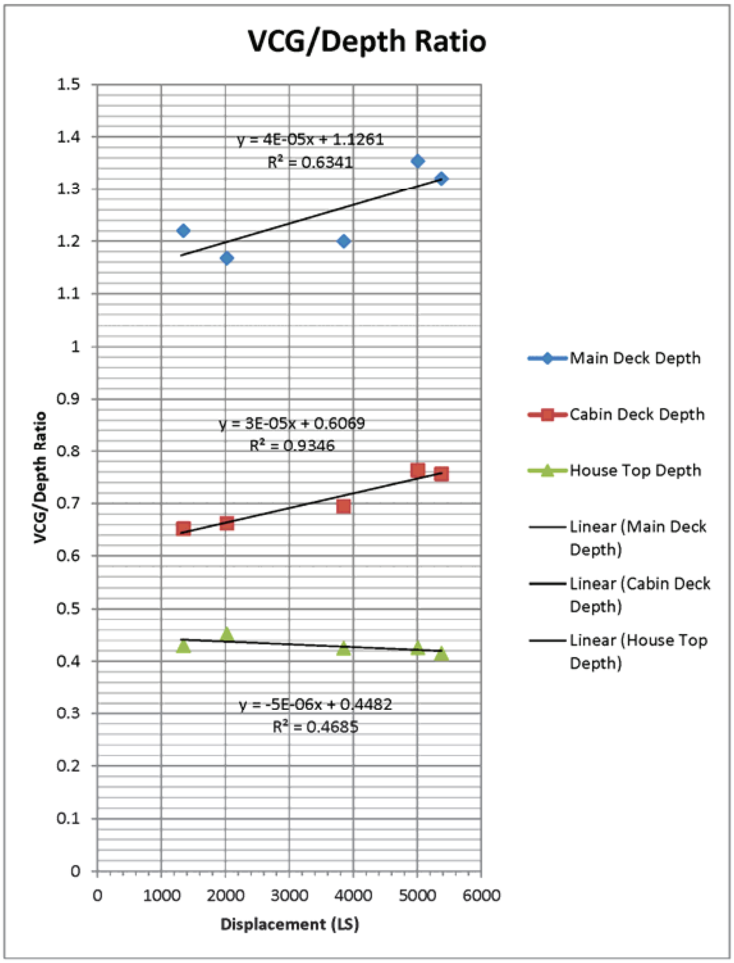

Figure 16 Lightship VCG/depth ratios

3.5.4 Margins

The service life margin is supplied to ensure that the vessel remains viable to the end of its service life. The margin is used to ensure the draft at the end of the service life meets AMHS draft restrictions and is applied on top of the lightship displacement and loading conditions.

The growth rate of vessel lightship weight was compiled for the existing AMHS vessels *Aurora*, *LeConte*, *Malaspina*, *Taku*, and *Tustumena*. The average growth rate, in long tons per year (calculated to be 5.29 LT/yr), was multiplied by a service life of 64 years to arrive at the service life margin weight of 263.37 LT. This represents a 6.6% increase in lightship displacement over the life of the vessel.

To aid in the development of the estimated lightship displacement at this feasibility stage of the design, two margins were applied to the calculations. A design and build weight margin is assumed to be 16.35% of the lightship weight estimate with the VCG margin being 12% of lightship VCG. This design and build margin is the allowance we have assumed for the shipyard in developing and constructing the vessel.

Contract modifications to weight and VCG margins were included to account for possible changes made in the design by AMHS or the regulatory agencies as the vessel design matures.

The margins used are the standard margins for this stage of design based on recommendation of the Society of Weight Engineers (SAWE) and Glosten historical experience. Table 9 reflects the allocation and utilization of margins in the lightship weight estimate.

Table 9 Margin summary

Item	% of Lightship	Weight (LT)	ΔKG (ft)
Design and Build Weight margin	16.35	589.49	
Design and Build VCG margin	12.00		2.13
Contract Mods Weight margin	1.25	49.38	
Contract Mods VCG margin	0.75		0.23

3.5.5 Weight and VCG Adjustments

To allow adjustments with the increasing availability of detail, the light ship weight and VCG were split into one digit SWBS weight categories. The proportions used for each category were taken from the *Kennicott* weight estimate.

Table 10 *Kennicott* weight proportions

SWBS	Weight Category	Kennicott Proportions
100	Hull Structure	61.48%
200	Propulsion Plant	5.85%
300	Electric Plant	3.38%
400	Command and Surveillance	0.42%
500	Auxiliary Systems	14.20%
600	Outfit and Furnishings	11.85%
700	Mission	2.82%

The calculation was made in reverse, as shown in Table 11. Starting with the parametrically estimated weight and VCG the standard margins are applied to work up to the single digit SWBS weights. The longitudinal centers of gravity (LCGs) were added to the weight breakdown based on first estimates using the structure model and the general arrangement.

Table 11 Lightship weight SWBS breakdown

SWBS	Group Description	Margin	Weight	Margin	LCG	TCG	VCG Margin	VCG	VCG Margin
No.		%	LT	LT	ft Aft Fr 0	ft +Stbd	%	ft ABL	ft ABL
100	Hull Structure	15.00%	2216.51	332.48	152.78	0.38	12%	28.85	3.46
200	Propulsion Plant	15.00%	211.04	31.66	190.00	0.00	0%	20.20	0.00
300	Electric Plant	20.00%	121.71	24.34	132.00	0.00	0%	30.47	0.00
400	Command and Surveillance	20.00%	15.31	3.06	142.47	0.00	0%	38.70	0.00
500	Auxiliary Systems	20.00%	511.98	102.40	148.88	0.00	0%	24.23	0.00
600	Outfit and Furnishings	20.00%	427.17	85.43	160.67	0.00	0%	40.70	0.00
700	Mission	10.00%	101.73	10.17	258.00	0.00	0%	49.56	0.00
	Lightship		**3,605.44**		**157.56**	**0.23**	**0.07**	**29.77**	**31.90**
	Design/Build Weight Margin	16.35%	589.49						
	Design/Build VCG Margin	12.00%						2.13	
	Contract Mods Weight Margin	1.25%	45.07						
	Contract Mods VCG Margin	0.75%						0.22	
	Parametric Lightship (with Margins)		**4,240.00**		**157.56**	**0.23**		**32.12**	

The structural and the elevator design are well advanced compared to the other SWBS groups so adjustments to Group 100 and 700 were made to the weight split to obtain an improved design lightship weight for hull shape optimization and stability analysis. This adjusted lightship weight estimate is shown in Table 12.

Table 12 Improved lightship weight estimate

SWBS	Group Description	Margin	Weight	Margin	LCG	TCG	VCG Margin	VCG	VCG Margin
No.		%	LT	LT	ft Aft Fr 0	ft +Stbd	%	ft ABL	ft ABL
	Lightship (W/ D&B Margins)		**4,194.93**		**157.56**	**0.23**		**31.90**	
100	add ice belt	15.00%	10.00	1.50	50.00	0.00	5%	20.00	1.00
100	remove steel wt estimate	15.00%	-2216.51	-332.48	152.78	0.38	12%	28.85	3.46
100	add calculated steel wt	15.00%	1882.00	282.30	154.87	0.38	5%	30.30	1.52
700	remove elevator estimate	10.00%	-101.73	-10.17	258.00	0.00	0%	49.56	0.00
700	add calculated elevator	10.00%	181.33	18.13	260.43	0.00	12%	31.70	3.80
	Lightship		**3,950.02**		**160.83**	**0.21**		**30.91**	
	Contract Mods Weight Margin	1.25%		49.38					
	Contract Mods VCG Margin	0.75%						0.23	
	Design Lightship		**3,999.40**		**160.83**	**0.21**		**31.14**	

3.6 Subdivision and Stability

3.6.1 Intact Stability

3.6.1.1 Model

A new General Hydrostatics (GHS) model, software version 14.00 (Reference 21), was developed from the new hull shape to confirm the intact stability. The current model includes the hull form, tanks and compartments, and a sail profile based on the updated general arrangement.

Longitudinal locations are referenced from Frame 0 at the forward point of the design waterline, positive aft. Transverse locations are measured from centerline, positive to starboard. Vertical locations are referenced from the baseline at the molded bottom of the keel, positive up.

3.6.1.2 Criteria

The vessel is a USCG 46 CFR Subchapter H passenger vessel subject to the applicable intact stability requirements in 46 CFR Subchapter S. The requirements include 46 CFR §170.170

(*Weather criteria*), 46 CFR §170.173 (*Criterion for vessels of unusual proportion and form*), and 46 CFR §171.050 (*Passenger heel requirements for a mechanically propelled or a non-self propelled vessel*).

Note that the Assumed Average Weight per Person (AAWPP) is currently established as 185 pounds. However, the Coast Guard may implement updates to the AAWPP at any time with less than one year of public notice when required for public safety reasons.

The vessel is not subject to SOLAS, but the USCG accepts compliance with the International Code of Intact Stability, 2008 (2008 IS Code), as an alternative to the passenger heel criteria. We applied the USCG CFR criteria to the vessel design.

Icing is also a consideration for the vessel. 44 LT was added on the exterior surfaces while evaluating the intact stability. The icing load was increased 10% from the Recon Study to account for the increased size of the vessel.

3.6.1.3 Loads

Loadings were scaled from the existing *Tustumena* using the current design capacities for this new vessel. 12 40-foot vans (68,000 pounds each) and 27 cars (6,000 pounds each) were used for the full load condition with 250 passengers and 37 crew at 185 pounds each, plus effects.

Larger fuel, ballast, sewage, and potable water tanks were modeled explicitly. Smaller tanks were estimated based on system requirements but combined as a fixed weight called Misc Liquids.

Table 13 Fixed weight items

Item	Weight (LT)	LCG (ft)	TCG (ft)	VCG (ft)
Icing	44.08	156.4	0	55.59
Crew & Effects	6.19	136.0	0	32.98
Passengers & Effects	24.00	127.0	0	55.97
Stores & Provisions	13.83	146.0	0	18.00
Vehicles	436.60	150.0	-4	33.50
Outfit	36.40	158.0	0	18.40
Misc Liquids	64.26	156.4	0	5.00
Service Life Margin	263.37	158.3	0	39.34

The analysis examined five conditions that described extreme situations the *Tustumena Replacement Vessel* would potentially experience. Three conditions had icing, crew, outfit, and service life margins. The fourth condition removed icing and the service life margin with 10% loading of passengers and vehicles, while the fifth condition removed icing, passengers, vehicles, and the service life margin. The weight loading conditions are listed in Table 14.

Table 14 Weight loading conditions

Loading	Condition 1 Full Load Condition (Departure)	Condition 2 Half Fuel Condition (Departure)	Condition 3 Low Fuel (Arrival)	Condition 4 Light Operating Condition	Condition 5 Shipyard Departure
Passengers	100%	100%	100%	10%	No
Vehicles	100%	100%	100%	10%	No
Stores	100%	100%	100%	10%	10%
Fuel	Full	50%	10%	10%	10%
Water	Full	65%	20%	40%	20%
Sewage	25%	25%	25%	25%	25%
Service Life Margin	Yes	Yes	Yes	No	No
Icing	Yes	Yes	Yes	No	No

The results of the calculations are summarized in Table 15.

Table 15 Weight estimate summary for Full Load Condition

	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
Item	**Weight (LT)**	**Weight (LT)**	**Weight (LT)**	**Weight (LT)**	**Weight (LT)**
Lightship	3,999.40	3,999.40	3,999.40	3,999.40	3,999.40
Tankage	770.46	571.59	352.19	395.89	293.93
Vehicles/Passengers	517.0	517.0	517.0	60.57	11.57
Icing	44.1	44.1	44.1	0	0
Subtotal	5,330.96	5,132.11	4,912.69	4,455.86	4,304.90
Service Life Margin	263.37	263.37	263.37	0	0
Total	5,594	5,395	5,176	4,456	4,305
Draft	16.73	16.31	15.58	14.29	13.96
Freeboard	7.77	8.18	8.65	10.22	10.56

These drafts satisfy the requirements as defined in Section 1.

3.6.1.4 Results

The current vessel model passes the intact stability criteria with adequate margins for the representative sample loading conditions.

3.6.2 Subdivision and Damage Stability

3.6.2.1 Subdivision

46 CFR §171.060 states that a vessel of this size and service must be shown to satisfy the requirements for Type I subdivision. The calculations prescribe the maximum allowable distance between main transverse watertight bulkheads as a relationship between floodable length and the factor of subdivision.

3.6.2.2 USCG Deterministic Method

46 CFR §171.080 details the deterministic criteria for damage stability standards for vessels with Type I subdivision. A floodable length calculation with two compartment flooding was performed to ensure that the margin line is never submerged in flooding scenarios.

3.6.2.3 SOLAS Probabilistic Method

While the vessel is not a SOLAS passenger vessel, it will be classed by the American Bureau of Shipping (ABS). ABS Steel Vessel Rules (Reference 17 Part 3, Chapter 3.3 and Part 5C, Chapter 7, Section 3) state that SOLAS Probabilistic Stability Regulations II-1/4 through 8-1 are to be applied for damage stability. The Coast Guard indicated that the SOLAS probabilistic method would be acceptable in lieu of the Deterministic criteria.

3.6.2.4 Compartments

Main transverse watertight bulkheads (MTWB) are located at Frames 14, 32, 44, 68, 92, 116, 152, 200, 224, 242, 272, and 302. These bulkhead locations were selected to meet the subdivision requirements above. A floodable length calculation using a 3 inch margin line was used.

3.6.2.5 Results

The analysis computed the probability of flooding for each compartment and combination of compartments, and whether the vessel meets the criteria after damage. The probabilities were added together to obtain a partial probability index for each draft.

The analysis was run at three displacements corresponding to a light draft, a partial subdivision draft and a deep subdivision draft. Each draft must meet a required partial probability index and a weighted average must meet an overall probability index.

The index requirements are a function of the number of passengers and crew without life boats and the subdivision length. They are:

Partial Required Index:	0.6275
Overall Required Index:	0.6973 (Weighted Load Conditions)

The vessel as currently configured attained the following subdivision indexes:

Light Subdivision Draft Index:	0.799
Partial Subdivision Draft Index:	0.727
Deep Subdivision Draft Index:	0.657
Overall Attained Index:	0.713 (Weighted Load Conditions)

3.6.3 Water-on-Deck Criteria

3.6.3.1 IMO and Stockholm Agreement Methodology

The IMO Panel of Experts developed recommendations for water-on-deck provisions after the *Estonia* disaster in 1994. The US is not a signatory to the IMO water-on-deck criteria.

Another convention was held in Stockholm and in 1996 the Stockholm Agreement was passed that imposes water-on-deck damaged stability conditions similar to the IMO.

Both water-on-deck criteria allow for demonstrating compliance through model testing and a number of passenger ships use this method because it is less conservative.

Water-on-deck is currently not a required criterion, but evaluation is warranted to evaluate the robustness of the design. This will be undertaken at a future stage of the design development.

3.7 Main Machinery

The propulsion configuration for the *Tustumena Replacement Vessel* consists of a twin shaft arrangement with medium speed diesel engines driving controllable pitch propellers through reduction gears. A power take-off (PTO) on each reduction gear will drive a connected generator. This configuration is similar to that found on the *M/V Kennicott* with one notable difference. The PTO generators on the new vessel will be variable speed generators.

A bow thruster compartment forward will house the electric motor-driven bow thruster and its variable frequency drive. The bow thruster will be a transverse-tunnel type, similar to the *M/V Tustumena*, but with considerably more power.

A Main Machinery Room (MMR) will be provided for major propulsion machinery, PTO generators, and supporting auxiliary systems. An Auxiliary Machinery Room (AMR) will be provided for the two ship service diesel generators (SSDGs), main 480V switchboard, oil-fired boiler, and other auxiliary systems. The Engineer's Operating Station (EOS) will be accessed directly from the Main Deck without entering the MMR (see Appendix A Drawing No. 13105.05-201-01, Machinery Arrangement).

3.7.1 Operational Background

3.7.1.1 Operational Profile

The operational profile of the new vessel was determined based on information provided by AMHS from both the *M/V Tustumena* and the *M/V Kennicott* route and vehicle loading data. The operational profile was used for developing load profiles when performing the life cycle cost analysis. Predicted operating time spent each day was gathered from the original *M/V Kennicott* propulsion study and extrapolated to the Southwest route exclusively. Calculated values and assumed parameters are summarized in Table 16.

Table 16 Operational profile

Mission	Speed (knots)	Operating Time (days)
Transit	15	251
Maneuvering	5	16.8
Dockside	0	67
Annual		**335**

3.7.1.2 Power Requirements

The Environmental Protection Agency (EPA) regulations require diesel engine emissions to meet new standards. A detailed background of requirements can be found in Appendix J, Power Generation Report. Currently only General Electric (GE) has provided an on-engine solution to meet the new EPA Tier IV requirements in the power levels required by the

Tustumena Replacement Vessel. Due to the complexity and cost of installing a selective catalytic reduction (SCR) unit with urea injection, AMHS directed the main propulsion engines be General Electric. GE uses exhaust gas recirculation (EGR) technology and is able to meet emission requirements without off-engine aftertreatment.

Speed requirements include achieving 15.0 knots in Sea State 4. The chosen main engines are General Electric 12V250MDC, 1000 RPM at 4687 HP each. Figure 17 indicates a total required transit power of 7600 HP including gearing/shafting losses (3687.5 HP delivered to each shaft). Main engines were selected based on an assumed MCR of 95% maximum for worst case transit condition. Speed and power is discussed further in Section 3.2.4 of this report.

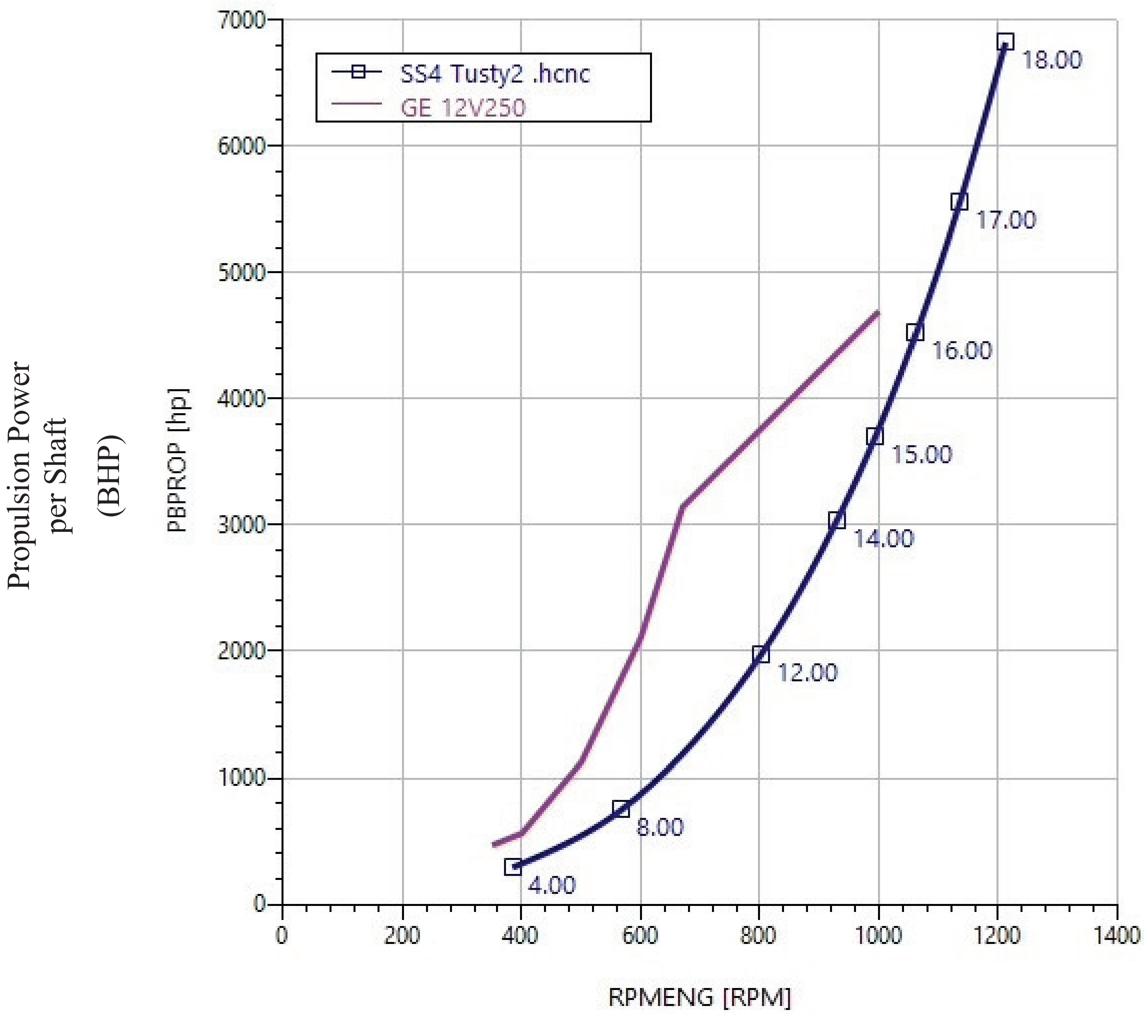

Figure 17 Estimated propulsion power vs. speed for Sea State 4

The bow thruster sizing was based on the *M/V Kennicott* installation, which is well regarded by the AMHS operators. Scaling the thrust for reduced windage area of the *Tustumena Replacement Vessel* yields a required thrust of 22,000 lbs. This is the minimum thrust required and is comparable to the *M/V Columbia* (25,300 lbs). Calculations verify this thruster should allow vessel maneuvering in winds up to 30 knots.

A summary of the developed power requirements can be seen in Table 17 below. The bow thruster accounted for 1150 ekW and was only utilized during maneuvering. The vehicle elevator accounted for about 300 ekW and was only utilized dockside. The vehicle elevator load was included in the ship service electrical load of 850 ekW, based on the electrical load analysis (Drawing No. 13105.05-300-02, Appendix A). Totals include assumed shafting and conversion efficiencies from Appendix J to establish accurate engine loads.

Table 17 Engine Load Profile

	Units	Transit	Maneuvering	Dockside
Average Propulsion Load	kw	5500	600	0
Average Elec. Load (PTO)	ekW	850	1900	850
SS Load	ekW	850	750	850
Bow Thruster	ekW	0	1150	0
Total	kw	6586	2669	917
Engine load (%MCR)	%	94.2%	38.2%	13.1%
Chosen Engine Speed	RPM	1000	600	350

3.7.2 Ship Service Generators

The electric power generation configuration consists of two 1000-ekW variable-speed PTO generators powered from the main engines and two 550-ekW Caterpillar C18 ship service generators. The ship's electrical system will be powered from the PTO generators during transit and short port calls. The two, 550-ekW SSDGs are available for extended in-port situations. This combination of electrical power generation provides the lowest lifecycle cost solution and meets all expected operational situations.

The original power generation configuration coming out of the earlier Recon Study, Reference 1, was an AMHS traditional 3 SSDG electrical plant with no PTO generators. As the vessel design matured, the size of the required electrical generating plant increased such that the size of generators necessary to retain a traditional three-SSDG design became larger than can be supported with Caterpillar C18 generators and exceeded 600 bkW. To maintain compliance with EPA Tier IV requirements for engines above 600 bkW and stay within the available Caterpillar generator availability would have necessitated adding urea injection systems and selective catalytic reduction (SCR) to the SSDG exhaust systems. As discussed in Reference 1 this would increase the operating costs for the engines, add complexity to the engine exhaust systems and partially negated the decision to use EGR based main engines (i.e. non urea/SCR requiring engines).

A study of potential electric power generation options was undertaken and is summarized in Appendix J.

3.7.2.1 Variable Speed Generation

In the electrical power generation study utilizing new variable speed electric power generation technology for power generation with the PTO generators was investigated. This technology allows the engine RPM to vary for optimal fuel efficiency based on the load demand rather than being limited to synchronous speed, offering additional fuel savings and operational flexibility over other traditional constant speed/frequency options. It also enables load sharing by the PTO generators and load sharing with ship service generators.

3.7.2.2 PTO Impacts

Available power reserve on the main engines becomes important when PTO generators are used during transit and maneuvering. Variable speed generation would allow sharing of the PTO generators and would allow each main engine to share the ship service load evenly. Without this capability, a single engine would see the entire electrical load or the electrical plant would need to be configured for split bus operation.

The main engines operate at 81% MCR during transit and 8.8% MCR during maneuvering in Sea State 4 before considering the PTO generator load. Adding the ship service or bow thruster load from the PTO generators to each main engine brings engine operation up to 94% MCR during transit and 38% MCR during maneuvering. In both cases specific fuel consumption is improved and variable speed PTO generators allow for even load sharing between main engines.

An electrical system overview can be found in Figure 18 below.

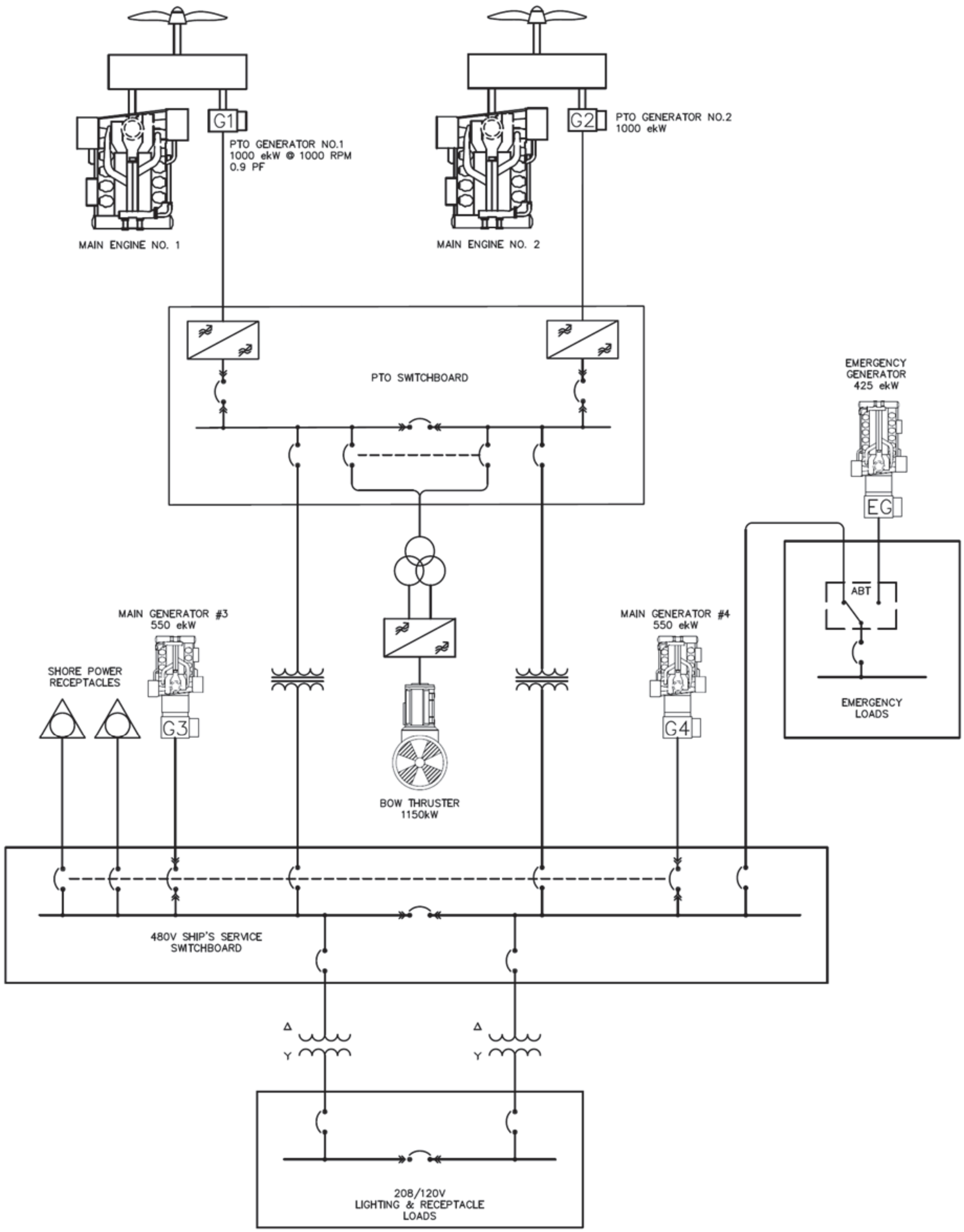

Figure 18 Electrical system overview

3.8 Auxiliary Systems

Auxiliary systems are modelled after AMHS fleet standards. All system components and architecture will follow the fleet standards as much as possible. Notable design decisions or deviations from these standards are discussed below.

3.8.1 Control and Monitoring

The vessel automation is critical to operation of the auxiliary systems. System design will be based on ABS ACC requirements. System design is anticipated to involve automation beyond ACC and increased automation above that presently on AMHS mainline ships. The design will allow near complete monitoring and control from the EOS and should ensure better system monitoring and performance.

3.8.2 Plastic Piping

It is recommended that AMHS pursue the use of SeaCor PVC plastic pipe as follows:

1. Above the Main Deck for most water systems.
2. Below the Main Deck for most water systems where able to avoid watertight penetrations.

SeaCor PVC plastic pipe would be a corrosion resistant and weight saving solution for any non-vital water system for the *Tustumena Replacement Vessel*. The system is both ABS and USCG approved and has been installed on a handful of vessels. Using the SeaCor PVC plastic pipe in way of watertight penetrations is not recommended, as the penetration detail is cumbersome and expensive.

Note: SeaCor PVC plastic pipe is not allowed in the vehicle space as all piping must be metallic per ABS Rules for "hazardous zones".

3.8.3 Heating, Ventilation, and Air Conditioning

All passenger spaces will be maintained within the design conditions of indoor dry bulb of 75°F in cooling season and 70°F in heating season. Heating will be a combination of centralized steam heat supplemented by steam or electric terminal reheat and unit heaters. Air conditioning will consist of a centralized chilled water plant and distributed chilled water system.

The Cabin Deck and Mezzanine Deck will be served by high pressure air handlers and double-walled duct, reducing duct sizes and noise. Most other areas will be served by traditional medium velocity systems utilizing centrally located air handlers. Certain remote spaces such as the Engineer Operating Station (EOS) will be served by overhead fan coil units.

The machinery spaces will be served by dedicated powered supply and powered exhaust systems.

The Vehicle Space ventilation system will consist of power supply and exhaust systems to meet the 6 air changes/hour requirement of ABS. The design will include the capability of the supply fans running in reverse while the side doors are open for increased air flow during loading/unloading. This will allow up to 10 air changes/hr and will provide safe loading by reducing car exhaust gasses in the Vehicle Space.

The Vehicle Space will be served by steam unit heaters throughout the space to maintain temperatures above freezing with an outside temperature of 10°F. This will require the external boundaries of the Vehicle Space to be thermally insulated (except the side doors/ramps and in way of the structural fire protection insulation). In order to accommodate heating this space, waste heat silencers will be installed on the main engine exhaust to supplement the main steam boiler.

The Solarium will be heated by overhead electric resistance heaters. Steam heaters were not chosen because there have been issues on other vessels with freezing of condensate lines when the heaters are secured. Using electric heating will add to the ship service load but will be highly beneficial for maintenance and equipment life.

3.8.4 Boilers and Steam System

Steam will provide heat to various compartments and systems throughout the vessel. Steam will be piped to as many heating components as possible (above 3 kW) to reduce the load on the electrical system. Waste heat boiler/silencers in the exhausts of each main engine will be the primary source of steam. An oil-fired steam boiler will supplement the waste heat boilers and be sized for the entire steam load for redundancy.

3.8.5 Sprinkling Systems

A deluge system for the Vehicle Space is required by USCG and ABS. The system will be a dry type system with sprinkler heads evenly spaced in the overhead of the Vehicle Space typical of other AMHS vessels.

Current ABS requirements require a wet pipe automatic sprinkling system in all accommodation and service spaces, similar to the systems installed on the SOLAS vessels. The zone protecting the solarium will be dry to avoid freezing.

The fire pumps will provide backup to both sprinkling systems.

3.8.6 Sanitary System

Two marine sanitation devices (MSD), each sized for 300 persons will be installed. This will provide enough capacity for peak demand as well as redundancy should one unit fail. Each MSD will be USCG-accepted Type II, physical/chemical treatment with no sludge produced. It is standard AMHS practice to discharge treated effluent overboard when allowable by the USCG. When near ports the vessel will have a large enough tank capable of holding necessary sewage for the entire crew/passenger complement.

An aft lift station will be required to serve all fixtures aft of the MVZ. This tank will then be pumped to the main storage tank forward for further processing.

3.8.7 Sanitary Flushing

Flushing of all sanitary fixtures will be accomplished with seawater. Investigation into potable water flushing determined vessel demand was substantial and would have required watermakers to keep up with flushing requirements. Seawater flushing is fleet standard and was determined to be the correct design course.

3.8.8 Bilge and Oily Waste System

The bilge system design will follow applicable rules and customary AMHS designs. The Clean Water Act requires special consideration and treatment of all water on deck. Water must be collected and treated before being discharged overboard if oil may be present (i.e., in the Vehicle Space). A separate collection tank, 15 ppm USCG-accepted oily water separator, and trash pump will be dedicated to Vehicle Space water collection and treatment.

Design consideration must also be given to collecting water in the Vehicle Space while maintaining emergency dewatering capabilities. It is critical that, if water enters the Vehicle Space, it can be routed overboard without filling the collection tank. The proposed solution is to fabricate various overboard collection sumps around the deck. The overboard discharge will be located part way up the sump, while the drain line to the collection tank will be located at the bottom. This configuration should allow water to pass into the collection tank, unless a large amount of water is present, in which case it will be diverted directly overboard.

3.8.9 Ballast

Locked-in freshwater ballast will be provided along with a transfer system between four tanks. The transfer system will have a dedicated pump and be capable of discharging from any tank and filling any tank. Ballast tanks will be positioned for use with list and/or trim correction. A shore connection will provide filling and discharge capabilities in port.

3.8.10 Fuel System

Two sets of day tanks will be provided, two for main engines and two for generator engines. The main engine day tanks are on the engine room flat level and generator engine day tanks are on the tank top level. Each engine has unique requirements about fuel oil supply pressure and return height. Each set of day tanks are cross-connected with their respective tanks and filled through the fuel oil purifiers from the settling tanks.

There is a leak-off tank required by the main engines with dedicated pump and float switch to return fuel to the day tanks. The main engines' maximum flow rate to the leak-off tank is 2 liters per minute during normal operations.

3.8.11 Fire Extinguishing

Novac 1230 or other low global warming potential (GWP) and ozone depletion potential (ODP) breathable extinguishing agents will be used throughout the vessel for fire extinguishing. For the MMR and AMR, a dedicated fire extinguishing room will provide manifolded tanks and headers supplying extinguishing agent to each respective space. A single bottle will be placed in the Paint Locker and the EDG Room to protect each space.

Local area firefighting will also be installed to protect each of the two propulsion engines, each of the two generator engines, and each of the two fuel oil purifiers. Hi-Fog type system or equal will be used and piped to the necessary locations. The Hi-Fog skid will be located remotely in the MSD room.

3.8.12 Engine Exhaust

Each main engine exhaust will be fitted with a waste heat silencer capable of achieving the specified sound attenuation while providing steam for heating ship's systems. Silencers will be critical grade spark arresting type. Special consideration will be given to access and maintenance of the stack boilers and related system components.

3.9 Electrical System

The ship's electrical system will provide power to vital, auxiliary, and ship service systems throughout the vessel. Two variable-speed PTO generators, connected through the reduction gear in each main engine shaftline, will provide power during transit and maneuvering scenarios. Two ship service generators will provide power dockside when the main engines are secured.

The two PTO generators will feed into a PTO switchboard. This switchboard is split into two sections with the bow thruster capable of being fed from either side. The PTO switchboard is located in the Main Engine Room, flat level. Two feeds to the main 480V ship service switchboard are provided, one from either side of the PTO switchboard (See Figure 18). This will allow the bow thruster to be fed from one PTO and the ship service loads to be fed with the other in complete isolation from each other.

The two ship service generators will be connected directly to the main ship service switchboard, located in the flat level of the AMR. The switchboard will be split into two sections per ABS regulations. Transformers on either side of the bus tie will feed the main 208/120V switchboard located next to the 480V switchboard. This switchboard will also be split into two sections with a transformer feeding either side.

3.9.1 Power Management

Each PTO generator will be connected to the PTO switchboard through an active front end (AFE) converter to allow for variable speed generation of power. The PTO and converter will be sized to maintain peak power at various operating cases and corresponding engine RPMs. Allowing engine RPM to be reduced while still maintaining ship service power provides a fuel efficient solution for running the PTO generators.

The ship service generators will be capable of load sharing with the main switchboard bus tie closed and be capable of load transfer to the PTO generators. The PTO generators will be capable of load sharing with the main switchboard bus tie closed as well. This means PTO generator sizes can be reduced and main engine loading is equal at all times.

3.9.2 Power Quality

Power quality for the *Tustumena Replacement Vessel* is a high priority as large loads such as the bow thruster and vehicle elevator can cause harmonics problems in the rest of the ship service loads. AMHS has experienced problems on other vessels in the fleet and special consideration has been given to maintain clean power.

Maximum total harmonic distortion shall be kept to 5% and single harmonic distortion kept to 3% per regulations. Analysis will be done to determine the best plant configurations and electric drives for the vessel.

Loads will be evaluated for quality and harmonics. Use of 24 pulse drives is a potential that would provide less disturbance. Another avenue that has been investigated is the use of normally open bus ties to limit the interaction of loads such as the bow thruster from affecting small ship service loads. Due to the concern that this issue presents, investigation into this issue will continue as the design matures.

3.9.3 Emergency Power

A dedicated emergency diesel generator set and switchboard will be located in the EDG Room on the Cabin Deck. This generator will automatically start on loss of primary ship's power and will provide backup power to vital shipboard systems and emergency lighting as required by ABS/USCG regulations.

The electrical loads required to support the propulsion machinery for one of the two propulsion shaft lines will be connected to the emergency power system. To meet the cooling demands of one main engine, the fire pump connected to the emergency power system will be cross-connected to the main engine seawater cooling system.

3.9.4 Uninterruptible Power Source

Uninterruptible power supplies (UPS) will be used in vital systems such as navigation, controls, and communication. UPSs preferred for other non-vital ship systems will be provided as required but will be kept separate from emergency equipment.

3.9.5 Shore Power

Vessel operation involves disconnecting/connecting to shore power on a regular basis when at port for extended stays. All equipment and the bus connection will involve robust equipment. Shore power locations will be near the vehicle elevator doors just inside the vessel on the Main Deck port and starboard. The location will provide easy access and maneuverability for crew and shoreside workers. The shore power arrangement shall be configured for "bumpless" transfer as allowed by the regulations.

3.10 Seakeeping Analysis

3.10.1 Analysis

3.10.1.1 Approach and Limitations

The *Tustumena Replacement Vessel* will be traversing the North Pacific Ocean between Dutch Harbor, Kodiak and Homer, Alaska year-round (except no sailings to Dutch Harbor during the winter months). This inhospitable environment creates challenges to vessel operations and passenger comfort. AMHS has not requested specific seakeeping criteria, so this section focuses on a comparative analysis between a smaller existing vessel, *M/V Tustumena*, and a larger existing vessel, *M/V Kennicott*, as a means of providing meaningful results to AMHS and its ridership. Both *Tustumena* and *Kennicott* currently serve the Aleutian and cross-gulf routes.

The US Navy Ship Motions Program (SMP) was used to analyze the three vessels. SMP does frequency-domain seakeeping analyses using linear strip theory. The vessel is treated as a three-dimensional rigid body with freedom to translate and rotate about its axes. The position, velocity, and acceleration of any point on the vessel can be calculated from this information. Appendix K provides the full seakeeping analysis report.

3.10.1.2 Operating Environments and Load Conditions

The vessels were analyzed in two nominal sea states likely to be encountered in the Gulf of Alaska: a moderate sea (Sea State 4, SS4), and a rough sea (Sea State 6, SS6). Table 18 summarizes the key properties of these sea states.

Table 18 Climatology for seakeeping analysis

	Sea State 4	Sea State 6
Wave significant height (H_s, ft)	8.2	19.7
Wave peak period (T_p, s)	8.8	13.8

The vessels are analyzed at all headings relative to the waves because they travel back and forth in essentially open-ocean conditions. Vessel heading is at the discretion of the master, so it is likely that the most unfavorable headings could be avoided in practice.

The vessels were compared at the fully loaded condition because existing seakeeping models of the *Tustumena* and *Kennicott* were available in that condition. Particulars of the full-load conditions of the vessels are provided in Appendix K.

3.10.1.3 Roll Mitigation

Existing AMHS vessels assigned to the cross-gulf and Aleutian routes (viz. *Tustumena* and *Kennicott*) are fitted with bilge keels and active-fin roll-stabilization systems to decrease roll motions. The *Tustumena Replacement Vessel* also includes these features. The active-fin system employed in this seakeeping analysis is the Rolls-Royce Neptune 300 system with 94.0-ft^2 fins. This model is the largest of its kind in the Rolls-Royce line that fits within the present vessel arrangement. Additional fin stabilizer systems from other manufacturers are currently under consideration.

Table 19 compares the areas of skegs, rudders, bilge keels, and stabilizer fins. These surfaces are all considered important contributors to roll damping and roll reduction. Table 19 also compares wave-slope capacity, which is a gross measurement of the fins' power to stabilize roll motions. Mathematically it is the ratio of the fins' maximum induced rolling moment to the vessel's static righting moment per degree of roll angle.

Table 19 Roll-mitigating surfaces and wave-slope capacity

	Tustumena	*Tustumena Replacement*	*Kennicott*
Area of skeg[1] (ft^2)	141.5	395.0	572.5
Area of rudder[2] (ft^2)	73.0	96.8	136.8
Area of bilge keel[3] (ft^2)	255.5	284.8	174.3
Area of stabilizer fin[4] (ft^2)	84.0	94.0	161.5
Wave-slope capacity[5] (deg)	5.9	4.0	4.4

1. Projected area of the skeg.
2. Projected area of one rudder.
3. Flattened projected area of one bilge keel.
4. Planform area of one stabilizer fin.
5. Wave-slope capacity is calculated at cruising speed with the maximum fin angle.

With its current fins, the *Tustumena Replacement Vessel* has a smaller wave-slope capacity than do *Tustumena* or *Kennicott*. *Tustumena* and *Kennicott* have fins with flaps that allow significantly more lift to be developed for a given platform area.. Flapped fins are still under evaluation for the *Tustumena Replacement Vessel*.

3.10.1.4 Measures of Relative Merit

Roll and pitch angles are evaluated as general global indicators of how the three vessels ride in a seaway. Roll and pitch angles are positively correlated with the magnitudes of roll and pitch accelerations and, by extension, they are also positively correlated with structural loads and passenger discomfort. There are three additional local measures of merit evaluated in this analysis:

- Accelerations on the vehicle deck.
- Vertical acceleration at the helicopter winching (or, for *Kennicott*, landing) zone.
- Passenger motion sickness.

Motion sickness incidence (MSI) is a commonly used measurement of passenger comfort. It predicts the fraction of the general population who would experience motion sickness for a specific exposure time, based on exposure to vertical accelerations.

Table 20 and Figure 19 through Figure 21 identify the nine points where local measures of merit are evaluated on each vessel. All points located off centerline are placed on the port side of the vessel.

Table 20 Key points for comparative measures of merit

Point	Location	Metric
1	Forwardmost vehicle	3-degree-of-freedom acceleration
2	Forward outboard vehicle	3-degree-of-freedom acceleration
3	Aft outboard vehicle	3-degree-of-freedom acceleration
4	Aftmost vehicle	3-degree-of-freedom acceleration
5	Helicopter winching zone	Vertical acceleration
6	Forward Cabin	Motion sickness incidence (MSI)
7	Forward Lounge	Motion sickness incidence (MSI)
8	Dining Lounge	Motion sickness incidence (MSI)
9	Aft Cabin	Motion sickness incidence (MSI)

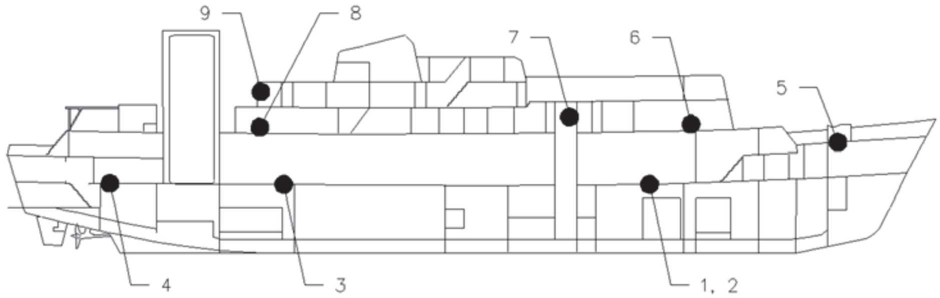

Figure 19 Inboard profile of *Tustumena* with points of interest identified by number

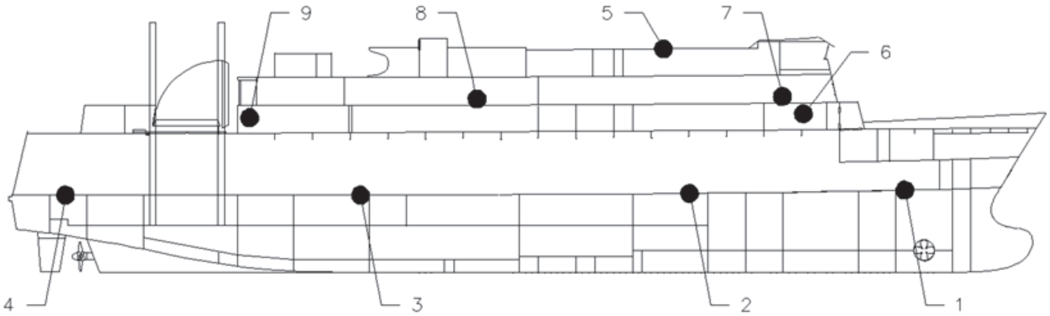

Figure 20 Inboard profile of the *Tustumena Replacement Vessel* with points of interest identified by number

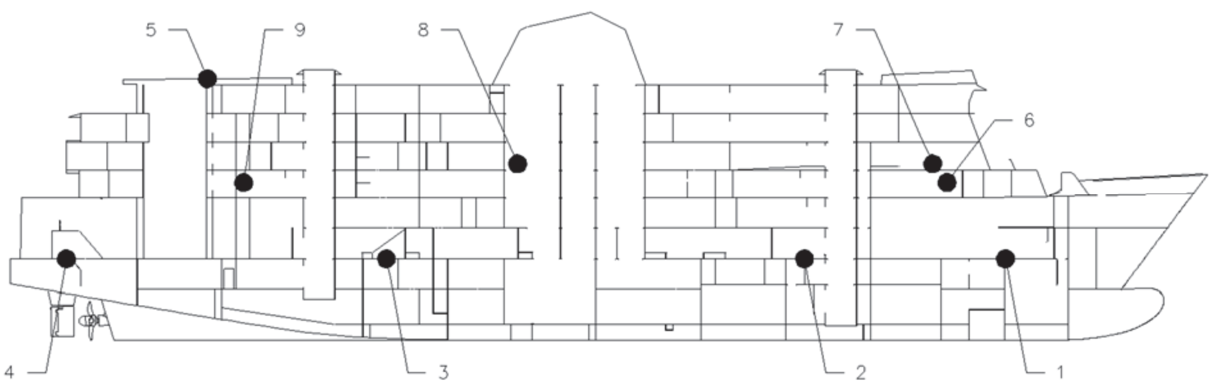

Figure 21 Inboard profile of *Kennicott* with points of interest identified by number

3.10.2 Results

The following subsections contain polar plots of comparative seakeeping results, with the angular abscissa representing vessel heading angle relative to the waves and the radial ordinate representing the magnitude of vessel response. Each result is shown for SS4 and SS6. The scale of each plot is based on the range required to represent each result at the same scale for both sea states. All of the plots refer to the *Tustumena Replacement Vessel* as the TRV. Results for local responses are asymmetrical when the point of interest is not located on centerline.

For acceleration and motion responses, the plots present the root-mean-square (RMS) statistics (i.e., the standard deviation). RMS values are often used to describe stochastic phenomena because they can be easily scaled to represent useful statistics if the properties of the underlying probability distribution are known. Ocean waves and vessel responses are assumed to be a stationary, zero-mean, Gaussian random process, which means that (per Reference 19):

- The average response amplitude is 1.25 times the RMS response amplitude.
- The greatest response amplitude in 1,000 cycles is predicted with 90% confidence by multiplying the RMS response amplitude by 4.29.

3.10.2.1 Roll and Pitch Angles

RMS roll angles are presented in Figure 22 and Figure 23, and RMS pitch angles are presented in Figure 24 and Figure 25. The *Tustumena Replacement Vessel*'s motions generally fall between those of the smaller *Tustumena* and those of the larger *Kennicott*. The *Tustumena Replacement Vessel* exhibits the highest roll response for a following sea in SS6. Additional roll stabilization power could probably reduce this response.

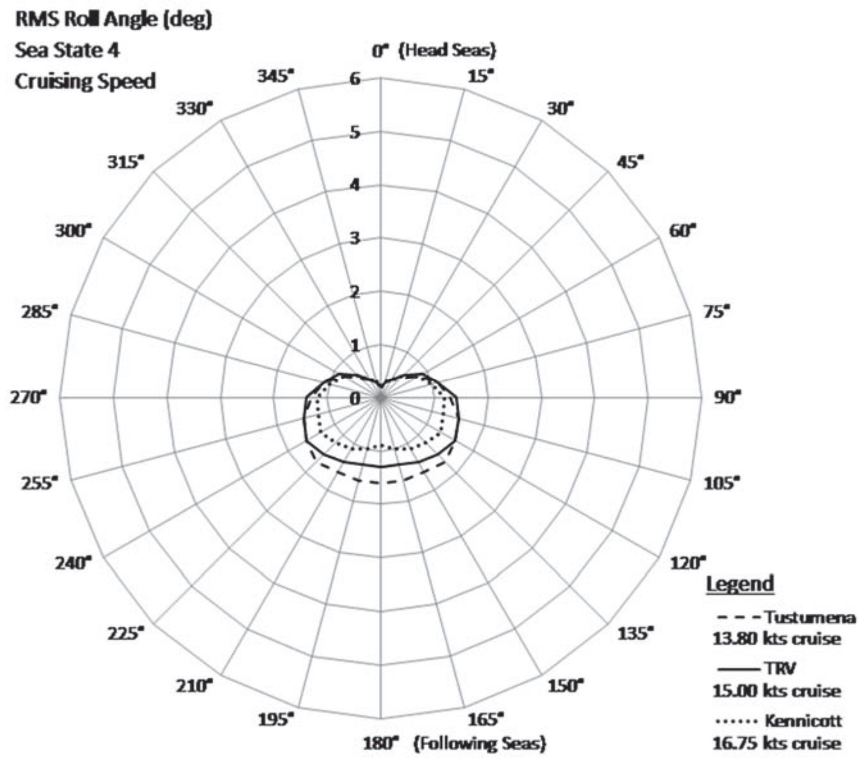

Figure 22 Comparison of RMS roll angles, Sea State 4

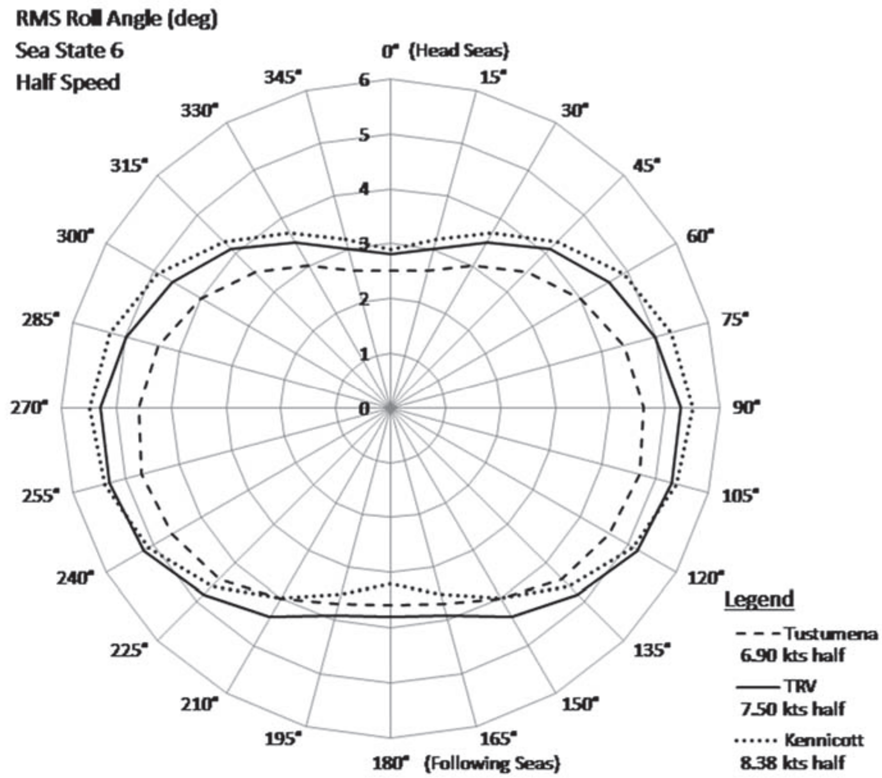

Figure 23 Comparison of RMS roll angles, Sea State 6

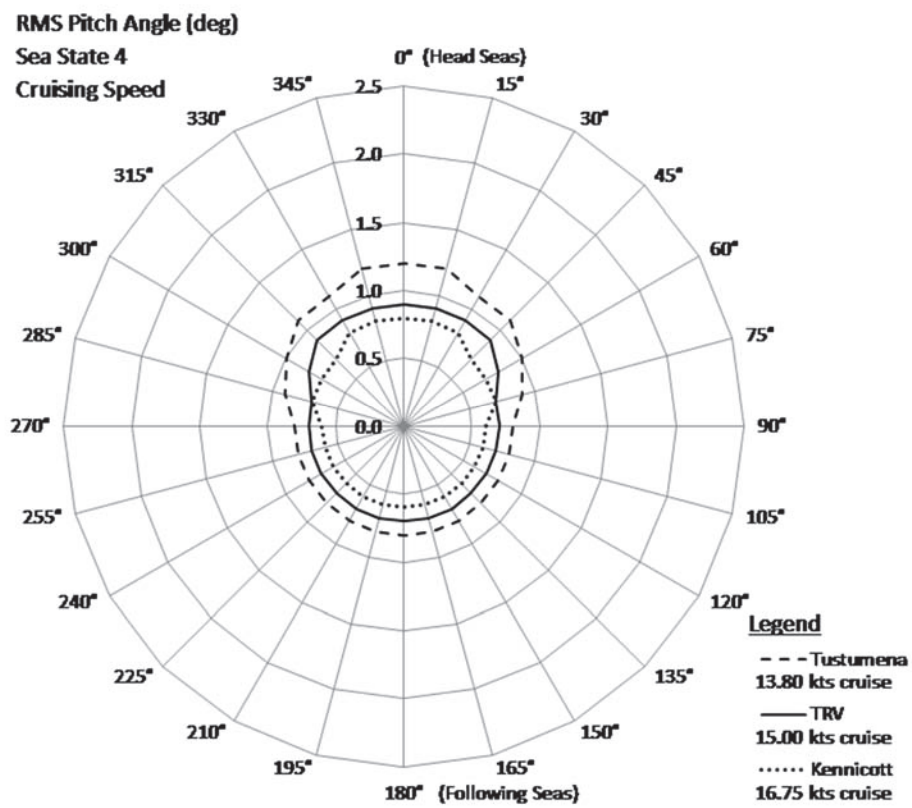

Figure 24 Comparison of RMS pitch angles, Sea State 4

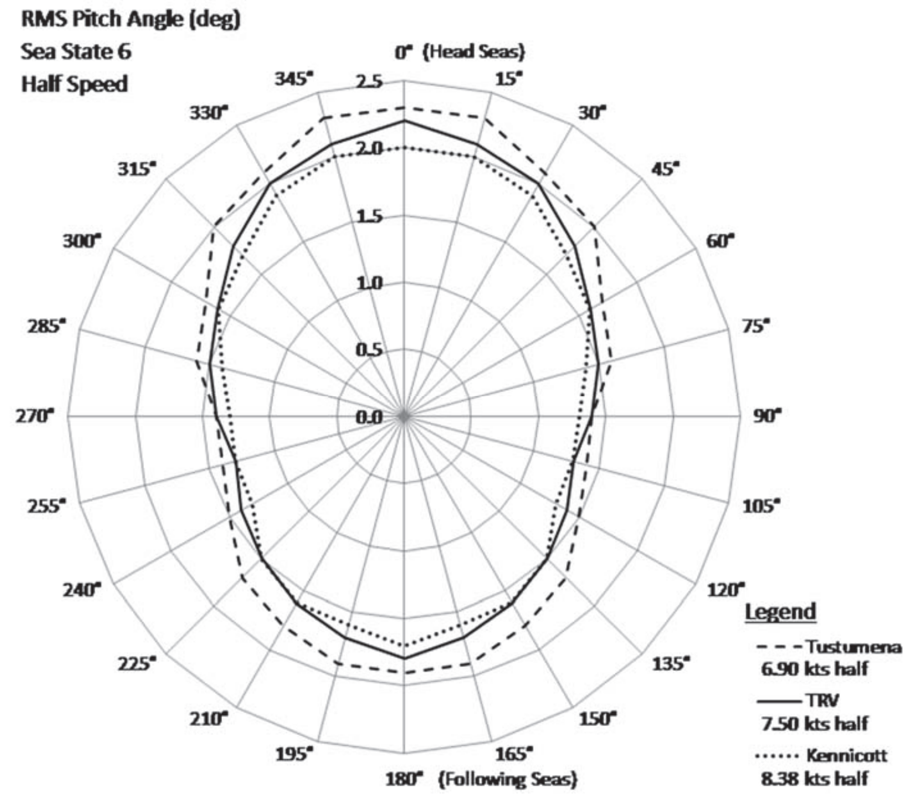

Figure 25 Comparison of RMS pitch angles, Sea State 6

3.10.2.2 Motion Sickness Incidence in Passenger Spaces

Figure 26 and Figure 27 show the percentage of passengers who would experience motion sickness in the Forward Lounge within the vessel during a three-hour exposure to Sea States 4 and 6, respectively. The prevalence of motion sickness in the *Tustumena Replacement Vessel* generally falls between that of the smaller *Tustumena* and that of the larger *Kennicott*.

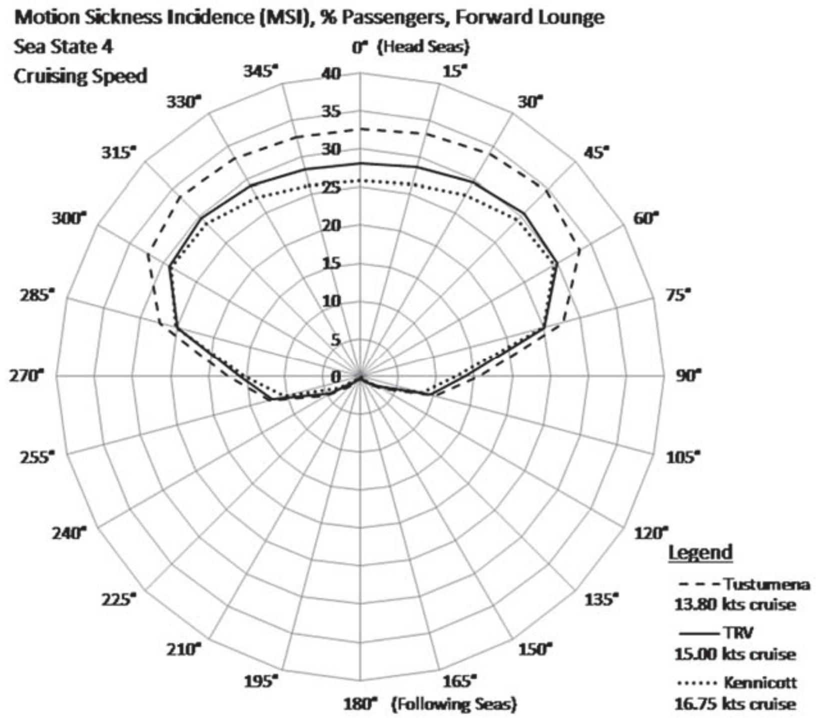

Figure 26 Comparison of motion sickness incidence (MSI), Forward Lounge (point #7), Sea State 4

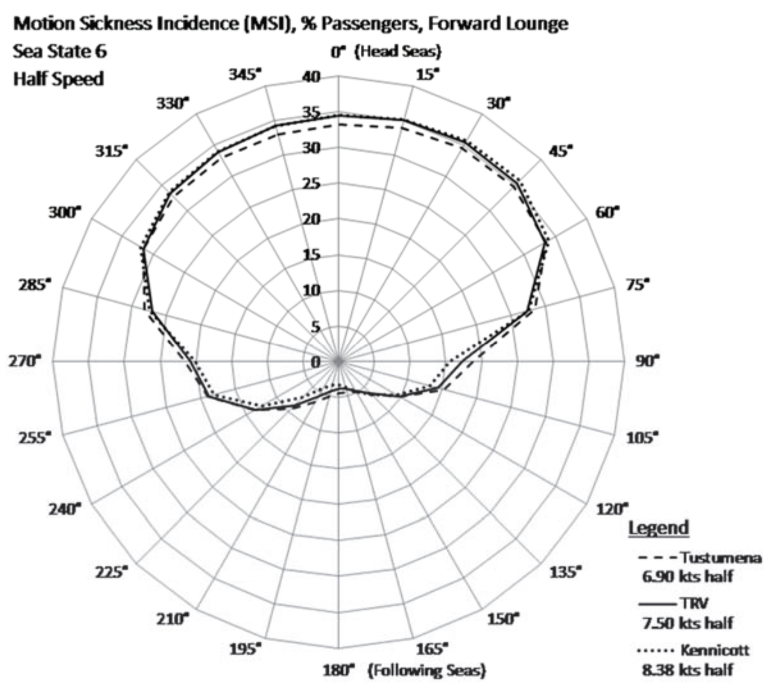

Figure 27 Comparison of motion sickness incidence (MSI), Forward Lounge (point #7), Sea State 6

3.10.3 Conclusion

The *Tustumena Replacement Vessel* generally exhibits seakeeping behavior between the smaller *Tustumena* and the larger *Kennicott*. Design accelerations on the vehicle deck may be slightly higher than are those found on *Tustumena* or *Kennicott*, but they can be accounted for in the structural design. Vertical accelerations at the helicopter winching zone on the *Tustumena Replacement Vessel* fall between those of *Tustumena* and those of *Kennicott*. Passenger comfort is generally likely to be better than that of the smaller *Tustumena* but not as good as that of the larger *Kennicott*.

Roll motions and accelerations could be reduced by installing more roll stabilization power on the *Tustumena Replacement Vessel*. More power could be achieved in one of three ways:

- **Flapped fins.** Flapped fins require additional maintenance, but they are substantially more effective than are un-flapped fins of the same size. The current availability and performance of flapped fins for this application is under development.
- **Larger un-flapped fins.** Larger un-flapped fins protrude farther into the vessel, affecting the arrangement of structure and machinery. They also protrude farther outside the vessel when extended, improving performance but also increasing drag.
- **Two pairs of fins.** When two pairs of fins are installed, each fin can be smaller. The system becomes more complex, more expensive, and more maintenance-intensive, but it also provides some redundancy.

These three options may be considered as the design progresses, pending the receipt of data from manufacturers of roll stabilization systems.

Section 4 Regulatory Considerations

4.1 Introduction

This section outlines the primary sources of regulatory requirements and classification society rules that will govern the design, construction, operation, and maintenance of the *Tustumena Replacement Vessel*, as well as those that will guide interactions with the regulatory bodies with respect to plan and other technical reviews, and assignment of any vessel operational constraints.

This section also identifies requirements for various types of systems and equipment derived from these sources, where the need for such systems and equipment, or related system or equipment requirements, are predicated upon the vessel's service type, route, or its physical or operational characteristics.

A full discussion of all relevant regulatory and classification issues affecting the design, construction, and operation of the new vessel is included in Appendix N.

The following are current vessel physical and operational characteristics of the subject vessel that bear on the regulatory and rule information contained in this report:

Service Type:	Domestic-Only
Service Route:	Oceans (< 50 nautical miles off shore)
Gross Tonnage (Domestic):	Greater than 1,600
LOA:	330'-0" (100.6m)
LWL:	314'-6" (95.9m)
Number of Passengers:	250
Number of Officers/Crew:	< 50
Total Lifesaving:	< 300
Number of Passenger Staterooms:	43

Discussion of requirements pertaining to environmental concerns (i.e., oil and air pollution prevention, garbage processing, and aquatic nuisance species and hazardous materials control) and regulatory guidelines and expectations as they relate to Americans with Disabilities Act (ADA) compliance are addressed in separate sections of this report (Appendix O and Section 3.1.5, respectively).

The US Coast Guard (USCG) has substantive agreements in place with the following classification societies as they relate to the review and approval of vessel and systems' design plans and inspection of in-process vessel construction:

- American Bureau of Shipping (ABS).
- Det Norske Veritas Germanischer Lloyd (DNV GL).
- Lloyd's Register (LR).

All of the foregoing classification societies are authorized to act on the USCG's behalf under the terms of the Alternate Compliance Program (ACP). The State of Alaska currently intends to have the vessel registered with and inspected by the American Bureau of Shipping (ABS), as permitted by the USCG ACP. Another classification society may be selected before design and construction begins and the applicable requirements will be defined at that time.

Assuming ABS is selected for classification, the following ABS class notations and symbols would apply to the vessel:

✠A1	-	Hull and Equipment built under ABS survey
✠AMS	-	Machinery, Boiler and Systems built under ABS survey
✠ACC	-	Shipboard Automation Systems built under ABS survey
Ⓔ	-	Anchor Equipment and Chain Cables built under ABS survey

The ship's complete classification symbol would therefore be:

✠A1, Vehicle Passenger Ferry - Limited Oceans Service, Ⓔ, ✠AMS, ✠ACC

Optional ABS class notations recommended for the *Tustumena Replacement Vessel* include: HAB and COMF.

The details of the above notation are described in Appendix N.

4.2 Recommended Regulatory Considerations

4.2.1 Vessel Classification

The ACP requires vessels to be classed with an ACP-authorized Classification Society (ACS) and certified under a subchapter of 46 CFR which permits alternate compliance. For new construction, a request for enrollment in the ACP is required from both the shipyard and the owner since enrollment in this program will influence both parties. The controlling documents pertaining to vessels enrolled in ACP are:

- SOLAS, as amended.
- MARPOL, as amended.
- NVIC 2-95, Change-2.
- Volume II, Section B Chapter 9 of the USCG *Marine Safety Manual*.
- The Rules publications of the cognizant ACS (ABS in this case).
- A USCG-approved supplement to the ACS' rules.

A vessel enrolled in the ACP must satisfy all the requirements contained in the applicable sections of each of these documents prior to the issuance of the Certificate of Inspection (COI).

The process for enrollment in ACP is defined in the aforementioned sections of the USCG *Marine Safety Manual* and NVIC 2-95, the latter of which is the guiding document for ACP administration and policy. The owner and shipyard should consult with the intended classification society (ABS in this case) as early in the design phase as possible, since the design, fabrication sequences, and construction cost may be affected by the intended enrollment of the vessel in an ACS.

4.2.2 USCG Domestic Service Regulations

Subchapters E, F, H, J, S, and W of 46 CFR (Reference 2) and Part 80 Subpart W of 47 CFR (Reference 3) will apply to the *Tustumena Replacement Vessel.* Various sections of the report in Appendix N list systems and equipment that will be required by these sections, other USCG guidelines, and USCG documentation and inspections that will be required of the vessel.

4.2.3 American Bureau of Shipping (ABS) Rules

The ABS *Rules for Building and Classing Steel Vessels* (Reference 17), *Guide for Building and Classing Passenger Vessels* (Reference 22), and *Guide for Shipbuilding and Repair Quality Standard for Hull Structures during Construction* (Reference 23) will pertain to the *Tustumena Replacement Vessel* since ABS is the selected classification authority for the vessel. Various sections of the report in Appendix N list systems and equipment that will be required by these sections, other USCG guidelines, and USCG documentation and inspections that will be required of the vessel.

4.3 Optional Classification Considerations

Myriad optional class notations are available from ABS. Many can be applied to any type of vessel, but others are available for consideration only for a vessel of a particular type or engaged in a particular type of service (e.g., Vessels under 90 meters in Length, High-Speed Craft, Motor Pleasure Yacht, Service on Rivers and Intracoastal Waterways, Barges in Offshore Service, etc.). These notations and symbols pertain to hull structure, analyses, equipment, machinery, automation, surveys, and other aspects of vessel design, construction, and operation.

Obtaining optional class notations may be attractive to AMHS for a variety of reasons, including:

1. Certain ABS class notations allow AMHS to demonstrate compliance with accepted industry standards for environmental "greenness" which may be beneficial from a marketing perspective to the public or legislative authorities.
2. Certain ABS class notations require construction to accepted standards understood by both AMHS and shipyards, reducing the potential for quality disputes during construction.
3. Certain ABS class notations require machinery and equipment manufactured to accepted standards, ensuring a known level of quality for AMHS.

The full list of available and applicable ABS class notations is included in Appendix N. Those class notations deemed most likely of interest to AMHS have been singled out for discussion below.

4.3.1 Habitability Classifications

There are several class notations that can be applied to any vessel meeting the criteria and approved by ABS. Some of the optional improved habitability notations are recommended for consideration by AMHS for the *Tustumena Replacement Vessel*.

HAB notation regards the quality of the crew quarters. A level of HAB notation is recommended for the *Tustumena Replacement Vessel* because it will help AMHS allow

ABS to enforce high standards of quality for the crew quarters. The notation could be dropped after vessel construction is complete to avoid AMHS having to continually pay ABS for maintaining this certification.

(HAB –) This notation is assigned to vessels which comply with the minimum criteria for accommodation area design, whole-body vibration (separate criteria for accommodation areas and workspaces), noise, indoor climate, and lighting as included in the ABS *Guide for Crew Habitability on Ships*.

(HAB+ –) This notation is assigned to vessels which comply with more stringent habitability criteria with respect to accommodation areas, whole-body vibration and noise aimed at increasing crew comfort and safety as included in the ABS *Guide for Crew Habitability on Ships*.

(HAB++ –)This notation is assigned to vessels which comply with more stringent habitability criteria with respect to accommodation areas, whole-body vibration, noise, and indoor climate as included in the ABS *Guide for Crew Habitability on Ships*.

COMF notation applies to the passenger accommodations, and is recommended for the *Tustumena Replacement Vessel* to allow AMHS to use ABS in enforcing quality standards. The notation could be dropped after vessel construction is complete to avoid AMHS having to continually pay ABS for maintaining this certification.

(COMF) is a notation that may be assigned to a passenger vessel complying with specified minimum criteria for passenger accommodations and the ambient environment (i.e., vibration, noise, indoor climate and lighting). This notation is assigned to passenger vessels built in accordance with the requirements of the ABS *Guide for Passenger Comfort on Ships.*

(COMF+) is a notation that may be assigned to a passenger vessel complying with specified minimum criteria for passenger accommodations and the ambient environment (i.e. vibration, noise, indoor climate and lighting) and additional criteria with respect to whole-body vibration, including motion sickness. This notation is assigned to passenger vessels built in accordance with the requirements of the ABS *Guide for Passenger Comfort on Ships*.

4.3.2 International Certification Systems

AMHS has stated that it does not intend to have the subject vessel designed or certificated for International voyages; however, AMHS intends to have certain systems and equipment incorporated into the vessel that currently are only required for vessels conducting International voyages, including:

- Voyage Data Recorder (VDR)
- Automatic Identification System (AIS)
- Local Application Firefighting System (LAFF)

The following are other miscellaneous items that are only required on vessels conducting International voyages, but that are commonly found on AMHS' domestic-service-only vessels and thus may be desired on the *Tustumena Replacement Vessel*:

- Fireman's Outfits [46 CFR 77.35-1]
- Signaling Light/Lamp [46 CFR 111.75-18]

Section 5 Cost Estimates

5.1 Acquisition Cost

Vessel shipyard and program cost estimates have been developed to establish a project cost. All estimates are in 2014 dollars (or have been adjusted to 2014 dollars).

In support of AMHS in developing these estimates for the *Tustumena Replacement Vessel*, it is important to understand the various program and construction cost elements. Both are significant drivers to identifying and establishing a total program cost.

5.1.1 Vessel Shipyard Construction Cost

An independent vessel shipyard construction cost estimate was developed using the preliminary design of the *Tustumena Replacement Vessel* and applying a Ship Work Breakdown Structure (SWBS) method.

The SWBS-based cost estimate assigned units, quantities, unit labor, unit materials, and unit subcontracts to specific work items to develop the base capital cost. Work items include major SWBS category items for engineering and yard services, hull structure, propulsion, electrical plant, command and surveillance, general machinery, outfit and furnishings, and post construction support. In the Recon Report, most systems were not yet defined so a parametric analysis was performed to develop the costs.

The steel weight was based on detailed modeling and calculations. The vessel dimensions increased over what was estimated in the Recon Report with the length increasing by 5 feet, the beam by 2 feet, and the depth by 1.5 feet.

In the Recon Report, the steel weight was based on the 1st generation 350' long Alaska Class Ferry (ACF), assuming the *Tustumena Replacement Vessel* would be about 10% lighter (Reference 24). The 350' ACF weight estimate was also used for high level detail weight estimates with further equipment identification weights further defined.

Due to the importance and significant cost of the vehicle elevator, a specific cost for this item was identified and estimated at $15 million. In a similar fashion, the fin stabilizer pair was estimated at $2 million, uninstalled.

A material markup of 15% (a typical Contractor markup) was also added to the base capital cost.

The vessel capital cost estimate is shown in Table 21. The cost estimate is presented in 2014 dollars. Historically, the Consumer Price Index (CPI) growth rate is 2.5% so related costs will increase proportionally to the year when the vessel is actually constructed.

This cost estimate is based on construction of the vessel in a Gulf Coast facility with a labor rate of $69.60 per hour. Recon Report cost results indicated a premium for construction on the West Coast, with a comparable labor rate of $79.40 per hour to be used for the DSR input.

If the project is partially or fully federally funded, labor rates may change due to prevailing wages and fringe benefits for the area where the vessel is constructed.

Cost allowances include an owner contingency of 10% to cover shipyard costs as the design and cost estimates are refined. This contingency will be adjusted going forward as the design and cost estimates mature.

Table 21 Shipyard construction cost estimate summary (2014 dollars)

Cost Basis	SWBS Method (Gulf Coast)	SWBS Method (West Coast)
Estimated capital cost	$151,000,000	$161,000,000
Owner contingency (10%)	$15,000,000	$16,000,000
Total	$166,000,000	$177,000,000

Refined construction cost estimates from the current preliminary design phase are compared below in Table 22 to concept design costs from the Recon Report (Reference 1).

Table 22 Concept vs preliminary design cost comparison (2014 dollars)

Cost Basis	Volumetric Method (Concept Design) (Reference 1)	SWBS/Parametric Method Gulf Coast (Concept Design) (Reference 1)	SWBS Method Gulf Coast (Preliminary Design)
Estimated capital cost	$173,000,000	$160,000,000	$151,000,000
Owner contingency (10%)	$17,000,000	$16,000,000	$15,000,000
Total	$190,000,000	$176,000,000	$166,000,000

5.1.2 Program Costs

Program costs are other items not directly related to the shipyard constructing the vessel, but required to execute the project.

Table 23 reflects program costs and is composed of the following elements:

- Program contingency of 10% to cover changes in program and construction costs.
- ICAP of 4.79% (Indirect Cost Recovery Plan).
- Loose outfitting and equipage to cover outfitting of the vessel not supplied by the shipyard.
- Construction support of 10%. This is for the on-site team and all construction support including consultants, travel, and per diem.

  Note: the estimated Construction engineering (CE) percentage for the Tustumena Replacement Vessel is higher than that used on the recently designed and contracted Dayboat Alaska Class Ferries based on the greater complexity of the vessel.

Table 23 Program cost basis (2014 dollars)

Item	Estimated Cost (Gulf Coast)	Estimated Cost (West Coast)
Program contingency (10%)	$16,600,000	$17,700,000
ICAP (4.79%)	$8,000,000	$8,500,000
Loose outfitting and equippage	$3,500,000	$3,700,000
Construction support (10%)	$16,600,000	$17,700,000
Total Program Cost	$44,700,000	$47,600,000

5.1.3 Total Estimated Project Cost

The total estimated project cost range is the summation of all the shipyard construction costs and program costs and are given in 2014 dollars. The costs are given as a range to account for the variability in the construction location (West Coast or Gulf Coast) as well as the preliminary nature of the design at this point. As the design progress and further detailed information becomes available, it is expected that the cost range will narrow.

Based upon the preceding information, the estimated project cost range for the current preliminary design would be $211-225 million as shown in Table 24. However, given there are several major recommendations from the VE study that have yet to be incorporated into the preliminary design, it is prudent to retain the $237 million Volumetric Method estimate from the Recon Report as the upper limit for the current cost estimate.

Table 24 Total program estimate cost summary (2014 dollars)

	Volumetric Method (Reference 1)	SWBS Method (Gulf Coast)	SWBS Method (West Coast)
Estimated Shipyard Construction Cost	$190,000,000	$166,000,000	$177,000,000
Estimated Program Cost	$47,600,000	$44,700,000	$47,600,000
Total	**$237,600,000**	**$210,700,000**	**$224,600,000**

5.2 Operating Cost

Two major factors drive the operational costs of the vessel:

- Manning cost.
- Fuel consumption.

Operating costs were calculated using the operational profile of the vessel, which was determined based on information gathered from AMHS on the *M/V Tustumena* route and vehicle information. The operational profile was used for developing load profiles when evaluating the life cycle cost analysis. Cruising speed and weather conditions were based on meeting the schedule of the current *M/V Tustumena*. Although the new vessel is capable of faster speeds, it was assumed the faster speeds would only be used to make up for delays in schedule. Operating time spent on each day was gathered from *M/V Kennicott* propulsion study and was extrapolated to maintain the Southwest route exclusively. Calculated values and assumed parameters are summarized in Table 25.

Table 25 Operational profile

Mission	Transit	Maneuvering	Dockside	Total
Speed (knots)	13.8	5	0	
Summer Operating Time (days)	93.1 (70%)	13.3 (10%)	26.6 (20%)	133 (19 weeks)
Winter Operating Time (days)	64.4 (40%)	16.1 (10%)	80.5 (50%)	161 (23 weeks)

The remaining 10 weeks of the year the vessel was assumed to be taken out of service for maintenance.

5.2.1 Annual Manning Cost

Manning costs presented have been estimated by AMHS based on manning and crew requirements developed in Appendix F. Manning operation was assumed to be seven days per week during a 19-week summer season and 23-week winter season. Overhaul and preventative maintenance was accounted for during the remaining four weeks of the year.

Table 26 Annual manning cost (USD$)

	Weeks	Crew	Cost/Week ($)	Total Cost ($)
Summer	19	38	230,000	4,400,000
Winter	23	34	210,000	4,800,000
Overhaul	10	2	19,000	190,000
Total				**$9,400,000**

5.2.2 Fuel Consumption Estimate

Power requirements used for fuel consumption can be seen in Table 27. All ship service electrical power was assumed to be developed by the PTO generators during transit and maneuvering. The ship service generators were used for dockside operation only. The oil-fired boiler was assumed to operate at half capacity during transit, maneuvering, and dockside operations in the winter weeks only, as well as during the 10 week overhaul period.

Ship service peak electrical load calculated from the electrical load analysis (Drawing No. 13105.05-300-02, Appendix A) was estimated at 850 ekW. Average ship service load was assumed to be 540 ekW averaged year round. An average load of 200 ekW is factored into the dockside calculation for the vehicle elevator. An updated power requirement can be seen in Table 27 below which has been adjusted for annual consumption.

Table 27 Estimated power requirements average over one year*

	Transit	Maneuvering	Dockside
Propulsion Power, kW (hp)	2220 (2975)	615 (825)	0
Total Shaft Power, kW (hp)	2220 (2975)	615 (825)	0
Average Electric Load, kW	540	1,080	540
SS Load, kW	540	540	540
Bow Thruster, kW	0	540	0

*Shafting, gear, and electrical efficiencies included.

Estimated annual fuel consumption can be seen in Table 28 below.

Table 28 Annual fuel consumption

		Summer Fuel Consumption Gal/Yr	Winter Fuel Consumption	Fuel Cost ($3.30/gallon)
Transit	Main Engine	390,000	270,000	$2,178,000
	Generators	-	-	-
	Boiler	-	70,000	$231,000
Maneuvering	Main Engine	35,000	42,000	$254,000
	Generators	-	-	-
	Boiler	-	17,000	$56,000
Dockside	Main Engine	-	-	-
	Generators	25,000	76,000	$333,000
	Boiler	-	87,000	$287,000
Overhaul	Boiler	-	76,000	$251,000
Total		**450,000**	**638,000**	**$3,590,000**

Lube oil cost was assumed 1% of annual fuel consumption cost and was accounted for in the operating cost summary.

Operating costs in Table 28 were calculated to maintain the current schedule with a 13.8 knot transit speed. An analysis was performed with the vessel transiting at 15 knots to determine the increased fuel consumption necessary to maintain the 1.2 knots of increased speed. At 15 knots the propulsion power increases from 2,975 HP (Table 27) to 3,900 HP. Updating Table 28 for the increased propulsion power, the annual fuel consumption increases by $350,000. This represents an increase of 10% of the annual fuel consumption cost.

5.2.3 Summary Operating Cost

The estimated annual operating cost can be seen below.

Table 29 Annual operating cost

	Units	Annual Operating Cost
Manning		
Annual Cost	(USD$/yr)	$9,400,000
Fuel Cost		
Annual Cost	(USD$/yr)	$3,590,000
Lube Oil Cost	(USD$/yr)	$36,000
Total	**(USD$/yr)**	**$13,000,000**

Section 6 Vessel Technical Description

6.1 Basis of Design

The Vessel Technical Description was created in the SWBS organizational structure in order to both document the basis of design for the *Tustumena Replacement Vessel,* and to provide specific references to various elements that were developed in the preliminary design phase.

The intent is to continue to design the vessel in accordance with the Vessel Technical Description and use this document as a baseline for development of detailed shipyard specifications for AMHS during the PS&E phase.

Most of the Basis of Design documents have already been reviewed by the AMHS Steering Committee as the DSR developed. Comments received from the Steering Committee have been tracked and addressed during this phase of the project. Various reports were created to support Basis of Design documents, such as Appendix J, the Power Generation Report.

6.2 Vessel Technical Description Document

The Vessel Technical Description document presents information in the SWBS structure for the AMHS Steering Committee to review and agree upon as the vessel design progresses to a bid design. The information in this document includes section and system specific regulatory requirements, AMHS requested features, selected major equipment, and desired features that will be present in the vessel owner design. Appendix Q contains the Vessel Technical Description document.

Section 7 Value Engineering Study

7.1 Purpose and Objectives

A Value Engineering (VE) study sponsored by The Glosten Associates and facilitated by Value Management Strategies, Inc., was conducted for the *Tustumena Replacement Vessel* Project for the Alaska Marine Highway System (AMHS). The study was conducted at the offices of The Glosten Associates from September 8 to 11, 2014. The VE study is included as Appendix T.

The VE study was conducted after the draft Design Study Report (DSR) was submitted so that preliminary study results could be included with the DSR.

An implementation meeting between Glosten, AMHS, and VMS was held on October 1, 2014 to discuss the study and determine which recommendations will be applied to the vessel design as the contract design is developed.

The objective of the VE study was to identify viable value-adding design alternatives by:

- Analyzing the current project design, estimate and schedule.
- Providing possible cost and/or schedule saving recommendations.
- Providing performance improvement recommendations.

7.2 Evaluation of Baseline Concept

During the course of the VE study, a number of analytical tools and techniques were applied to develop a better understanding of the baseline concept. A major component of this analysis was Value Metrics which seeks to assess the elements of cost, performance, time, and risk as they relate to project value. These elements required a deeper level of analysis, the results of which are detailed in Appendix T. The key performance attributes identified for the project include:

- Operational Performance.
- Operational Expense.
- Passenger Experience.
- Vessel Organization.
- Operational Flexibility.

The evaluation of the baseline design concept determined that the initial design is a very effective approach to fulfill the purpose and need of the project while also meeting or exceeding the AMHS requirements for the replacement vessel. The defining feature of the vessel, the vehicle elevator, is of a newer and untested design, but appears to be quite thoroughly detailed. Being that the current design is at an early stage, some of the ship components and systems lack full definition or type selection, but these details are a result of the VE study occurring at this time. The project design is currently on schedule. That being said, the design has “Good” to “Very Good” initial perceived attribute scores in most every performance category, with notable exceptions being “Fair” scores in Operational Maintenance Expenses and the Passenger Experience Galley/Dining Facility attributes.

The conclusion of the stakeholders present at the VE study was that Operational Performance (both At Sea and Loading/Unloading) carried a significant weight to the project's purpose and need (28% and 16%, respectively). The Maintenance Operational Expense attribute, as well as the Passenger Experience of the Galley/Dining Spaces, were weighted lower (16% and 15%, respectively), but were still considered very important to the project's performance. Other areas of operational expense and passenger experience were considered, but each provided weights of below 10%. The baseline concept was graded by the stakeholders, posting high scores on a scale of 1 to 10, but establishing the fact that there were still areas for improvement.

7.3 VE Study Results

7.3.1 Initial VE Recommendations

The VE team developed 27 VE alternatives that were organized into a single VE strategy (combination of alternatives). At this stage in the design development process, it was recommended that all of the VE alternatives be considered.

While the VE team did not quantify schedule savings for any individual VE alternative, it was felt that collectively, the minor schedule improvements could reduce the overall project schedule by 2 months if all alternatives were implemented. Performance was assessed to be approximately 17% higher than the original design concept. The aggregate effect of the performance improvements and schedule savings results in a net value improvement of 19%. It is important to note that a major consideration of the VE strategy that is not easily quantified in this analysis is the overall mitigation or reduction of the operational risk that the recommended alternatives represent.

The VE team considered the combined effect of all VE alternatives for the VE strategy on performance. The combined VE alternatives offer significant performance improvements for the high-priority attributes such as At-Sea Operational Performance and Maintenance Operational Expense.

The strategy provides a slight improvement in the delivery schedule and a major improvement in performance, depending on stakeholder input regarding attribute preference and baseline design performance. It is important to note that the strategy does increase the overall cost of the project, it does not take into account the effects of life-cycle savings in the overall 19% total value improvement number displayed.

Appendix T provides additional details on this analysis, including how improvements to performance, cost, and value were calculated. Also included in Appendix T is the outcome of the implementation meeting, which incorporates feedback from AMHS on the proposed VE alternatives.

7.3.2 Final VE Recommendations

After the initial VE recommendations were developed, the list was revised by VMS, AMHS and Glosten to determine which items to carry forward into the next design phase. Of the 27 VE alternatives the team developed, 19 have been accepted for implementation. Three alternatives were identified for further study before final determination could be made, and all but one of the Design Suggestions are noted for implementation consideration. During the implementation meeting, performance improvements resulting from the accepted VE alternatives were assessed to be approximately 8.8% higher than the original baseline concept. The VE alternatives vary in size and impact of design on the ship, and are summarized in the next section.

7.3.2.1 Accepted VE Alternatives

Accepted VE Alternatives
Increase car capacity with hoistable vehicle deck
Eliminate interior camber to simplify construction
Eliminate interior sheer to simplify construction
Use flap-type stabilizer fins to improve passenger comfort
Change conventional rudders to high performance rudders
Provide uptake space to allow for Selective Catalytic Reduction for main engines
Include electrical room adjacent to wheelhouse
Use proven systems for the elevator lift and handling systems
Simplify engine room ventilation controls
Do not backfeed the Main Switchboard from the Emergency Switchboard
Use a conventional PTO drive instead of variable frequency PTO drive
Use LED lighting throughout the ship
Use UV grease extraction in lieu of mechanical extraction to reduce grease contamination and handling
Locate galley floor drains at ingress/egress points
Subdivide refrigerated and frozen bulk storage areas to ensure food safety
Provide separate work stations for food preparation in galley
Separate scullery into different zones, one for pot/pan and another for ware washing to improve personnel efficiency
Store four vehicles on elevator platform to increase car capacity
Enhance safety by incorporating portable end barrier gate on both ends of vehicle hoist platform and car deck (use heavy cable netting)
Enhance safety by using framed mesh handrails on passenger-accessible decks

A substantial list of accepted VE alternatives evolved from the Value Engineering process. Some of the VE alternatives were accepted as proposed, others were altered somewhat to better fit the overall design objectives. An example of a major VE proposed change is to increase the vehicle capacity of the ferry by 6 standard Alaska vehicles (12%) through implementing a port side fixed deck with hoistable ramp on the Main Deck. Although the VE initially proposed hoistable decks for both sides of the vehicle deck, the starboard side is not adequate since it would intrude on van capacity. This change will eliminate some crew staterooms but the vessel will still have accommodations for 38 crew.

Another substantial VE change resulting in a reduction in construction costs will be achieved by eliminating the camber on all interior decks. This will also facilitate the use of standard height bulkhead panels and furniture to match orthogonal surfaces. A straight-line camber will be used on exterior decks instead of the curved camber to help shed water. This VE alternative has a significant initial cost saving of $952,000. Costs will also be saved by eliminating the interior sheer to simplify construction on the Main Deck and the Mezzanine Deck. It should be noted that the Main Deck will only be modified if the sheer is not needed to provide a deeper load line. The foredeck will be built with a sheer in order to facilitate shedding of water.

To improve passenger comfort, the VE alternative of using flap-type stabilizer fins is accepted. This VE alternative is appropriate for the vessel because of its operational environment. This adjustment will have an increase in maintenance costs but sees an overall savings between the validated initial cost savings and validated subsequent cost savings. A second VE alternative which is accepted, based on the operational environment, is to replace the conventional rudders with high-performance rudders. This will allow for improved vessel operation in more adverse weather conditions and low maneuvering speeds.

An accepted VE alternative which allows flexibility in main engine options is to provide sufficient spacing for the future installations of a selective catalytic reduction module. The engine room will also see an adjustment to provide two-speed exhaust fans. These allow the engineer to control the engine room temperature utilizing VFD powered supply fans as opposed to baseline design which used two PID loops. Another VE adjustment to the ship configuration is the inclusion of an electrical room adjacent to the wheelhouse. Although adjacent rooms will need to be shifted, this facilitates simpler electronic installation and later modifications. The main switchboard will also see minor adjustments through implementation to not backfeed the main switchboard from the emergency switchboard. This minor adjustment improves safety by reducing the risk of damage to the conventional switchboard. Throughout the ship, the use of LED lighting will be used wherever possible.

The most significant VE alternative which was accepted is changing the design of the vehicle elevator lift. The proven cable lift technology suggested meets the top-level design requirements. The most influential of these being that the wire rope systems are tolerant of installation processes, they can operate in adverse weather conditions and the wire drum systems utilize winch arrangements where all drive, reduction, braking and drum components are located on one assembly. The baseline ball-screw system was undesirable mainly because it requires high precision installation and maintenance and the system is not proven in inclement weather.

After the VE study, the galley design will see several adjustments. The use of UV grease extraction in lieu of mechanical extraction will be implemented. This will provide significant subsequent cost savings of approximately $568,000. This modification increases the grease extraction from the galley which in turn reduces fire risk and provides a cleaner ship with less work from the galley crew. In the galley, the floor drains will be located at ingress and egress points through use of a longitudinal trough. Another accepted VE alternative which impacts the galley is to subdivide the refrigerated and frozen bulk storage areas to ensure food safety. This concept will be verified by the FDA and/or State of Alaska requirements to ensure compliance. Two VE alternatives which are accepted but reflect no change in cost are to provide separate work stations for food preparation in the galley and to separate scullery into different zones. These adjustments promote “safe food handling” procedures and multitasking within the galley.

An additional way to increase the capacity of the ferry is to store two additional cars on the elevator platform during transit. This increases the vehicle capacity by about 4%. The vehicle hoist platform will see an increase in safety by incorporating portable end barrier gates on both ends of the platform and car deck. The last VE alternative accepted by the team further increases the safety of passengers by using framed mesh handrails on passenger-accessible decks.

7.3.2.2 VE Alternatives Requiring Further Investigation

Three VE alternatives require further investigation before they can be accepted changes for the *Tustumena Replacement Vessel*. The use of Holland Profile stiffeners (i.e. bulb flats) has been considered. This VE alternative would increase the initial cost by a proposed value of $1,095,000 but also has a proposed subsequent savings of $839,000.

A second VE alternative which requires further study is the increase in car deck plate thickness to minimize long-term maintenance.

Finally, further study is needed to consider using cylinder and tiller type steering gear in lieu of the proposed rotary vane type. An investigation is necessary to determine whether this steering gear would be compatible with the high performance rudders.

7.3.2.3 Rejected VE Alternatives

Five VE alternatives were rejected throughout the value engineering process. VE alternative 7.0 proposed changing the tunnel thruster to an omnidirectional thruster. Although this would improve the maneuverability and lower wakes on confined harbors, it is significantly more expensive than the traditional bow thrusters and adds weight while reducing buoyancy.

Moreover, it was decided to keep the variable frequency PTO drive instead of changing it to a conventional PTO drive. This concept was rejected based on cost, fuel savings and the ability to revert back to the conventional PTO should the variable frequency PTO fail.

On a smaller scale, the VE alternative suggested to reduce food waste weight and volume using a waste dehydrator was rejected because of lower service levels on the remote transit.

In lieu of accepting the VE alternative of using a “scatter food serving” system in the galley, the straight line system will remain in order to ensure adequate seating for passengers.

Finally, there will not be an additional evaporative coil installed in each refrigerator. This decision was made based on cost and flexibility provided by subdivision of refrigerated and frozen areas.

The Value Engineering process was an important design stage for the *Tustumena Replacement Vessel*. Design decisions were questioned and many valuable VE alternatives were proposed and accepted, which will improve the overall design of the ferry.