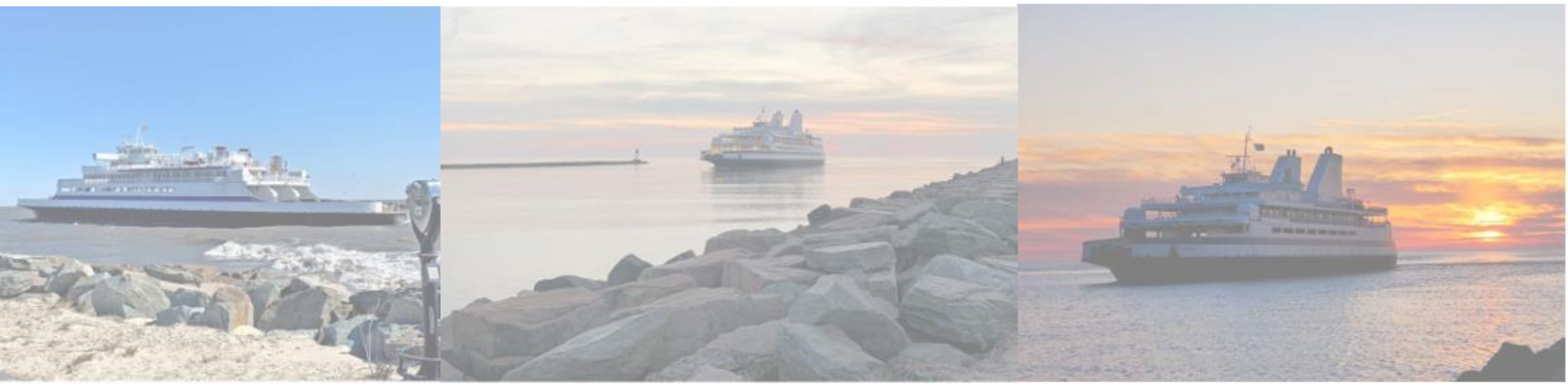

Marine Master Plan

2021

Prepared for: Delaware River and Bay Authority

May 8, 2023

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Executive Summary

Since beginning service in 1964, the Cape May-Lewes Ferry (CMLF) has carried more than 17 million vehicles and 45 million passengers between Cape May, New Jersey and Lewes, Delaware.

Due to an aging fleet and increased maintenance costs, the Delaware River and Bay Authority (DRBA) undertook a planning effort to create a Marine Master Plan that would layout a vision for the future CMLF fleet and would guide investments to replace the current fleet to maintain reliable service and continue to provide the economic benefits to the region[1].

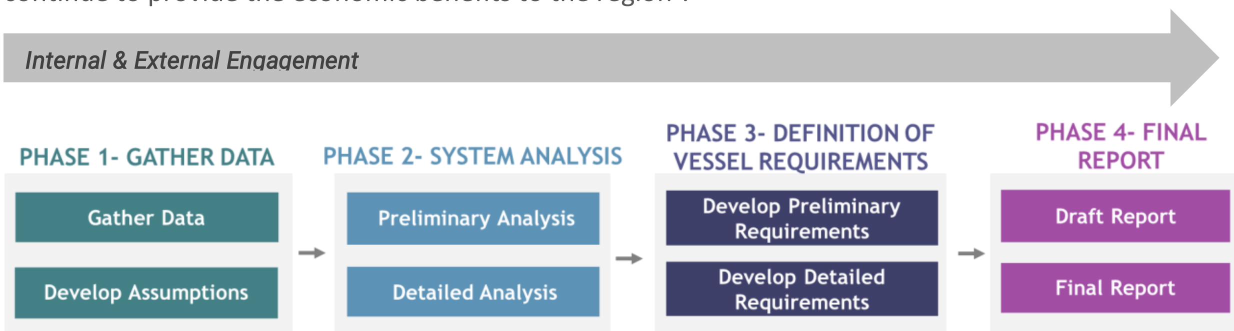


Figure 1: Four-Phase Planning Approach

The four-phase planning process included internal and external engagement with CMLF personnel and the general public via email communications, online workshops and surveys. Three key fleet options were analyzed in detail and are outlined below.

Ultimately, **Option 2, a fleet of vessels with an approximate 75-vehicle capacity** was selected by the DRBA Board due to its Subchapter H Coast Guard Classification, its moderate capital cost, and its adequate seakeeping ability. All vessel capacity options in this report are representative and will be finalized during vessel design. Vehicle capacity as a concept can be relative and dependent on the size of vehicles most often carried. While the existing upon original commissioning boasted capacity for 100 vehicles, the size of modern-day vehicles has increased, therefore changing the carrying capacity of vessels.

Table 1: Vessel Basic Characteristics for Each Option

CHARACTERISTIC	OPTION 1	*SELECTED* OPTION 2 2A & 2B	OPTION 3
Length. x Breadth x Depth	303' x 68' x 17'	**275' x 68' x 16'**	244' x 68' x 16'
Quantity of Vessels	3	**3, 4**	5
Max Operating Speed (kts)	17.1	**16.25**	15.31
Approx. Vehicle Capacity (per vessel)	100	**75**	55
Passenger Capacity (per vessel)	500	**350**	250
Subchapter	H	**H**	K
Min Crew Required (per vessel)	8	**8**	5

Note: Operating speed subject to change based on vessel design.

[1] Councilfire, The Power of Twenty: An Analysis of the Economic Benefits of the Cape-May Lewes Ferry System, https://www.cmlf.com/sites/default/files/sept-2020-report_cf_drba_cmlf_final.pdf

Vessel General Arrangement

Based on the vessel size decision and feedback from CMLF personnel, a list of preliminary vessel requirements was developed from which a notional general arrangement (See **Appendix I**) for the new vessels was also developed. The general arrangement will be used as a basis to stimulate discussion for the next phase of design of the new vessels which will begin in the first quarter of 2023.

Next Steps

While vessel design is being conducted, a detailed transition plan is recommended to identify the path to move operations from the current fleet to the new fleet as the new vessels come online. The plan should identify strategies to ease the transition from a crewing perspective while still providing the desired level of service for customers.

Introduction

The Delaware River and Bay Authority is a bi-state government agency that has served New Jersey and Delaware through transportation and economic development since 1962. The DRBA owns and operates the Delaware Memorial Bridge Twin Span, the Cape May-Lewes Ferry, and the Forts Ferry Crossing. The authority also operates five aviation facilities throughout New Jersey and Delaware. All DRBA operating revenues are generated through the bridge, ferry, and airport facilities.

Since beginning service in 1964, the Cape May-Lewes Ferry (CMLF) has carried more than 17 million vehicles and 45 million passengers between Cape May, New Jersey and Lewes, Delaware. The CMLF now operates its 85-minute crossing daily with a fleet of three vessels, each accommodating up to 100 standard-sized vehicles and 800 passengers. The ferry has between 4 and 9 scheduled round trips daily, with increased service on weekends and during the summer months of July and August.

As with many ferry systems in the nation and across the world, CMLF has experienced challenges with maritime staffing and maintenance with an aging fleet. This plan seeks to suggest ways to relieve these challenges, as well as to achieve the goals listed below.

Plan Goals

The purpose of this Marine Master Plan (MMP) is to identify a future CMLF fleet configuration that will serve customers now and into the future. The goals of this report would be to develop a plan for future vessel investments that is mindful of costs (both capital and operating), operational needs, navigational requirements, and environmental considerations. To achieve this aim and guide the master planning process, plan goals and priority areas were identified and refined with input from internal DRBA staff and members of the public. The priority areas represent key values of DRBA that were to be kept in mind throughout the planning process.

1. Background & Context/Existing Conditions

1.1 Planning Work

DRBA has a robust history and current practice of planning efforts that have helped guide the organization and support long-term operational goals. Other master plans have been developed for the CMLF since the ferry began operating, and these plans have contributed to the success of ferry operations up to this point. This Marine Master Planning effort represents the next step in a long legacy of fleet planning and is a vital step needed for internal financial planning and securing external grant funds.

Apart from the fleet planning work, DRBA has also completed terminal master plans, the most recent of which was completed in 2016. These plans facilitated the successful construction of multiple terminal improvements including the recent passenger tube modifications completed in **2014.** Other terminal updates proposed in these plans are ongoing.

Concurrent with this effort, DRBA is developing a Green Master Plan to help support the low and zero emissions operation of the future fleet. The Green Master Plan will outline a phased approach for developing the electrical infrastructure and renewable energy generation needed to support reduced and/or zero-emission operations of the future fleet. Together, the MMP and the Green Master Plan will guide decision making, transforming the dream of an efficient, sustainable, and zero emissions CMLF fleet into a reality.

1.2 Current Legislative Context

The 2021 passage of the Build Back Better Act has contributed to the growing political and legislative support for green technology across all sectors, and notably for the maritime industry. The Act sparked a substantial increase in Ferry Boat Formula Grant Funding and has also led to increased funding for ferries that are exploring low and zero emissions technologies. This trajectory toward clean infrastructure supports recent trends in ferry electrification being explored by DRBA and ferry operators worldwide.

DRBA is participating in this movement toward green infrastructure through repowering, waste management, and systems updates on land and at sea. Currently, two of the three CMLF vessels have been repowered, saving more than $130,000 per vessel per year in maintenance costs and resulting in approximately a 40% reduction in emissions for each vessel. There is potential for all three vessels to be replaced by a new fleet of ferries that will be partially or completely battery powered, resulting in a near zero or zero-emissions fleet. Current CMLF Operations

The CMLF operates one route, year-round with a fleet of three vessels. Each can carry up to 100 standard vehicles and up to 800 passengers per crossing, transporting locals and tourists alike. Summer is the busiest season for CMLF, while fewer riders travel on the ferry during the colder winter months. Year-round the CMLF is very reliable and is often reviewed positively. However, like many ferry operators around the county and the world, success of future operations is threatened by aging vessels and looming workforce challenges.

When evaluating the passenger ridership, it was noted that in 2019 the passenger count never exceeded 360 on any sailing and the 95th percentile passenger count was 324 even though the current CMLF vessels are outfitted and crewed to carry up to 800 passengers. It was also observed that the vehicle ridership varied greatly by season. Table 2 summarizes the daily vehicle findings by season.

Table 2: 2019 Vehicle Ridership Per Day

	Minimum	*Mean*	*95th Percentile*	*Maximum*
Winter	143	354	603	755
Shoulder	275	808	1472	1762
Summer	569	1258	1840	1992
Full Year	**143**	**746**	**1593**	**1992**

1.2.1 Current Ride Reliability

Despite their age and increased maintenance requirements, the current vessels are very reliable, for example between 2012 and the end of January 2021, 3,316 days, there were 120 days with 540 canceled sailings due to mechanical issues or unscheduled shipyard periods and 44 days with 264 cancelations due to hurricanes, high winds, or low tides. During the same timeframe, DRBA completed 40,903 sailings which is a completion rate of 98%. In 2022, the ferry system did not experience a single cancelation due to mechanical failure.

1.2.2 Aging Vessels

The current fleet has an average age of 45 years, which include the MV Delaware (47), MV Cape Henlopen (40), and MV New Jersey (47). Costs, service outages, and needed maintenance have risen significantly for the vessels in the last few years, due to their age. To help maintain reliability of the aging equipment, DRBA has conducted recent overhauls, including a propulsion engine replacement to the M/V Delaware and M/V New Jersey. Overhauls of the older equipment will continue to get more expensive and require more out of service time. Additionally, since vessel technology has changed significantly in the past 40+ years, finding parts that will work with the older systems has become increasingly expensive and difficult. These old systems are also expensive to retrofit to reduce the emissions or transition to greener technologies.

1.2.3 Workforce Challenges/ Availability [Licensing]

As an increasing number of maritime employees become eligible for retirement, attrition within the job class has become one of the most significant challenges facing the maritime workforce. The aging workforce, compounded with fewer people entering the maritime industry, often leads to higher pay rates for remaining full-time employees and a gap in the qualified licensed workforce.

Due to the aging and limited maritime workforce, there are concerns of available and qualified personnel with the required training and licenses to maintain the required summer complement as older mariners retire. All three of the current CMLF vessels require additional licensing requirements due to the admeasure of the vessels in excess of 1600 gross regulatory tons, which requires deck officers to have an unlimited tonnage license. Obtaining this license requires additional years of experience which narrows an already limited workforce pool. Within the CMLF and throughout the industry, there is a shortage of mariners with this rating, making it difficult to replace retirement eligible employees.

1.2.4 Navigational Considerations

The DRBA ferry route through the mouth of the Delaware Bay is a unique operating environment with shallow water at Crow Shoal on the New Jersey side and limited harbor depths at both terminals. Silting can also be a challenge in these already shallow waters. Winter weather often increases wind and waves in the bay and occasionally there is the added challenge of ice in the bay (refer to **Appendix K**).

2. The Planning Process

This section summarizes the methodology conducted throughout the planning process. Launched early in 2021, the MMP aimed to identify capital investments and a configuration for the future CMLF fleet. Four key phases were included in the process: Phase 1 involved gathering data on the current CMLF system and setting goals for the effort. Phase 2 focused on analyzing the gathered data to develop reasonable options for the future fleet and analyzed how these fleet options performed in comparison to one another. Phase 3 involved developing vessel design requirements while Phase 4 included the development of this report. Outreach in each phase included internal engagement with DRBA staff and external engagement with the public to ensure that considerations from all relevant stakeholders could be adequately incorporated into the final plan.

2.1.1 Goals Identification

The first stage in the planning process was to identify the plan goals and priority areas that would guide the remainder of the process and the ultimate fleet decision. A draft set of goals was developed, then shown to internal staff for review and posted to a dedicated webpage on the CMLF website. Feedback received lead to refinements, with the finalized plan goals, as shown in Figure 2.

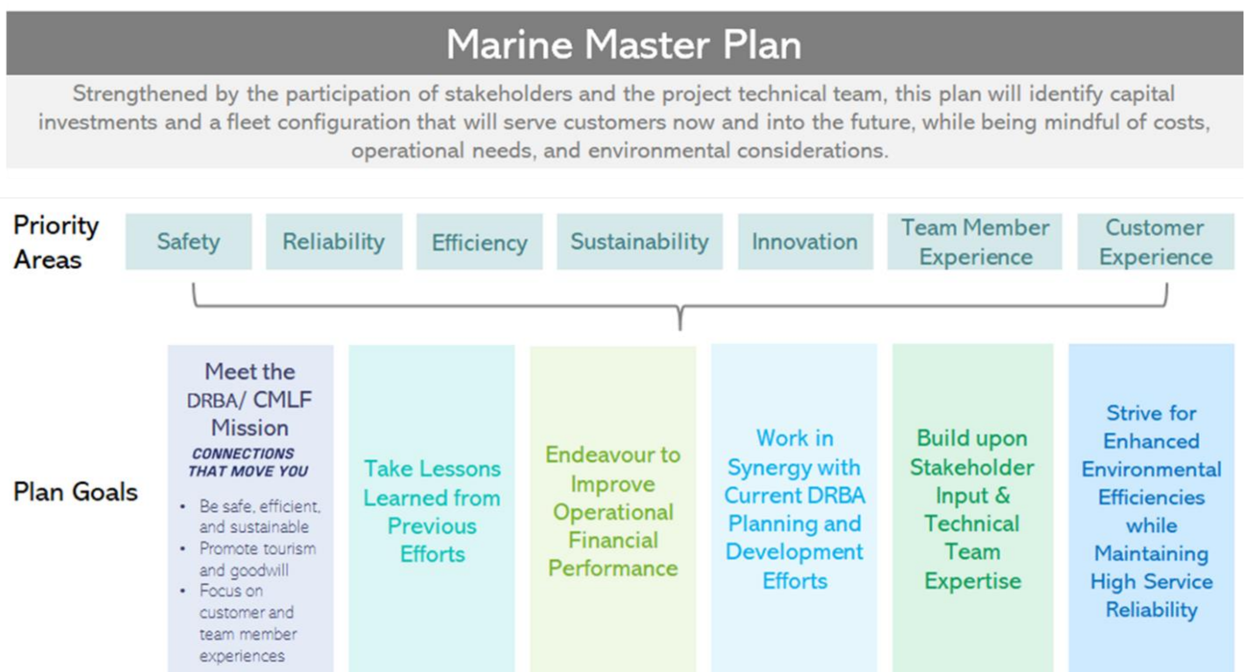


Figure 2: Marine Master Plan Priority Areas and Goals

Six goals were developed for the plan. The first key was for the plan to align with the existing DRBA/CMLF mission, and its key aims around efficiency, safety, tourism, and customer and team member experiences. By aligning with the existing mission, this goal ensured that the MMP is representative of CMLF as a part of DRBA and that it aligned with organizational precedent. The second plan goal was to take lessons learned from previous efforts. The third key aim of this plan was to develop a path forward for the CMLF that would endeavor to improve operational financial performance. Financial sustainability is vital to any organization, and CMLF's greatest opportunity for improving financial sustainability is through improved operational financial performance. Goal four was for the MMP to work in synergy with other DRBA planning and development efforts that are currently ongoing. The fifth goal was to build upon stakeholder input and technical team expertise and utilize existing knowledge and expertise. The final goal was to strive for new investments to enhance environmental efficiency while maintaining the high service reliability it is known for. Improved environmental efficiencies included evaluation on potential electrification efforts for the new fleet.

2.2 Methodology

Guided by the goals of the project, the consultant team conducted a robust analysis of the current CMLF system and its needs. A brief summary of the four-phase project methodology is included below. Phase 1 involved the initial data gathering and development of key fleet assumptions. Phase 2 was an analysis of the CMLF system and potential fleet configurations, while Phase 3 was focused on defining requirements for the new vessels. Key findings for Phases 1 through 3 are shared in more detail in the following sections. Please refer to appendices of this plan for additional detail. Phase 4 of the project was the drafting and finalization of this report to communicate the final plan.

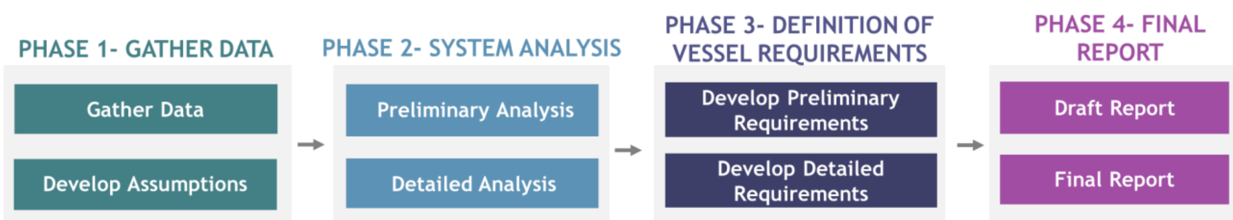


Figure 3: Project Methodology

2.2.1 Phase 1: Data Gathering & assumptions Identification

Before planning for the new fleet could begin, it was essential to understand the current conditions of the fleet and of the CMLF system as whole. Data gathering focused on four key areas:

1. Fleet and vessel condition
2. Ridership trends
3. Operational conditions of the current route
4. Terminal conditions

Once data was gathered, the next phase of the project was to identify viable potential future fleet configuration options, with the goal of generating three options for detailed study. Foundational assumptions regarding future fleet needs were developed to narrow the realm of potential fleet options to those most reasonable for the CMLF. These assumptions are detailed in Chapter 4 of this report.

2.2.2 Phase 2: System Analysis

The first step in the system analysis was to develop viable fleet options that would serve the needs of DRBA into the future, keeping goals of the study in mind. A high-level review of these options was then conducted to narrow the options down to the three most viable for more detailed study. The options varied from status quo for vehicle capacity with efficiencies to a fleet of five smaller ferries. The five options are listed below, with detailed analysis of these fleet configurations in the following report sections. Vessel capacities identified below are characterizations of a future fleet prior to vessel design, therefore some changes may result as design is underway.

Table 3: Fleet Options

CHARACTERISTIC	OPTION 1	OPTION 2 (2A & 2B)	OPTION 3	OPTION 4	OPTION 5 MIXED FLEET	
				removed from consideration	removed from consideration	
Quantity of Vessels	3	3, 4	5	2	2	2
Vehicle Capacity (per vessel)	100	75	55	150	100	55
Passenger Capacity (per vessel)	500	350	250	700	500	250
Subchapter	H	H	K	H	H	K

Detailed system analysis was then conducted by the consultant team on each remaining option to evaluate its performance on meeting service needs, costs/financial metrics, port fit constraints, seaworthiness goals, and transition considerations. Findings of the system analysis were presented to the DRBA Board and Executive Committee who then coordinated with CMLF captains and staff to assist in their decision-making process.

2.2.3 Phase 3: Develop Vessel Requirements

Following the fleet decision, the consultant team developed a detailed list of owner's requirements for the vessel type in the selected fleet. This list of vessel requirements was informed by DRBA staff working groups as outlined below.

2.3 Engagement

To develop and communicate a meaningful and informed MMP, early and inclusive outreach to the CMLF working groups was performed throughout the entirety of the planning process outlined above.

Additionally, the engagement approach needed to be flexible to allow for the project team to adapt and respond to ever-evolving COVID-19 restrictions. Due to the differences between internal and external stakeholder audiences, engagement activities differed slightly between groups and were tailored to each audience. The following sections briefly summarize methods and goals of internal and external outreach. Following these, a timeline of engagement events is included. Feedback gained through the engagement process informed decisions on things like fleet configuration and notional vessel design criteria. It was through the engagement process that DRBA's owner requirements, the elements desired in a future ferry, were established. For more detailed information regarding engagement, please refer to **Appendix J**.

2.3.1 Internal

There is a wealth of technical expertise among internal DRBA personnel related both to vessel operations and guest experience. As a result, engagement with internal audiences was focused not only on informing stakeholders about the process but also gathering crucial feedback and technical data to inform the fleet and vessel analyses conducted throughout the study. To ensure ample opportunity for internal stakeholders to provide feedback, internal outreach was conducted during each phase of the master planning process, using a variety of methods, including:

- Virtual meeting workshops
- Email communications
- Voicemail feedback line
- Online survey

Key areas of interest for internal stakeholders included maintaining service levels, accommodating service growth, and concerns over whether the new boats would maintain seaworthiness and passenger comfort. Internal personnel also expressed a strong desire for new vessels and were supportive of fleet replacement.

2.3.2 External

Riders of the ferry, members of the local community, and local legislators were key external stakeholders engaged in this effort. Throughout all phases, engagement with external stakeholders was focused on promoting understanding about why the plan was needed along with how each phase of the plan analysis was being conducted and what the findings of each phase were. Key communication methods included:

- Website updates
- Virtual webinars
- Online survey

External stakeholders expressed support for the selected fleet to be green or environmentally friendly. Individuals also expressed support for maintaining the current service levels or increasing service/sailings. Lastly, members of the public expressed support for the new fleet including an elevator and being accessible for users with disabilities.

3. Phase 1: Data Gathering

3.1 Existing Vessel Assessment

PHASE 1

Gather Data

- Existing vessel assessment
- Ridership trends
- Operational conditions
- Route profile
- Terminal conditions
- Crew & staffing policies

The first step in the data gathering phase was to gain a robust understanding of the condition of each vessel in the current fleet: the CAPE HENLOPEN, the DELAWARE, and the NEW JERSEY.

The following information was collected and evaluated as a part of the fleet condition assessment.

- Matterport 3D Scan of each vessel
- Past vessel ship checks information and photos
- Regulatory (USCG and ABS) survey information
- Prior vessel condition surveys
- Supporting Information on maintenance practices
- Financial expenditures for maintenance, preservation, and improvements
- Input from crew and staff on vessel condition

The assessment determined that both the MV DELAWARE and MV NEW JERSEY don't have any systems requiring major investment at this time, while the MV Cape Henlopen does. This was primarily due to the legacy propulsion system which has not been replaced as it has been aboard the other vessels.

Due to the observed condition of all three vessels, investments required to keep the fleet operational for the next 10 years were deemed to be a minimum of $2.5 million per dry docking, translating to about $1 million per year per vessel. MV Delaware will require an additional $2.0-2.5 million investment

and the MV Cape Henlopen will require an additional $15-20 million, if a repower and refurbishment is needed to extend its useful life. General structural work for the MV Delaware, MV Cape Henlopen, and MV New Jersey requires $200,000 to $300,000 per vessel every year or few years according to ABS findings. Refer to **Appendix A** for a breakdown of the work necessary for each vessel and for additional information regarding the fleet condition assessment.

3.2 Ridership Trends

Beyond vessel conditions, trends in system ridership were also evaluated to determine the level of service for the new fleet. Ridership in 2017, 2018, and 2019 were all examined, and all three years showed similar trends. Due to these similarities, 2019 was picked as a representative ridership year, as it offers demand data for the most recent non-pandemic year.

Ridership Trends

- The current vessels provide almost double the passenger capacity than is needed.
- Vehicle ridership is the key constraint on the system.
- Ridership is **highest in the summer** and **lowest in the winter**.
- In the summer, the period between **10:00 am and 5:00 pm** has the highest ridership, with most sailings at capacity for vehicles.

3.2.1 Passenger vs Vehicle Load

The current CMLF vessels are outfitted to carry up to 800 passengers. However, early data gathering showed that the vessels were half full or less for nearly every sailing (see Table 2). The current vessels are oversized for passenger counts, but experience many full vehicle loads, particularly during the summer months. As a result, it became clear that the vehicle ridership and vehicle loads provide more constraints to the current system than passengers. Additionally, vessels that are certified to carry more passengers often require more crew in order to sufficiently support the emergency evacuation of maximum passenger volumes.

3.2.2 Seasonality

Ridership varies widely across the year for the CMLF system. The winter months of November through March experience generally low vehicle loads with a few ridership spikes around key holidays such as Christmas and Thanksgiving. The summer months of June, July, and August experience much higher ridership demand, with an average number of vehicles carried per day that is approximately 3.5 times higher than in the winter.

Between the extremes of summer and winter, a more moderate level of ridership is experienced in the shoulder season which occurs in April, May, September, and October.

3.2.3 Peak Time of Day

Most Fridays, Saturdays, and Sundays in the summer season carry more vehicles and passengers than other days. On these and other summer days, peak summer demand tended to occur between 10:00 am and 5:00 pm. While ridership during this peak period was high, if not completely full, later evening sailings and some early morning sailings were less full. This pattern was generally observed in other busy summer days as well, with a more marked decrease in ridership on early morning sailings. Figure 4 shows an example of the number of vehicles for each sailing on June 30, 2019.

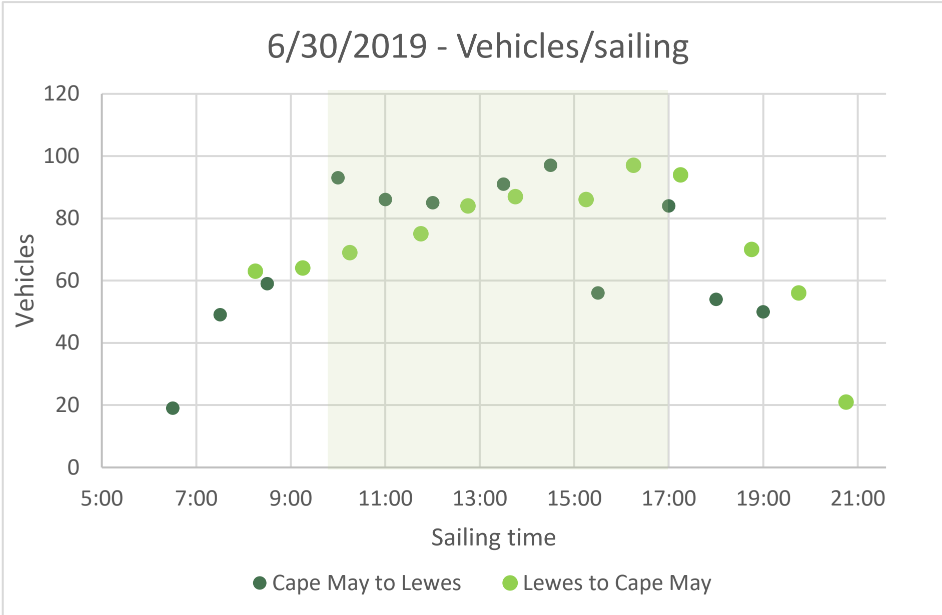


Figure 4: Example Summer Ridership with Peak Travel Window Highlighted

3.3 Operational Conditions

The mouth of the Delaware Bay is a unique operating environment. The ferry route running NE-SW is exposed to the swell of the Atlantic and subject to river and ice flowing from the Delaware River. Prevailing winter winds are out of the NW, opposing the swells entering from the Atlantic Ocean to the SE.

Shallow water is a distinct challenge for the CMLF operation, with Crow Shoal on the New Jersey side of the crossing plus the limited harbor depths at both the Cape May and Lewes terminals. Vessels with a draft of more that 7'-6" would be unable to operate successfully in these shallow conditions at low tide. Additionally, the channel the ferry traverses is not often dredged, and tidal conditions often result in silt entering the channel, which further limits water depths and creates shifting channel conditions.

Operational Conditions

- Vessels travelling the route experience a **crosswind**, particularly in the winter.
- **Shallow water** and **silting** pose operational challenges at terminals and along the route path.
- Seas are generally **rougher in winter** than in the summer.

Winter seas are rougher than summer conditions along the CMLF route, due to stronger winds and larger waves. A review of past wind and wave data indicated that there are very infrequent larger sea states along the route, but when significant wave heights occur, they range between 1.6 to 7.0 feet (0.5 to 2.1 meters), with an average of about 4.6 feet (1.4 meters) in the winter and just under one meter (3 feet) in the summer. Most days where current sailings must be cancelled due to weather occur during the winter season. Beyond the slight increase in larger sea states, the winter season can also bring ice events that can clog the terminal areas and make navigation across the bay impossible.

3.4 Route profile

The existing route was analyzed, and key segments of the route were identified. Each segment refers to a specific geographic distance with its own operational characteristics and was used to understand how the ferries currently move between Cape May and Lewes. These route segments were used to develop an overall profile of the existing route.

The current route has approximately eight legs/subsections (see Table 4), with vessels using slower operating speeds between terminals and jetties (legs 1, 7, and 8), yielding a crossing time of approximately 85 minutes. Occasionally, when traversing the shallow depths of Crow Shoal at low tide, the CMLF vessels need to slow down to allow for safe maneuvering.

Table 4: Route Profile

Leg	***Description***	***Distance (nm)***
1	**CM Terminal to Canal Inlet**	**0.35**
2	Canal Inlet to Crow Shoal	2.15
3	Dep. Crow Shoal	0.3
4	Crow Shoal to Buoy #2	2.5
5	Buoy #2 to Harbor of Refuge	5.6
6	Harbor of Refuge to Inner Harbor	1.95
7	**Inner Harbor to CO. Jetty**	**0.75**
8	**Co. Jetty to LW Terminal**	**0.3**

3.4.1 Single-ended Vessel Maneuvering

The current CMLF vessels have propulsion on the stern only. After taking on vehicles in Cape May, the vessel must back up and turn around to leave the channel. When approaching Lewes, the vessel must then turn again to enter the dock in the appropriate orientation to allow vehicles to exit the vessel. In discussions with DRBA staff and analysis of terminal video, it was determined that the time spent undergoing these maneuvers adds approximately 7 minutes to the one-way route trip time.

Though these turning maneuvers are not required when traveling from Lewes to Cape May, the current CMLF sailing schedules reflect the same travel time for both directions. This symmetrical schedule is easier for customers to use and accommodates the longer maneuvering time needed when traveling from Cape May to Lewes.

In addition to travelling the bay and maneuvering near terminals, time must be accounted for unloading and loading of vehicles and passengers. The unloading and loading processes are estimated to add about 20 minutes to the 85-minute crossing time, yielding a one-way trip time of approximately 105 minutes. This time also accounts for the time to deploy and stow the passenger tube ramps and time for passengers and vehicles to unload and load.

3.5 Terminal Conditions

Any new fleet would continue to dock at the existing terminals in Cape May and Lewes. Understanding the conditions at and near these terminals, including what in-water and passenger infrastructure is currently available, is vital to understanding how current vessels successfully operate. Gathering data about the existing terminals is also useful in understanding potential design considerations for future vessels.

3.5.1 Existing infrastructure

The vessel landing infrastructure at both the Cape May and Lewes terminals is attached to a fixed concrete wharf (see Figure 5). Due to the fixed shape of the wharf, it would be very difficult and expensive to modify the wharf to accommodate wider vessels or those with a differently shaped bow. Even vessels that are narrower than the existing vessel could be made to fit within the existing wharf configuration, however the narrower vessels would not align with the centerline of the loading ramp, which could cause maneuvering challenges, particularly for larger vehicles trying to drive on or off the boat.

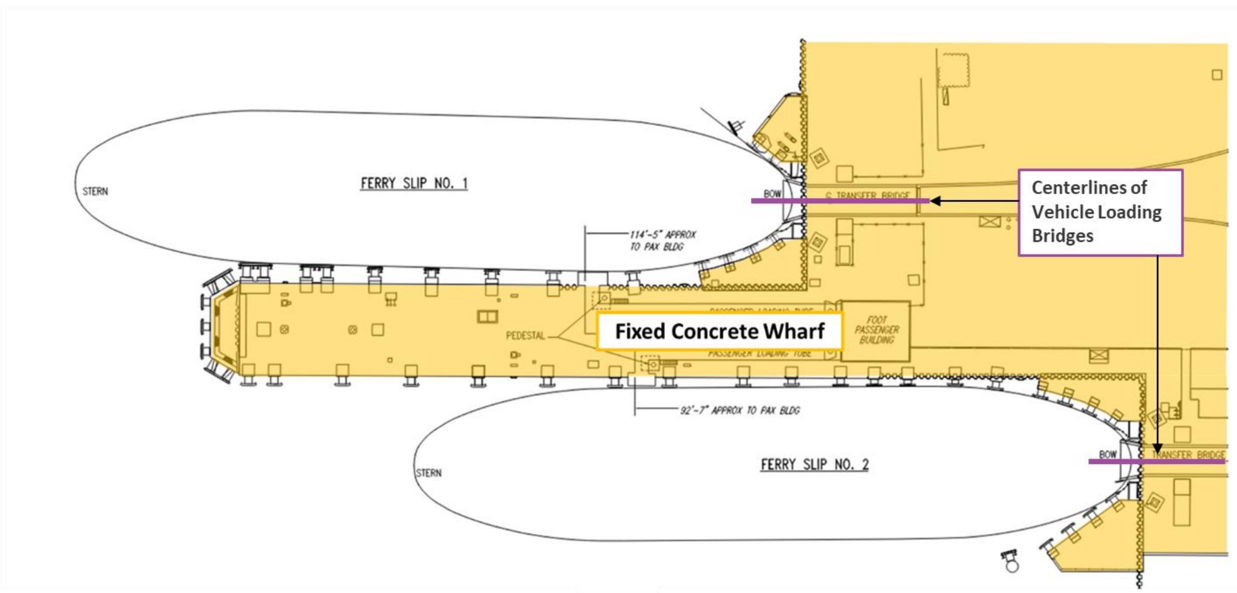


Figure 5: Cape May Terminal Schematic

Beyond the fixed wharf, it was noted that the existing Cape May Terminal currently has a fixed amount of overnight tie-up space (refer to Figure 6). Since all vessels typically start and end their day in Cape May, all vessels in any proposed new feet would need to be able to moor within the existing space.

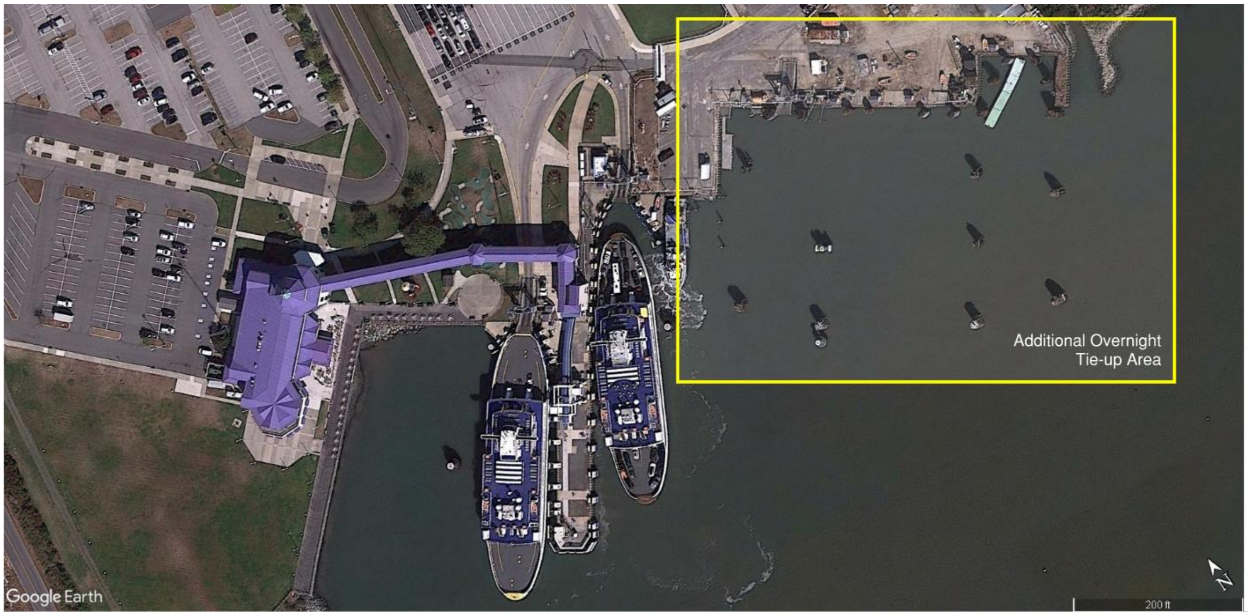


Figure 6: Cape May Terminal Aerial

Though the current fleet has three vessels, CMLF has operated in the past with a fleet of five vessels, with all vessels tying up overnight at the Cape May terminal. As a result, the terminal has overnight tie-up space for as many as five vessels, though an infrastructure assessment of the less frequently used tie-ups would be recommended before returning them to regular use. Figure 7 shows how three additional vessels were historically tied-up at night at the Cape May terminal, while the fourth and fifth vessels could tie-up for the evening in the operating slips.

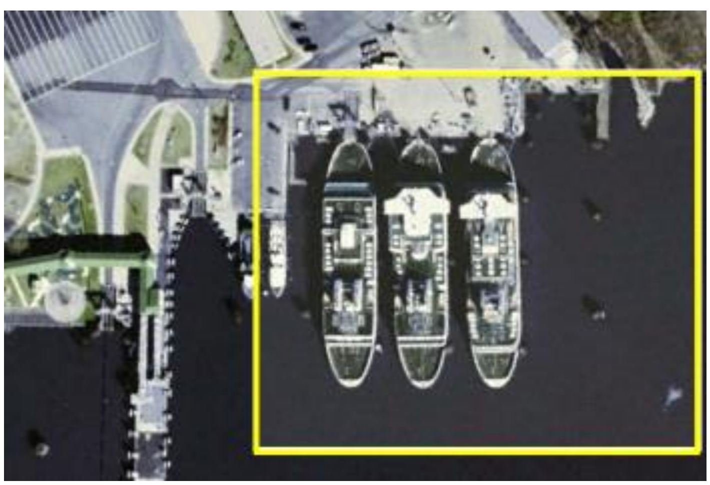


Figure 7: Additional Boats Mooring at Cape May Terminal (2002)

At the existing Cape May and Lewes terminals, walk-on passengers access the vessel via fixed passenger loading tubes. These loading tubes have a fixed length, while the height of the tubes can be adjusted within a set range that accommodate the existing vessels throughout the normal range of tides. To be able to use these passenger tubes, any new vessels would need to be mindful of freeboard and passenger deck heights.

The current terminal vehicle ramps are one lane wide and cannot be widened without extensive and expensive capital improvements. As a result, the new CMLF vessels must accommodate single lane loading and unloading of vehicles.

Parking at the terminal is sufficient for passenger and crew needs and is not a limiting factor for a future fleet. Additionally, vehicle and passenger queuing space are adequate to support current and future CMLF service. Vessel moorage is also a consideration, any vessel with less length than the current fleet would require the movement of moorage dolphins or piles to provide stability to the vessel while tied up. For a 75-car ferry, one new dolphin would be required at Slip 3, a condition assessment will be needed at Slip 4 and 5, and additional crew parking will likely be required to accommodate more crew members during peak season.

3.5.2 Power grid capacity for vessel electrification

To align with emissions goals, it was determined that all fleet options would explore electrification of operations to the greatest extent feasible. Initial outreach was conducted to evaluate the potential power grid capacity available near to the Cape May terminal that could be used to power electric vessels. It was discovered that limited power was available at the terminal from the utility provider. However, ongoing coordination and green energy projects in the Cape May area are still being explored. Due to the complicated nature of electrification planning and the multiple potential terminal energy scenarios, DRBA decided to undertake a separate Green Master Planning effort to address electrification planning in more detail.

For Phase 1 of the Green Master Plan. 1 MW of power was assumed to be available at the Cape May terminal and this was confirmed during discussions with Atlantic City Electric. By installing charging infrastructure including a shoreside battery energy storage system, the available power could be used to achieve a 79% reduction in greenhouse gas emissions during winter operations and a 25% reduction on peak summer weekend days. If an additional 1 MW were to become available, and additional shoreside infrastructure provided, reductions would increase to 100% in the winter and 42% on peak summer weekends. When the Green Master Plan is fully implemented, the ferries would conduct normal operations on 100% renewable electric power. Refer to **Appendix L** for more detailed information.

3.6 Crew and Staffing Policies

CMLF values their staff and crew immensely and focuses on a crewing policy that best serves staff while delivering the safest and highest quality passenger experience.

Though only 9 crew members are required to operate the vessels per the approved certificates of inspection (COI), as a policy, the CMLF sails with 14 personnel (10 marine crew + 4 food & retail staff) in the summer to meet desired service standards and to provide customer amenities. Table 5 shows a comparison of the COI crew requirement in comparison to the current crew complement that CMLF vessels sail with.

Table 5: Crewing Complement

	Current COI	Complete CMLF Complement
Master	1	1
Pilot	1	1
Mates	-	-
Chief Engineer	1	1
Able Body Seaman (AB)	4	4
Ordinary Seaman (OS)	2	2
Asst. Engineer / Oiler / Wiper	-	1
Food & Retail Staff	-	4
TOTAL	**9**	**14**

Safety and emergency preparedness are important to the CMLF and to DRBA. As a result, current crewing policies require each ferry to sail with an additional engineer. This extra crew member provides additional support for the chief engineer and is available in case of emergency.

The CMLF provides more than just a mode of transportation and strives to provide a cruise like atmosphere with numerous benefits and amenities to customers. Crucial to the experience are the onboard giftshop and the provision of food and beverages, including bar service. To support these amenities, additional personnel are required onboard each sailing. The current amenities set up on the vessels employs up to four personnel, including three food service workers and one giftshop cashier.

Maintaining current crewing policies into the future poses challenges as the maritime workforce is experiencing shortages of qualified workers industrywide. The current CMLF vessels are classed for unlimited tonnage. To sail vessels of this kind, officers are required to be licensed for unlimited tonnage, a license that requires years of experience to obtain. Due to the shortage of mariners with this type of license, retaining the current employees is crucial to operating the existing CMLF vessels.

Labor costs are one of the most significant components of annual operating costs for CMLF service. While the service has no plans to reduce pay for existing staff, decreasing the tonnage of the CMLF vessels and thus decreasing the resulting licensing requirements could provide an avenue for reducing labor costs for future employees. A lesser level of licensing would increase the future labor pool to operate vessels and would improve operational efficiency and financial performance. To change the licensing requirements and remove the pilotage requirement, any new vessels would need be designed to be under 1600 gross regulatory tons.

4. Phase 1: Assumption Identification

List of Assumptions

1. The fleet will be designed to meet current demand and to accommodate a small level of growth over the next 40 years of operation.
2. Vessels of the new fleet will serve both passengers and vehicles.
3. The new vessels will meet or beat the current total trip time to, at a minimum, maintain the current customer experience related to trip time. *[Total trip time includes crossing, maneuvering, and the loading/ unloading time.]*
4. Future vessels will not require major structural changes to the dock/wharf. These changes can be costly and a new vessel should work within the current configuration as much as possible
5. The new fleet will be designed to maintain or lower operating costs when compared to the current operation.
6. New vessels will improve customer and crew amenities.
7. The new fleet will be more environmentally friendly.

Following the initial data gathering, it was then necessary to identify some key baseline assumptions that would guide the consultant's fleet identification and analysis. These assumptions were intended to limit the scope of analyses and to identify a key guiding framework for the analyses to come. Assumptions related to the five key areas were identified and are expanded in more detail in the call-out box to the left.

The first area was ***ridership***, and these assumptions were targeted at identifying the type and approximate level of riders that the new proposed fleet would serve.

The second key area of assumptions was ***travel time***, which helped guide the type of vessels that could be used and the speed of travel.

Assumptions regarding how the vessels would interact with the existing CMLF ***terminals*** were evaluated next. These assumptions helped narrow the general vessel sizes and shapes that could be considered by the Phase II and Phase III analyses.

Financial assumptions were then generated. These assumptions were related to the DRBA's financial goals for the analyses.

The final area of assumptions was related to ***vessel characteristics,*** which helped with identify alternative propulsion technologies, the vessel service type, and how the vessel will be outfitted.

5. Phase 2: Preliminary System Analysis

5.1 Fleet Option Development

PHASE 2

Preliminary Analysis

1. Fleet options development
2. Narrow options for detailed analysis

Based on the assumptions developed in Phase 1, five fleet options were initially identified for consideration. During this initial stage, an analysis tool was created in excel to arrive at a rough performance metrics of service and costs while accounting for some of these assumptions, constraints, and requirements (AC&R). The following fleet options were the focus of this initial configuration modelling:

Table 6: Fleet Options

CHARACTERISTIC	OPTION 1	OPTION 2 (2A & 2B)	OPTION 3	OPTION 4	OPTION 5 MIXED FLEET	
				removed from consideration	removed from consideration	
Quantity of Vessels	3	3, 4	5	2	2	2
Vehicle Capacity (per vessel)	100	75	55	150	100	55

5.2 Narrow Options for Detailed Analysis

Per the stated scope of work for this project, only three of the five options listed above were analyzed in detail by the consultant team. A high-level model of the five initial options was developed to provide an initial overview of the options and allow them to be narrowed down to three for more detailed study.

Option 4 was not selected as the larger vessel fleet provides significant excess capacity. Challenges were also observed with the 150-vehicle vessel size requiring increased service speed. Additionally, with only two vessels in the fleet, this option had significant operational risk, as 50% of fleet capacity is lost if one vessel were to go down for maintenance reasons. Moreover, engineering challenges were observed in how a 150-vehicle vessel would interact with the terminals. To achieve the 150-vehicle capacity while still fitting into the fixed dock shape at the terminals, a mezzanine deck would be necessary. With the addition of a mezzanine deck, vessels in Option 4 would need increased dwell times to load and unload extra vehicles which was deemed unattractive and ultimately eliminated flexibility from this configuration. Due to all these factors, Option 4 was not advanced to the detailed fleet analysis.

Option 5 performed similarly to Option 2 with four 75-car vessels but had added complications including higher capital expenses, maintenance expenses, crew certification requirements, and general complexity in operations due to the mixed nature of the fleet. Overall, these issues would result in cost inefficiencies and Option 5 was abandoned in favor of Option 2.
The three options selected for detailed analysis include:

- Option 1: Three 100-vehicle Ferries

- Option 2:
    - Option 2A: Three 75-vehicle Ferries
    - Option 2B: Four 75-vehicle Ferries
- Option 3: Five 55-vehicle Ferries

The three options that were moved forward were analyzed for performance in six key areas: Subchapter K feasibility, double-ended feasibility, service performance, costs, port fit, and transition considerations. Table 7 shows the characteristics of the three options.

Table 7: Summary of Fleet Options Selected for Detailed Analysis

CHARACTERISTIC	OPTION 1	OPTIONS 2A & 2B	OPTION 3
Length. x Breadth x Depth	303' x 68' x 17'	275' x 68' x 16'	244' x 68' x 16'
Quantity of Vessels	3	3, 4	5
Max Operating Speed (kts)	17.1	16.25	15.31
Vehicle Capacity (per vessel)	100	75	55
Passenger Capacity (per vessel)	500	350	250
Subchapter	H	H	K
Min Crew Required (per vessel)	8	8	5

6. Phase 2: Detailed System Analysis

PHASE 2

Detailed Analysis

- Service analysis
- Cost analysis
- Subchapter K feasibility
- Double-ended analysis
- Seaworthiness analysis
- Transitional analysis

The consultant team conducted an in-depth fleet analysis to compare the proposed fleet options. The key findings of the analyses conducted are summarized below. Further analysis of alternative vessels can be found in **Appendix B**.

6.1 Service Analysis

All fleet options were evaluated for their ability to meet the CMLF service demand. This service analysis involved developing example service schedules for all fleet options to evaluate their capacity to meet current CMLF ridership. Due to the wide variation in seasonal ridership, different schedules were developed for each of the established ridership seasons. These schedules were designed to generate enough capacity to meet the current 95th percentile ridership day for each season. In the winter season, additional service was provided on the weekends where needed to meet 100% of the ridership levels observed in 2019.

Service Analysis Findings

- All three fleet configuration options **can meet the ridership benchmark** for each season.
- **Options 2B and 3 allow for increased service flexibility** by having a higher number of vessels.
- **More throughput in the peak summer period** provides additional capacity in the key times that passengers want to travel.

Based on the service analysis, all fleet options were able to meet daily ridership benchmarks. Moreover, by assuming a double-ended configuration for all vessel sizes, in conjunction with the increased vessel speeds allowable by new technology, it was determined that all fleet options could achieve a one-way total trip time of 80 minutes in comparison to the 105-minute one-way total trip time of the fleet's current vessels.[2] This faster travel speed allows all three options to provide a greater level of service than can be provided by the current fleet.

[2] The 80-minute travel time would be possible with single-ended vessels but would require higher travel speeds and would likely burn more fuel in operations.

Figure 8 below summarizes the daily service capacity provided by each fleet option in comparison to the ridership benchmark for each season.

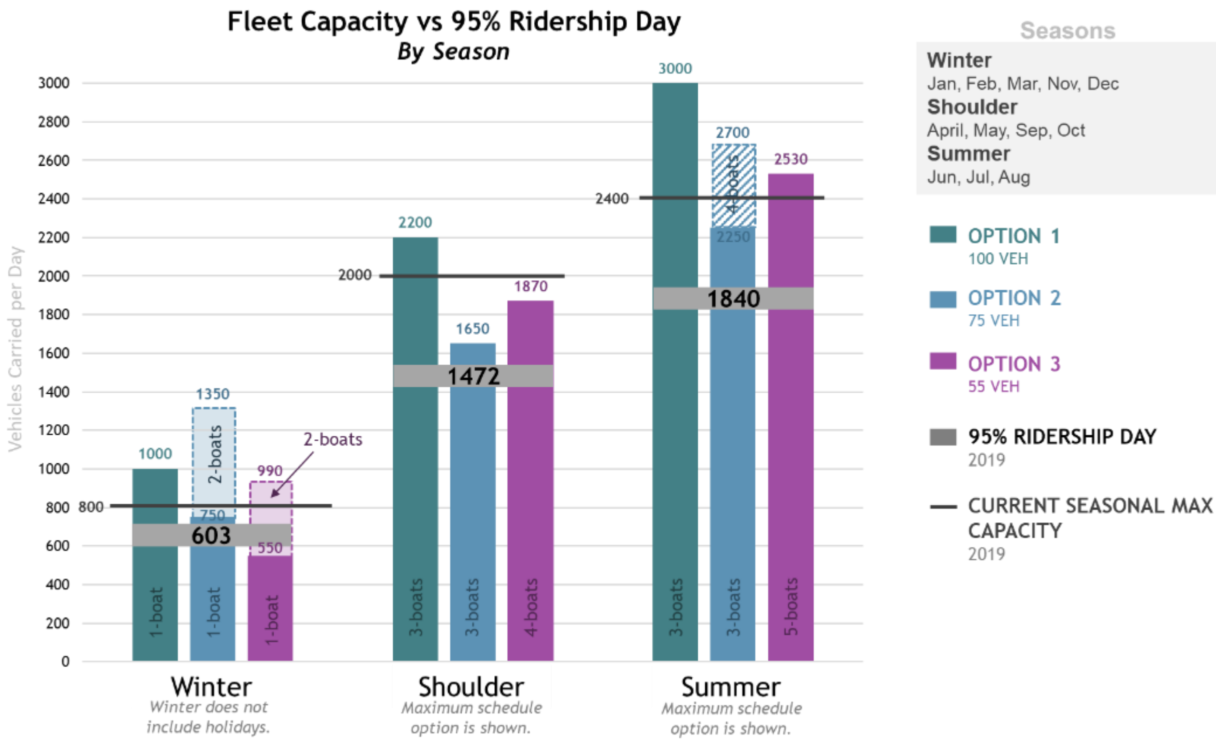


Figure 8: Summary of Fleet Option Capacity

Beyond the daily service capacity, the ridership of each fleet option during the peak window of 10:00am to 5:00pm was also analyzed. With the increased service tempo, this analysis indicated that all fleet options except Option 2A can carry more riders in the peak window than the current fleet. Most riders want to travel in the peak window, so providing more capacity at these times helps support growth, while providing less capacity in this window could lead to loss of riders and loss of revenue. Further ferry operations analysis can be found in Appendix C.

SUMMER VEHICLE THROUGHPUT [ONE-WAY TRIPS X VESSEL VEHICLE CAPACITY]

	OPTION 1	OPTION 2A	OPTION 2B	OPTION 3
Peak Period *Compared to current*	16 One-Way Trips 16 X 100= 1600 *+ 3 Trips* *+300 Vehicles*	16 One-Way Trips 16 X 75= 1200 *+ 3 Trips* *-100 Vehicles*	22 One-Way Trips 22 X 75= 1650 *+ 9 Trips* *+350 Vehicles*	28 One-Way Trips 28 X 55= 1540 *+ 15 Trips* *+240 Vehicles*
Daily	30 One-Way Trips 30 X 100= 3000	30 One-Way Trips 30 X 75= 2250	36 One-Way Trips 36 X 75= 2700	46 One-Way Trips 46 X 55= 2530

Figure 9: Peak Period Ridership Capacity

6.2 Cost Analysis

The master plan cost model included capital and operating cost estimates for all three fleet options. Similar modeling assumptions were used to develop a model of the current DRBA fleet using the simplified schedules developed in the service analysis. The model of the current fleet allowed for comparison between the new fleets and the current operation. While feasibility cost modeling has some limitations and are representative of costs in a snapshot in time of analysis it provides a representative comparison of alternatives.

The cost analysis determined that all new fleet options represent an operational savings compared to the current fleet. Labor costs represent the highest cost in the CMLF system and in all proposed new fleet options. Figure 10 below summarizes the output of the cost models developed in this analysis. At the time of analysis, the cost model assumed a double-ended vessel in 2020 dollars using high-level vessel design assumptions available at the time of the analysis. A single-ended vessel would have increased operational costs due to increased fuel consumption for operating at faster speeds to compensate for turning times. However, this cost would only apply during the peak periods of the schedule that occur a few times per week[3].

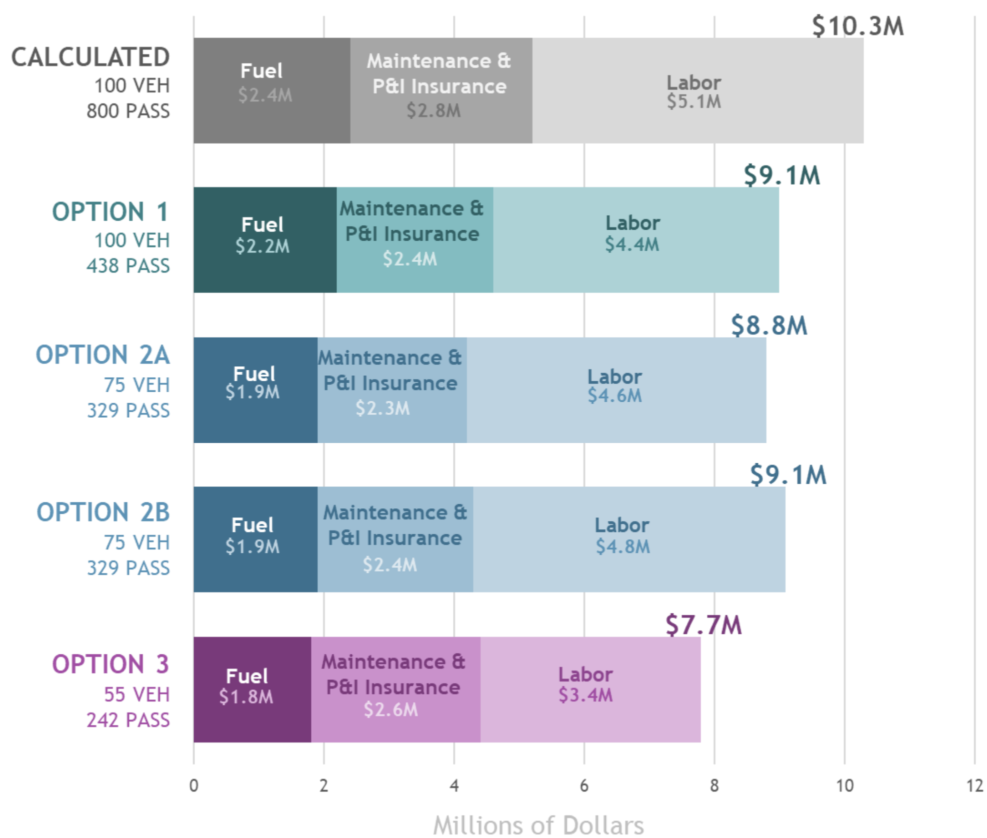


Figure 10: Annual Operational Costs by Cost Category

Capital costs were also developed for each fleet option. These costs include vessel purchase costs and the capital costs of any needed terminal improvements. All fleet options included an estimated $20M in

[3] Classification of costs for the preferred alternative will be provided as part of the next phase of design.

terminal improvements to support electrification. Any other terminal improvements needed to support service were also included. Table 8 below shows the results of the capital cost analysis. See Appendix D for Major Cost Factor Analysis.

Table 8: Capital Cost Summary

	OPTION 1 100 VEH	OPTION 2A 75 VEH	OPTION 2B 75 VEH	OPTION 3 55 VEH
Capital Cost Per Vessel	$115M	$76M	$76M	$45M
Total Estimated Vessel Costs	**$345M**	**$228M**	**$304M**	**$225M**
Electrification Terminal Costs	$15M	$15M	$15M	$15M
Dolphin Costs	$0	$1.1M	$1.1M	$4.3M
Passenger Tube Costs	$0	$0	$0	$3M
Total Estimated Terminal Costs	**$15M**	**$16.1M**	**$16.1M**	**$22.3M**
TOTAL CAPITAL COSTS	**$360M**	**$244M**	**$320M**	**$242M**

Note: The capital costs in Table 7 represent a hybrid vessel in 2020 dollars. A hybrid-ready vessel may see a five percent capital cost savings.

6.3 Subchapter K feasibility

The current DRBA fleet vessels are classified by the US Coast Guard as subchapter H vessels. However, as a part of this planning effort, DRBA was interested in the possibility of certifying the new vessels under 46 CFR Subchapter K rather than Subchapter H. This has implications for arrangements, propulsion configuration, crewing costs, and capital costs.

To be certified under 46 CFR Subchapter K it is required that the vessel be less than 100 gross regulatory tons (GRT) and carry more than 150 passengers or have overnight accommodations for more than 49 passengers. Other than framing and crewing, subchapter H and K are very similar with respect to system requirements.

Subchapter K Analysis Findings

- Subchapter K vessels **have less stringent licensing requirements** for crew.
- Only the 55-vehicle vessels in **Option 3** would be capable of Subchapter K classification.

The subchapter K feasibility analysis determined that only Option 3 would be possible to certify to Subchapter K. Subchapter K has it challenges: to be under 100 GRT the vessel framing is arranged to take volume out which makes the engine room and propulsion arrangement challenging due to limited open space. While it is possible to get creative by placing the machinery elsewhere such as above the deck on the aft end of the vessel or the side of the vessel, the consultant's previous design experience has shown that it is difficult to get larger vessels, like those in Options 1 and 2, to less than 100 GRT.

Due to the additional weight of the tonnage frames, subchapter K vessels are heavier than subchapter H vessels. The heavier weight decreases their fuel efficiency and increases the capital cost throughout the life of the vessel. These costs are more than offset, however, by reductions in labor costs.

The consultant team determined that Options 1 and 2 would likely require 8 crew members and Option 3 would likely require 5.

Certifying to subchapter K has advantages such as requiring fewer crew to operate the vessel, less stringent licensing of personnel, and not requiring pilotage. The minimum crew size for a specific vessel is set by Officer in Charge, Marine Inspection (OCMI) and depends on additional factors including the number of passengers, number of passenger decks, number of crew required to operate lifesaving devices and the operation duration per day. Final vessel crew size may ultimately be higher than the minimum required by OCMI due to employer practices.

6.4 Double-ended analysis

Double-Ended Analysis Findings

- Double-ended vessels **remove the need to turn around** which can decrease overall trip time.
- Double-ended vessels will have **slightly higher capital costs** and maintenance costs.
- CMLF crew, captains, and maintenance personnel are not familiar with double-ended technology and would require **retraining**.

All fleet options were deemed to be able to be constructable in a double-ended configuration. A double-ended configuration would have a propulsion system on each end of the vessel, allowing the vessel to switch travel directions with the bow able to become the stern and vice versa.

Double-ended vessels do require slightly more installed HP to go the same speed as single-ended vessels, and thus more weight, which may negate some of the fuel efficiency gained with the slower crossing speed. This study assumed that to go the same speed, double-ended vessels would increase the vessel construction cost by 12% due to the larger installed propulsion plant.

The drive shaft and engine equipment of the double-ended vessels extend below the hull of the vessel, but the consultant team determined that the shallow water depths would not pose a significant risk to the equipment and that double-ended vessels would have higher maneuverability to prevent groundings.

Though double-ended vessels will have slightly higher capital expenditure (CAPEX) costs and maintenance costs, the consultant team recommended them for all fleets due to their improved maneuverability and their ability to decrease the transit time. By decreasing turning time, double-ended vessels are best able to meet an increased service tempo to support growth, per the developed assumptions, while a single-ended vessel could not meet the required transit times without more expensive, higher power engines, higher fuel use, and more stress on the vessels. As a result, double-ended vessels were used as the basis for the schedule models in the service analysis.

6.5 Fuel

The current vessels consume 185-200 gallons of ultra-low sulfur diesel (ULSD) per one-way crossing. In 2019, they used 930,087 gallons at a total cost of $1.83 million which is about $1.97 per gallon. There is currently an ongoing worldwide movement to reduce emissions from vessels due to emissions causing climate change. A growing number of countries have made commitments to achieve carbon neutrality or "net zero" emissions within the next few decades and IMO has adopted mandatory measures to reduce the emissions of greenhouse gases from international shipping. While not specific to DRBA the IMO's pollution prevention treaty (MARPOL) made the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) mandatory for new international shipping vessels [2].

Given the ongoing movement to reduce emissions, the new vessels should look to minimize their environmental impact. This can be done by using more energy efficient technologies (automated docking/undocking), using emission control technologies, and using alternative fuels. There are also operational changes that can minimize the environmental impact such as operating at slower speeds and shutting down the engines while in port.

This study looked at the possibility of using alternative fuels and electrification. While there are many potential alternative fuels only methanol, biofuels, and LNG were considered due to their ability to use modified versions of existing diesel engine technology.

Multiple factors must be considered when looking at alternative fuels including energy density, fuel storage, fuel weight, flammability, toxicity, fuel cost, and capital costs. Energy density for fuel only is very different than the overall energy density when storage tanks and necessary systems are included. For example, LNG has a gravimetric energy density (the available energy per unit mass) of approximately 53 MJ/kg and a volumetric density of approximately 22 MJ/L when looking at the fuel only, but when the storage systems are included, the values drop to approximately 25 MJ/kg (50% less) and approximately 13 MJ/l (62% less). For reference, the gravimetric density of diesel is approximately 45.6 MJ/kg and the volumetric density is 38.6 MJ/L.

Methanol shows particular promise for internal combustion engines in passenger vessels. It has relatively good combustion performance, is able to utilize existing converter technology, and is a liquid at atmospheric pressures and normal temperatures. While methanol is a low-flashpoint fuel, the technology for its safe handing is well developed. Methanol has a low acute toxicity to humans.

As DRBA moves forward with the development of a new ferry, they should allow for consideration of alternative fuels. This should entail building in space, weights, and stability margins such that, over a 40-year vessel life, new technologies can be adopted for the benefit of passengers and vessel crews.

6.6 Seaworthiness Analysis

The seaworthiness or seakeeping ability of the fleet options were evaluated, with a particular emphasis on the 55-vehicle vessels, due to their much smaller size. A smaller and lighter vessel's motions and accelerations may be larger and could result in a lower weather limit for operations. For example, a shorter vessel will tend to pitch more than a longer vessel, resulting in higher vertical accelerations at each end. Vessel vertical accelerations are a primary factor in motion discomfort (sea sickness).

The analysis determined that the 55-vehicle ferries may be required to cancel service based on wave height about 2.3 days per year more than the current ferries are required to cancel service. See Appendix E for more information on interaction with the Marine Environment.

6.7 Transitional Analysis

Each fleet option was compared to existing operations to provide a preliminary understanding of how easy it would be to transition to. A preliminary rationale of vessel replacement to vessel retirement was also evaluated. For Option 1, the new vessels are the same size as the existing vessels, and a one-to-one vessel replacement ratio would facilitate a relatively simple transition with no service level disruptions. For Options 2 and 3, the new vessels would have a smaller individual capacity, and as a result, two new vessels would need to be available before one existing could be retired to maintain existing service levels

Many issues can impact a fleet transition, and this analysis conducted a high-level inventory of potential benefits and challenges each option might pose. Development of a detailed transition plan for the selected fleet is proposed to follow this effort. This transition plan will create a detailed hiring and crewing strategy and interim schedules for when a mixed fleet of new and old vessels are operating.

6.8 Fleet Options Summary

The system analysis determined that all fleet options could provide operational cost savings in comparison to existing DRBA operations. All three options met the benchmark ridership day selected for the study. All fleets were deemed viable options for the future of the CMLF, and a summary of each option is included on the following pages. However, the option that met most of the criteria for optimal operational flexibility, service performance, and seaworthiness while requiring minimal terminal improvements was Option 2B

Option 1: Optimized Current Fleet

This fleet option is the most similar to the current CMLF vessels, being of the same capacity and approximate size. This fleet would include three 100-vehicle capacity vessels. The larger vessel size in this fleet would be least affected by adverse wind and wave conditions but would be the most expensive both to construct and to operate.

Operational Flexibility ●●●○○

This fleet has approximately the same operational flexibility as the current CMLF fleet.

Service Performance ●●●○○

Though able to provide a higher level of service than the existing fleet, this fleet still has vessels that are oversized for winter demand.

Terminal Fit ●●●●●

This option has excellent compatibility with the current terminal landing infrastructure and the existing passenger tubes. Existing mooring infrastructure can be used to support operations and overnight tie-up of all vessels. Additional upland maintenance facility improvements should not be necessary.

Costs ●●○○○

Though operationally cheaper than the current fleet, this option is tied for the highest operational cost of all new fleet options. Additionally, this fleet option has the highest capital cost of any analyzed option.

Seaworthiness ●●●●●

This option should have a level of seaworthiness that is of the same high level as the current fleet.

Transition ●●●●○

As this option is most similar to the existing fleet, transitioning to this fleet would be the simplest from a logistical and operational perspective. Crew will still require some form of training for the new vessels, but this should be minimal in comparison to the other fleets. Moving from the current fleet to this option would be feasible with a one-to-one vessel retirement to replacement ratio, allowing more consistent customer experience during the transition period.

Option 2: Mid-Size Fleet *2B was selected as the future fleet arrangement*

Composed of 75-vehicle capacity vessels, this fleet option represents a middle ground in many ways. A four-vessel fleet (2B) was originally proposed, but a three-vessel option (2A) was also explored after initial ridership and cost analysis identified that it might be viable. The four-vessel fleet would be more expensive but would have greater operational complexity. The three-vessel option would be cheaper but could lead to revenue loss due to a decreased service capacity in the peak window when most summer riders are looking to travel.

Operational Flexibility

Option 2A ●●●○○

This fleet has approximately the same operational flexibility as the current CMLF fleet.

Option 2B ●●●●○

More scheduling choices are possible throughout the year, resulting in higher operational flexibility than the current CMLF fleet. However, other examined fleets had even greater flexibility.

Service Performance

Though both options can achieve a higher daily level of service than the existing fleet, they vary greatly in their ability to meet traffic in the summer peak window.

Option 2A ●○○○○

This fleet can carry only 1,200 vehicles in the peak window, 100 vehicles fewer than the current fleet. Losing capacity in this time frame could lead to revenue loss and would hamper service growth opportunities

Option 2B ●●●●●

Option 2B is sized well that one vessel could be used to meet all daily ridership demand in the winter season. This option performs best in the summer peak period, expanding system capacity in the times people most want to travel.

Terminal Fit ●●●●○

Due to the smaller vessel length, some minor terminal infrastructure improvements would be required at Slip 3 to maintain alignment with the vehicle ramp. Moorage infrastructure needs would not vary between Options 2A and 2B.

Option 2B

Additional crew parking may be required during peak season. With four vessels, more total crew members will likely be working than there are currently in the summer.

Costs

Both Options 2A and 2B represent an operational cost savings compared to the current fleet, but Option 2A has lower overall costs than Option 2B.

Option 2A ●●●●○

Option 2A has capital cost that is only $2M higher than the lowest cost option. Operational costs of this option are also the second lowest of all analyzed fleet options.

Option 2B ●●●○○

Option 2B is second highest in capital costs and tied for highest operational cost.

Seaworthiness ●●●●○

The 75-vehicle vessels will be slightly more susceptible to wind and wave action than the current fleet.

Transition ●●●●○

Transitioning to 75-vehicle vessels will be slightly more challenging than Option 1. However, the vessels in Option 2 will still be Subchapter H boats, meaning that regulatory requirements will be consistent for all boats throughout the transition. Crew training will be needed for the new vessels and moving from the current fleet to this option would be feasible with a one-to-two vessel retirement to replacement ratio.

Option 3: Smaller Vessel Fleet

This fleet option represents the greatest change from current CMLF operations and would include five 55-vehicle capacity vessels. The smaller vessel size will be more susceptible to wind and wave action and the transition to this fleet will have the highest complexity of any analyzed option. With more vessels, this fleet allows for shorter time between sailings and greater operational flexibility. Capital and operating cost savings are highest with this fleet option.

Operational Flexibility ●●●●●

With the greatest number of vessels, this fleet provides the most sailing options for customers and the highest level of operational flexibility. More scheduling choices are possible throughout the year.

Service Performance ●●●●○

Option 3 can provide a higher level of service than the existing fleet and is sized well that one vessel could be used to meet daily ridership demand in the winter season. This fleet also performs well in the summer peak period and expands system capacity in the times people most want to travel.

Terminal Fit ●●○○○

Of all of the fleet options, Option 3 presents the most challenges for fit with the existing terminals. The passenger tube serving Slip 2 at Cape May will need to be modified as to accommodate the shorter, 55-vehicle ferries in Option 3. The shorter vessel length will also require modifications to the existing overnight moorage infrastructure. Due to the amount of in-water work required in comparison to the other fleet options, permitting for this fleet will require a greater effort.

Costs ●●●●●

Option 3 represents the greatest operational and capital cost savings of any analyzed fleet option. Labor cost savings are a prime contributor to overall operational savings.

Seaworthiness ●●●○○

Though the increase in cancelled sailings due to weather is minimal, the smaller vessels in this fleet will be more impacted by wind and wave than any other analyzed option.

Transition ●●○○○

Transitioning to the Option 3 would be the most logistically and operationally complicated, due to the vessels being Subchapter K while the current boats are Subchapter H. A greater period of time would likely be spent operating a mixed fleet of large and small vessels, and two new vessels would be required to replace one retiring vessel in order to maintain service levels. Staging of terminal improvements would also need to be considered.

6.9 Fleet Decision

OPTION 2
selected

The data collected by the consultant team was provided to the DRBA Executive Committee and the DRBA Board. The Board and Executive Committee met on numerous occasions to discuss the data produced by the consultant analysis. Additional crew input was sought regarding the fleet decision and data collected during the consultant analysis. As a result, DRBA captains and staff visited the Steamship Authority (SSA) in October of 2021 and April of 2022 to ride vessels of a similar size to the 55-car capacity vessel proposed in fleet Option 3 and a 75-vehicle ferry as proposed in Option 2. DRBA staff talked with the SSA crew about their experiences running smaller and double-ended vessels. Additionally, DRBA also set up an opportunity for the captains to use MITAGS simulators in March **of 2022** to experience the maneuverability of a proxy vessel in the CMLF route conditions. Using the simulators helped to evaluate the general maneuverability of smaller vessels and double-ended vessels.

To make a fleet decision, a subcommittee of the Board was created to propose a fleet recommendation based on the consultant-provided data, the priorities of DRBA as an organization, and the observations staff and captains had in response to the SSA visits and MITAGS simulator use. At the Board’s subcommittee meeting in October of 2022, the subcommittee selected Fleet Option 2 to maintain acceptable seakeeping of the future fleet and what DRBA viewed as sufficient crewing, while maintaining a moderate capital cost. Following this decision, the consultant team began the next phase of the master planning effort.

7. Phase 3: General Vessel Requirements

Based upon the fleet options and data collected, a list of general vessel requirements was developed through engagement with CMLF staff and crew through a series of workshops. The general requirements list was refined and edited based upon the feedback received during internal meetings and via an internal survey. This information was used to generate a Statement of Owner's Requirements which can be found in Appendix H. Based on the survey, a list of the top 15 vessel requirements was developed, with Subchapter H regulations and a vehicle capacity of 75 identified as the two most important requirements. Table 9 below includes the complete top 15 list of vessel requirements as ranked by CMLF staff and crew. The first requirements, Subchapter H relates to the size and crew needed for operation which has a direct correlation to cost. Capacity for passengers and vehicles is next, followed by the maneuvering capability.

Table 9: Top 15 Vessel Requirements

1st	US Regulations - 46 CFR Subchapter H
2nd	Vehicle Capacity 75
3rd	Total Passengers Onboard < 400
4th	Maneuvering
5th	ADA compliant components (walkways, etc.)
6th	Speed
7th	Crew Space
8th	Design Life - 40 years
9th	Hull (Single/Double ended)
10th	Crossing Time
11th	Fire Suppression
12th	Passenger Space
13th	Propulsion
14th	Corrosion / Painting
15th	Design - Minimal modifications needed

Item 9 and 13, propulsion has to do with the type of power system that moves the vessel through the water and how it is configured either on both sides of the vessel ends or controlled from one end. This refined list was used to as a baseline for the development of the detailed owner's requirements and vessel general arrangement.

8. Phase 3: Detailed Vessel Requirements

The initial vessel requirements were refined which led to the development of a notional (or preliminary) General Arrangement for a future vessel.

The notional diesel-electric propulsion arrangement consists of two thrusters and one centerline shaft for a 75-vehicle and 400-passenger capacity that meets subchapter H US Coast Guard certification and under 1,600 gross tons. The hull depth and draft will match existing terminal condition, along with the relationship and connection to the existing passenger loading tubes. The superstructure arrangement and orientation will be similar to the existing fleet with double-ended loading at the car and passenger levels.

To assist with the notional General Arrangement, the project team completed a basic scantling calculation and stability assessment. Electrical requirements for the diesel-electric propulsion system were calculated and a basic machinery arrangement was developed to show approximate size and locations of the diesel-electric generators, the engineer operating station (EOS), the ship service switchboard, the propulsion switchboards, and the electric motor for the centerline shaft. Ultimately, the propulsion arrangement may change, and the analysis of this arrangement is one of the next major steps. A draft profile of the notional design is shown in Figure 11 below. See **Appendix I** for the notional general arrangement and discussion of vessel requirements.

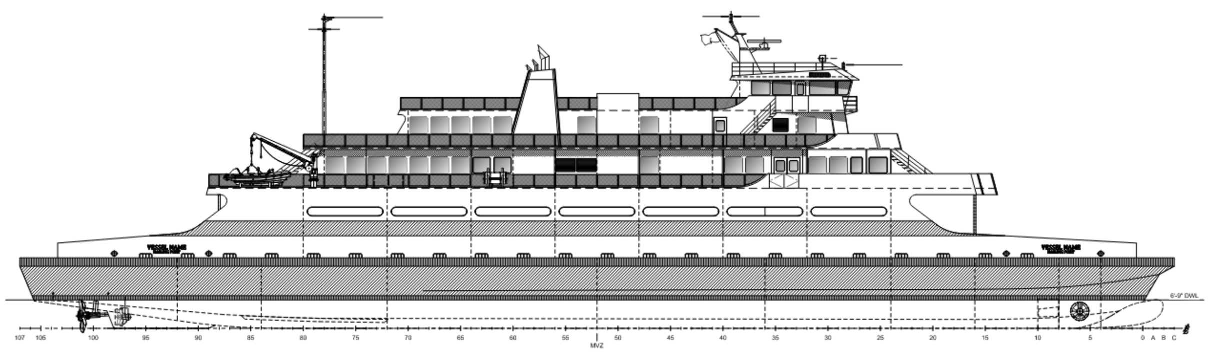


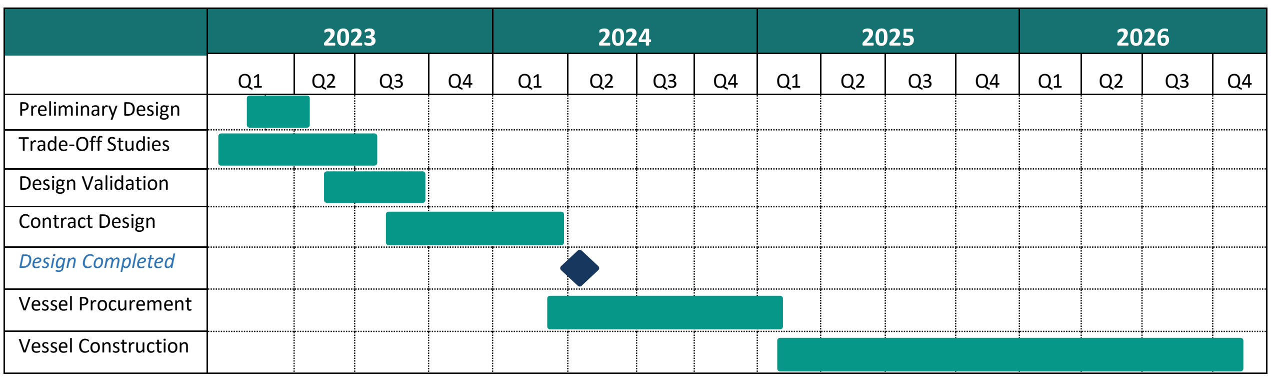
Figure 11: Notional Design Profile

9. Next Steps

With the fleet selected and vessel arrangement in hand, DRBA is on the path to replacing their vessels and meeting their vision of the future fleet. To make this vision a reality, a detailed transition planning effort is being explored. This transition plan will break down the steps needed to switch operations from the old fleet to the new fleet and should include proposed phasing and a vessel retirement schedule. The transition plan should also evaluate actions to take and identify policies needed to prepare for the change in the CMLF system.

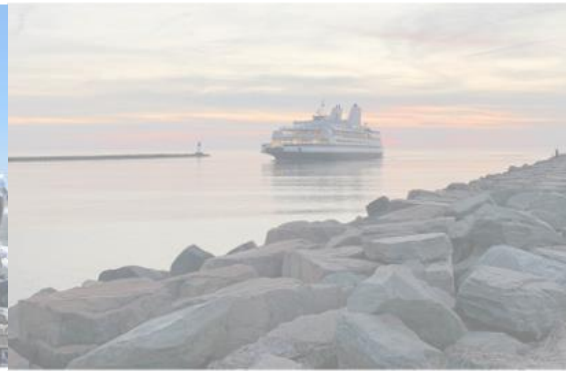
While the transition plan is being developed, detailed vessel design will be developed concurrently. The detailed design will lead to vessel construction, the timeline of which will be identified in the transition plan. These two efforts will support implementation of this MMP, with a goal of starting the two-year vessel construction process as early as 2024.

Table 9: Vessel Design Schedule



APPENDIX A

Phase 1 Task A – Fleet Assessment


2021 Marine Master Plan

Fleet Assessment Report

Prepared for: Delaware River and Bay Authority

Ref: Phase 1 – Task A: Fleet Assessment

June 4, 2021

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

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1. EXECUTIVE SUMMARY

This fleet condition assessment has identified that the DELAWARE and NEW JERSEY each having no systems requiring major investment, while the CAPE HENLOPEN has ten. This is a result of the CAPE HENLOPEN having not undergone a repower like the other vessels.

The required investments for the vessels at a minimum are approximately $2.5 million per dry docking. This translates into about $1 million per year per vessel since each vessel must be drydocked a minimum of twice every five years. The DELAWARE will require an additional $2.0-2.5 million investment, with the CAPE HENLOPEN requiring an additional $15-20 million if a repower and refurbishment is desired.

2. INTRODUCTION

To analyze the Cape May – Lewes Ferry System (CMLF) and provide good recommendations, it is necessary to first assess the condition of the existing infrastructure. This document focuses on the condition of the existing CMLF vessels.

The fleet currently consists of three vessels, the CAPE HENLOPEN, DELAWARE, and NEW JERSEY. These vessels serve the 14-mile route between Cape May, NJ and Lewes, DE.

2.1 PROCEDURE AND DOCUMENT STRUCTURE

Information gathered to support this fleet assessment include:

- Matterport 3D Scan of Each Vessel
- Past vessel ship checks information and photos
- Regulatory (USCG and ABS) Survey Information
- Prior vessel condition surveys
- Supporting Information on Maintenance Practices
- Financial expenditures for maintenance, preservation, and improvements
- DRBA review and input on vessel condition

Each vessel is discussed individually in the sections that follow; these condition reports are organized by industry standard Ship Work Break Down System (SWBS) that organize the information into the following categories:

SWBS Group	Description
100	Structure
200	Propulsion
300	Electrical
400	Command, Control and Communication
500	Auxiliary Systems
600	Outfit

The discussion summarizes the condition ratings, and identification of work required within the next 10 years. A more detailed tabulation is available in the appendices.

The vessel condition is scored using the following scale:

1	New
2	Good
3	Fair
4	Poor
5	Unsatisfactory
6	Failure

Work within the next 10 years is identified using the following scale:

1	None
2	Some
3	Major
4	Overhaul

This report concludes with an overall summary that ranks the vessels based on condition and anticipated investment.

Figure 1: CMLF Fleet

2.2 VESSEL CHARACTERISTICS SUMMARY

A summary of the fleet is provided below. In general, all three vessels were constructed from the same or similar plans and share the same dimensions, capacity, hull form, and overall arrangements. The vessels range in age from 40 to 47 years, significantly outliving the 25 to 30-year service life that they were originally designed for[1]. However, there have been and continue to be significant investments into these assets that have resulted in a prolonged vessel life.

CHARACTERISTIC	M/V DELAWARE	M/V NEW JERSEY	M/V CAPE HENLOPEN
Year Built Interior Refurbishment Repower	1974 2001* 2016	1974 1999 & 2021 2021	1981 1998 TBD
Builder	Todd Houston	Todd Houston	Norfolk Shipbuilding
Contract Price[2]	$3.9 million	$3.9 million	$10.7 million
Official Number	555834	560370	637807
Length (ft) Beam (ft) Depth (ft)	320 68 16.5	320 68 16.5	320 68 16.5
Gross Tonnage Net Tonnage	2108 1416	2108 1416	2120 1424
Nominal Capacity	800 Passengers 100 Vehicles	800 Passengers 100 Vehicles	800 Passengers 100 Vehicles
COI Capacity	863 Passengers	863 Passengers	798 Passengers
Propulsion	Diesel Reduction, 4000HP	Diesel Reduction, 5000HP[3]	Diesel Reduction, 4000HP
Minimum Crewing (COI)	9, of which 6 must be certified lifeboatmen	9, of which 6 must be certified lifeboatmen	9, of which 4 must be certified lifeboatmen

* House structure refurbishment in addition to interior work

[1] *Vessel Useful Life and Cost to Extend Report*: March 10, 2011 by AMSEC LLC
[2] *A Ferry Tale*, William J. Miller, Jr., Delapeake Publishing Co, 1984
[3] Pending completion of the current repower.

3. M/V DELAWARE

The DELAWARE is the sistership of the NEW JERSEY, the vessel is 47 years old but has undergone significant investments, including a repower in 2016.

The 2011 fleet condition survey[4] of the DELWARE provided a good starting point for the vessel condition survey.

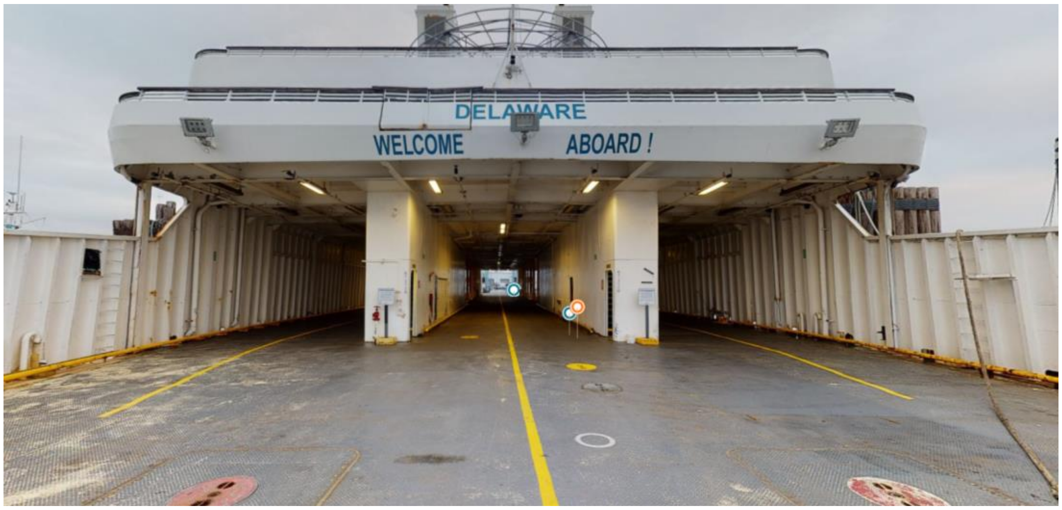


Figure 2. Vehicle deck of M/V DELAWARE

3.1 SWBS 100 – STRUCTURE

Vessel Condition Survey: DELAWARE			
SWBS	Element	Condition	Work within 10 years
100	**Structure**		
110	Hull Plating	3	2
111	Hull Structure	3	2
130	Hull Decks	4	3
150	Superstructure	3	2
162	Stacks	3	2
162	WT Hull Doors, Hatches, BERPs	3	2
170	Masts	4	3
180	Foundations	3	2

The structural elements of the DELAWARE have an average condition rating of slightly worse than fair and they are expected to require some on-going work within the next 10 years. These assessments are

[4] *Vessel Useful Life and Cost to Extend Report*: March 10, 2011 by AMSEC LLC

reflective of the vessels age and the corrosion and wastage issues that will continue to be identified as a result.

3.1.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

#3 Void Side Shell - Per ABS Open Comments the #3 Void has side shell damage at Fr. 50 that will likely need to be repaired in the next few years. Estimated Cost: $10,000

Bottom/Bilge Plating Wastage - Per the ABS 10-yr Findings in 2011 – there is a pattern of bottom/bilge plating wasted or exhibiting pitting. Estimated Cost: $10,000

General Hull and Superstructure Steel – Recently, significant amounts of plate were put into void spaces and the curtain plate based on Shipyard receipts. However, several other bid items, mostly above main deck, did not receive work. In 2017 more superstructure work was completed. Given this historic trend of steel work and accounting for inflation and accelerated steel wastage as the vessel ages, approximately $250,000 to $300,000 in steel work will be needed each drydock period going forward.

3.2 SWBS 200 –PROPULSION

Vessel Condition Survey: DELAWARE			
SWBS	Element	Condition	Work within 10 years
200	**Propulsion Plant**		
202	Propulsion Control system	1	1
230	Main Engines	1	1
231	Reduction gears	1	1
243	Shafting system	3	2
245	Propulsors	1	1
256	Cooling System	2	1
259	Exhaust System	2	1
261	Fuel Service System	2	2
264	Lube Oil System	2	2

The propulsion plant systems on the DELAWARE are mostly in new or good condition because of the repower that occurred in 2016. The cooling system is expected to require work because of the many ongoing issues observed within the last 10 years.

3.2.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

3.3 SWBS 300 – ELECTRICAL

Vessel Condition Survey: DELAWARE			
SWBS	Element	Condition	Work within 10 years
300	**Electrical Plant**		
310	Generator Sets	3	3
320	Electrical Distribution System	3	2
330	Lighting Systems	3	2

The electrical systems on the DELAWARE are in fair condition requiring ongoing maintenance work resulting from the system's age. The diesel end of the ship service generators were overhauled in 2018. Much of the lighting system appears to be the original installation. As with all systems that include original equipment, the costs of maintaining them will continue to increase with age.

3.3.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Replacement of the electrical ends of the ship service generators and associated switchboard components - This upgrade has been noted and planned as part of future shipyard availabilities. Estimated Cost: $500,000.

Lighting system upgrade to LED fixtures - This upgrade has also been noted and planned for future shipyard availabilities. Estimated Cost: $75,000.

3.4 SWBS 400 – COMMAND, CONTROL, AND COMMUNICATION

Vessel Condition Survey: DELAWARE			
SWBS	Element	Condition	Work within 10 years
400	**Command and Surveillance**		
420	Navigation Systems	3	3
422	Electrical Navigation Aids (incl. Nav. Lights)	3	2
430	Interior Communications	3	3
432	Telephone Systems	3	3
433	Announcing Systems	3	3
436	Alarm, Safety, & Warning Systems	3	2
438	Integrated Control Systems	2	2
439	Recording & Television Systems	2	2
440	Exterior Communications	3	2
446	Security Equipment Systems	3	2

The command-and-control systems on the DELAWARE are in fair condition requiring ongoing maintenance work resulting from the systems age. There were no specific expenses noted by the CLMF for future shipyard availabilities.

With regard to interior communication systems, the public address system and sound powered telephone system in the engine room were noted by the crew as having specific problems that need to be addressed. However, it does not appear that these systems need a complete replacement or upgrades.

Similarly, the RADARS were replaced in 2018 but there are issues with the radar rotating assemblies and displays. These may be repair or upgrade projects in lieu of replacement.

3.4.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we expect the following project will need to be executed to maintain vessel operation reliability and an acceptable level of customer experience:

Upgrade/Replacement of Alarm and Monitoring System - The sensors for the main engines were upgraded as part of the repowering in 2016, however the remainder of the system is the original installation. Continued efficient operation of the vessel will likely require an upgrade/replacement of these systems in the next ten years. Estimated Cost: $850,000 - $900,000 based on the estimate the DRBA received for the M/V New Jersey and M/V Cape Henlopen.

Radio Upgrades and FCC Licensing - Currently the crew use VHF radios for primary communication. A dedicated VHF channel and system will eliminate interference from other vessels. Estimated Cost: $10,000.

3.5 SWBS 500 – AUXILIARY SYSTEMS

Vessel Condition Survey: DELAWARE			
SWBS	Element	Condition	Work within 10 years
500	**Auxiliary Systems, General**		
506	Overflows, Air Escapes, and Sounding Tubes	3	2
513	Machinery Space Ventilation System	3	2
514	HVAC System	2	2
521	Firemain System	2	1
522	Sprinkler System	3	2
526	Deck Drains	2	1
528	Plumbing Drainage	3.5	2.5
529	Bilge System	3.5	2.5
530	Fresh Water Systems	3.5	2.5
533	Potable Water	2	2
551	Compressed Air Systems	2.5	2
555	Fire Extinguishing System	2	2
561	Steering Systems	2	2
562	Rudder	2	2
568	Maneuvering Systems	3	2
581	Mooring Systems	3	2
583	Life Saving Equipment, Rescue Boats, etc.	2	2

The auxiliary systems on the DELAWARE have a wide range of condition ratings reflecting their individual maintenance status. Of note, the machinery space ventilation system is likely to require significant investment in the upcoming years. Water based systems, including plumbing and drainage, bilge, and freshwater systems will require some investment to abate ongoing corrosion issues resulting from vessel age.

3.5.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Overhaul of Machinery Space Ventilation System – Replacement of all fan coils and AHUs except for the new Galley AHU that was installed in 2020. May involve overhaul of boiler which may incur additional costs. Estimated Cost: $45,000

Upgrade of HVAC Control System – The existing system is reported to be highly unreliable. Replacing the existing control system will require having vendors provide and integrate new equipment and wiring at minimum. Estimated Cost: $20,000

Descaling or Replacement of Original Sewage Piping – Some piping has already been replaced. Increased replacement will be necessary within the next 10 years. Estimated Cost: $100,000

Tank Gauging Integration with ICS – Problems with the existing tank gauge system are observed. While the potable water system may need work beyond this scope of work, the replacement of the gauging system and integration with the ICS is noted a s a discrete work scope. Estimated Cost: $10,000

Beyond the projects identified above, any piping system that has not undergone any replacement may require work due to corrosion, pitting, scaling, and buildup that occurs over time. The scope and cost of such work will depend heavily on the length and location of piping that will need to be replaced.

3.6 SWBS 600 – OUTFIT

Vessel Condition Survey: DELAWARE

SWBS	Element	Condition	Work within 10 years
600	**Outfit & Furnishings, General**		
602	Nameplates, Notices & Markings	2	1
612	Railings, Stanchions & Lifelines	2	2
621	Joiner Bulkheads	3	2
622	Floor Plates & Gratings	2	1
623	Ladders	2	1
624	Joiner Doors	3	2
625	Windows	3	2
631	Painting	2	2
633	Cathodic Protection	2	2
634	Deck Coverings	3	2
635	Insulation, Linings & Ceilings	3	3
640	Furniture & Furnishings	2	2
644	Sanitary Spaces	3	2
645	Community Spaces	3	2
650	Service Spaces	3	2
662	Machinery Control Centers Furnishings	3	2

The outfitting systems on the DELAWARE are in good or fair condition. Issued noted by USCG inspections include SFP deficiencies in various areas that will need to be addressed. Also, by visual inspection the ceiling panels appear outdated and damaged in some places. Replacement of the ceiling system in the public spaces is recommended.

3.6.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Address Structural Fire Protection Deficiencies – Various issues require attention. Estimate Cost: $25,000.

Passenger Space Ceiling Replacement – Recommend installing new ceiling system throughout the public spaces on the vessel. Estimate Cost: $350,000.

Figure 3. Large modern windows on passenger deck of DELAWARE

3.7 OVERALL SUMMARY

The DELAWARE is a well-maintained vessel that has undergone significant investment within the last decade. With continued maintenance and strategic investment, the vessel should be able to attain another 10 years without significant planned costs. However, unplanned costs due to systems being at or past their recommended life span are expected to continue to reduce reliability and escalate unplanned service outages.

4. M/V NEW JERSEY

The NEW JERSEY is the sister vessel of the DELAWARE. There is a significant amount of information available on the NEW JERSEY's structural condition from BMT's vessel condition assessment report[5]. In addition, EBDG developed the design and engineering guidance for the repowering and Upper Deck refurbishment project currently underway at Caddell Shipyard. The repower/refurbishment is expected to be complete in the Summer of 2021.

Figure 4. M/V NEW JERSEY

[5] *Report of Findings for the Corrosion Assessment of the MV NEW JERSEY*, by BMT Designers & Planners, February 2017

4.1 SWBS 100 – STRUCTURE

Vessel Condition Survey: New Jersey			
SWBS	Element	Condition	Work within 10 years
100	**Structure**		
110	Hull Plating	3	2
111	Hull Structure	3	2
130	Hull Decks	2	2
150	Superstructure	2	2
162	Stacks	1	1
162	WT Hull Doors, Hatches, BERPs	2	2
170	Masts	4	3
180	Foundations	3	1

The structural elements of the NEW JERSEY have a wide variation in condition ratings mostly ranging from new to fair. Of note, the mast and supporting structure is expected to require significant investment within the next 10 years.

4.1.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Per the latest ABS Survey notes there are several areas that should be addressed during the vessel's repower:

- Bow Thruster Room Structure
- Port and Starboard Stern Tubes[6]
- Locations within the Engine Room
- Fiddly and Engine Room Access Spaces in way of Main Deck
- Deck in way of Salon near Galley and Heads
- Wheelhouse Deck
- Main Deck in several Locations

However, due to the vessel's age local areas of pitting are likely to continue occurring in the hull. EBDG finds that the original steel from the mill tends to exhibit similar corrosion resistance properties throughout the vessel unless the shipyard changes steel suppliers during construction. This means that if localized pitting begins to occur in one place in the vessel, as it has with the NEW JERSEY, then similar phenomena will continue to spread throughout the vessel.

Even assuming the latest areas identified by ABS are addressed, it is safe to assume there will be a nominal amount of steel work that will have to occur periodically. Estimate Cost: $300,000 every 3-5

[6] The stern tube replacement is noted as part of repower scope of work.

years. This periodic replacement could mean extended or unplanned service outages within this time frame.

4.2 SWBS 200 –PROPULSION

Vessel Condition Survey: New Jersey			
SWBS	Element	Condition	Work within 10 years
200	**Propulsion Plant**		
202	Propulsion Control system	1	1
230	Main Engines	1	1
231	Reduction gears	2	1
243	Shafting system	2	1
245	Propulsors	1	1
256	Cooling System	2	2
259	Exhaust System	1	1
261	Fuel Service System	1	1
264	Lube Oil System	1	1

The propulsion plant systems on the NEW JERSEY are in new or good condition because of the currently ongoing repower.

4.2.1 RECOMMENDED FUTURE PROJECTS

Given the extent of new and refurbished equipment and systems installed during the current shipyard, few, if any of the propulsion systems on the vessel will need to be addressed in the next ten years. Normal maintenance to address hull antifouling, corrosion, and cathodic protection will be required.

4.3 SWBS 300 – ELECTRICAL

Vessel Condition Survey: New Jersey			
SWBS	Element	Condition	Work within 10 years
300	**Electrical Plant**		
310	Generator Sets	3	2
320	Electrical Distribution System	3	2
330	Lighting Systems	3	3

The electrical systems on the NEW JERSEY are in fair condition requiring ongoing maintenance work resulting from the systems age. The diesel portion of the generators were overhauled in 2018, SSDG1 was repaired and overhauled in 2020, and the electrical sections are being replaced as part of the repowering effort. The generator switchboard circuit breakers are also being replaced as part of this effort. As with all systems that include original equipment, the costs of maintaining them will continue to increase with age.

4.3.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Lighting system upgrade to LED fixtures - This upgrade has also been noted and planned for future shipyard availabilities. Estimated Cost: $75,000.

4.4 SWBS 400 – COMMAND, CONTROL, AND COMMUNICATION

Vessel Condition Survey: New Jersey			
SWBS	Element	Condition	Work within 10 years
400	**Command and Surveillance**		
420	Navigation Systems	2	2
422	Electrical Navigation Aids (incl. Nav. Lights)	2	2
430	Interior Communications	3	3
432	Telephone Systems	3	3
433	Announcing Systems	3	3
436	Alarm, Safety, & Warning Systems	2	2
438	Integrated Control Systems	2	2
439	Recording & Television Systems	2	2
440	Exterior Communications	3	3
446	Security Equipment Systems	3	3

The command-and-control systems on the NEW JERSEY are in good or fair condition requiring ongoing maintenance work resulting from the systems age. There were no specific expenses noted by the CLMF for future shipyard availabilities. The main engine alarm and monitoring system is being replaced as part of the current repowering effort. The estimated cost for this effort is $700,000.

Regarding interior communication systems, the public address system and sound powered telephone system in the engine room were noted by the crew as having specific problems that need to be addressed. However, it does not appear that these systems need a complete replacement or upgrades.

The RADARS were replaced in 2018 and the pilothouse console is being replaced as part of the repower.

4.4.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience:

Upgrade of Alarm and Monitoring System – Incorporating other vital ship systems into the upgraded alarm and monitoring system provided during the repowering effort will require new sensors, integration and potentially cables. Estimated Cost: $150,000 - $200,000.

Radio Upgrades and FCC Licensing - Currently the crew use VHF radios for primary communication. A dedicated VHF channel and system will eliminate interference from other vessels. Estimated Cost: $10,000.

4.5 SWBS 500 – AUXILIARY SYSTEMS

Vessel Condition Survey: New Jersey			
SWBS	Element	Condition	Work within 10 years
500	**Auxiliary Systems, General**		
506	Overflows, Air Escapes, and Sounding Tubes	3	2
513	Machinery Space Ventilation System	3	2
514	HVAC System/ Heating	4	3
521	Firemain System	4	3
522	Sprinkler System	2	1
526	Deck Drains	2	2
528	Plumbing Drainage	3	2
529	Bilge System	2	2
530	Fresh Water Systems	3.5	2.5
533	Potable Water	4	3
551	Compressed Air Systems	2	2
555	Fire Extinguishing System	2	2
561	Steering Systems	2	2
562	Rudder	2	2
568	Maneuvering Systems	2	2
581	Mooring Systems	2	2
583	Life Saving Equipment, Rescue Boats, etc.	3	2

The auxiliary systems on the NEW JERSEY have a wide range of condition ratings reflecting their individual maintenance status. Of note, the machinery space ventilation system is likely to require significant investment in the upcoming years. Systems including firemain and potable water have ongoing observed issues that will require investment within the next 10 years. Note that the HVAC system is currently undergoing some investment as part of the passenger space upgrades.

4.5.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Overhaul of Machinery Space Ventilation System – Multiple ABS findings from 2018 and 2019 indicating on-going problems. Estimated Cost: $50,000

Renewal of Firemain System – Estimated Cost: $200,000

Overhaul of Potable Water System – Problems with the existing tank gauge system are observed. While the potable water system may need work beyond this scope of work, the replacement of the gauging system and integration with the ICS is noted a s a discrete work scope. Estimated Cost: $15,000

Beyond the projects identified above, any piping system that has not undergone any replacement may require work due to pitting, scaling, and buildup that occurs over time. The scope and cost of such work will depend heavily on the length and location of piping that will need to be replaced.

4.6 SWBS 600 – OUTFIT

Vessel Condition Survey: New Jersey			
SWBS	Element	Condition	Work within 10 years
600	**Outfit & Furnishings, General**		
602	Nameplates, Notices & Markings	2	2
612	Railings, Stanchions & Lifelines	2	2
621	Joiner Bulkheads	1	1
622	Floor Plates & Gratings	2	2
623	Ladders	3	2
624	Joiner Doors	2	2
625	Windows	1	2
631	Painting	1	2
633	Cathodic Protection	2	2
634	Deck Coverings	2	2
635	Insulation, Linings & Ceilings	2	1
640	Furniture & Furnishings	2	1
644	Sanitary Spaces	3	2
645	Community Spaces	2	1
650	Service Spaces	3	2
662	Machinery Control Centers Furnishings	1	2

The outfitting systems on the NEW JERSEY are generally in good condition. The NEW JERSEY is undergoing a passenger lounge refurbishment as part of the current shipyard period, as well as complete exterior repainting. New exterior windows and doors surrounding the passenger lounge, new deck and refurbished deck covering, new gift and passenger self-serve food areas, with some seating upgrades.

4.6.1 RECOMMENDED FUTURE PROJECTS

Given the extent of refurbishment and painting during the current shipyard, few, if any of the outfitting areas on the vessel will need to be addressed in the next ten years.

4.7 OVERALL SUMMARY

The NEW JERSEY is a well-maintained vessel that is currently undergoing significant investment. With continued maintenance and strategic investment, the vessel should be able to attain another 10 years without significant costs.

5. M/V CAPE HENLOPEN

The CAPE HENLOPEN is the youngest vessel in the CMLF fleet at 40 years of age, and the only vessel that has yet to undergo a repower. While the engineering and design in support of a repower and Upper Deck refurbishment has been completed (like that underway on the NEW JERSEY), there are no current plans to execute that work on the CAPE HENLOPEN.

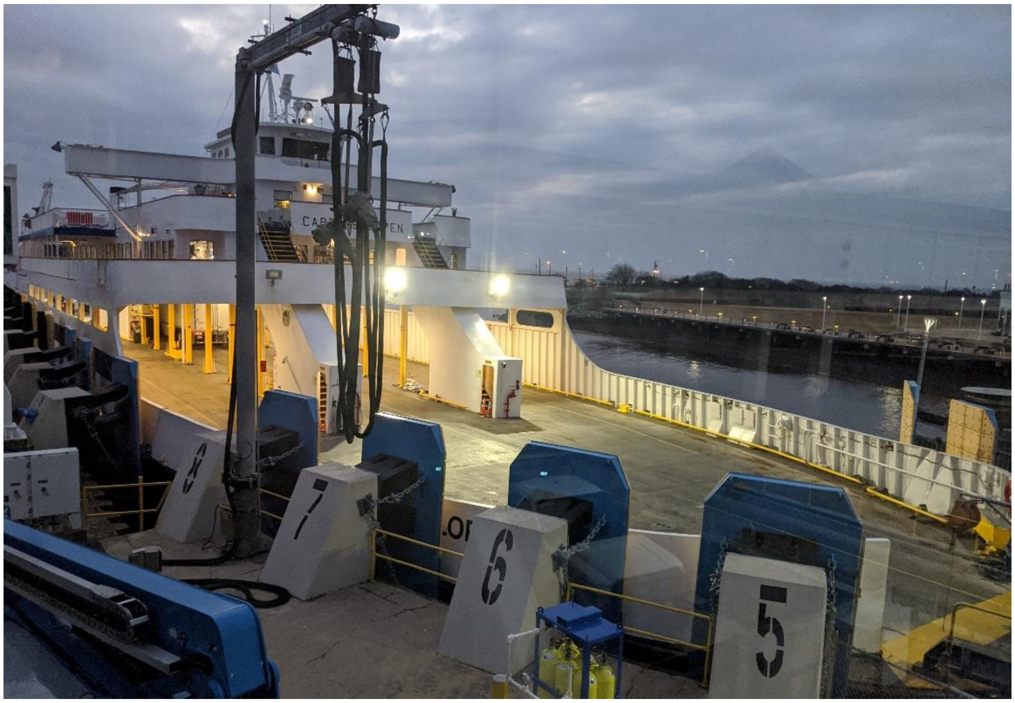


Figure 5. M/V CAPE HENLOPEN at Terminal

5.1 SWBS 100 – STRUCTURE

Vessel Condition Survey: Cape Henlopen			
SWBS	Element	Condition	Work within 10 years
100	**Structure**		
110	Hull Plating	3	2
111	Hull Structure	3	2
130	Hull Decks	4	2
150	Superstructure	3	3
162	Stacks	3	2
162	WT Hull Doors, Hatches, BERPs	3	2
170	Masts	3	2
180	Foundations	3	2

The structural elements of the CAPE HENLOPEN are in fair or worse condition ratings. Of note, In the hull decks and superstructure appear ongoing corrosion issues that will require continued maintenance, and issues have been observed on the stacks and foundations.

There was *significant* work put into the Cape Henlopen in 2019. Almost $450,000 in 02 Deck Steel repair and more than $600,000 in the car deck and curtain plate. But there are still many areas of the hull that are flagged for monitoring in the engine room and in way of the Bow Thruster channel coolers. If this vessel undergoes a repowering it would be good to address these additional areas.

Superstructure wastage is evident in way of the windows in the Upper Deck and Pilothouse exterior bulkheads. If refurbishment work is undertaken on the Upper Deck passenger lounge as done on the NEW JERSEY most of these issues would be rectified.

5.1.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

General Structural Repair- Recommend budgeting $200,000 for steel work every three years until the vessel is retired.

As part of a recommended *Main Propulsion System Replacement* project identified under SWBS 200 below, structural upgrades would include upgraded foundations, new stern tubes, and new larger stack structures. Costs are included in SWBS 200.

As part of a recommended *Upper Deck Passenger Lounge Refurbishment* project identified under SWBS 600 below, structural upgrades would include refurbished exterior bulkheads and adjacent structure in way of the windows and doors. Costs are included in SWBS 600.

5.2 SWBS 200 –PROPULSION

Vessel Condition Survey: Cape Henlopen			
SWBS	Element	Condition	Work within 10 years
200	**Propulsion Plant**		
202	Propulsion Control system	3	4
230	Main Engines	3	4
231	Reduction gears	3	4
243	Shafting system	2	4
245	Propulsors	1	1
256	Cooling System	4	4
259	Exhaust System	3	4
261	Fuel Service System	3	4
264	Lube Oil System	3	4

The propulsion plant systems on the CAPE HENLOPEN need significant investment. The propulsors and shafting system have had recent investment and are in good condition as a result, except for the stern tubes, which are original. If new engines are installed as was done on the NEW JERSEY new shafting and larger diameter stern tubes will be required.

5.2.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Main Propulsion System Replacement – Includes replacing the main engines, reduction gears, propulsion shafting, exhaust systems, and upgrading most of the propulsion support systems such as controls, lube oil, fuel oil, and compressed air. Structural modifications to support this effort include updated foundations, new stern tubes, and new stack structures on the 03 level. Estimated cost: $12-$15million.

5.3 SWBS 300 – ELECTRICAL

Vessel Condition Survey: Cape Henlopen

SWBS	Element	Condition	Work within 10 years
300	**Electrical Plant**		
310	Generator Sets	2	2
320	Electrical Distribution System	3	2
330	Lighting Systems	3	3

The electrical systems on the CAPE HENLOPEN are in fair condition requiring ongoing maintenance work resulting from the systems age. The diesel end of the ship service generators were overhauled in 2019. Much of the lighting system appears to be the original installation. There are issues with the generator main circuit breakers. As with all systems that include original equipment, the costs of maintaining them will continue to increase with age.

5.3.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Generator Overhauls - Replacement of the electrical ends of the ship service generators and associated switchboard components. This upgrade has been noted and planned as part of future shipyard availabilities. Estimated Cost: $500,000.

Lighting system upgrade to LED fixtures - This upgrade has also been noted and planned for future shipyard availabilities. Estimated Cost: $75,000.

5.4 SWBS 400 – COMMAND, CONTROL, AND COMMUNICATION

Vessel Condition Survey: Cape Henlopen			
SWBS	Element	Condition	Work within 10 years
400	**Command and Surveillance**		
420	Navigation Systems	3	3
422	Electrical Navigation Aids (incl. Nav. Lights)	3	3
430	Interior Communications	3	3
432	Telephone Systems	3	3
433	Announcing Systems	2	1
436	Alarm, Safety, & Warning Systems	3	3
438	Integrated Control Systems	3	3
439	Recording & Television Systems	3	3
440	Exterior Communications	2	2
446	Security Equipment Systems	3	3

The command-and-control systems on the CAPE HENLOPEN are in good or fair or better condition requiring ongoing maintenance work resulting from the systems age. There were no specific expenses noted by the CLMF for future shipyard availabilities.

Regarding interior communication systems, the public address system and sound powered telephone system in the engine room were noted by the crew as having specific problems that need to be addressed. However, it does not appear that these systems need a complete replacement or upgrades.

Similarly, the RADARS were replaced in 2018 but there are issues with the radar rotating assemblies and displays. These may be repair projects in lieu of replacement.

5.4.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Upgrade/Replacement of Alarm and Monitoring System - The original alarm systems on the vessel are still in use. Continued efficient operation of the vessel will likely require an upgrade/replacement of these systems in the next ten years. Estimated Cost: $850,000 - $900,000 based on the estimate received by DRBA.

Radio Upgrades and FCC Licensing - Currently the crew use VHF radios for primary communication. A dedicated VHF channel and system will eliminate interference from other vessels. Estimated Cost: $10,000.

5.5 SWBS 500 – AUXILIARY SYSTEMS

Vessel Condition Survey: Cape Henlopen			
SWBS	Element	Condition	Work within 10 years
500	**Auxiliary Systems, General**		
506	Overflows, Air Escapes, and Sounding Tubes	3	2
513	Machinery Space Ventilation System	3	2
514	HVAC System	1	2
521	Firemain System	1	1
522	Sprinkler System	2	2
526	Deck Drains	3	2
528	Plumbing Drainage	3.5	2.5
529	Bilge System	3.5	2.5
530	Fresh Water Systems	3.5	2.5
533	Potable Water	4	3
551	Compressed Air Systems	4	3
555	Fire Extinguishing System	4	3
561	Steering Systems	1	1
562	Rudder	1	1
568	Maneuvering Systems	3	2.5
581	Mooring Systems	3	2
583	Life Saving Equipment, Rescue Boats, etc.	3	2

The auxiliary systems on the CAPE HENLOPEN have a wide range of condition ratings but all are fair or better. There has been significant investment in the HVAC, firemain, steering and rudder systems within the last 10 years. The systems requiring the most attention are the machinery space ventilation, potable water, compressed air, and fire extinguishing systems.

5.5.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Refurbishment of Machinery Space Ventilation System – On-going repairs and replacements: Estimated Cost: $25,000

Overhaul of Potable Water System – The full extent of work required for the potable water system is unknown. At least a condition assessment of pressure tank and tank gauging integration with ICS will be required. Estimated Cost: $15,000 (minimum)

Beyond the projects identified above, any piping system that has not undergone any replacement may require work due to pitting, scaling, and buildup that occurs over time. The scope and cost of such work will depend heavily on the length and location of piping that will need to be replaced.

5.6 SWBS 600 – OUTFIT

Vessel Condition Survey: Cape Henlopen			
SWBS	Element	Condition	Work within 10 years
600	**Outfit & Furnishings, General**		
602	Nameplates, Notices & Markings	5	3
612	Railings, Stanchions & Lifelines	2	2
621	Joiner Bulkheads	3	3
622	Floor Plates & Gratings	2	2
623	Ladders	2	2
624	Joiner Doors	4	4
625	Windows	4	4
631	Painting	1	2
633	Cathodic Protection	1	2
634	Deck Coverings	2	2
635	Insulation, Linings & Ceilings	2	2
640	Furniture & Furnishings	2	2
644	Sanitary Spaces	3	2
645	Community Spaces	3	2
650	Service Spaces	3	2
662	Machinery Control Centers Furnishings	3	2

The outfitting systems on the CAPE HENLOPEN are in fair condition. Notable exceptions include the Upper Deck passenger lounge windows and exterior access doors, and the nameplates, notices, and markings which have many recorded issues within the last 10 years. The vessel underwent an extensive repainting project in 2019.

5.6.1 RECOMMENDED FUTURE PROJECTS

Within the next 10 years we recommend the following projects be executed to maintain vessel reliability and an acceptable level of customer experience.

Upper Deck Passenger Lounge Refurbishment – Includes replacing all lounge perimeter windows and exterior doors, repairing all structure bulkhead and deck steel in way of the window and door replacements, upgrades to the gift shop and passenger food service as completed on the NEW JERSEY. Estimated cost: $2.5-$3 million.

5.7 OVERALL SUMMARY

Vessel repowering and Upper Deck passenger space refurbishment investments are recommended for the CAPE HENLOPEN, to continue operation for another 10 years.

6. FLEET CONDITION SUMMARY

SWBS condition ratings are tallied for each vessel below.

	Excellent Condition	Fair Condition	Requiring Increased Maintenance	Requiring Major Investment
DELAWARE	11	41	11	0
NEW JERSEY	15	37	11	0
CAPE HENLOPEN	8	25	20	10

The above table shows that the CAPE HENLOPEN will require the most investment, and that the condition ratings of the NEW JERSEY and the DELAWARE are similar, both having undergone a repower and some level of passenger space refurbishment. The NEW JERSEY reflects a slightly better condition rating relative to the DELAWARE because the scope of work during the repower was greater, and the occurrence is more recent.

For continued operation of the existing three vessels for the next 10 years the following investment needs have been identified. Each CMLF vessel must be drydocked twice every five years.

1. The DELAWARE will require steady investments of regular dockings, plus additional investment in steel work and updates to the electrical system and various electronic controls equipment. Typical drydocking costs for CMLF vessels run approximately $2.5 million. The added steel, electrical and electronic work will require an additional $2.0 -$2.5 million over the next 10 years.

2. The NEW JERSEY will only require steady investment of regular dockings ($1 million per year) until retirement after the current repower and refurbishment period.

3. The CAPE HENLOPEN will require a significant investment of $15-20 million for a repower and upper deck refurbishment if operation for the next 10 years is desired. By way of comparison, the cost of the current NEW JERSEY repower/refurbishment project is about $22 million, which includes the drydock costs as well as a complete repainting of the entire vessel exterior. The CAPE HENLOPEN underwent a similar repainting effort in 2019. If the vessel is to be retired sooner, remaining shipyard visits can be estimated to cost $2.5million per docking. A docking in 2021-2022 will be required.

The above rough order of magnitude budgetary estimates are based in part on historical DRBA costs as well as future projections. As vessel's age, many older systems and equipment will be prone to unexpected failure, and as a result vessel reliability decreases over time. The magnitude and repair costs associated with these issues depend on specifics but can often result in longer times out of-service. Further, impacts beyond repair costs to service reliability and customer experience must also be considered.

Traditionally, commercial vessel service life is assumed to be about 30 years. However, two of the major passenger vehicle ferry operators in the US, Washington State Ferries (WSF) and the Alaska Marine Highway System (AMHS) have found through practice that the operational life of their vessels can be between 60 and 65 years. To achieve this useful life, vessels must be built with sufficiently robust scantlings, and major refurbishments to vessel coatings, passenger spaces and mechanical systems are needed on regular intervals. In general, coatings must be redone every 10 years, passenger space refurbishments are necessary every 20 years, and the vessel needs to be repowered every 30 years. Beyond this estimated vessel life, the vessel's operational reliability decreases to an acceptable level requiring greater unexpected investments at increasing frequency.

There are many decision factors to consider when planning a vessels retirement. For fleet operators such as WSF and AMHS, the decision is typically driven by decreased reliability and the associated difficulty planning maintenance, operations, and finances. Because these vessels carry passengers, and safety is the highest priority, it is not advisable to wait for critical system failure to dictate retirement. As a vessel approaches retirement, the planned investments may decrease as efforts to extend the vessels life are minimized.

The CMLF fleet of vessels, with ages greater than 40 years, are at the latter stages of their useful life. To keep them in reliable operation continued investment will be required, but ultimately planning for retirement and replacement is necessary. As the only vessel that has not been repowered, DRBA must decide if the CAPE HENLOPEN will be invested in or retired.

ATTACHMENT A

VESSEL CONDITION SUMMARY TABLES

Vessel Condition Survey: New Jersey

SWBS	Element	Condition 1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Customer Experience Yes/No	Critical equipment SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	Work within 10 years 1 None 2 Some 3 Major 4 Overhaul	Comments
100	**Structure**					
110	Hull Plating	3	No		2	
111	Hull Structure	3	No		2	
130	Hull Decks	2	Yes		2	
150	Superstructure	2	Yes		2	Upper deck bhds refurbished as part of repower, considerable repair iwo deck/bhd intersections. Much of the 02 and 03 deck has been replaced during the 2021 repower.
162	Stacks	1	Yes		1	Replaced as part of repower.
162	WT Hull Doors, Hatches, BERPs	2	Yes		2	
170	Masts	4	Yes		3	
180	Foundations	3	No		1	ME & Red Gear Fdns refurbished in 2021 repower
200	**Propulsion Plant**					
202	Propulsion Control system	1	No		1	In process of overhaul with repower.
230	Main Engines	1	No	SVCM	1	New main engines with 2021 repower.
231	Reduction gears	1	No	SVCM	1	New reduction gears with 2021 repower
243	Shafting system	2	No		1	New shafts with 2021 repower
245	Propulsors	1	No		1	New propellers with 2021 repower.
256	Cooling System	2	No	SVCM	2	Major work on going with repower.
259	Exhaust System	1	No		1	In process of overhaul with repower.
261	Fuel Service System	1	No		1	In process of overhaul with repower.
264	Lube Oil System	1	No		1	In process of overhaul with repower.
300	**Electrical Plant**					
310	Generator Sets	2	No	SVMC	2	Generator diesels rebuilt in 2018 and 2020. The electrical section are being replaced as part of the re-powering.
320	Electrical Distribution System	3	No		2	Most of the installation is original. Switchboards and distribution panels continue to be maintained and upgraded on an as needed basis. Switchboard grooming and cleaning performed during shipyard periods. The SSDG tie breakers are being replaced as part of the repowering.
330	Lighting Systems	3	Yes		3	Upgrade to LED lighting indicated as potentially within next three years in future vessel drydock costs.
400	**Command and Surveillance**					
420	Navigation Systems	2	No	FD / SVCM	2	RADARS replaced 2018. Pilot house console being replaced as part of the repower.
422	Electrical Navigation Aids (incl. Navig. Lights)	2	No		2	Pilot house console and RADARS replaced 2018
430	Interior Communications	3	No		3	Limited information. The soundproof booth may be required for in engine room for emergency steering.
432	Telephone Systems	3	No		3	No informaiton
433	Announcing Systems	3	Yes	FD	3	Limited information. Public address speaker required in the engine room.
436	Alarm, Safety, & Warning Systems	2	No	FD / SVCM	2	Pilot house console being repace as part of the repower. Engine alarms will be upgraded as part of repower effort
438	Integrated Control Systems	2	No	FD	2	Engine control system will be upgraded as part of the repower effort
439	Recording & Television Systems	2	Yes		2	Passenger televisions appear relatively new in scan. CCTV cameras in passenger areas also appear relatively new.
440	Exterior Communications	3	No	FD	3	Radios appear fairly new in scan.
446	Security Equipment Systems	3	No	FD	3	Limited information. Dedicated VHF channel and system would be helpful to the crew.
500	**Auxiliary Systems, General**					
506	Overflows, Air Escapes, and Sounding Tubes	3	No		2	Assumed same condition as DELAWARE.
513	Machinery Space Ventilation System	5	No		4	Multiple ABS findings to indicate on-going problems in 2018 and 2019.
514	Air Conditioning System/ Heating	4	Yes		2	Current AC unit arrangement designed by Seaworthy in 2006. * New heaters are being installed in the passenger louge during 2021 repower. New heat pumps installed 2018. Heat pumps do not hold up long in current location.

Vessel Condition Survey: New Jersey

SWBS	Element	Condition	Customer Experience	Critical equipment	Work within 10 years	Comments
		1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Yes/No	SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	1 None 2 Some 3 Major 4 Overhaul	
521	Firemain System	3	No	FD / SVCM	3	No SY cost data to show any renewal of firemain system.
522	Sprinkler System	2	No	SVCM	1	Car deck sprinkler system was renewed in 2018. Below deck piping as part of repower in 2021.
526	Deck Drains	2	Yes		2	No SY cost data to show any renewal of deck drain system. All drains renewed 2018 SY.
528	Plumbing Drainage	3	Yes		2	No SY cost data to show any renewal of plumbing system, one valve issue was corrected in 2013. Sewage and gravity drains to CPVC as part of repower in 2021.
529	Bilge System	2	No		2	Bilge manifolds replaced during 2021 SY/Repower
530	Fresh Water Systems	3.5	Yes		2.5	Assumed same condition as DELAWARE. No OWS.
533	Potable Water	4	Yes		3	No SY cost dat to show any renewal of potable water system, potable water tank failure noted in 2019. Pressure tanks could use internal condition assesment. Tank gauging unreliable. Possible integration with ICS.
551	Compressed Air Systems	2	No	FD	2	Some work on system during repower.
555	Fire Extinguishing System	2	No		2	Rust and damaged lines reported for fixed fire fighting and portable fire extinguisher systems in 2019 and 2020. Fixed CO2 system upgraded as part of repower.
561	Steering Systems	2	No		2	2021 SY includes repair and furbishment
562	Rudder	2	No		2	2021 SY includes repair and furbishment
568	Maneuvering Systems	2	No	FD	2	2021 SY includes repair and furbishment
581	Mooring Systems	2	No		2	No data available.
583	Life Saving Equipment, Rescue Boats, etc	3	Yes		2	Observed issues in 2019/2020 appear to have been adressed. MES installed 2018. New Rescue Boat cradles on order. Existing rescue boat davits installed ~1995.
600	**Outfit & Furnishings, General**					
602	Nameplates, Notices & Markings	2	Yes		2	Name plates and signage appear to be in good condition based on vessel scan.
612	Railings, Stanchions & Lifelines	2	Yes		2	Exterior teak handrails refinished as part repower
621	Joiner Bulkheads	1	Yes		1	Passenger space joiner bulkheads updated as part of 2021 SY work. Rated new in 2017 BMT Corrosion Assessment in 2017.
622	Floor Plates & Gratings	2	No		2	ER Floor plating appear to be in reasonable condition in vessel scans, being reconfigured and repainted during the 2021 repower.
623	Ladders	3	Yes		2	No data available on ladders. There will likely be some repairs required based on ladder corrosion findings on other vessels.
624	Joiner Doors	2	Yes		2	Some joiner doors are original equipment, and will need to be repaired as instances of failure increases. Three joiner doors on the car deck replaced in the 2021 repower, plus six exterior doors on Upper Deck.
625	Windows	1	Yes		2	Upper Deck exterior windows replaced as part of repower. Cracks were found in bridge window in 2020 suggesting other window replacements are likely required within the next decade.
631	Painting	1	Yes		2	Paint appears to be in good condition on vessel scan. Note that BMT Corrosion Assessment report from 2017 outlines many deck and hull compartments in need of paint update. During the 2021 repower the hull, car deck, superstructure exterior and decks bulkheads are being repainted.
633	Cathodic Protection	2	No		2	Anodes renewed as part of 2021 drydock/repower.
634	Deck Coverings	2	Yes		2	Flooring systmes appear intact but outdated on vessel scans. Note multiple patched areas of PH flooring in vessel scan. Passenger lounge deck covering being replaced or renewed during 2021 SY work.
635	Insulation, Linings & Ceilings	2	Yes		1	BMT corrosion assessment from 2017 notes fair/new condition of insulation. Passenger space linings & ceilings refurbished/replaced during 2021 SY work.

Vessel Condition Survey: New Jersey

SWBS	Element	Condition 1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Customer Experience Yes/No	Critical equipment SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	Work within 10 years 1 None 2 Some 3 Major 4 Overhaul	Comments
640	Furniture & Furnishings	2	Yes		1	Interior passenger furnishings appear to be in good condition. Exterior chairs appear to be in good condition.
644	Sanitary Spaces	3	Yes		2	Spaces appear serviceable, but have no interior views or information about the equipment.
645	Community Spaces	2	Yes		2	Back galley food prep area extremly cluttered and ineffecient work space. Space needs to be optmized and old equipment removed. Gift shop and food service spaces accessible to the public being upgraded in 2021.
650	Service Spaces	3	No		2	Pilot house and crew rest room appear to be in fair condition, slightly outdated. Pilot house could use more stowage spaces. Carpeting in wheelhouse and crew breakroom worn. Should be replaced with solid surface.
662	Machinery Control Centers Furnishings	1	No		2	EOS space appear to be in fair condition, slightly outdated. EOS could use additional space so it can be utilized as a break room. EOS is being upgraded during the 2021 vessel repower, doors replaced.

Vessel Condition Survey: DELAWARE

SWBS	Element	Condition (1 New, 2 Good, 3 Fair, 4 Poor, 5 Unsatisfactory, 6 Failure)	Customer Experience (Yes/No)	Critical equipment (SV Secure Vessel, ND Nearest Dock, FD Finish Day, SVCM Secure Vessel in Cape May, O Only if loss occurs while underway)	Work within 10 years (1 None, 2 Some, 3 Major, 4 Overhaul)	Comments
100	**Structure**					
110	Hull Plating	3	No		2	
111	Hull Structure	3	No		2	
130	Hull Decks	4	Yes		3	For all 100 SWBS: Assume some structural work will be necessary in the next 10 years; where there is poor condition now then assume major work will be required in the future.
150	Superstructure	3	Yes		2	
162	Stacks	3	Yes		2	
162	WT Hull Doors, Hatches, BERPs	3	Yes		2	
170	Masts	4	Yes		3	
180	Foundations	3	No		2	
200	**Propuslion Plant**					
202	Propulsion Control system	1	No		1	Assumed upgraded with repower in 2015/2016
230	Main Engines	1	No	SVCM	1	Replaced with repower in 2015/2016
231	Reduction gears	1	No	SVCM	1	Replaced with repower in 2015/2016
243	Shafting system	3	No		2	Sterntube packing changed to Duramax in 2018, SY costs for straightening tail shaft and to confirm shaft alignment in 2017. Stern tube wall thickness a concern.
245	Propulsors	1	No		1	Propellers were replaced in 2018.
256	Cooling System	2	No	SVCM	1	Keel cooler repaired in 2020, valves replaced in 2020. ME & SSDG cooling changed to keel coolers (2015/16). Consider changing JW to corrosion inhibitors.
259	Exhaust System	2	No		1	Exhaust system replaced during 2015/2016
261	Fuel Service System	2	No		2	Assumed upgraded with repower in 2015/2016
264	Lube Oil System	2	No		2	Assumed upgraded with repower in 2015/2016
300	**Electrical Plant**					
310	Generator Sets	3	No	SVMC	3	Diesel ends rebuilt in 2018. Electrical ends planned replacement during next shipyard availability.
320	Electrical Distribution System	3	No		2	Most of the installation is original. Switchboards and distribution panels continue to be maintained and upgraded on an as needed basis. Switchboard grooming and cleaning performed during shipyard periods. The generator tie breaker is scheduled for replacement during the next shipyard period.
330	Lighting Systems	3	Yes		2	Upgrade to LED lighting indicated as potentially within next three years in future vessel drydock costs.
400	**Command and Surveillance**					
420	Navigation Systems	3	No	FD / SVCM	3	Radars upgraded in 2018. Issues with radar rotating assemblies and displays. Gyros have proved to be reliable. However, Sperry parts unavailable at times.
422	Electrical Navigation Aids (incl. Navig. Lights)	3	No		2	Limited information. Navigation lightds upgraded to LED models recently (2018 or 2019)
430	Interior Communications	3	Yes		3	Limited information. The soundproof booth may be required for in engine room for emergency steering.
432	Telephone Systems	3	No		3	No information
433	Announcing Systems	3	Yes	FD	3	Comment about about dificulty understanding announcements from 2011 report. No additoinal information beyond that comment. PA speaker required in engine room.
436	Alarm, Safety, & Warning Systems	3	No	FD / SVCM	2	Original alarm system continues to be in use. System was expanded with two murphy panels in 2015 to support reppower.
438	Integrated Control Systems	3	No	FD	2	Original systems still in use. Some extension to alarm panels made during repower but no substansive upgrades.
439	Recording & Television Systems	2	Yes		2	Passenger televisions appear relatively new in scan. CCTV cameras in passenger areas also appear relatively new.
440	Exterior Communications	3	No	FD	2	Radios appear to be in good condition on scan.

Vessel Condition Survey: DELAWARE

SWBS	Element	Condition 1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Customer Experience Yes/No	Critical equipment SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	Work within 10 years 1 None 2 Some 3 Major 4 Overhaul	Comments
446	Security Equipment Systems	3	No	FD	2	Limited information. Dedicated VHF channel and system would be helpful to the crew.
500	**Auxiliary Systems, General**					
506	Overflows, Air Escapes, and Sounding Tubes	3	No		2	Sounding tube in void4 was renewed in 2017.
513	Machinery Space Ventilation System	3	No		2	Chiller compressors rebuilt in 2018. Fan and coil renewed in 2020. Equipment renewal in 2020 and 2021.
514	HVAC System	2	Yes		2	New AC chillers and flush system installed in 2017, sea water piping was heavily overhauled in 2017 including sea chest. New Galley AHU installed 2020. All remaining Fan Coils and AHUs in poor condition. HVAC control system is very unreliable and hard to access. Chillers perform well when maintained properlly.
521	Firemain System	2	No	FD / SVCM	1	SY costs show significant investment in fire main piping in 2017 and 2020.
522	Sprinkler System	3	No	SVCM	2	No SY costs to show investment since fleet condition survey in 2011.
526	Deck Drains	2	Yes		1	Significant SY costs in 2017 and 2020 for drain system overhaul.
528	Plumbing Drainage	3.5	Yes		2.5	No SY costs to show investment since fleet condition survey in 2011. Some sewage piping has been replaced. Original piping left is heavily scaled.
529	Bilge System	3.5	No		2.5	Bilge pump likely needs to be replaced
530	Fresh Water Systems	3.5	Yes		2	OWS removed prior to 2018
533	Potable Water	2	Yes		2	No issues obvserved in 2011, noted fresh water line repairs in 2017. Tank gauging unreliable. Possible integration with ICS
551	Compressed Air Systems	2.5	No	FD	2	Do not believe new compressors were installed.
555	Fire Extinguishing System	2	No		2	Sprinkler pump suction lines renewed in 2017, CO2 System design and materials purchased in 2020.
561	Steering Systems	2	No		2	Steering system overhauled 2020. Steering flat access limited with cars on hatch. Sperry steering controls very outdated
562	Rudder	2	No		2	
568	Maneuvering Systems	3	No	FD	2	Electric bow thruster and omni thruster was rebuilt in 2017, further inspection and repair in 2020.
581	Mooring Systems	3	No		2	Anchor and chain has no means of retrieval noted in 2011. Retrieval with equipment on the vessel not a regulatory requirement, existing equipment matches the other vessels.
583	Life Saving Equipment, Rescue Boats, etc	2	Yes		2	Rescue boat davits were serviced in 2017 and life raft cable was renewed in 2017. MES installed 2018. New Rescue Boat cradles on order. Existing rescue boat davits installed ~1995.

Vessel Condition Survey: DELAWARE

SWBS	Element	Condition (1 New, 2 Good, 3 Fair, 4 Poor, 5 Unsatisfactory, 6 Failure)	Customer Experience (Yes/No)	Critical equipment (SV Secure Vessel, ND Nearest Dock, FD Finish Day, SVCM Secure Vessel in Cape May, O Only if loss occurs while underway)	Work within 10 years (1 None, 2 Some, 3 Major, 4 Overhaul)	Comments
600	**Outfit & Furnishings, General**					
602	Nameplates, Notices & Markings	2	Yes		1	Signage through out appears to be in fair condition based on vessel scans. Some upkeep work required within the next decade.Freeboard markings and vessel nameplates were repainted in 2017 suggesting that vessel has been repainted since scan.
612	Railings, Stanchions & Lifelines	2	Yes		2	Railings look sound but scans show areas of rust and potential corrosioin. Wood railing tops in passenger exterior spaces similarly need maintenance. Noted many SY cost items in 2017 for blasting and renewing railing paint systems suggesting that vessel has been repainted since scan.
621	Joiner Bulkheads	3	Yes		2	There are Joiner bulkheads in the Upper Deck Lounge around the gift shop boundaries forward and as corridor partitions aft, plus some boundaries inside the Crow's Nest on the 02 Level. Assume these were installed during refurbishement work around 2000.
622	Floor Plates & Gratings	2	No		1	Engine room deck plates were painted in 2020.
623	Ladders	2	Yes		1	Ladders were assumed to be included in repainting scope within voids in 2017.
624	Joiner Doors	3	Yes		3	Most joiner doors are original equipment. Doors will need to be repaired as instances of failure increases. Doors on control room are shot.
625	Windows	3	Yes		3	Pilothouse windows look to be original. Passenger lounge windows on both decks were added/replaced on the DELAWARE during the refurbishment work around 2000. The ones on the Upper Deck side bulkheads protected from the weather look to be in good shape. There are signs of corrosion around all the exposed windows on all levels.
631	Painting	2	Yes		2	Vessel scan shows many rusty areas. Noted many SY cost items for blasting and rewing paint systems throughout suggesting that vessel has been repainted since scan.
633	Cathodic Protection	2	No		2	Zinc anodes were replaced in 2017 and 2020. Anode replacement part of normal biannual drydock work.
634	Deck Coverings	3	Yes		2	Noted some areas of repair in pilot house flooring. Otherwise normal wear and tear.
635	Insulation, Linings & Ceilings	3	Yes		3	Ceiling panels appear outdated and damaged in vessel scans. Requires overhaul in passenger spaces. Certain SFP issues identified by USCG in 2019 and 2020.
640	Furniture & Furnishings	2	Yes		2	Interior passenger chairs appear to be in good condition. Exterior passenger chairs, awnings and furnishings look outdates on vessel scans.
644	Sanitary Spaces	3	Yes		2	Spaces appear serviceable, but have no interior views or information about the equipment.
645	Community Spaces	3	Yes		2	Food service and gift shop spaces appear to be in good condition, may be slightly outdated in terms of aesthetics.
650	Service Spaces	3	No		2	Pilot house and crew rest room appear to be in fair condition, slightly outdated. Pilot house could use more stowage spaces.
662	Machinery Control Centers Furnishings	3	No		2	EOS space appear to be in fair condition, slightly outdated. EOS could use additional space so it can be utilized as a break room.

SWBS	Element	Condition	Customer Experience	Critical equipment	Work within 10 years	Comments
	Vessel Condition Survey: Cape Henlopen	1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Yes/No	SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	1 None 2 Some 3 Major 4 Overhaul	
100	**Structure**					
110	Hull Plating	3	No		2	
111	Hull Structure	3	No		2	
130	Hull Decks	4	Yes		2	
150	Superstructure	3	Yes		3	Based on recent SY receipts. Upper Deck Refurbishment around passenger lounge similar to NJ recommended to address rust and structural degradation issues around windows.
162	Stacks	3	Yes		2	Stacks would have to be replaced as part of a repower, due to larger silencers. If not repowered, primary structure adequate with normal maintenance.
162	WT Hull Doors, Hatches, BERPs	3	Yes		2	
170	Masts	3	Yes		2	
180	Foundations	3	No		2	
200	**Propuslion Plant**					
202	Propulsion Control system	3	No		4	Recommend refurbishment with repower.
230	Main Engines	3	No	SVCM	4	Recommend replacement similar to New Jersey.
231	Reduction gears	3	No	SVCM	4	Recommend replacement similar to New Jersey.
243	Shafting system	2	No		4	Tailshaft liners, stern tube packing, seals replaced in 2019. Stern tube wall thickness a concern. Recommend replacement similar to New Jersey.
245	Propulsors	1	No		1	Propellers and rope guards replaced in 2019.
256	Cooling System	4	No	SVCM	4	Keel cooler repaired in 2019, further failure of BT cooler in 2020. Recommend refurbishment with repower. Consider changing to JW with corrosion inhibitors.
259	Exhaust System	3	No		4	Recommend refurbishment with repower.
261	Fuel Service System	3	No		4	Recommend refurbishment with repower.
264	Lube Oil System	3	No		4	Recommend refurbishment with repower.
300	**Electrical Plant**					
310	Generator Sets	3	No	SVMC	3	Generator diesel section rebuild included in 2018 drydock costs. However generator electrical section replacement within two years shown in future drydock costs.
320	Electrical Distribution System	3	No		2	Most of the installation is original. Switchboards and distribution panels continue to be maintained and upgraded on an as needed basis. Switchboard grooming and cleaning performed during shipyard periods. Issues with generator main circuit breaker. Should be replaced when generator electrical section is replaced.
330	Lighting Systems	3	Yes		2	Upgrade to LED lighting indicated as potentially within next three years in future vessel drydock costs. However the lights look fairly new on vessel scan.
400	**Command and Surveillance**					
420	Navigation Systems	3	No	FD / SVCM	3	Bridge electronics upgrade in 2018. Issues with radar rotating assemblies and displays. Gyros have proved to be reliable. However, Sperry parts unavailable at times.
422	Electrical Navigation Aids (incl. Navig. Lights)	3	No		3	Bridge electronics upgrade in 2018.
430	Interior Communications	3	No		3	Limited information. The soundproof booth may be required for in engine room for emergency steering.
432	Telephone Systems	3	No		3	No information.
433	Announcing Systems	2	Yes	FD	1	PA system upgraded in 2018. PA speaker(s) required in the engine room.
436	Alarm, Safety, & Warning Systems	3	No	FD / SVCM	3	No informaiton.
438	Integrated Control Systems	3	No	FD	3	Would be part of any repower effort
439	Recording & Television Systems	3	Yes		3	Passenger televisions appear somewhat old in scan. CCTV cameras in passenger areas not visible in scan.
440	Exterior Communications	2	No	FD	2	Bridge electronics upgrade in 2018.
446	Security Equipment Systems	3	No	FD	2	Limited information. Dedicated VHF channel and system would be helpful to the crew.

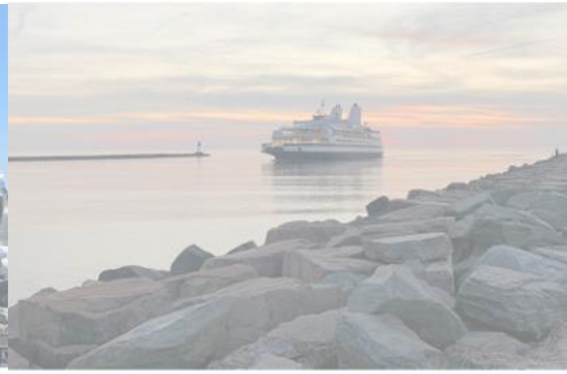
Vessel Condition Survey: Cape Henlopen

SWBS	Element	Condition	Customer Experience	Critical equipment	Work within 10 years	Comments
		1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Yes/No	SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	1 None 2 Some 3 Major 4 Overhaul	
500	**Auxiliary Systems, General**					
506	Overflows, Air Escapes, and Sounding Tubes	3	No		2	Sewage vent line was renewed in 2018.
513	Machinery Space Ventilation System	3	No		2	#1 and #3 boiler passed inspections in 2019. Two failing fire dampers were repaired in 2019. Heat pumps replaced in 2020.
514	Air Conditioning System	1	Yes		2	HVAC system was overhauled in 2019.
521	Firemain System	1	No	FD / SVCM	1	Firemain system was overhauled in 2019.
522	Sprinkler System	2	No	SVCM	2	Entire piping system renewed 2019-2020. Some corrosion observed at manifold in 2020.
526	Deck Drains	3	Yes		2	STBD Bridge Wing Deck Drains were replaed in 2018. Weather deck drain lines were invested in in 2018 and 2019. All drain lines renewed 2019
528	Plumbing Drainage	3.5	Yes		2.5	Assumed same as DELAWARE. System partially changed to CPVC in 2019.
529	Bilge System	3.5	No		2.5	Assumed same as DELAWARE.
530	Fresh Water Systems	3.5	Yes		2.5	Assumed same as DELAWARE. No OWS.
533	Potable Water	4	Yes		3	No SY Cost data to show potable water system investment. Pressure tanks could use internal condition assesment. Water tanks painted 2015. Tank gauging unreliable. Possible integration with ICS.
551	Compressed Air Systems	4	No	FD	3	New control air dryer installed in 2020.
555	Fire Extinguishing System	4	No		3	Rust and damaged lines reported for fixed fire fighting and portable fire extinguisher systems in 2019 and 2020.
561	Steering Systems	1	No		1	Steering system overhauled in 2019.
562	Rudder	1	No		1	Rudder overhauled in 2019.
568	Maneuvering Systems	3	No	FD	2.5	Omni thruster serviced in 2019.
581	Mooring Systems	3	No		2	No data available.
583	Life Saving Equipment, Rescue Boats, etc	3	Yes		2	Rescue boat davit overhauled in 2019. MES installed 2018. New Rescue Boat cradles on order. Existing rescue boat davits installed ~1995.
600	**Outfit & Furnishings, General**					
602	Nameplates, Notices & Markings	5	Yes		3	Name plates and signage appear to be in good condition based on vessel scan. Noted multiple safety signs missing in 2019 and 2020.
612	Railings, Stanchions & Lifelines	2	Yes		2	Teak handrails were maintained in 2018 and 2019. Handrails were painted in 2019. Handrails removed and refinished 2020 SY
621	Joiner Bulkheads	3	Yes		2	Joiner bulkheads surround the existing gift shop and are in reasonable condition. Recommend that the gift shop be reconfigured and upgraded as part of an Upper Deck passenger lounge refurbishment.
622	Floor Plates & Gratings	2	No		2	ER Floor painting was painted in 2018.
623	Ladders	2	Yes		2	Note ladder repairs in 2018.
624	Joiner Doors	4	Yes		4	Joiner doors are original equipment. Doors will need to be repaired as instances of failure increases. EOS doors need to be replaced.
625	Windows	4	Yes		4	Recommend replacing the Upper deck windows as part of a refurbishment of the Passenger Lounge, due to extensive corrosion around the window perimeters.
631	Painting	1	Yes		2	Vessel has been repainted in 2018 and 2019.
633	Cathodic Protection	1	No		2	Zinc anodes replaced in 2019-2020 shipyard period.
634	Deck Coverings	2	Yes		2	02 Deck interior flooring replaced in 2019.
635	Insulation, Linings & Ceilings	2	Yes		2	Insulation in car deck area was replaced in 2019.
640	Furniture & Furnishings	2	Yes		2	Interior passenger furnishings appear to be in good condition. Exterior chairs appear to be in ok condition.
644	Sanitary Spaces	3	Yes		2	Spaces appear serviceable, but have no interior views or information about the equipment.

	Vessel Condition Survey: Cape Henlopen					
		1 New 2 Good 3 Fair 4 Poor 5 Unsatisfactory 6 Failure	Yes/No	SV Secure Vessel ND Nearest Dock FD Finish Day SVCM Secure Vessel in Cape May O Only if loss occurs while underway	1 None 2 Some 3 Major 4 Overhaul	
SWBS	Element	Condition	Customer Experience	Critical equipment	Work within 10 years	Comments
645	Community Spaces	3	Yes		3	Food service and gift shop spaces appear to be in good condition, may be slightly outdated in terms of aesthetics. Back galley food prep area extremly cluttered and ineffecient work space. Space needs to be optmized and old equipment removed. Recommend spaces be upgraded as part of an Upper Deck passenger lounge refurbishment.
650	Service Spaces	3	No		2	Pilot house and crew rest room appear to be in fair condition, slightly outdated. Pilot house could use more stowage spaces. Carpeting in wheelhouse and crew breakroom worn. Should be replaced with solid surface.
662	Machinery Control Centers Furnishings	3	No		2	EOS space appear to be in fair condition, slightly outdated. EOS could use additional space so it can be utilized as a break room. Doors on control room are shot.

APPENDIX B

Phase 2 Task C – Alternative Vessel Analysis



2021 Marine Master Plan

Alternative Vessel Analysis

Prepared for: Delaware River and Bay Authority

Ref: Phase 2 – Task C: Alternative Vessel Analysis

February 1, 2023

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1. EXECUTIVE SUMMARY

The alternative vessel analysis has identified three fleet configurations that will be studied further. One option may be feasible to certify under 46 CFR Subchapter K and two would be under 46 CFR Subchapter H. Given the age of the existing vessels, it was determined that it would be best to retire them as soon as new vessels were ready to go into service to replace them. The CAPE HENLOPEN should not be repowered, and the order of retirement should be CAPE HENLOPEN, DELAWARE, then NEW JERSEY. Service life of the new vessels is typically estimated at 30 years, but vessels are rarely actually retired after 30 years as the life is extended with proper maintenance and mid-life refurbishments.

As with all ferry operations, crew costs are a large part of the CMLF operational expenses. The new vessels should be sized to be under 1600 GRT (gross register tonnage) to remove the existing unlimited tonnage licensing requirement. Another large part of the CMLF operational expenses is fuel. A hybrid-diesel vessel should be considered to reduce the fuel consumption and improve emissions. To support a hybrid-electric vessel the electrical infrastructure at each terminal would need significant improvements. Four additional alternative fuel sources were looked into and should be further investigated once a final vessel design is chosen.

The three fleet configurations being investigated can use the existing terminals. Option 2B and 3 would require modifications to the existing dolphins to support vessel tie up overnight. Option 3 would require modifications to the passenger loading tubes. A double ended vessel would decrease the transit time but will have slightly higher CAPEX costs and maintenance costs. Five cooling systems were explored and should be investigated further during the vessel design process. Fuel tanks need to account for changes in trim as fuel is consumed and should not be shell tanks.

2. INTRODUCTION

To analyze the Cape May – Lewes Ferry System (CMLF) and provide good recommendations, it is necessary to assess alternative vessels, schedules to retire the existing vessels, costs including crew, repair and maintenance, fuel, and long-term capital expenses.

The fleet currently consists of three vessels, the CAPE HENLOPEN, DELAWARE, and NEW JERSEY. These vessels serve the 14-mile route between Cape May, NJ and Lewes, DE.

2.1. ALTERNATIVE FLEET CONFIGURATION

From the Fleet Configuration Analysis three fleet configurations were chosen to further investigate. Option 1 is an optimized current fleet with three 100-car ferries, option 2 is a mid-size fleet with four 75-car ferries and option 3 is a smaller vessel fleet with five 55-car ferries. The table below provides a summary of the alternative fleet characteristics.

Table 1: Alternative Fleet Characteristics

CHARACTERISTIC	OPTION 1	OPTIONS 2, 2A, 2B	OPTION 3
Len. x Breadth x Depth	303' x 68' x 17'	275' x 68' x 16'	244' x 68' x 16'
Quantity of Vessels	3	4, 3, 4	5
Max Operating Speed (kts)	17.1	16.25	15.31
Vehicle Capacity (per vessel)	100	75	55
Passenger Capacity (per vessel)	500	350	250
Subchapter	H	H	K
Min Crew Required (per vessel)	8	8	5

3. FEASIBILITY OF SUBCHAPTER K

DRBA is interested in the possibility of certifying the new vessels under 46 CFR Subchapter K rather than Subchapter H. This has implications for arrangements, propulsion configuration, crewing costs, and capital cost.

To be certified under 46 CFR Subchapter K it is required that the vessel be less than 100 gross regulatory tons (GRT) and carry more than 150 passengers or have overnight accommodations for more than 49 passengers.

Certifying to subchapter K has advantages such as requiring less crew to operate the vessel, less stringent licensing of personnel, and not requiring pilotage. The minimum crew size for a specific vessel is set by the United States Coast Guard (USCG) and depends on additional factors besides the subchapter of the vessel including the number of passengers, number of passenger decks, number of crew required to operate lifesaving devices and the operation duration per day. Final vessel crew size may be higher than the minimum required by OCMI due to employer practices. EBDG has determined that options 1 and 2 would likely require 8 crew members and option 3 would likely require 5. Option 3 may require some personnel to have QMED rating.

Subchapter K also has it challenges, to be under 100 GRT the vessel framing is arranged to take volume out which makes the engine room and propulsion arrangement challenging due to limited open space. Due to the additional weight of the tonnage frames, subchapter K vessels are heavier than subchapter H vessels. The heavier weight decreases their fuel efficiency and increases the capital cost throughout the life of the vessel however their reduced operating costs usually more than offsets these capital costs.

Other than framing and crewing, subchapter H and K are very similar with respect to system requirements. While it is possible to get creative by placing the machinery elsewhere such as above the deck on the aft end of the vessel or the side of the vessel, EBDG's previous design experience has shown that it is difficult to get larger vessels to less than 100 GRT. Given this, EBDG has determined that only option 3 would be potentially possible to certify to Subchapter K.

4. SCHEDULE TO RETIRE EXISTING VESSELS

The replacement cycle for a ferry vessel in the US is determined by the following factors: availability of capital, limited market for used vessels, level of maintenance which might cost-effectively extend the life, technological obsolescence as regulations change or equipment spares become sparse, and commercial obsolescence. As vessels age, they can suffer more service interruptions, maintenance challenges and increased regulatory scrutiny.

During phase 1, it was determined that all three existing vessels would require an investment of approximately $1 million per year to perform the USCG required drydocking. The DELAWARE will require an additional $2.0-2.5 million in investments and the CAPE HENLOPEN will require an additional $15-20 million in investments to extend their feasible life another ten (10) years.

The CAPE HENLOPEN is reaching the end of its service life and requires a repower to be able to operate much longer. EBDG recommends that the repower not happen and that the CAPE HENLOPEN be the first vessel to retire. The vessel can be retired as soon as enough new vessels have been constructed to replace it which will depend on which fleet option is chosen.

The DELAWARE is also nearing the end of its service life and should be the second vessel to be retired. The NEW JERSEY is in the best condition due to the recent repower and refurbishment and can continue operating without significant additional expense and should be the final vessel to be retired.

The vessels in the replacement fleet will be similar to each other but may have minor modifications made to the later vessels after the first vessels are placed into service. After the contract design is completed and a construction contract is awarded, the detailed design for each fleet option will take approximately 9-12 months including review time at the required public agencies. Procurement of the steel and equipment can start 6-9 months after the award of the construction contract. The schedule in Figure 1, assumes that funding will be available and space in the shipyard will allow the subsequent vessel to start construction 6 months after the prior one to capitalize on lessons learned.

For option 1, each vessel will take 24-30 months to construct and train the crew prior to it being placed in operation. Assuming the longest durations, the vessels will be placed into service approximately 39, 45, and 51 months after design has started. CAPE HENLOPEN can be retired when the first vessel enters service, DELAWARE when the second vessel enters service, and NEW JERSEY when the third vessel begins service.

For option 2, each vessel will take 21-27 months to construct and train the crew prior to being placed in operation. Assuming the longest durations, the vessels will be placed into service approximately 36, 42, 48, and 54 months after the design has started. CAPE HENLOPEN can be retired when the first vessel enters service. Depending on the time of year and the passenger/vehicle demands at the time when the next vessels enter service, the DELAWARE can be retired when the second or third vessel enters service and NEW JERSEY when the third or fourth vessel enters service.

For option 3, each vessel will take 18-24 months to construct and train the crew prior to being placed in operation. Assuming the longest durations, the vessels will be placed into service approximately 33, 39, 45, 51, and 57 months after the design has started. The retirement of the existing vessels will largely depend on the time of year and passenger/vehicle demands at the time when the new vessels are completed. It is likely that the CAPE HENLOPEN can be retired when the first or second vessel enters service, DELAWARE when the second, third, or fourth vessel enters service and NEW JERSEY when the third, fourth, or fifth vessel enters service.

See Figure 1 for a visual depiction of the above timeline. The start of the timeline is the award of the construction contract.

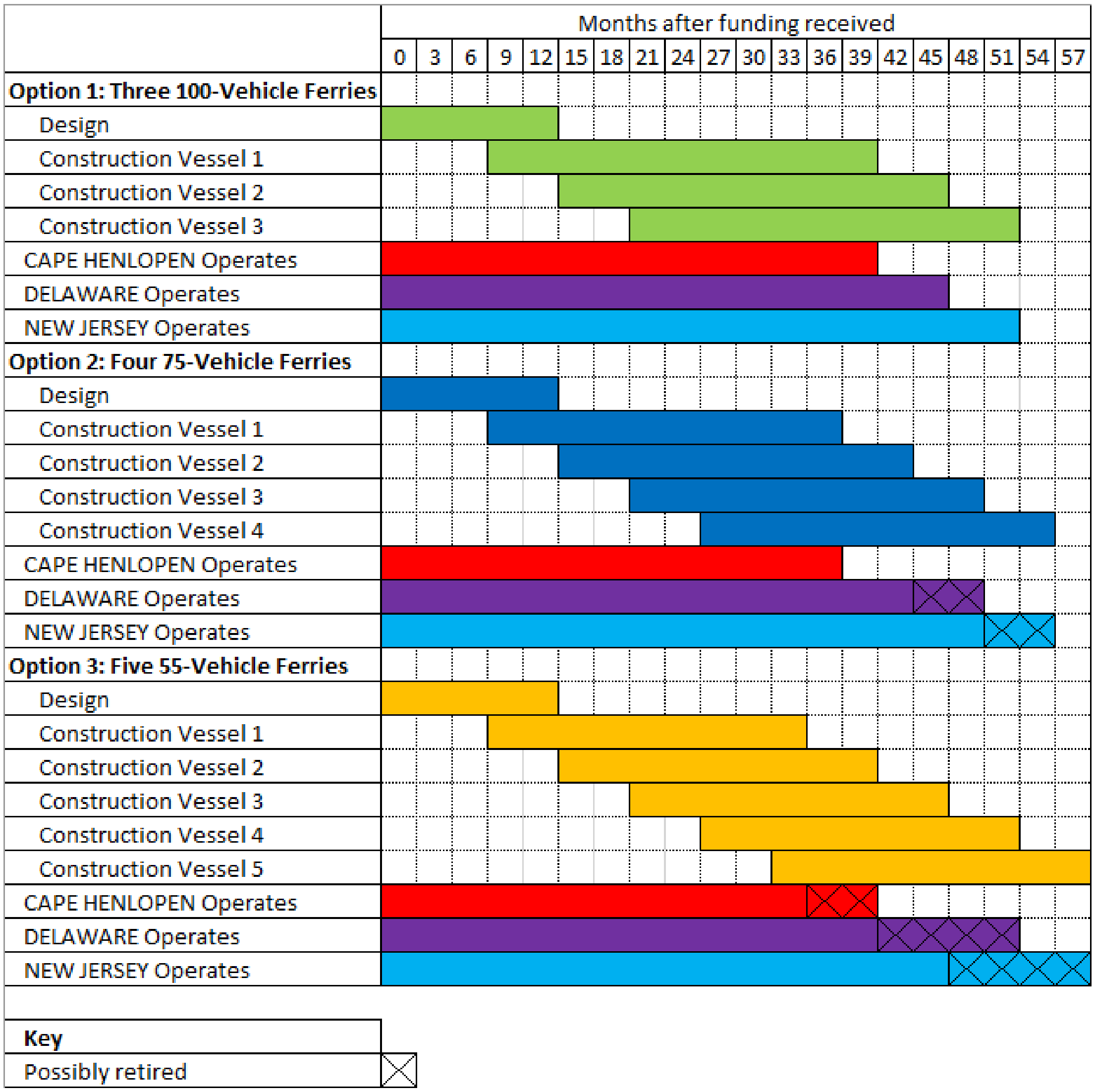

Figure 1: Design, Construction, and Retirement timeline

Service life for new vessels in the U.S. is typically 30 to 40 years, but as proven by Washington State Ferries (WSF) and the Alaska Marine Highway System (AMHS) the life of a vessel can be extended to 60 or 65 years with the proper maintenance. This presumes complete coatings every 10 years, passenger space refurbishments every 20 years, and repowering the vessel every 30 years.

5. ANALYSIS OF COSTS

Table 2 shows the average operating costs for the current vessels. The average includes recorded data from 2018, 2019, 2020, and the budgeted amount for 2021.

Table 2: Current Average Yearly Operational Costs

	2018-2021 AVERAGE OPERATING COST
Vessel Operation Wages & Benefits	$6.94M
Routine Maintenance (Includes wage & benefits)	$2.23M
Fuel & Lubricants	$1.77M
Other Vessel Operational Costs	$0.07M
Hull and P&I Insurance	$0.31M
Other (Non-Vessel Related)	$9.6M
Total	$20.92M

The following are included in the other (non-vessel related) category as they are not vessel dependent: Director of Operations, clerical staff, public relations & ads, customer service, terminal maintenance, warehouse, bus operation, cleaning, benefits for CMLF employees that are not vessel or maintenance employees. These costs are assumed to be constant and will not change due to the vessel configuration.

5.1. CREW COSTS/LABOR

Crew cost are roughly 40% of CMLF operational expenses. The crew size of a vessel depends on multiple factors including minimum manning set by the local OCMI, the CMLF staffing practices, the duration of vessel operation per day, lifesaving devices, and degree of automation of the vessel.

The current vessels are classed for unlimited tonnage which requires officers be licensed for unlimited tonnage. Obtaining this license requires years of experience which deserves a higher rate of pay. Additionally, there is currently a shortage of mariners with this rating so retaining the current employees is crucial. There may be labor cost benefits to decreasing the tonnage and the resulting requirements to the CMLF vessels. To change the licensing requirements and remove the pilotage requirement, the new vessels should be designed to be under 1600 GRT.

Per the Marine Safety Manual Volume III [1], the minimum crew size for options 1 and 2 is 8. Given the crew requirements in an emergency, option 3 could potential operate with a minimum crew of 5. The crew required for each fleet option and the current COIs are shown in Table 3.

Table 3: COI Crewing Complement

	Current COI	Option 1 100 Veh	Option 2 75 Veh	Option 3 55 Veh
Master	1	1	1	1
Pilot	1	-	-	-
Mates	-	1	1	1
Chief Engineer	1	1	1	-
Able Body Seaman (AB)	4	3	3	-
Ordinary Seaman (OS)	2	2	2	-
Deckhand	-	-	-	3
Total	9	8	8	5*

*Some personnel may require QMED rating.

The current DRBA schedule has 8 unique options that adjust the number of daily departures to meet the ridership demand. The proposed optional fleets can travel faster and will have a shorter transit time. To compare the fleet options, we created two schedules (weekday and weekend) for each of the three seasons (summer, shoulder, and winter) for each fleet option. We also created a similar, simplified schedule for their current operation. For this analysis we have called this simplified schedule "Calculated".

One major factor in the crew size is the duration of vessel operation per day. Per the USCG rules, if the vessels operate for more than 12 hours a day, two full crews are required. This should be considered when determining the optimal ferry schedule.

Table 4 shows the estimated hourly and yearly labor costs using the current labor rates. Deckhands were assumed to have the same rate as an OS. With Option 3 requiring less licensing it could potentially have a 15% reduction in the hourly rate for each person.

Table 4: Labor Costs

	Calculated	OPTION 1 100V	OPTION 2A (3F) - 75V	OPTION 2B (4F) - 75V	OPTION 3 55V
Total Hourly Crew Rate	$498	$439	$439	$439	$258
Yearly Crew Hours	10,246	9,972	10,489	10,824	13,139
Yearly Labor Costs	$5.1M	$4.4M	$4.6M	$4.8M	$3.4M

Actual manning practices aren't as straightforward as the previous two tables due to employees sailing up/sailing down or being seasonal. Seasonal employees have a different labor rate than what is published in the wage schedule. For example, the average combined hourly labor rate on August 10, 2019, was $469.86 and on January 16, 2019, it was $546.79.

5.2. PREDICTED REPAIR AND MAINTENANCE

Over the last four years, CMLF has spent on average approximately $2.23 million for routine maintenance not including shipyard labor, fuels and lubricants. The total yearly vessel operating hours were approximately 8,140 which gives a rough maintenance per hour cost of $273.96. The routine maintenance costs are assumed to be proportional to the length of the vessels. For the proposed vessels, the routine maintenance cost estimates are given in Table 5. The calculated rate shown in the table use the simplified schedule that we created which are different than the actual hours DRBA operated the vessels in 2019.

Table 5: Routine Maintenance

	Calculated	OPTION 1 100V	OPTION 2A (3F) - 75V	OPTION 2B (4F) - 75V	OPTION 3 55V
Cost/Hour	$274	$259	$235	$235	$208
Vessel Hours	9,128	8,617	9,077	9,392	11,454
Routine Maintenance	$2.5M	$2.2M	$2.1M	$2.2M	$2.4M

In addition to regular, routine maintenance, the CAPE HENLOPEN requires and will continue to require a significant investment to continue to operate. There are many areas of pitting in the steel that have been flagged for monitoring. Additionally, the vessel needs a repower and refurbishment to the upper deck passenger lounge. The total projected investments for the next 10 years are $22.5 - $27.5 million (see Section 5 of the Phase 1 Task A Fleet Assessment report for the breakdown by SWBS category).

The DELAWARE requires a moderate investment over the next 10 years with a projected cost of $10 million (see Section 3 of the Phase 1 Task A Fleet Assessment report for the breakdown by SWBS category). The vessel does have areas of corrosion with accelerated steel wastage that will need to be replaced.

The NEW JERSEY also requires a moderate investment over the next 10 years with a projected cost of $8.6 - $9 million (see Section 4 of the Phase 1 Task A Fleet Assessment report for the breakdown by SWBS category). The vessel did have areas of pitting that were replaced during the recent repower but given the age of the vessel additional pitting will occur that will need to be addressed.

Estimated shipyard maintenance costs for the first 10 years for the new fleet options range from $14.0M for Option 2A to $19.6M for Option 1.

5.3. FUEL

The current vessels consume 185-200 gallons of ultra-low sulfur diesel (ULSD) per one-way crossing. In 2019, they used 930,087 gallons at a total cost of $1.83 million which is about $1.97 per gallon. Table 6 shows the estimated cost of fuel for each option.

Table 6: Annual Fuel Costs

	SINGLE-ENDED			DOUBLE-ENDED			
	OPTION 1 100V	OPTION 2 (4F) 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2A (3F) 75V	OPTION 2B (4F) 75V	OPTION 3 55V
Vessel Hours	8,617	9,392	11,454	8,617	9,077	9,392	11,454
Estimated GPH	191.1	148.2	115.7	131.9	104.0	104.0	78.8
Total Fuel Cost	$3.24M	$2.74M	$2.61M	$2.24M	$1.86M	$1.92M	$1.78M

The single-ended vessels are estimated to have a higher gallon per hour consumption than the double ended due to the higher transit speed necessary to keep the travel and port times the same.

There is currently an ongoing worldwide movement to reduce emissions from vessels due to emissions causing climate change. A growing number of countries have made commitments to achieve carbon neutrality or "net zero" emissions within the next few decades and IMO has adopted mandatory measures to reduce the emissions of greenhouse gases from international shipping. While not specific to DRBA the IMO's pollution prevention treaty (MARPOL) made the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) mandatory for new international shipping vessels [2].

According to IMO [3], "the EEDI for new ships is the most important technical measure and aims at promoting the use of more energy efficient (less polluting) equipment and engines. The EEDI requires a minimum energy efficiency level per capacity mile for different ship type and size segments. EEDI can also be expressed as the ratio of the "environmental cost" divided by "benefit for society" [4]. EEDI is a function of the installed power, speed of vessel and cargo carried. It reflects a ship's energy efficiency in actual use and is used to ensure new ships are designed to be energy efficient. It takes into consideration special design features and needs, including the use of energy recovery, use of low carbon fuels, performance of ships in waves and the need for ice strengthening of certain ships. It takes the calculated EEDI of a vessel and compares it to a baseline that is set by type and size of vessel. The EEDI is a non-prescriptive, performance-based mechanism that leave the choice of technologies to use in a specific ship design to the industry.

According to IMO [3], "the SEEMP is an operational measure that establishes a mechanism to improve the energy efficiency of a ship in a cost-effective manner. The SEEMP also provides an approach for shipping companies to manage ship and fleet efficiency performance over time using the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool." The EEOI enables operators to measure the fuel efficiency of a ship in operation and to gauge the effect of any changes in operation such as improved voyage planning, more frequent propeller cleanings, or the introduction of technical measures such as waste heat recovery systems or a new propeller [3].

Given the ongoing movement to reduce emissions, the new vessels should look to minimize their environmental impact. This can be done by using more energy efficient technologies (automated docking/undocking), using emission control technologies, and using alternative fuels. There are also operational changes that can minimize the environmental impact such as operating at slower speeds and shutting down the engines while in port.

This study only looked at the possibility of using alternative fuels and while there are many alternative fuels available only methanol, biofuels, and LNG were considered due to their ability to use modified versions of existing diesel engine technology. Electrification was also considered and is covered in Section 7.

Multiple factors must be considered when looking at alternative fuels including energy density, fuel storage, fuel weight, flammability, toxicity, fuel cost, and capital costs. Energy density for fuel only is very different than the overall energy density when storage tanks and necessary systems are included. For example, LNG has a gravimetric energy density (the available energy per unit mass) of approximately 53 MJ/kg and a volumetric density of approximately 22 MJ/L when looking at the fuel only, but when the storage systems are included, the values drop to approximately 25 MJ/kg (50% less) and approximately 13 MJ/l (62% less). For reference, the gravimetric density of diesel is approximately 45.6 MJ/kg and the volumetric density is 38.6 MJ/L.

The additional capital cost for using alternative fuels includes the necessary converter, storage tank, and any additional processing systems required. When comparing storage tanks, the converter efficiency, tank storage utilization factor and storage lifetime must be considered.

Figure 2, from the Methanol Institute [5], provides a summary of various marine fuels' readiness.

	HFO	Low-sulfur HFO	Marine diesel	Methanol	LNG
Engine technology	Existing	Existing	Existing	Some existing engines can be converted at similar cost as scrubber installations. Converted engines can be expected to perform at efficiency levels equal to or higher than scrubbers. Future engines built for methanol are expected to be more efficient. Methanol needs a pilot fuel/ignition enhancer.	Dual-fuel LNG engines on market. Retrofit of diesel engines can be performed at two to three times the cost of retrofitting to methanol. Gas-only engines are also available
Heating of fuel	Needed	Needed	May not be needed	Not needed. Cooling may be required	Not needed
Fuel separators	Needed	Needed	May not be needed	Not needed	Not needed
Piping	Standard	Standard	Standard	Double-walled. Purging possible	Vacuum-insulated, double-walled
Safety	Existing rules	Existing rules	Existing rules	Apart from low flashpoint, most properties are the same as diesel. Low-flashpoint fuel, risk-based rules, regulations coming based on LNG regulations. May be simplified in future	Low-flashpoint fuel with many demands due to low temperature and high pressure requirements. Boil-off from tanks has to be handled if not in service
Bunkering	Existing	Existing	Existing	Can use same type of barges as for HFO/MGO. Precautions for fire. System for purging the fuel supply system. Bunkering from mobile terminals on land developed	Special built barges. 20-30 times more expensive than for liquid fuels. Special precautions for bunkering including purging of system after bunkering
Terminals	Existing	Existing	Existing	Terminals can be built at low cost	LNG terminals are few and need large volumes to justify cost. About 10 times more expensive than methanol terminals
Distribution and logistics	Existing	Existing	Existing	Available globally. Transported in tank ships, barges, trucks and rail.	LNG terminals are under construction in Europe, but still relatively few are in operation.
Scrubber	Needed	Not needed	Not needed	Not needed	Not needed

Figure 2: Marine Fuels' Readiness

Figure 3, from the U.S. Department of Energy [6], show the various fuel properties of low sulfur diesel, biodiesel, LNG, and Methanol.

	Fuels			
Property	Low Sulfur Diesel	Biodiesel	Liquefied Natural Gas (LNG)	Methanol
Fuel Material (feedstocks)	Crude Oil	Fats and oils from sources such as soybeans, waste cooking oil, animal fats, and rapeseed	Underground reserves and renewable biogas	Natural gas, coal, or woody biomass
Gasoline or Diesel Gallon Equivalent (GGE or DGE)	1 gal = 1.12 GGE 1 gal = 1.00 DGE	*B100* 1 gal = 1.05 GGE 1 gal = 0.93 DGE *B20* 1 gal = 1.11 GGE 1 gal = 0.99 DGE	1 lb. = 0.19 GGE 1 lb. = 0.17 DGE	1 gal = 0.50 GGE 1 gal = 0.45 DGE
Energy Comparison [2]	1 gallon of diesel has 113% of the energy in 1 GGE due to the higher energy density of diesel fuel.	1 gallon of B100 has 93% of the energy in 1 DGE, and 1 gallon of B20 has 99% of the energy in 1 DGE due to a lower energy density in biodiesel.	5.37 lb. of LNG has the same energy as 1 GGE, and 6.06 lb. of LNG has the same energy as 1 DGE. (a)	1 gallon of methanol contains 50% of the energy as 1 GGE.
Energy Content (lower heating value)	128,488 Btu/gal (c)	*B100* 119,550 Btu/gal *B20* 126,700 Btu/gal (c)	21,240 Btu/lb (a)	57,250 Btu/gal (c)
Energy Content (higher heating value)	138,490 Btu/gal (c)	127,960 Btu/gal for B100 (c)	23,726 Btu/lb (c)	65,200 Btu/gal (c)
Physical State	Liquid	Liquid	Cryogenic liquid (lighter than air as a gas)	Liquid
Flash Point	165°F (j)	212° to 338°F (d)	-306°F (k)	52°F (j)
Autoignition Temperature	~600°F (j)	~300°F (d)	1,004°F (k)	897°F (j)
Maintenance Issues		Lubricity is improved over that of conventional low sulfur diesel fuel. For more maintenance information, see the Biodiesel Handling and Use Guidelines—Fifth Edition. (d)	LNG is stored in cryogenic tanks with a specific hold time before the pressure build is relieved. The vehicle should be operated on a schedule to maintain a lower pressure in the tank.	Special lubricants must be used as directed by the supplier as well as M85-compatible replacement parts. Can cause serious damage to organs in the body if a person swallows it, breathes it in, or gets it on their skin.
Energy Security Impacts	Manufactured using oil. Transportation accounts for approximately 30% of total U.S. energy needs and 70% of petroleum consumption. (l)	Biodiesel is domestically produced, renewable, and reduces petroleum use 95% throughout its lifecycle. (m)	LNG is domestically produced from natural gas and renewable biogas. The United States has vast natural gas reserves.	Methanol is domestically produced, sometimes from renewable resources.

Figure 3: Fuel Properties Comparison

5.3.1. METHANOL

Methanol is an excellent replacement for gasoline and is used in mixed fuels. It can achieve a good level of performance in converted diesel engines with the energy efficiency as high or higher than traditional fuels. It does require an ignition enhancer, such as diesel oil, to be used in diesel engines.

Dual fuel engines that operate with methanol and diesel are available on the market and it is possible to retrofit some existing diesel engines to be able to run on methanol. Methanol systems are high pressure systems that require double-walled piping. Methanol is toxic; the double walled piping is to minimize the possibility of leakage and prevent people from direct contact with methanol in the event of a pipe rupture. The system can be purged with nitrogen gas to allow service to the engine.

Methanol can significantly reduce emissions. It can reduce sulfur oxides (SO_X) up to 99%, nitrogen oxides (NO_X) up to 60% and particulate matter (PM) up to 95%. The levels of Nitrogen Oxide are low enough to be in line with Tier III NO_X emissions. However, methanol does have a low heating value (19.5 MJ/kg) when compared to diesel. To get equivalent energy density, the space needed for storing methanol is approximately twice that of traditional diesel fuels [5].

The main benefits for methanol are its relatively good performance, being able to utilize existing converter technology, and low tank costs. Methanol burns cooler than diesel which can lower the temperature in the engine room.

There are some drawbacks of methanol, while there are many ways to produce methanol the most common one uses fossil fuels. All fossil-based fuels contribute to the greenhouse effect and affect global warming, while methanol does produce lower emissions of CO_2 the lower CO_2 amounts may be counteracted by methane slip from the engine and losses in the distribution chain. Methane is 20-30 times stronger than CO_2 as a greenhouse gas which makes it a large contributor to global warming [5].

Methanol can currently be delivered to a vessel by truck and while methanol is a low-flashpoint fuel, the technology for handing it is well developed and there is ample experience with handling it safely. Methanol is somewhat flammable and has a low acute toxicity to humans. Unlike LNG, methanol is a liquid at ambient temperature and pressure, meaning it can be stored in ordinary tanks with few modifications.

Methanol is a polar liquid that is dissolvable in water which means when released into the environment it biodegrades rapidly.

The cost associated with installing a dual fuel engine using methanol and diesel are more compared to a conventional engine using marine gas oil (MGO).

5.3.2. BIOFUELS

Biofuels can be blended with conventional fuels, or they can be used in existing installations without major technical modifications. The most promising biofuels are hydrotreated vegetable oil (HVO), fatty acid methyl ester (FAME) and liquefied biogas (LBG). HVO is used on several ferries operating in Norway without negative effects.

Biodiesel is a clean, domestic, sustainable, renewable fuel for diesel engines made from fats and oils, such as soybean oil and used cooking oil. It is a high-quality advanced biofuel [7]. According to National Biodiesel Board, "Advanced biofuel means renewable fuel, other than ethanol derived from cornstarch, that has lifecycle greenhouse gas emissions that are at least 50 percent less than baseline lifecycle greenhouse gas emissions.

Biodiesel is produced from a variety of renewable resources, such as plant oils, animal fats, recycled grease, and even algae making it one of the most sustainable fuels on the market. Biodiesel is made by a transesterification process that produces mono-alkyl esters that are chemically similar to diesel fuel. Biodiesel and biodiesel blends are available nationwide.

Biodiesels are biodegradable, non-toxic and produce lower emissions than fossil fuels. Biodiesels have a lower flashpoint than conventional diesels which means they ignite at higher temperatures and are less likely to ignite accidently. Biodiesels can be used in some diesel engines made after 1987. Biodiesel has a great lubricating effect that improves the working life of the engine due to less wear and tear [8].

One disadvantage of biodiesel is that it is temperature sensitive much like diesel is. Gelling can happen when the temperature drops, and the paraffin component of the diesel starts to solidify and become gel-like. At around 10°F biodiesel starts to become a gel and may clog the tank, narrow fuel lines and fuel filters. Additionally, in warm weather biodiesel can grow mold. Biodiesel also damages rubber items thus gaskets and seals must be made of materials other than rubber.

The January 2021 Clean Cities Alternative Fuel Price Report [9] found that in Central Atlantic both B20 and B99/B100 biodiesels were cheaper than conventional diesel. See Figure 4 and Figure 5.

Region	B20 Prices ($/gal)	Diesel Prices ($/gal)	Price Difference*
New England	$2.22	$2.63	-$0.41
Central Atlantic	$2.40	$2.86	-$0.46
Lower Atlantic	$1.82	$2.60	-$0.78
Midwest	$2.27	$2.53	-$0.26
Gulf Coast	$2.33	$2.26	$0.07
Rocky Mountain	$2.90	$2.41	$0.49
West Coast	$2.78	$3.39	-$0.61
NATIONAL AVERAGE	**$2.42**	**$2.64**	**-$0.21**

Figure 4: Biodiesel (B20) and Diesel Average Retail Prices by Region

Region	B99/B100 Prices ($/gal)	Diesel Prices ($/gal)	Price Difference*
New England	$2.50	$2.63	-$0.13
Central Atlantic	$2.19	$2.86	-$0.67
Lower Atlantic	---	$2.60	---
Midwest	---	$2.53	---
Gulf Coast	---	$2.26	---
Rocky Mountain	$1.81	$2.41	-$0.60
West Coast	$3.84	$3.39	$0.45
NATIONAL AVERAGE	**$3.18**	**$2.64**	**$0.54**

Figure 5: Biodiesel (B99/B100) and Diesel Average Retail Prices by Region

Additionally, B20 biodiesel can have a reduced fuel efficiency of 1-2% and can reduce the power on average by about 10% when compared to conventional diesel. However, the price difference can overcome these effects. The January 2021 Clean Cities Alternative Fuel Price Report [9] found that the national average for B20 biodiesel was 17 cents cheaper on a per diesel gallon equivalent (DGE) than regular diesel.

The costs associated with installing biodiesel systems are approximately the same as conventional diesel engines.

5.3.3. LNG

Natural gas is virtually free of sulfur and ash which results in the exhaust also being free of SO_X compounds and the associated particulate matter, additionally it has a low combustion temperature that results in lower NO_X emissions. Natural gas is mostly composed of methane and contains about 13% to 15% less carbon than typical petroleum-based oils on a mass basis that results in lower CO_2 emissions. While LNG does burn cleaner than fossil fuels, a recent study by the International Council on Clean Transport [10] found that over a 100 -year time frame, the maximum life cycle GHG benefit of LNG is a 15 percent reduction compared with MGO and that is only if the ship uses a high-pressure injection dual fuel (HPDF) engine and upstream methane emissions are well-controlled. The life cycle GHG emissions looked at the production emissions, the combustion emissions, and the unburned methane (methane slip). Controlling the production emissions will be more difficult as more LNG production shifts to shale gas.

Looking at the 20-year global warming potentials (GWPs) the study concluded that there is no climate benefit from using LNG, regardless of engine technology. The study found that HPDF engines emit 4% more lifecycle GHG emissions than MGO. The most popular LNG engine technology is low-pressure dual fuel, four-stroke, medium-speed emits 70% more life cycle GHGs than MGO and 82% more than using MGO in a comparable medium-speed diesel (MSD) engine.

Additionally, LNG has about 40% lower volumetric energy density than diesel. When accounting for the storage system LNG has roughly 1/3 the volumetric energy as diesel. Thus, LNG requires more storage space (2-3 times larger) than diesel but is lighter. LNG also requires special refrigerated refueling pipes. LNG is very flammable, but not toxic. Due to the storage temperature, it does require special handling considerations.

Advanced Energy Experts [11] concluded in 2016 that LNG fueling was possible at both terminals. Cape May offered a smoother operation for fueling, but there were limited LNG providers which would limit the ability to obtain competitive LNG pricing. The Lewes terminal required more work to develop a fueling system/logic plan, but that it looked doable, and that there was a wider pool of LNG providers which would assist in obtaining a competitive LNG price.

LNG systems do cost more than conventional propulsion systems. LNG requires unique (Type C) storage tanks, additional piping, and additional insulation. Furthermore, LNG engines cost more than diesel engines.

5.4. LONG-TERM CAPITAL COSTS

There are many long-term capital costs associated with vessels including maintenance, repowering, interior refurbishments, and compliance with emergent regulations.

There are two levels of maintenance: routine maintenance and shipyard maintenance. Routine maintenance is typically handled by the ship's crew. Shipyard maintenance are large scale items that are typically handled by a shipyard such as painting the underwater hull while the vessel is drydocked, engine overhauls, electronics upgrades, and security improvements.

Alaska Marine Highway System (AMHS) and the Washington State Ferries (WSF) have found that with regular preventative maintenance and by completing certain shipyard maintenance tasks on a regular schedule they can get around a 60-year service life for their vessels. The shipyard maintenance schedule includes complete coatings every 10 years, complete passenger space refurbishments every 20 years, and repowering the vessel every 30 years. Most AMHS vessels that have been successful at operating for 50-60 years were built in the 1960s and 1970s, with the rate that technology is progressing it is unclear how technological change will impact these durations in the future. It can be assumed that electronics upgrades will play a bigger role and be required more frequently.

Long term capital costs can be estimated as a percentage of the cost of a new vessel per Table 7. These percentages only include shipyard maintenance as routine maintenance is covered in Section 5.2.

Table 7: Long Term Capital Cost Percentage of New Vessel Cost

CATEGORY	PERCENTAGE (%)	Occurrence
Drydock and Minor Maintenance	1.25	Twice every 5 years
Engine Overhaul	1.25	Every 10 years
Complete Coatings	15	Every 10 years
Complete Passenger Space Refurbishment	20	Every 20 years
Repower	25	Every 25 years

Table 8 shows the estimated fleet cost for these maintenance categories each time they are completed.

Table 8: Total Fleet Long Term Costs Per Category

CATEGORY	SINGLE-ENDED			DOUBLE-ENDED			
	OPTION 1 100V	OPTION 2 (4F) 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2A (3F) 75V	OPTION 2B (4F) 75V	OPTION 3 55V
Drydock and Minor Maintenance	$3.85M	$3.40M	$2.51M	$4.31M	$2.85M	$3.81M	$2.82M
Engine Overhaul	$3.85M	$3.40M	$2.51M	$4.31M	$2.85M	$3.81M	$2.82M
Complete Coatings	$46.18M	$40.77M	$30.17M	$51.72M	$34.25M	$45.66M	$33.79M
Complete Passenger Space Refurbishment	$61.58M	$54.36M	$40.23M	$68.96M	$45.66M	$60.89M	$45.05M
Repower	$76.97M	$67.95M	$50.28M	$86.21M	$57.08M	$76.11M	$56.32M

In addition to the above maintenance, a hybrid diesel/electric vessel will require replacing the batteries about every 7 years depending on the depth of discharge rate. As technology advances the cost of batteries has been decreasing and is estimated to continue decreasing. We have assumed that for the first battery replacement the batteries will cost $500/kW-hr and will decrease by $100/kW-hr for each subsequent replacement. See Section 7 for the required battery capacities for each fleet option.

6. VEHICLE DECK AND END CONFIGURATION

The existing vessels have a single end propulsion system. This requires the vessels loading in Cape May to back out of the slip, turn around, traverse the bay, turn around, and then back into the slip at Lewes. Vessels going the other direction do not need to turn around at all. EBDG estimates that a vessel with a double ended propulsion system can reduce the slow speed maneuvering time by half which either allows a shorter trip time (thus more through put) or potentially lowers the crossing speed and increase fuel efficiency. Double-ended vessels do require slightly more installed HP, and thus more weight, which may negate some of the fuel efficiency gained with the slower crossing speed. For this study EBDG has assumed that double-ended vessels increase vessel construction cost by 12% due to the larger installed propulsion plant.

The vehicle deck arrangement is not dependent on the vessel propulsion system, so the dwell time at the terminal is not impacted by the choice of end configuration. A vessel with single-ended propulsion would have a double-ended vehicle deck arrangement like the existing vessels. This would allow vehicles to drive forward straight on/off without having to turn around.

The operational reliability is the same for both types of vessels. A double-ended vessel would be able to operate more efficiently and complete the route quicker than a single-ended vessel in the event of a failure. In the event of a propulsion system failure, a double-ended vessel would turn around and use the other end's propulsion system to complete the run while a single-ended vessel would complete the run at half the normal power and the vessel would have to maneuver with a single engine.

In addition to having a double ended vehicle deck, it is also possible to have a ramped double-deck or to use a lift-deck to increase vehicle capacity in the same size ferry. There are multiple vessels in operation that have either option. For example, the *Island Home* owned by the Steamship Authority has two vehicle lift decks which can increase the vehicle capacity by 16 cars. Lift decks provide flexibility and allow vessel crew to alter the vehicle loading configuration depending on the balance of trucks and cars on any given trip. When not in use, lift decks can be stowed in the overhead and allow for additional over height vehicles.

Many of the Washington State Ferries use a ramped double-deck that has proven to be very successful. Due to the length required for a ramp, a ramped double deck works best on vessels greater than 300 ft in length which would limit its use to the 100-car option. Both options can complicate the loading process and what mix of vehicles can be carried. They also require vessel crew to pay attention to the vehicles being loaded. Long tractor-trailer combinations, or over height vehicles and vehicles with racks on top, can cause loading issues.

Either option will add a to the initial capital costs of the vessels. EBDG recommends that, if DRBA chooses to build the 100-car option, the vessel design should include a feasibility study for adding a ramp deck to the vessel in the future. If the 75-car option is chosen, we recommend a feasibility study adding a future lift deck. For the 55-car option, a future hoist able ramp could be considered. These options will affect the loading/unloading times for the vessels but may be a solution for accommodating increased throughput.

7. ELECTRICAL CONFIGURATION

Looking at the route profile and the energy required to complete the crossing the estimated number of batteries and the charging capacity required for each fleet option is shown in Table 9. This table assumes that the batteries will be charged at both terminals. If charging is only available at one terminal these numbers will be doubled.

Table 9: Energy Requirements

CATEGORY	SINGLE-ENDED			DOUBLE-ENDED		
	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V
Crossing Energy (kW-hr)	3,820	2,973	2,250	2,777	2,186	1,697
Battery Energy Storage – 50% discharge (kW-hr)	7,640	5,946	4,500	5,554	4,372	3,394
# Battery Racks (249 kW-hr/each)	31	24	19	23	18	14
Battery Weight (lbs)	230,640	178,560	141,360	171,120	133,920	104,160
Charging (kW)	11,576	10,136	9,122	8,331	7,287	6,788

Single-ended options requires more energy for each crossing due to the higher transit speed needed to maintain the same crossing time and dwell time as the double-ended vessel.

Battery life is heavily dependent on depth of discharge for our analysis we have assumed a discharge of 50% and have estimated the battery life to be approximately 7 years.

As shown in the above table, all options are capable of being hybrid-diesel. The percentage of the crossing time that they can operate on battery power will be dependent on the capacity and charging rate that the electrical utility is able to provide. The energy cost savings will also be dependent on the electrical rates that DRBA is able to negotiate with the electric company. The terminals currently do not have enough electrical capacity to support a hybrid vessel and will require approximately $20 million in electrical upgrades.

8. COOLING SYSTEMS

There are multiple options for cooling system arrangements that depend on machinery configuration and the environmental conditions that the vessel operates within. CMLF route presents special challenges with the shallow water and the potential for sea ice. The various options are sea chests, keel coolers, plate coolers, box coolers. These options will be further examined during the vessel design to determine which option is best for the chosen vessel.

8.1. SEA CHESTS

Each of the existing vessels has at least one sea chest for the seawater cooling system. The advantages of sea chests are they are installed inside of the vessel, they do not have to be in the bottom of the vessel but can be placed anywhere under the waterline, and there can be multiple sea chests with some installed high or lower to deal with ice blockage.

The disadvantages of sea chest are they can get mud/sand in them, and they can get clogged with ice.

Sea chests also require additional components such as heat exchanges to be installed inside the vessel.

8.2. KEEL COOLERS

Each of the existing vessels use keel coolers for the freshwater cooling system. The advantages of keel coolers are that they are manufactured units that can be sized for zero velocity through water to keep the system operating properly even when the vessel is at the terminal, and they are closed circuit systems that eliminate the need for seawater to enter the hull. They are also robust, reliable, and simple.

Some disadvantages of keel coolers are they are mounted on the exterior of the vessel thus they are either recessed into the hull or they require guards to protect them from collisions with objects in the water. Even with guards installed there is still a small chance that the keel coolers can be damaged by a grounding or debris in the water. Additionally, for a shallow draft vessel keel coolers can be mounted on either the side or the stern of vessel. However, they can get clogged with ice and maintenance requires the vessel to be drydocked.

Figure 6: Recessed Keel Cooler

Figure 7:External Mounted Keel Cooler with Guards

8.3. PLATE COOLERS

Some of the existing vessels were originally designed with plate coolers in the salt-water cooling system. These have since been removed from CAPE HENLOPEN and NEW JERSEY. Plate coolers are installed internal to the vessel and are more efficient at heat transfer compared to keel coolers and box coolers.

Some disadvantages of plate coolers are they are more expensive to install and maintain. The salt-water pump suction can become fouled from debris in the water. The plates also require regular cleaning and fluid must always be moving on both sides of the heat exchanger for it to work properly.

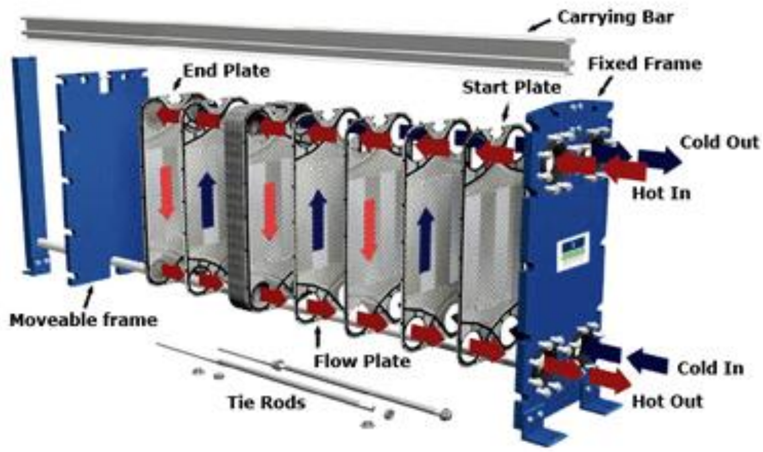

Figure 8: Plate Cooler

8.4. BOX COOLERS

Box coolers are similar to keel coolers, but they are installed on the side of the vessel. Box coolers are mounted in the hull of the vessel within a sea chest and can be mounted transversely or longitudinally. With openings at the bottom and sides of the sea chest, box coolers use thermal siphoning to transfer heat even when the vessel is stationary. They can be engineered to cool multiple heat sources from one cooler. It can be challenging getting water flow into and out of the protected area. Box coolers will not get clogged with ice and are good in shallow, sandy, and silt-polluted waters due to the smoother flow on the outside of the box cooler. Maintenance of a box cooler does require the vessel to be drydocked.

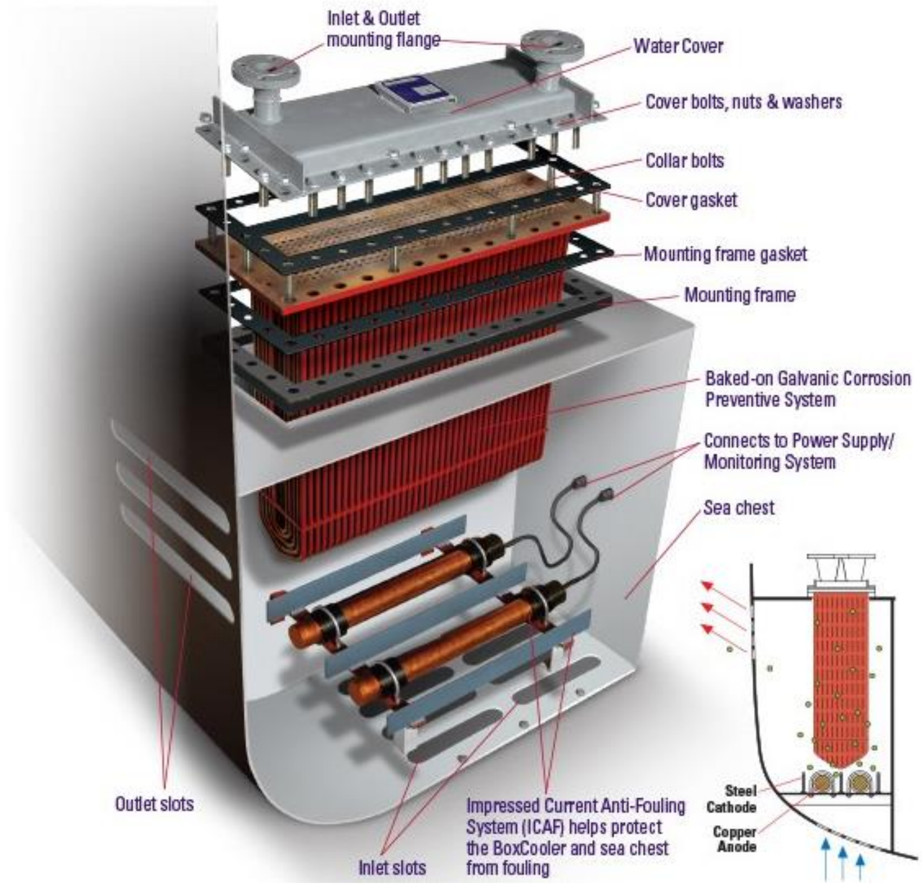

Figure 9: Box Cooler

9. ENERGY EFFICIENCY

Several factors can affect a vessel's energy efficiency including hull shape, size of propeller, number of propellers, and vessel weight. For this analysis we have considered a single-ended, two propeller, conventional hull as the baseline since this is the configuration of the existing fleet. Note that all numbers contained herein are based on parametric analyses using estimated hull form parameters. They are not intended to demonstrate comparative treads between the various hull and propulsion configuration and should not be considered more than a "ballpark" prediction of mature design results. Additionally, discussion regarding conventional propellers is based on fixed pitch propellers.

There are several ways to increase the energy efficiency of a vessel. A bulbous bow on a single-ended vessels can reduce the vessel drag by approximately 5%, however we do not recommend using a bulbous bow on this route due to shallow water effects. Adding a bow thruster to a single-ended vessel can add 2% to the resistance. The design draft of the vessel will take into consideration the shallow water that the vessels operate in and will not be greater than the existing fleet.

The route's shallow draft will affect the size of propellers that can be used. The more power pushed through a set propeller diameter, the less efficient the propellers are. To keep the same transit time as the double ended vessels, the single ended vessels will be required to travel at a faster speed to make up for the turning around time. This means they require more horsepower. Since single-ended vessels can have two propellers providing thrust, the open water propeller efficiency is 54% for the 100-car vessel with 72" propellers and 61% for the 55-car vessel with 60" propellers. Whereas the double ended vessel has only a single propeller providing thrust, so a 100-car vessel with one 72" propeller has a 46% efficiency and a 55-car vessel with one 60" propeller has a 53% efficiency.

Propeller rotation can also have an impact on efficiency and maneuverability. Saunders[1] wrote: “On the normal form of a twin screw vessel this often means that the propellers should rotate inward to produce the highest propulsive efficiency, with a RH (right hand) wheel on the port side and a LH (left hand) wheel on the starboard side. For good maneuvering of a twin-screw vessel, outward-turning twin screws usually perform best on a normal hull form. The direction of rotation depends on which requirement is most important or how much has to be sacrificed in one to meet the other.” With modern computational fluid dynamics (CFD) the difference in propulsive efficiency between inboard and outboard turning wheels can be quantified.

Another propulsion option is to use azimuth drives or Voith Schneider Propellers (VSPs). While these propulsors could be used on either vessel type, they are much better suited to a double-ended vessel. Using four azimuth drives on the 100-car vessel would increase the open water propeller efficiency to 54% which is equal to the single-ended 100-car vessel. For the 55-car vessel the azimuth drives would increase the efficiency to 67% which is greater than the single-ended 55-car vessel. The VSPs would lower the efficiency below the conventional propellers, but for a double-ended vessel there can be equal thrust at the bow and the stern which will decrease the size of the engine and the weight of the vessel. A lighter vessel will require less energy to move and have a greater efficiency.

Hull shape also has an impact on the vessel's efficiency. Double-ended vessels can be more efficient since there is a nicer distribution of displacement over the length of the vessel instead of having most of the weight in the stern. The sectional area of double ended vessels is also more efficient due to less volume being needed for the machinery space in the stern of the vessel. The use of VSPs would also allow a more efficient hull shape than conventional propellers and work well in shallower waters.

Hull shape and propulsion configuration can greatly impact the maneuverability of a vessel. VSPs offer the best maneuverability because they can provide near instantaneous thrust in any direction. Azimuth drives offer similar maneuverability due to the drives being able to spin 360°. Compared to single-ended vessels, double ended vessels have the most control over the bow and stern at slow speeds when using conventional propellers. A bow thruster would be necessary to have control over the bow on a single-ended vessel.

Once a vessel size has been chosen and it has been determined that the vessels will be single-ended vs double ended, azimuth drives and Voith Schneider drives should be further studied to determine if they would be better than conventional propellers.

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[1] H.E. Saunders, Hydrodynamics in Ship Design, Volume One, Pg. 484, The Society of Naval Architects and Marine Engineers, New York, NY, 1957

10. FUEL TANK LOCATION

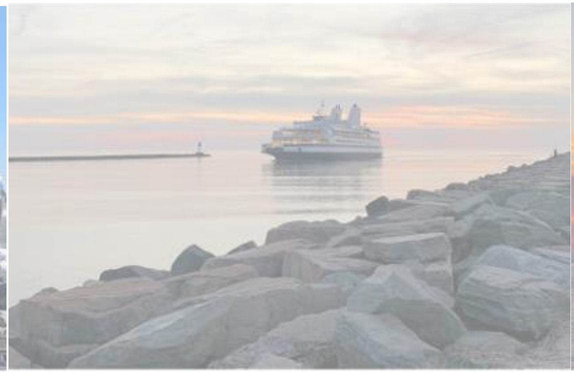
The location of the fuel tanks can be critical and must consider changes in trim as fuel is consumed as well as protection from spills due to damage from grounding, collision, or allision. One option is to mount the fuel tank near midship so that as fuel is burned the trim does not change. Another option is to have one fore and one aft on the vessel. This requires actively managing the levels in each tank to control the trim.

While it used to be common practice, fuel tanks should not be shell tanks due to the possibility of spills and leakage with grounding and collisions.

The fuel tanks shall be sized to have enough fuel to transit to shipyard and an appropriate reserve for emergencies. The vessels will likely be refueled every other day.

APPENDIX C

Phase 2 Task D – Ferry Operations Analysis


2021 Marine Master Plan

OPERATIONAL ANALYSIS MEMO

Prepared for: Delaware River and Bay Authority

Ref: Phase 2, Task D

September 22, 2021

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INTRODUCTION

As a component of the fleet analysis, the operational analysis was intended to develop service parameters for each of the fleet options and to compare the options in how well they meet DRBA's current vehicle ridership demand while also providing room for growth. Though five fleet options were initially considered, the options were reduced down to three in the initial Phase 2 analysis, as is discussed in the summary report. The following fleet options were the focus of this detailed operational analysis:

- Option 1: Three 100-vehicle Ferries
- Option 2
    - Option 2A: Three 75-vehicle Ferries
    - Option 2B: Four 75-vehicle Ferries
- Option 3: Five 55-vehicle Ferries
- Option 4: Two 150-vehicle Ferries [*removed from consideration]*
- Option 5: Two 55-vehicle Ferries and Two 100-vehicle Ferries [*removed from consideration]*

METHODOLOGY

The first step in the operational analysis was to evaluate the existing vehicle ridership and operational conditions of Cape May Lewes Ferry (CMLF). Following an identification of current fleet capacity and existing ridership, route trip times and representative service schedules were developed for each of the fleet options in the analysis. Preliminary crew shifts were then identified.

MODELED CURRENT FLEET: "CALCULATED OPTION"

To provide a more accurate comparison of the existing fleet to the new fleet options, a simplified model of the existing fleet's operations was developed as the basis of comparison. This model will be referred to as the Calculated Option.

CURRENT RIDERSHIP CONDITIONS ANALYSIS

This section summarizes the methodology that was used to evaluate the existing ridership trends observed by the CMLF system. Following a discussion of methodology, key ridership findings are discussed.

METHODOLOGY

Ridership in 2017, 2018, and 2019 were all examined, and all three years showed similar trends. 2019 was picked as a representative ridership year, as it represented the most recent non-pandemic year demand data. The year was broken up into three seasons based upon differences in observed ridership and the seasons as identified in the 2008 Master Plan. The seasons were defined as follows:

- Winter: January, February, March, November, December
- Shoulder: April, May, September, October

- Summer: June, July, August

The winter season analysis did not include holiday periods such as New Year's Day, Christmas, and Thanksgiving. The days on and around these holiday timeframes showed higher ridership, and it was assumed that for all fleet options a holiday schedule could be provided to meet the higher ridership during those instances.

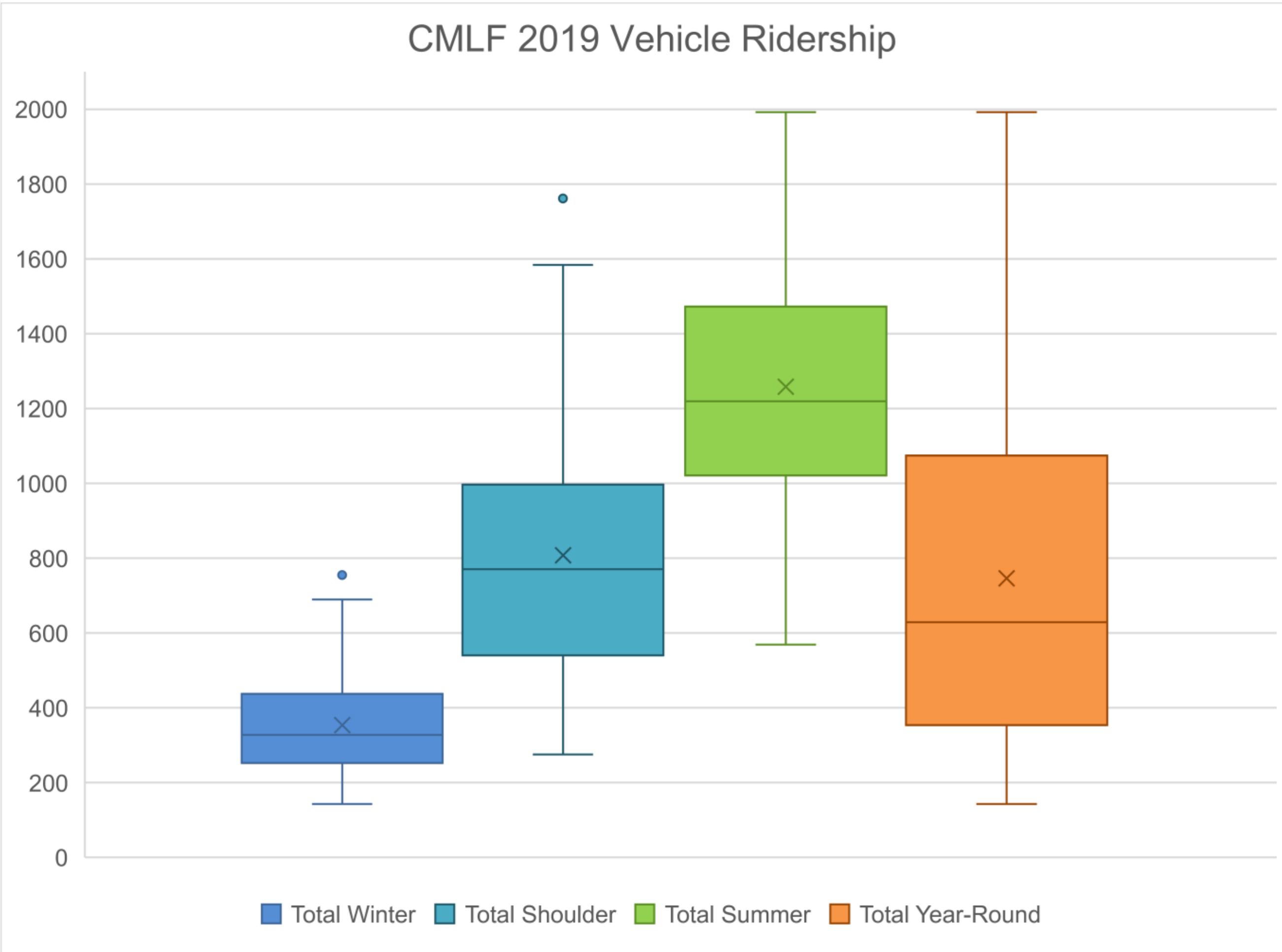
PASSENGER RIDERSHIP FINDINGS

When evaluating the passenger ridership, it was noted that in the 2019 example year the passenger count never exceeded 360 on any sailing and the 95th percentile passenger level was 324 passengers, even though the current CMLF vessels are outfitted to carry up to 800 passengers. As a result, the overall passenger level of all proposed vessel options for the new fleet was proposed to be a smaller level of passenger capacity that would better align with observed demand.

VEHICLE RIDERSHIP FINDINGS

In order to adequately evaluate how the fleet options performed in meeting the CMLF's service needs, it was first necessary to understand the vehicle ridership needs of the service. To understand these needs, an analysis was conducted of previous CMLF ridership trends including identifying times of higher and lower service throughput as well as identifying general levels of vehicle throughput. During this analysis it was identified that the CMLF ridership varied greatly by season. As a result, Figure 1 and the following sections summarize the key ridership findings by season in order to capture important seasonal service differences.

Figure 1- CMLF 2019 Vehicle Ridership Trends



	Minimum	*25th Percentile*	*50th Percentile/ Median*	*Mean (X on the graphs above)*	*75th Percentile*	*95th Percentile*	*Maximum*
Winter	143	253	328	354	437	603	755
Shoulder	275	541	771	808	997	1472	1762
Summer	569	1021	1240	1258	1473	1840	1992
Full Year	143	354	629	746	1075	1593	1992

The box represents the middle 50% of the data by season (25th percentile to 75th percentile). Outliers for each season are represented by individual circular points.

WINTER

Most winter days (middle 50% of the data) carried between 254 and 433 vehicles per day. The ridership benchmark for winter was the 95-percentile winter ridership day which carried 603 vehicles. Overall, the median number of vehicles per winter day was 328. In general, higher ridership was observed on the Fridays, Saturdays, and Sundays near the shoulder season. Additionally, the days in November and December carried more vehicles than the days in January to March.

The winter season analysis did not include holiday periods such as New Year's Day, Christmas, and Thanksgiving. The days on and around these holiday timeframes showed higher ridership, and it was assumed that for all fleet options a holiday schedule could be provided to meet the higher ridership during those instances.

SHOULDER

Most shoulder days (middle 50% of the data) carried between 544 and 990 vehicles per day, with a median daily ridership of 771 vehicles. The 95-percentile shoulder ridership benchmark was 1472 vehicles. The average daily vehicles carried in the shoulder season varied more than in the winter season. As was seen in some portion of the winter season, higher ridership was observed on the Fridays, Saturdays, and Sundays in the shoulder season. Additionally, the days in September and October carried more vehicles on average than the days in April to May.

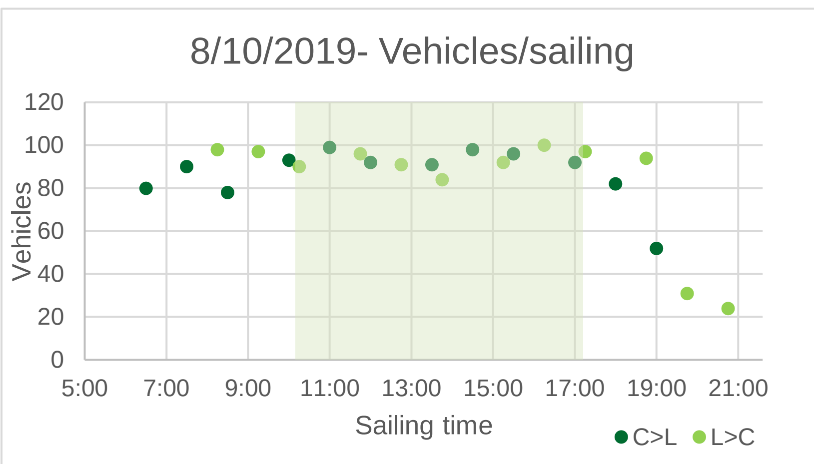


Figure 2- Peak Day Vehicle Ridership

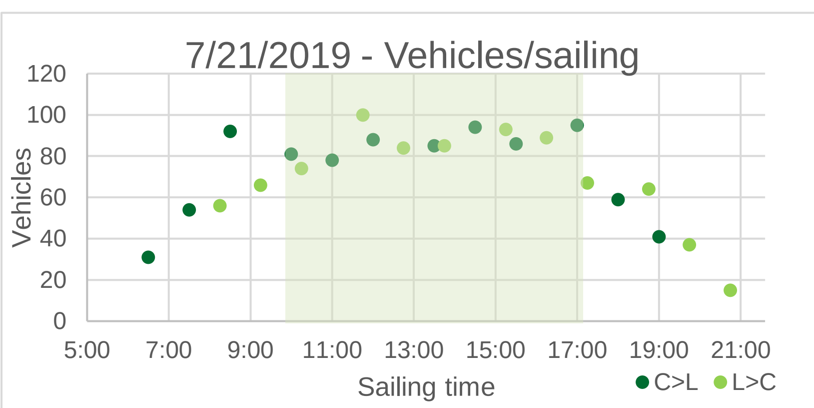


Figure 3- Example Summer Day Vehicle Ridership

SUMMER

The ridership analysis identified summer as the peak busiest season for DRBA in regard to vehicle ridership. Ninety-five percent of summer days in 2019 carried fewer than 1840 vehicles while the median number of vehicles per day was 1220. Most summer days (middle 50% of the data) carried between 1028 and 1448 vehicles per day.

Peak time of day

Fridays, Saturdays, and Sundays in the summer season appear to typically carry more vehicles and passengers than other weekdays. On these and other summer days, peak summer demand tended to occur between 10:00 am and 5:00 pm. This peak time is shown in Figures 2, 3 and 4.

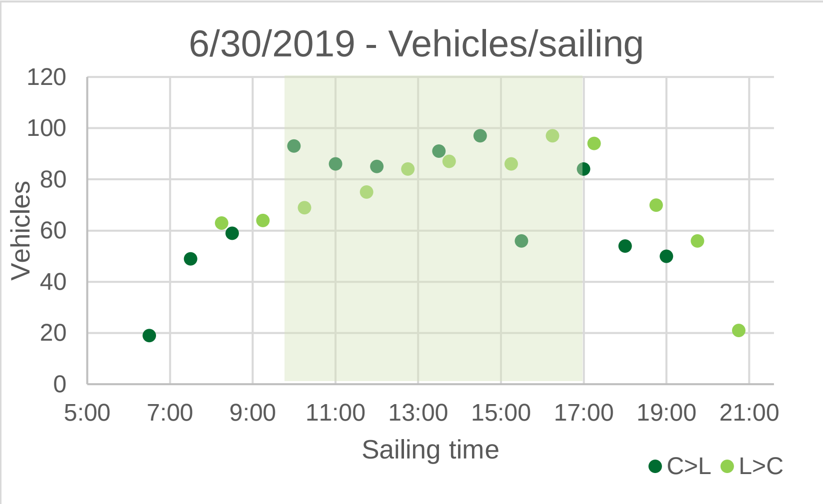


Figure 4- Example Summer Day Vehicle Ridership

Shown in Figure 2, the busiest day in 2019 was August 10th. 1992 vehicles were carried on this day, though the system's daily capacity was 2400 vehicles. This is because while ridership in the peak period was high, if not completely full, later evening sailings and some early morning sailings were less full. This pattern was generally observed in other busy summer days as well, with a more marked decrease in early morning sailings.

ROUTE PROFILE DEVELOPMENT

To develop service schedules for each of the fleet options, the first step was to identify the trip time for each of the proposed vessel sizes. Trip time equals transit time, plus maneuvering time, plus dwell time. By assuming a double-ended configuration for all vessel sizes, in conjunction with the increased vessel speeds allowable by new technology, it was determined that all fleet options could achieve a one-way trip time of 80 minutes in comparison to the 105-minute one-way trip time of the fleet's current vessels that was used for the calculated fleet model. Though the smaller vessels could potentially load and unload faster (reduced dwell time), some additional dwell time was maintained to ensure sufficient time for passenger loading ramp deployment and stowing (approximately 6 to 10 minutes), passenger loading, and loading of food items. But for each vessel option, the dwell time is somewhat offset by the vessel service speed.

Dwell Time Summary

Passenger ramp deployment takes approximately 6 to 10 minutes and must be included in the dwell time for all fleet options.

Dwell time is less for smaller vessels because fewer cars need to unload and load per vessel.

Food service items are currently loaded via the passenger ramps and this could be supported by the dwell times identified in the route profiles.

The 100-car vessel is the fastest service speed at 20.5 knots but has the longest dwell time at 22 minutes. The 75-car vessel is slower at 16.5 knots, but the dwell time is less at 20 minutes. The 55-car vessel is the slowest of the three at 15.31 knots, but also has the least dwell time at 17 minutes. What results is a trip time of 80 minutes being kept for ease of scheduling for all options and to facilitate schedules that would be easy to use for future customers. A primary benefit to achieving a faster trip time was increasing overall service throughput as a means to accommodate future ridership growth. The route profiles for each vessel size are shown in Figure 5 on the following page.

Figure 5- Route Profiles

Option 1: 100 Car Vessel

Leg	Route Leg Description	Distance (nm)	Speed (kts)	Time (min)
1	CM Terminal to Canal Inlet	0.35	4	5.3
2	Canal Inlet to Crow Shoal	2.15	17.07	7.6
3	Dep. Crow Shoal	0.3	17.07	1.1
4	Crow Shoal to Buoy #2	2.5	17.07	8.8
5	Buoy #2 to Hbr of Refuge	5.6	17.07	19.7
6	Hbr of Refuge to Inner Hbr	1.95	17.07	6.9
7	Inner Hbr to CO. Jetty	0.75	7.5	6
8	Co. Jetty to LW Terminal	0.3	6	3
	Total Transit Time			**58**
	Dwell Time			**22**
	TOTAL ONE-WAY TRIP TIME			**80**

Option 2: 75 Car Vessel

Leg	Route Leg Description	Distance (nm)	Speed (kts)	Time (min)
1	CM Terminal to Canal Inlet	0.35	4	5.3
2	Canal Inlet to Crow Shoal	2.15	16.25	7.9
3	Dep. Crow Shoal	0.3	16.25	1.1
4	Crow Shoal to Buoy #2	2.5	16.25	9.2
5	Buoy #2 to Hbr of Refuge	5.6	16.25	20.7
6	Hbr of Refuge to Inner Hbr	1.95	16.25	7.2
7	Inner Hbr to CO. Jetty	0.75	7.5	6
8	Co. Jetty to LW Terminal	0.3	6	3
	Total Transit Time			**60**
	Dwell Time		*16.5 minutes minimum*	**20**
	TOTAL ONE-WAY TRIP TIME			**80**

Option 3: 55 Car Vessel

Leg	Route Leg Description	Distance (nm)	Speed (kts)	Time (min)
1	CM Terminal to Canal Inlet	0.35	4	5.3
2	Canal Inlet to Crow Shoal	2.15	15.31	8.4
3	Dep. Crow Shoal	0.3	15.31	1.2
4	Crow Shoal to Buoy #2	2.5	15.31	9.8
5	Buoy #2 to Hbr of Refuge	5.6	15.31	21.9
6	Hbr of Refuge to Inner Hbr	1.95	15.31	7.6
7	Inner Hbr to CO. Jetty	0.75	7.5	6
8	Co. Jetty to LW Terminal	0.3	6	3
	Total Transit Time			**63**
	Dwell Time		*15 minutes minimum*	**17**
	TOTAL ONE-WAY TRIP TIME			**80**

SCHEDULE DEVELOPMENT

Using the newly calculated trip times for each fleet, representative schedules were then developed for each fleet option, using the existing fleet's schedules and length of operating day as a guide. Due to the wide variation in seasonal ridership, it was determined that different schedules would need to be developed for each of the established ridership seasons. An additional consideration is that CMLF currently runs seven to eight schedules per year and can run up to six schedule options per season, in order to right-size service to demand as much as possible. For the purposes of simplifying this analysis, only two schedules were developed for each season. To align with the simplified 2 schedules per season, a schedule model of the existing CMLF fleet was also created to ensure a more apples-to-apples comparison. Figure 6 below summarizes the schedules that were developed.

Schedule Summary

A model of the new fleet options and the existing fleet ("Calculated" option) was created.

This study created 2 schedules (weekday and weekend) for 3 seasons (Summer, Shoulder and Winter) for each fleet option.

All new fleet options provide more round trips (RTs) than the existing fleet.

This is because the new vessels can achieve a faster trip time.

All winter weekdays modeled use one vessel.

Option 2A and 2B only differ in summer weekends where they run 3 or 4 boats respectively.

Figure 6- Schedule Model

		Calculated Fleet Model	Option 1 100 VEH	Option 2A 75 VEH	Option 2B 75 VEH	Option 3 55 VEH
WINTER	Weekday Schedule	• 1 Vessel • 4 RTs	• 1 Vessel • 5 RTs	• 1 Vessel • 5 RTs	• 1 Vessel • 5 RTs	• 1 Vessel • 5 RTs
	Weekend Schedule			• 2 Vessels • 9 RTs	• 2 Vessels • 9 RTs	• 2 Vessels • 9 RTs
SHOULDER	Weekday Schedule	• 2 Vessels • 8 RTs	• 2 Vessels • 9 RTs	• 2 Vessels • 9 RTs	• 2 Vessels • 9 RTs	• 2 Vessels • 9 RTs
	Friday & Weekend Schedule	• 3 Vessels • 10 RTs	• 3 Vessels • 11 RTs	• 3 Vessels • 11 RTs	• 3 Vessels • 11 RTs	• 4 Vessels • 17 RTs
SUMMER	Weekday Schedule	• 3 Vessels • 10 RTs	• 3 Vessels • 13 RTs	• 3 Vessels • 13 RTs	• 3 Vessels • 13 RTs	• 4 Vessels • 18 RTs
	Friday & Weekend Schedule	• 3 Vessels • 15 RTs	• 3 Vessels • 15 RTs	• 3 Vessels • 15 RTs	• 4 Vessels • 18 RTs	• 5 Vessels • 23 RTs

These schedules were designed to generate enough capacity to meet the current 95% ridership day for each season. In the winter season, additional service was provided on the weekends where needed to meet 100% of the ridership levels observed in 2019.

The schedules were based on the existing CMLF schedule structure, with the primary difference being that all vessels in a new fleet configuration operate at an increased operating tempo with the one-way trip time of 80 minutes.

CREW SHIFT DEVELOPMENT

Following the development of operating schedules, a rough estimate of crew hours was needed for the purpose of estimating the labor cost of each fleet configuration. The following assumptions were used in crew schedule development:

- Crew shift lengths were designed to be in round increments of 30 minutes.
- Vessel start-up shifts begin between 45 mins and 1 hour before the first sailing on that vessel.
- Vessel tie-up shifts have at least 30 minutes of time for unload and tie-up *after* the last sailing arrives at the home port of Cape May.
- Mid-day shift change allows for 30 minutes of overlap.
- No crew member works more than one shift a day.
- Factor accounting for relief crew is not included in this level of crew analysis.

Based on these assumptions, the example crew shifts shown in Figure 7were drafted as needed to provide each service schedule.

Figure 7- Example Crew Shifts

<table>
<tr><th></th><th></th><th>Option 1
100 VEH</th><th>Option 2A
75 VEH</th><th>Option 2B
75 VEH</th><th>Option 3
55 VEH</th></tr>
<tr><td rowspan="2">WINTER</td><td>Weekday Schedule</td><td rowspan="2">• One 9-hr shift
• One 6.5-hr shift
• 16 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• 16 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• 16 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• 10 Crew</td></tr>
<tr><td>Weekend Schedule</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 24 to 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 24 to 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 15 to 20 Crew</td></tr>
<tr><td rowspan="2">SHOULDER</td><td>Weekday Schedule</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 24 to 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 24 to 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 24 to 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• 15 to 20 Crew</td></tr>
<tr><td>Friday & Weekend Schedule</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• One 7-hr Shift
• 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• One 7-hr Shift
• 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• One 12-hr Shift
• One 7-hr Shift
• 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• Three 12-hr Shifts
• 25 to 40 Crew</td></tr>
<tr><td rowspan="2">SUMMER</td><td>Weekday Schedule</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• Two 12-hr Shifts
• 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• Two 12-hr Shifts
• 32 Crew</td><td>• One 9-hr Shift
• One 6.5-hr Shift
• Two 12-hr Shifts
• 32 Crew</td><td>• Two 9-hr Shift
• Two 6.5-hr Shift
• Two 12-hr Shifts
• 30 Crew</td></tr>
<tr><td>Friday & Weekend Schedule</td><td>• Three 9-hr Shifts
• Three 6.5-hr Shifts
• 48 Crew</td><td>• Three 9-hr Shifts
• Three 6.5-hr Shifts
• 48 Crew</td><td>• Two 9-hr Shift
• Two 6.5-hr Shift
• Two 12-hr Shifts
• 48 Crew</td><td>• Two 9-hr Shift
• Two 6.5-hr Shift
• Three 12-hr Shifts
• 40 Crew</td></tr>
</table>

Due to providing the additional RT per day, crew shifts often will not fit into the traditional 8 hour day, which could create challenges for scheduling crews on a weekly basis if the goal is to achieve a 40 hour work week per crew person. This scheduling issue could result in less than 40 hour work weeks or alternatively a business decision by DRBA to grandfather in current employees and providing shoreside duties to each crew member to augment their schedule up to the typical 40 hour work week. If there is a crew scheduling benefit, the 12-hour shifts could be split into two separate approximately 6-hour shifts.

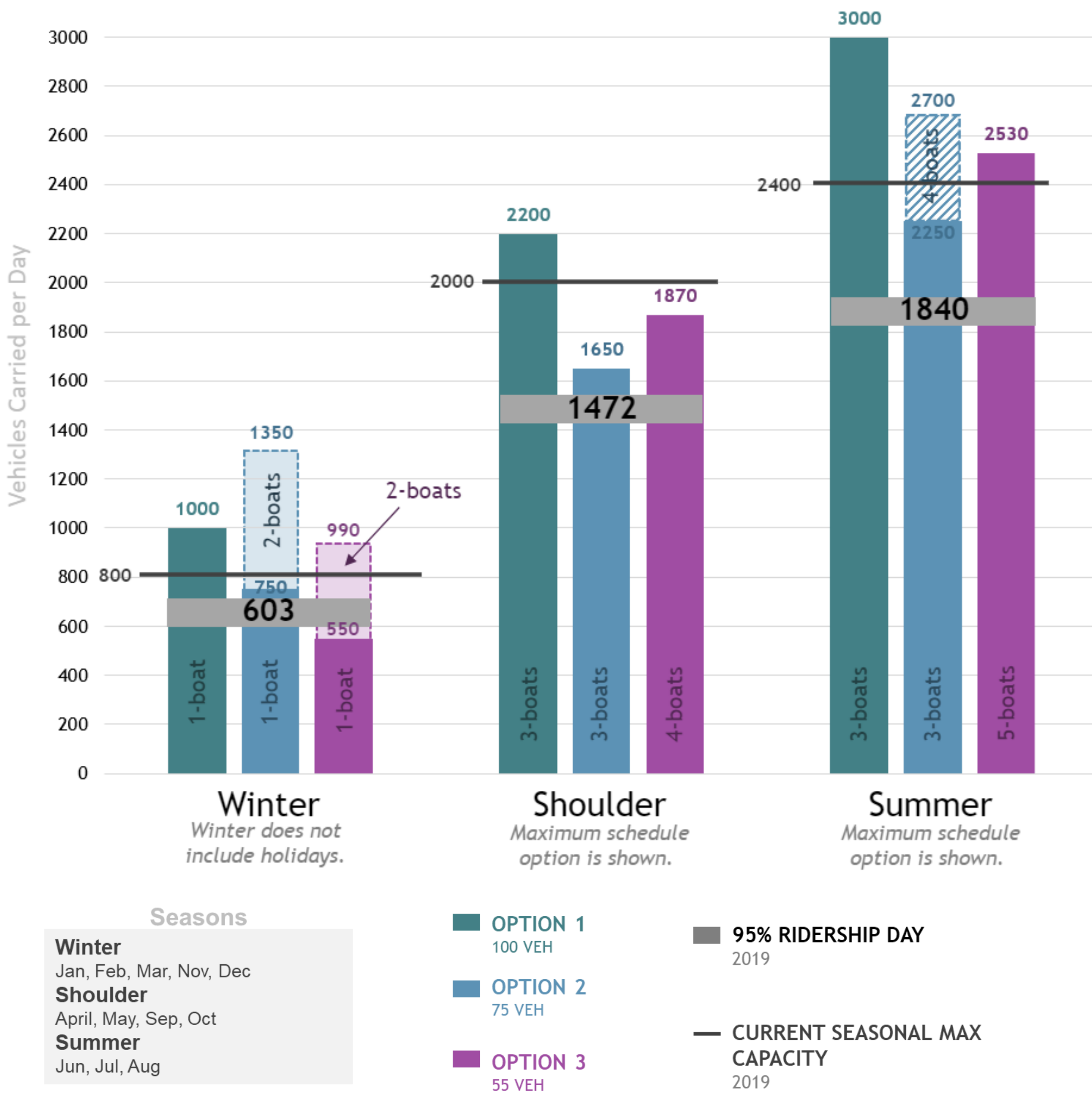
KEY FINDINGS

The developed crew and operating schedules were used to evaluate how well the various fleets met observed ridership demand, the flexibility and efficiency of each fleet, and how resilient the fleet options were to potential operational disruptions.

ABILITY TO MEET RIDERSHIP AND ACCOMMODATE SYSTEM GROWTH

Based on the schedules developed, all fleet options can meet the majority of the current vehicle ridership experienced by the CMLF fleet. A prime goal of the new fleet is to efficiently meet the CMLF system's ridership needs as they vary by season. Figure 8 summarizes fleet performance by season, with detailed seasonal findings included in the following sections.

Figure 8- Fleet Capacity vs 95th Percentile Ridership Day by Season



WINTER THROUGHPUT

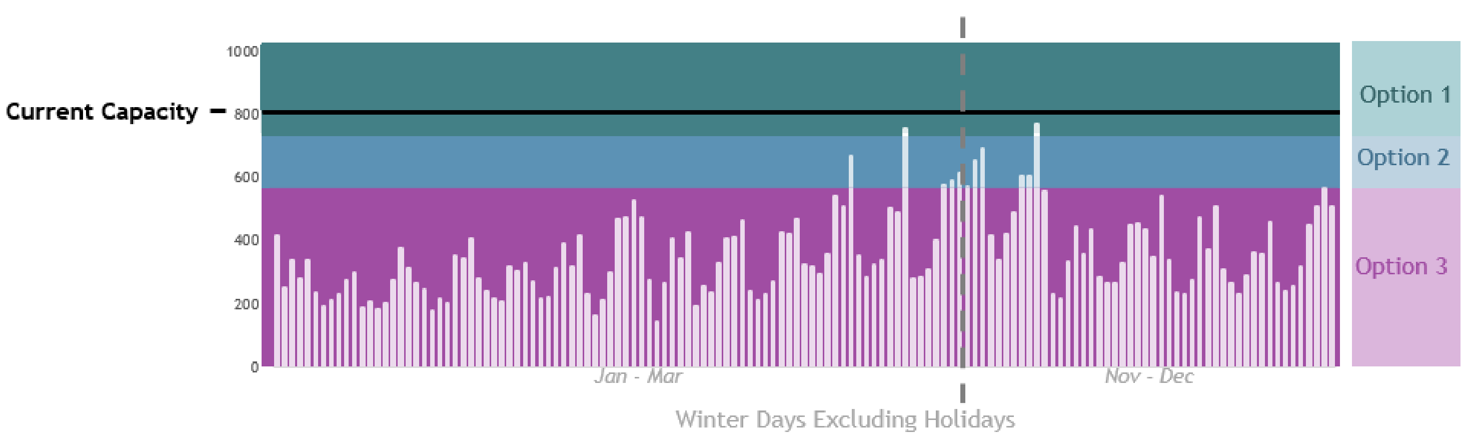
With the developed schedules all fleet options could meet all of the ridership that the CMLF experienced in Winter of 2019. Additionally, though two vessels would be need for Options 2 and 3 to achieve this, the *majority* of 2019 winter ridership could have been met with one vessel for all fleet options, with Option 1 providing the most vehicle throughput capacity overall. Figure 9 below summarizes the winter performance of fleet option and shows that Option 1 provides excess capacity.

Figure 9- Winter Performance

Fleet Option	Percent of 2019 winter ridership days met by 1 vessel	Number of days in winter 2019[1] where 2 vessels would be needed	Additional vehicle capacity provided over the maximum winter ridership day
1	100%	0	+233
2A/2B	99%	2	0
3	91%	13	0

It was observed that for Option 2a/2b and Option 3, the days where one vessel would be insufficient to meet demand were days on weekends and Fridays near the shoulder season. As a result, if one of the smaller vessels were selected for the future fleet, it would be possible to operate one vessel for all of the winter schedule and simply run the shoulder season schedule on weekends in late March and early November. The graph below shows the ridership on each Winter Day in 2019 for the CMLF fleet, with the colored boxes showing the amount of ridership that could be met by one vessel for each fleet option.

Figure 10- Winter Ridership Days 2019 vs Vehicle Capacity of One Vessel for Each Fleet Option



SHOULDER THROUGHPUT

With the developed schedules, all fleet options could meet the 95th percentile ridership level for the shoulder season. Options 2B and 3 provide more flexibility to meet variable shoulder season demand

[1] Not including holidays

than the current fleet and Options 1 and 2A. This is because Options 2B and 3 have more vessels in the fleet and thus, more ability to bring vessels into or out of service in alignment with demand.

SUMMER THROUGHPUT

With the developed schedules, all fleet options provide enough vehicle throughput to both meet and exceed the 95th percentile daily summer ridership level experienced by the CMLF service in the example ridership year. However, as the ridership analysis indicated that the peak period of summer demand was not experienced evenly across the summer day and was instead concentrated in a mid-day/early afternoon timeframe running between approximately 10am and 5pm. As a result, the performance of the fleets during this peak timeframe was also examined and compared to the current throughput of the fleet at this time. This analysis is summarized in Figure 11 below.

Figure 11- Summer Peak Throughput

Fleet Option	Number of Vessels	Number of One-Way Trips in Peak Window	Peak Throughput	Peak Throughput Compared to Current
Current	3	13	1300 vehicles	No change
1	3	16	1600 vehicles	+300 vehicles
2A	3	16	1200 vehicles	-100 vehicles
2B	4	22	1650 vehicles	+350 vehicles
3	5	28	1540 vehicles	+240 vehicles

Option 2B showed the greatest increase in throughput capacity, though all Options 1 and 3 also showed key increases. Additionally, it has been shown in other ferry systems that providing additional departure options in the same window of time can increase ridership due to customers appreciating the additional options and using additional choices to align with their travel needs. All fleet options have an increase in trip options during the peak window, but Option 3 has the greatest increase in trip options and thus the highest potential to attract new riders.

OPERATIONAL FLEXIBILITY

Due to the high variable in ridership demand experience by the service, the current CMLF fleet runs multiple schedule options to right size service to demand. Having additional vessels of smaller sizes provides greater flexibility in meeting demand, by allowing additional service to be added in smaller increments.

OPERATIONAL RESILIENCY

The current CMLF fleet has three vessels of the same size. As a result, during peak periods when all the vessels are in service, if one of the vessels goes out of service for an unexpected reason, a third of the overall fleet's capacity is lost which can be seen as a limitation on the fleet's ability to maintain service in the face on unexpected challenges.

Option 1 would have a similar level of resiliency, by having only 3 vessels as would Option 2A. However, Options 2B and 3 represent an increase in the overall fleet resiliency by having larger numbers of vessels. In the case of Option 2B, the loss of one vessel would result in a capacity loss of approximately 25%, while the loss of one vessel in Option 3 represents a capacity loss of 20%.

KEY OPERATIONAL FINDINGS BY FLEET

Option 1 with three 100-vehicle ferries is the most similar to the existing fleet, though it provides more daily throughput due to the increased service tempo. Of the new fleet options, Option 1 provides the greatest ridership capacity by service day and provides the second highest throughput capacity during the summer peak period (10am to 5pm). However, with only 3 large vessels, Option 1 has the least flexibility to meet low demand in winter and peak period.

Options 2A and 2B both meet the 95-percentile ridership day for all seasons. However, Option 2A represents a decrease in throughput capacity during the peak summer window while Option 2B represents the greatest *increase* in throughput capacity during that key window. As a result, Option 2B would be the option better equipped to handle any potential ridership growth. Additionally, as it has been modeled, Option 2B has the 4th boat only operating on the weekends in the summer. However, it could be run all summer, which could potentially increase ridership. However, doing so would also increase annual labor costs.

Option 3 has the highest flexibility and ability to right size the fleet to the varying seasonal ridership experienced. This is in part due to the five-vessel fleet providing the greatest number of vessels and thus, schedule options. One vessel in this fleet options was shown to meet most winter ridership with two vessels only needed on weekends in late March and early November. This fleet provides the greatest number of trip options in the peak summer window and the shoulder.

OPERATIONAL TRANSITION CONSIDERATIONS

In order to develop successful inputs for costing, this operational analysis focused on developing schedules and crew assumptions for each new fleet as they are envisioned to operate when all current DRBA vessels have been retired and all new vessels in the fleet are running. However, the transition to from the existing fleet to any of the new fleet options would take time and would have unique operating conditions that would vary from the conditions modeled in this analysis. In some cases, vessels of multiple sizes would be running simultaneously and scheduling would need to account for this. Furthermore, the transition period would vary depending upon which final fleet is selected. As a part of this work, some high-level transition considerations were identified and compared across the fleet options. These considerations include:

- Vessel Replacement Ratio/Phasing
- Operational Tempo and Scheduling
- Crewing Needs
- Training Needs

Following the completion of the DRBA Marine Master Plan, additional work could be undertaken to develop a transition plan that would outline the transition process for the selected fleet in further detail and could be used to guide implementation activities.

VESSEL REPLACEMENT RATIO/PHASING

Figure 12 represents the vessel replacement ratios that would be needed to maintain existing CMLF service levels.

Figure 12- Vessel Replacement Ratios

Option 1 100 VEH	**Option 2A** 75 VEH	**Option 2B** 75 VEH	**Option 3** 55 VEH
Retire 1 vessel, replace with 1 vessel	Retire 1 vessel, replace with 2 vessels	Retire 1 vessel, replace with 2 vessels	Retire 1 vessel, replace with 2 vessels

OPERATIONAL TEMPO AND SCHEDULING

All new fleet options modeled an increase in operating tempo and level of round trips. However, the transition scheduling would vary in complexity across the fleet options.

Due to replacing existing vessels with new vessels of the same vehicle capacity, Option 1 would represent the least disruption to operational tempo and schedule. During the transition, when operating alongside older vessels, the new vessels could run at a slower operating speed while still maintaining the existing schedule and level of provided service.

For fleet Option 2, two vessels are needed to replace the retirement of one existing vessel in order to maintain the existing level of service. As a result, effort will need to be undertaken to effectively schedule service, particularly in the summer, when both the old and new vessels are running on the same day.

For fleet Option 3, two vessels are also needed to replace the retirement of one existing vessel. As a result, effort will need to be undertaken to effectively schedule service, particularly in the summer, when both the old and new vessels are running on the same day. Scheduling effort will likely be higher for this option than Option 2, due to more vessels being purchased and a potentially longer transition period with more intermediate schedules needed.

Overall, Option 3 represents the greatest change in operational tempo for CMLF operations as a whole and during the fleet transition periods, with the most intermediate coordination needed, depending on timeline.

CREWING NEEDS

All options would require slightly different crewing needs than the existing fleet. Option 1 and Option 2, each require one fewer crew member to operate each vessel, and neither would require an unlimited tonnage license for crew members. As a result, a slightly smaller level of highly certified crew would be needed to support operations.

Option 3 requires the fewest crew members per vessel and the least certification, due to the vessels being classified in a different subchapter of United States Coast Guard requirements. During the transition period, it is likely that more crew may be on staff than are strictly needed, including those with higher pay rates and certification than may strictly be required due to vessel type. Gradual crew attrition will occur over time as fleet needs change. Running two different types of crews will create additional crew scheduling complexity and may present challenges when planning for relief during the times when new 55-vehicle vessels and old 100-vehicle vessels are both running in the schedule. It will need to be determined if crew will be scheduled in a way where staff operate on both vessel types of if crewing schedules will need to be separated by vessel type.

TRAINING NEEDS

Additional training will be needed as any new vessel comes online. However, additional levels of training will likely be necessary for vessels that are different from the existing vessels. As a result, training needs will likely be slightly higher for Option 2, due to the differing vessel size, and markedly higher for Option 3, due to the different vessel size and subchapter.

CONCLUSIONS

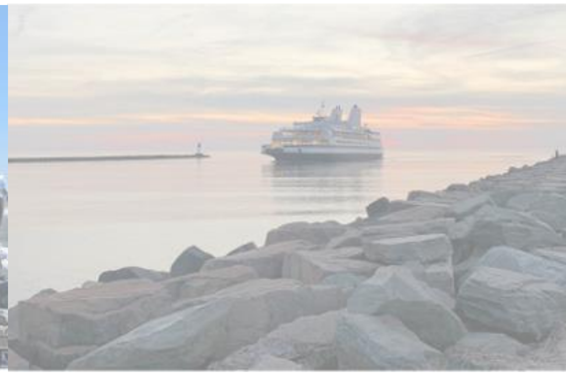
Per the analysis and modeled schedules, all fleet options can meet the 95th percentile ridership benchmark for all identified ridership seasons. Additionally, all fleet options can meet most of the CMLF winter ridership by operating just one vessel.

Option 1 provides the greatest overall throughput capacity and the least challenging operational transition. However, Option 1 represents the least operational and scheduling flexibility and the greatest risk and impact to level of service from a vessel casualty. On the other end of the spectrum Option 3 provides the greatest operational flexibility and ability to right size the fleet for winter service but involves the greatest change in operational tempo and thus faces the most challenges during the transition from the existing fleet to new fleet. Option 3 has the least amount of risk and impact to level of service from a vessel casualty.

Option 2B provides greater flexibility in comparison to the existing operation but provides less flexibility than Option 3. Option 2A faces challenges in providing adequate throughput capacity during the 10am to 5pm period where peak summer demand is observed. Option 2B has a slightly higher risk and level of service impact (25% capacity reduction) than option 3 from a vessel casualty (20% capacity reduction). Option 2A has a high risk and level of service impact from a vessel casualty (33% capacity reduction), but also carries with it an even higher impact to the overall system capacity, as it leaves the fleet with just 2 75 vehicles vessels operating (150 vehicles).

APPENDIX D

Phase 2 Task E – Major Cost Factor Analysis


2021 Marine Master Plan

Major Cost Factor Analysis

Prepared for: Delaware River and Bay Authority

Ref: Phase 2 – Task E: Major Cost Factor Analysis

February 1, 2023

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

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1. EXECUTIVE SUMMARY

The alternative vessel analysis identified three fleet configurations to study. Each fleet configuration has a different number of vessels with different capital, operational, and maintenance costs. The various costs were based on historic parametric data which was analyzed to determine which fleet configuration was the most cost-effective solution.

Since this report was prepared in March 2022, the U.S. shipbuilding industry has been adversely impacted by sharp increase in steel prices, an uncertain supply chain for critical equipment, and inflation of wages. Prices given below are indicative and should be assigned margins to account for uncertainties in cost trends.

2. INTRODUCTION

To determine the final vessel design for the CMLF system, it is necessary to know the initial capital investment, lifecycle costs and various cost factors for each option.

Three alternative fleet configurations are being analyzed. Option 1 is a three vessel 100-car system, option 2 is a four vessel 75 car system, and option 3 is a five vessel 55-car system. The lifecycle cost is over a 25-year time frame.

3. INITIAL CAPITAL INVESTMENT

If multiple vessels are built sequentially without delay between builds, Table 1 shows the assumed cost saving per vessel depending on the fleet size.

Table 1: Fleet Savings

VESSEL	COST % OF FIRST VESSEL
1	100%
2	100%
3	95%
4	90%
5	85%

The analysis uses cost data from EBDG's extensive library of vessel information for 12 vessels that are similar to the existing DRBA fleet and plots the vehicle capacity vs displacement and the displacement vs the cost. Trendlines are added to the graphs; these equations are then used to calculate the displacement of each fleet option and the estimated cost based on the estimated displacement.

Additionally, taken from the library of cost information are approximate percentages of the total cost for each SWBS category.

The capital costs for each option assuming diesel mechanical, single-ended vessels are shown in Table 2.

Table 2: Single-Ended Vessel Capital Cost

SWBS	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V
SWBS 000: PM and Admin	$6,946,808	$4,599,808	$2,722,987
SWBS 100: Hull	$21,152,792	$14,006,258	$8,291,401
SWBS 200: Propulsion	$8,292,565	$5,490,897	$3,250,492
SWBS 300: Electrical	$6,884,756	$4,558,721	$2,698,664
SWBS 400: Command, Control, and Communication	$4,178,543	$2,766,810	$1,637,892
SWBS 500: Auxiliary Systems	$14,302,801	$9,470,557	$5,606,364
SWBS 600: Outfit	$15,884,991	$10,518,199	$6,226,546
SWBS 800: Integration & Engineering	$6,822,008	$4,517,172	$2,674,068
SWBS 900: Shipyard Support Services	$4,774,737	$3,161,578	$1,871,585
Total For a Vessel	$89,240,000	$59,090,000	$34,980,000
Total For Fleet without Fleet Savings	$267,720,000	$236,360,000	$174,900,000
Total for Fleet with Fleet Savings	$263,258,000	$227,496,500	$164,406,000

The capital costs for each option assuming diesel mechanical, double-ended vessels are shown in Table 3.

Table 3: Double-Ended Vessel Capital Cost

SWBS	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V
SWBS 000: PM and Admin	$7,780,425	$5,151,785	$3,049,745
SWBS 100: Hull	$23,691,127	$15,687,009	$9,286,369
SWBS 200: Propulsion	$9,287,673	$6,149,805	$3,640,551
SWBS 300: Electrical	$7,710,927	$5,105,767	$3,022,504
SWBS 400: Command, Control, and Communication	$4,679,969	$3,098,827	$1,834,439
SWBS 500: Auxiliary Systems	$16,019,137	$10,607,024	$6,279,128
SWBS 600: Outfit	$17,791,190	$11,780,383	$6,973,732
SWBS 800: Integration & Engineering	$7,640,649	$5,059,233	$2,994,956
SWBS 900: Shipyard Support Services	$5,347,705	$3,540,967	$2,096,176
Total For a Vessel	$99,948,800	$66,180,800	$39,177,600
Total For Fleet without Fleet Savings	$299,846,400	$198,542,400 (3 Vessels) $264,723,200 (4 Vessels)	$195,888,000
Total for Fleet with Fleet Savings	$294,848,960	$195,233,360 (3 Vessels) $254,796,080 (4 Vessels)	$184,134,720

The values above are rough estimates. There are several decisions that CMLF must make that will affect the overall price of the vessel including determining if the vessel has a double-ended propulsion system or a single-ended propulsion system, as shown above. SWBS 200, 300, and 500 are greatly affected by the chosen type of propulsion system. For instance, an electric hybrid propulsion system can have a 2.3 cost factor for SWBS 200 and increase the overall vessel cost 15%. A propulsion study will be conducted during the vessel design to evaluate the different options.

The piping material can also greatly affect the SWBS 500 section. There are approved piping systems such as Chibro CuNiPress, Spears Marine OceanTUFF, Spears Marine EverTUFF and GF SeaCor that can be used in specific systems to greatly reduce the required shipyard labor for assembly and installation. Maintenance and repair for these systems is also easier and cheaper because welding is not required. During the design of the vessel, these alternative materials will be discussed and evaluated in further detail. See Appendix B for example cost comparisons that have been provided by W&O. There are additional features that can be added to the vessel to improve redundancy, and thus vessel availability for service, but they may increase the initial cost. These include three ship's service generators rather than two, two bow thrusters instead of one, and redundant pumps in cooling circuits. These options will be explored with the DRBA team in the preliminary design phase.

There are other trade-offs that have an initial high cost, but a much lower maintenance cost such as using stainless steel for handrails and Cu-Ni for seawater piping systems. A properly designed Cu-Ni system should last for 20 years or more and needs minimum maintenance to resist corrosion and biofouling whereas a steel system would probably need to be replaced in less than six years and must be protected from buildup of marine growth by a biofouling inhibition system [1]. Another option is to construct the superstructure of the vessel from aluminum instead of steel. This would save on maintenance and fuel costs due to a lighter structure. The lighter superstructure would also lower the vessels center of gravity which would increase the stability of the vessel. During the vessel design these options can be further explored to determine the if the higher cost offsets the lower maintenance.

Another factor that affects the overall cost of the vessel is classing (ABS or DNV) the vessels. There are advantages and disadvantages for classing the vessels, but overall, classing significantly increases both capital and operating costs with a rather small benefit.

4. 25 YEAR LIFECYCLE COSTS

EBDG modified the ferry lifecycle cost model developed by Volpe [2] to determine the 25-year lifecycle cost for each option. Given the required amount of funding for each vessel it is assumed that the vessels would not be built one after the other and fleet savings is not included. The cost model uses several general ferry operations data which are shown in Attachment A.

Table 4 shows the assumed vessel characteristics for service speed, round trip time and fuel consumption. The model assumed that options 1 and 2 would be certified under subchapter H with 8 crew members and option 3 would be certified under subchapter K with 5 crew members. The higher fuel consumption for the single-ended options is due to required increase in service speed to make up for the time spent turning around on one end of the route while keeping the dwell time the same as the double ended options.

Table 4: Vessel Data

VESSEL DATA	SINGLE-ENDED			DOUBLE-ENDED		
	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V
Stop Time (minutes)	22	16.5	12	22	20	17
Max Service Speed (kts)	19	18	17	17	16	15
Round Trip Time (min)	160	160	160	160	160	160
Fuel Consumption Round Trip (gal)	510	395	309	352	277	210
Crew requirement	8	8	5	8	8	5
Masters per Vessel	1	1	1	1	1	1
Mates per Vessel	1	1	1	1	1	1
Chief Engineers per Vessel	1	1	-	1	1	-
Able Body Seaman per Vessel	3	3	-	3	3	-
Ordinary Seaman	2	2	-	2	2	-
Deckhand	-	-	3	-	-	3
Est. Diesel Vessel Purchase Price	$89.2M	$59.1M	$35.0M	$100M	$66.2M	$39.2M
Est. Hybrid Vessel Purchase Price	$102.6M	$68M	$40.2M	$114.9M	$76.1M	$45.1M

The hourly operating costs per vessel are shown in Table 5. The fully loaded labor cost includes benefits and assumes the current 2021 wage rate. Due to less required licensing, Option 3 could have 15% lower labor cost. Fuel & Lubricant costs assume a diesel propulsion system and do not include diesel emission fluids that are required for Tier 4 engines. Diesel was used for the fuel due to information not being available at this time about the capacity and charging rate that the electrical utility can provide. The hourly maintenance cost is dependent on the vessel's length and based on the existing maintenance costs for the vessels. To estimate the hourly maintenance cost the existing yearly maintenance costs were divided by existing yearly vessel hours and the length of the vessel then were multiplied by the new vessel's length. The hourly P&I Insurance is based on the number of crew and was calculated using the 2020 P&I insurance cost.

Table 5: Vessel Hourly Operating Costs

	SINGLE-ENDED			DOUBLE-ENDED		
	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2 75V	OPTION 3 55V
Fully Loaded Labor Cost	$439	$439	$258	$439	$439	$258
Fuel & Lubricant Cost	$392	$304	$238	$271	$213	$162
Maintenance Cost	$259	$235	$209	$259	$235	$209
P&I Insurance Cost	$26	$26	$16	$26	$26	$16
Total Cost	$1,116	$1004	$721	$995	$913	$645

Table 6 shows the number of vessels needed for each season.

Table 6: # of Vessels Required

	SINGLE-ENDED			DOUBLE-ENDED			
	OPTION 1 100V	OPTION 2 (4F) 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2A (3F) 75V	OPTION 2B (4F) 75V	OPTION 3 55V
Summer Season, Weekend Hours	3	4	5	3	3	4	5
Summer Season, Weekday Hours	3	3	4	3	3	3	4
Shoulder Season, Weekend Hours	3	3	4	3	3	3	4
Shoulder Season, Weekday Hours	2	2	2	2	2	2	2
Winter Season, Weekend Hours	1	2	2	1	2	2	2
Winter Season, Weekend Hours	1	1	1	1	1	1	1

For most shipyard maintenance, percentages of the new vessel cost can be used to estimate the maintenance cost. These percentages are shown in Table 7.

Table 7: Shipyard Cost Percentage of New Vessel Cost

CATEGORY	PERCENTAGE (%)	Occurrence
Drydock and Minor Maintenance	1.25	Twice every 5 years
Engine Overhaul	1.25	Every 10 years
Complete Coatings	15	Every 10 years
Complete Passenger Space Refurbishment	20	Every 20 years
Repower	25	Every 25 years

Hybrid-diesel vessels will require the batteries to be replaced about every 7 years. With changes in technology, the cost of batteries has been decreasing and is estimated to continue decreasing. For this cost analysis it was assumed that batteries would cost $500/kW-hr for the first replacement, $400/kW-hr for the second and $300/kW-hr for the third.

Tables 9, Table 9, and Table 10 show what years of service it was assumed each category of shipyard maintenance would be completed for each vessel option during the first 25 years of operation for the fleet. Year 0 is the first year that the first vessel is in service. Repowering was not included in the 25-year lifecycle cost. Shipyard costs will significantly increase in year 26 for the repower.

Table 8: Vessel Option 1 (100V) & Vessel Option 2A (75V) Maintenance Completion Years

CATEGORY	Vessel #1	Vessel #2	Vessel #3
Drydock and Minor Maintenance	1, 4, 7, 10, 13, 16, 19, 22, 25	2, 5, 8, 11, 14, 17, 20, 23	3, 6, 9, 12, 15, 18, 21, 24
Engine Overhaul	10, 20	11, 21	12, 22
Complete Coatings	10, 20	11, 21	12, 22
Complete Passenger Space Refurbishment	19	20	21
Batteries	7, 13, 19	8, 14, 20	9, 15, 21

Table 9: Vessel Option 2B (75V) Maintenance Completion Years

CATEGORY	Vessel #1	Vessel #2	Vessel #3	Vessel #4
Drydock and Minor Maintenance	1, 4, 7, 10, 13, 16, 19, 22, 25	2, 5, 8, 11, 14, 17, 20, 23	2, 5, 8, 11, 14, 17, 20, 23	3, 6, 9, 12, 15, 18, 21, 24
Engine Overhaul	10, 20	11, 21	11, 21	12, 22
Complete Coatings	10, 20	11, 21	11, 21	12, 22
Complete Passenger Space Refurbishment	19	20	20	21
Batteries	7, 13, 19	8, 14, 20	8, 14, 20	9, 15, 21

Table 10: Vessel Option 3 (55V) Maintenance Completion Years

CATEGORY	Vessel #1	Vessel #2	Vessel #3	Vessel #4	Vessel #5
Drydock and Minor Maintenance	1, 4, 7, 10, 13, 16, 19, 22, 25	2, 5, 8, 11, 14, 17, 20, 23	2, 5, 8, 11, 14, 17, 20, 23	3, 6, 9, 12, 15, 18, 21, 24	3, 6, 9, 12, 15, 18, 21, 24
Engine Overhaul	10, 20	11, 21	11, 21	12, 22	12, 22
Complete Coatings	10, 20	11, 21	11, 21	12, 22	12, 22
Complete Passenger Space Refurbishment	19	20	20	21	21
Batteries	7, 13, 19	8, 14, 20	8, 14, 20	9, 15, 21	9, 15, 21

Table 11 shows a summary of the estimated lifecycle costs for the first 25 years of operation for a clean diesel propulsion system. Estimated cost for fleet assumes no fleet savings because it is unknown how much funding (grants, state, federal, etc.) will be available at the start o the project so it is unknown how many vessels will be able to be built in close succession to one another. Operating costs are labor, fuel and lubricants, hull insurance, P&I insurance, and routine maintenance excluding shipyard work. Hull insurance is assumed to be a percentage of the estimated value of the vessels using straight line depreciation with the salvage value after 25 years as 10% of the initial cost.

Table 11: Clean Diesel 25-Year Lifecycle Cost Summary

	SINGLE-ENDED			DOUBLE-ENDED			
	OPTION 1 100V	OPTION 2 (4F) 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2A (3F) 75V	OPTION 2A (4F) 75V	OPTION 3 55V
Number of Vessels	3	4	5	3	3	4	5
Service Speed (knots)	19	18	17	17	16	16	15
Estimated Cost Per Vessel	$89.2M	$59.1M	$35.0M	$100.0M	$66.2M	$66.2M	$39.2M
Estimated Cost for Fleet	$267.7M	$236.4M	$174.9M	$299.8M	$198.5M	$264.7M	$195.9M
Operating Costs	$295.9M	$288.5M	$250.8M	$268.3M	$253.8M	$266.2M	$227.6M
Total Capital (Shipyard) Costs	$168.4M	$148.5M	$109.7M	$188.7M	$124.9M	$166.3M	$122.9M
Total Cost	**$732.1M**	**$673.4M**	**$535.5M**	**$756.8M**	**$577.3M**	**$697.2M**	**$546.4M**

Table 12 shows the summary of the estimated lifecycle cost for the first 25 years of operation for a hybrid-diesel propulsion system. It has been assumed that the batteries would be charged at both terminals. Fuel costs were not modified to account for the hybrid operation since it is unknown at this time how much energy the electrical utility can provide. Fuel costs for the various propulsion systems will be further refined during the propulsion study.

Table 12: Hybrid-Diesel 25-Year Lifecycle Cost Summary

	SINGLE-ENDED			DOUBLE-ENDED			
	OPTION 1 100V	OPTION 2 (4F) 75V	OPTION 3 55V	OPTION 1 100V	OPTION 2A (3F) 75V	OPTION 2A (4F) 75V	OPTION 3 55V
Number of Vessels	3	4	5	3	3	4	5
Service Speed (knots)	19	18	17	17	16	16	15
Estimated Cost Per Vessel	$102.6M	$68.0M	$40.2M	$114.9M	$76.1M	$76.1M	$45.1M
Estimated Cost for Fleet	$307.9M	$271.8M	$201.1M	$344.8M	$228.3M	$304.4M	$225.3M
Operating Costs	$298.4M	$290.7M	$252.5M	$271.1M	$255.6M	$268.6M	$229.4M
Total Capital (Shipyard) Costs	$221.2M	$199.3M	$153.2M	$236.9M	$159.4M	$214.0M	$161.7M
Total Cost	**$827.5M**	**$761.8M**	**$606.8M**	**$852.8M**	**$643.4M**	**$787.0M**	**$616.4M**

Figure 1 shows a graph for the hybrid-diesel double ended option 3 with the estimated annual costs not including the initial cost of the vessels. See Table 10 above for the large capital (shipyard) costs in years 10, 11, 12, 20 and 21.

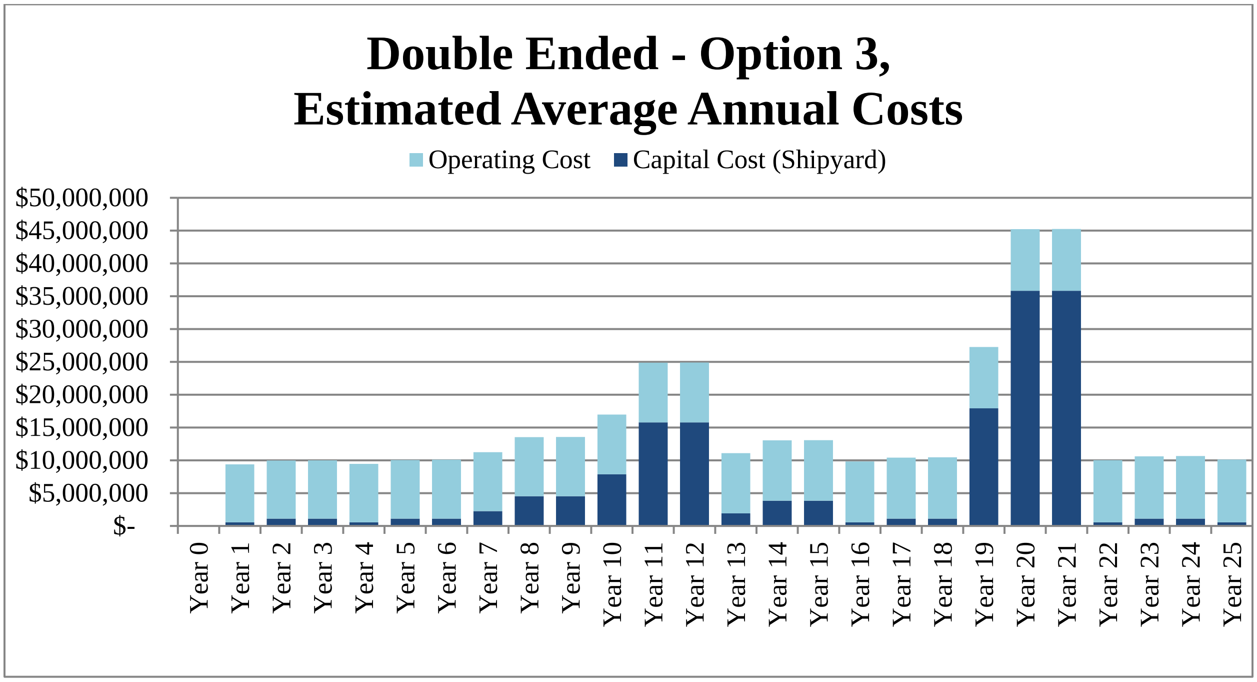


Figure 1: Double-Ended Option 3 Estimated Annual Costs

5. TERMINAL ALTERATION COSTS

At minimum, all fleet options will require some terminal modifications to support electrification which may include installation of a rapid charging system at the slip, battery storage and power management equipment upland, and new duct banks and electrical infrastructure. This work is expected to cost between $10 million and $20 million.

Both options 2 and 3 will require modifications to the mooring arrangement with the estimated cost for option 2 between $0.9 million and $1.3 million and option 3 between $3.6 million and $6.3 million.

Option 3 will require modifications to the slip 2 Cape May passenger tube. This work is expected to cost between $1.8 million and $4.2 million.

Therefore, the average terminal alteration costs for Option 1 is $15 million, Option 2 is $16.1 million, and Option 3 is $22.3 million. Further information on the terminal alteration costs have been included in the Phase 2 Task G write up.

6. FUNDING GATES

Throughout the process there will be opportunities for DRBA to validate the budgets and schedules. Cost estimates can be submitted at 30%, 60% and 90% completion and design drawings can be submitted at 60% and 90% completion for review/validation by DRBA. Any vendor quotes received to assist with the estimates can also be provided to DRBA. Final design documents will be submitted prior to the package going out for bid.

DRBA can request that bidders include a preliminary construction schedule with their bid to review while reviewing the bidder's price.

7. FUNDING SOURCES

One potential funding source is the US Department of Transportation Federal Administration (FTA) Passenger Ferry Grant Program. Further funding sources are shown in the Task H memo and additional sources can be researched during the design of the vessel.

8. REFERENCES

[1] Copper Development Association, "Application Data Sheet Copper-Nickel Piping for Offshore Platforms".

[2] Volpe, "U.S. Department of Transportation Volpe Center," December 2011. [Online]. Available: https://www.volpe.dot.gov/transportation-planning/public-lands/department-interior-bus-and-ferry-lifecycle-cost-modeling. [Accessed July 2021].

ATTACHMENT A

General Ferry Operation Data and Costs

Table 13: General Ferry Operation Data and Costs

Is this a new service, or will it be a new route added to an existing system?	Existing System	Labor Benefit Rate	53.4%
What is the estimated route distance in nautical miles?	28	Diesel Fuel Cost/Gallon	$1.97
How many stops will there be?	1	Annual Change in diesel cost/gallon	1%
Will the ferry transport vehicles?	Yes	Lubricant Cost/Gallon	$13.85
Summer Season: June 1-August 31		Is a spare vessel needed?	No
How many days in the summer season?	92		
How many days per week of peak demand	3		
How many days per week non-peak demand	4		
How many hours per day will the service operate during summer season?	13.33		
Shoulder Season: April 1-June 14 & Sept 11-Oct 31			
How many days in the shoulder season?	122		
How many days per week of peak demand	3		
How many days per week of non-peak demand	4		
How many hours per day will the service operate during shoulder season?	13.33		
Can spare vessels be used elsewhere during the shoulder season?	No		
Winter Season: November 1 – March 31			
How many days in the winter season?	151		
How many days per week of peak demand	2		
How many days per week of non-peak demand	5		
How many hours per day will the service operate during winter season?	13.33		
Can spare vessels be used elsewhere during the winter season?	No		

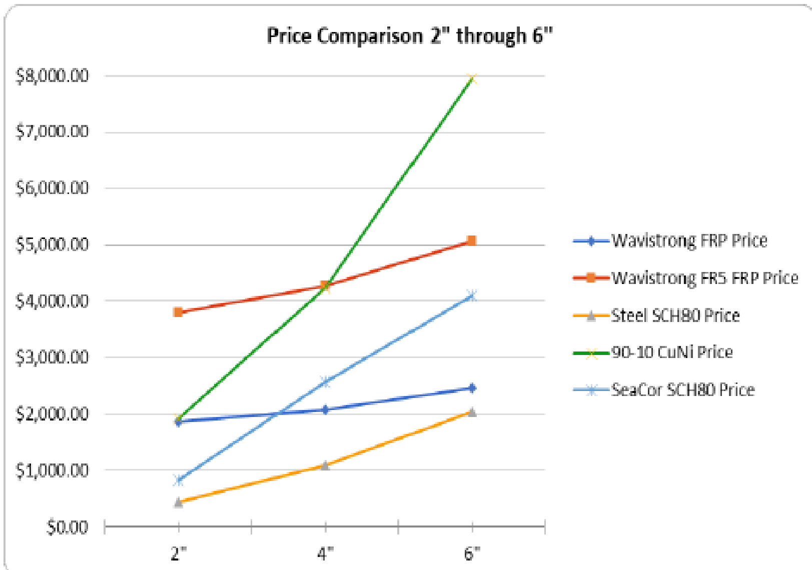
ATTACHMENT B

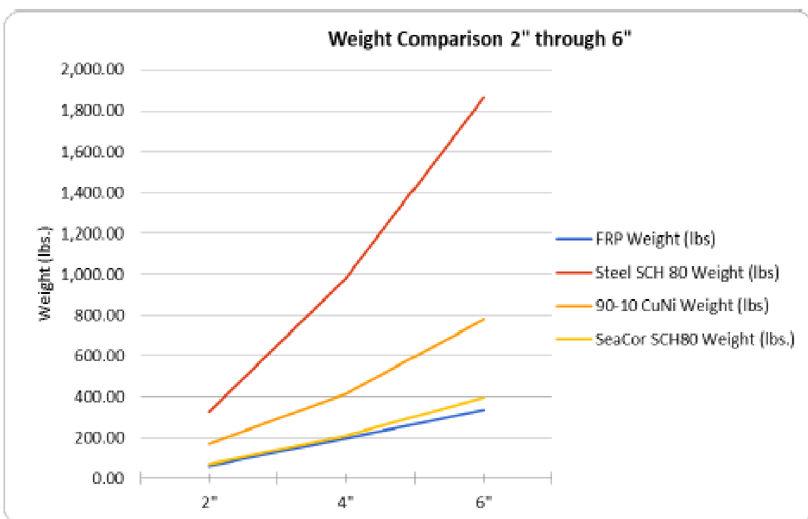
W&O Alternative Piping System Comparisons

Piping Material Cost and Weight Comparison

December 12, 2020

The graphs below compare various piping materials. These pipe segments consist of 60' of pipe, one tee, one elbow, and 4 flanges.





2877 Port Industrial Drive
Jacksonville, FL 32226
T. 904.354.3800
F. 904.354.5321
www.wosupply.com

SEACOR COMPARISON

POTABLE WATER SYSTEM

Installation Labor Comparision	**SeaCor Solvent Weld Man/Hours**	**Copper Press-fit Man/Hours**	**Steel/Stainless/Galv. Sch.40 Butt Weld Man/Hours**
Size	Installation Man/Hr	Installation Man/Hr	Installation Man/Hr
Pipe Per Foot			
3/4"	0.06	0.07	0.06
1"	0.06	0.07	0.08
1-1/4"	0.07	0.08	0.08
1-1/2"	0.07	0.08	0.1
2"	0.08	0.1	0.13
Couplings/Elbows/Bushings			
3/4"	0.12	0.16	0.84
1"	0.13	0.17	1.11
1-1/4"	0.15	0.21	1.39
1-1/2"	0.17	0.24	1.65
2"	0.19	0.28	2.2
Threaded Adaptors			
3/4"	0.17	0.11	0.44
1"	0.19	0.11	0.57
1-1/4"	0.21	0.13	0.71
1-1/2"	0.24	0.15	0.84
2"	0.26	0.17	1.11
Tee/Laterals			
3/4"	0.14	0.22	1.24
1"	0.15	0.17	1.65
1-1/4"	0.18	0.2	2.06
1-1/2"	0.2	0.34	2.47
2"	0.21	0.39	3.29
Flange 150# Socket/Slip-on			
3/4"	0.1	0.5	0.7
1"	0.11	0.5	0.85
1-1/4"	0.12	0.54	1
1-1/2"	0.13	0.55	1.12
2"	0.14	0.6	1.45
Man Hours Based on MCAA Labor Table			

SEAPRESS COMPARISON

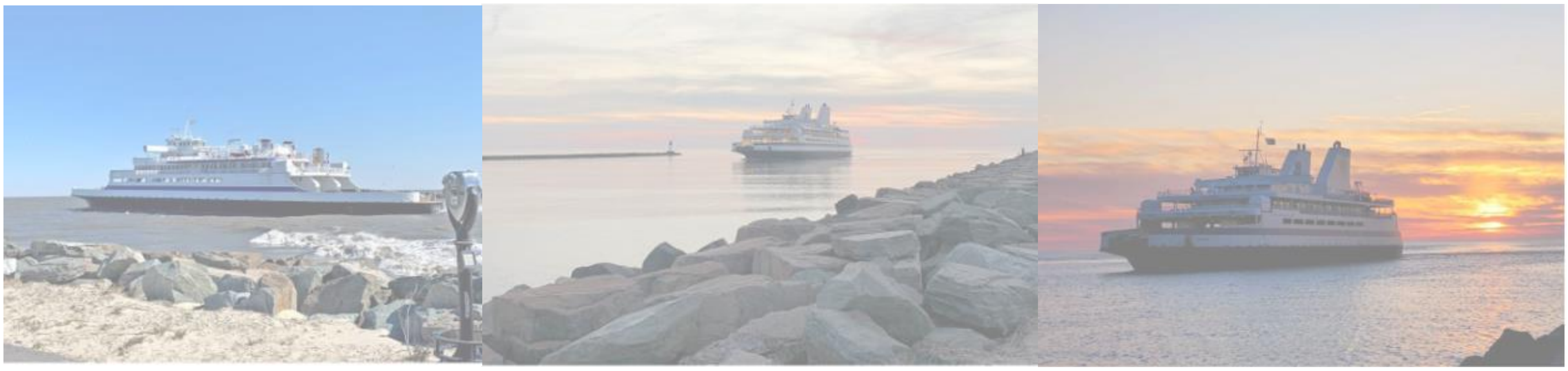
SEAWATER COOLING SYSTEM

		Brz. Silbraze		90/10 S/W		90/10 B/W		**SEAPRESS**	
Quant.	Type	Materials	Labor M/H	Materials	Labor M/H	Materials	Labor M/H	Materials	Labor M/H
10	1" 90's	$ 134.00	5	$ 262.00	5	$ 430.00	6.6	$129.50	0.4
5	1" Coupling	$ 16.25	2.5	$ 88.00	2.5	$ 45.00	3.3	$ 36.50	0.2
4	1" 45's	$ 18.20	2	$ 113.60	2	$ 82.00	2.64	$ 58.20	0.16
2	1" Tee's	$ 14.10	1.5	$ 85.00	1.5	$ 101.80	2	$ 34.70	0.12
2	1" Flanges	$ 48.00	0.5	$ 108.00	0.5	$ 108.00	0.66	$ 82.00	0.04
		$ 230.55	11.5	$ 656.60	11.5	$ 766.80	15.2	$340.90	**0.92**

Labor Based on Prep & Weld Time Only

APPENDIX E

Phase 2 Task F – Interaction with the Marine Environment



2021 Marine Master Plan

Interaction with Marine Environment

Prepared for: Delaware River and Bay Authority

Ref: Phase 2 – Task F: Interaction with Marine Environment

February 1, 2023

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

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1. PURPOSE

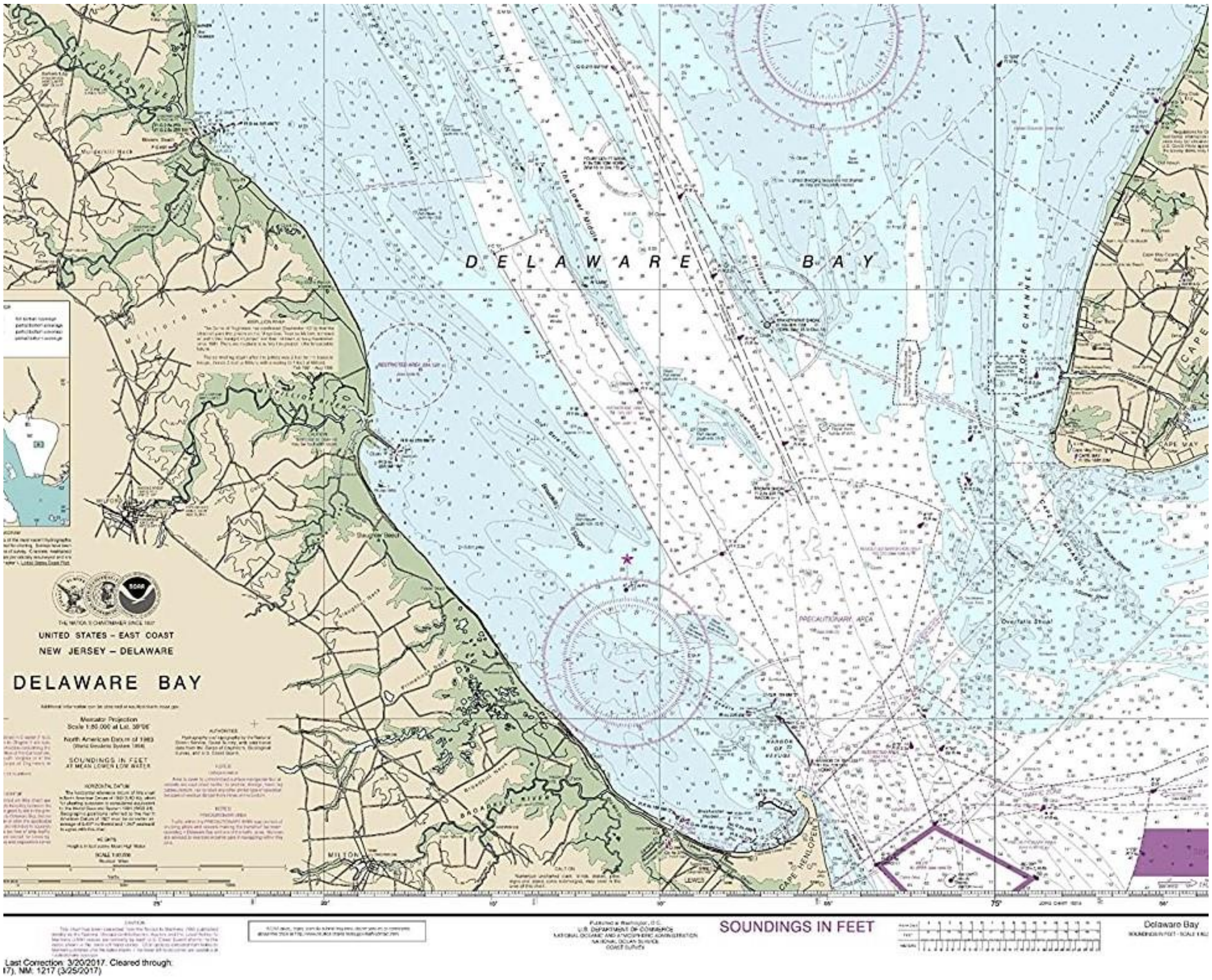


Figure 1: Lower Delaware Bay[1]

The mouth of the Delaware Bay is a unique operating environment. The ferry route running NE-SW is exposed to the swell of the Atlantic and subject to river and ice flowing from the Delaware River. Prevailing winter winds are out of the NW, opposing the swells entering from the Atlantic Ocean to the SE. Shallow water is a special challenge, with Crow Shoal on the New Jersey side of the crossing plus the limited harbor depths at both the Cape May and Lewes terminals. Finally, winter can bring ice events that can clog the terminal areas and make navigation across the bay extremely hazardous.

[1] From NOAA Chart 12304, copy for presentation purposes, not for navigation

The purpose of this task is to more completely identify the various parts of the marine environment that the CMLF vessels operate within, and discuss the vessel design features that affect, or are affected by, that environment.

2. ENVIRONMENTAL FACTORS

2.1. WATER DEPTH

As can be seen by the marine chart in Figure 1 above, there are considerable areas of shallow water where CMLF operates. One of the constraints identified in the original design mandate for the existing vessels was to keep the draft below 7'-6" to ensure that the vessels could traverse across Crow Shoal without dredging the shoal regularly[2]. Another challenge is the area in the vicinity of the Cape May terminal in the Cape May Canal, when the vessels back out and turn around. Draft limitations due to shallow water are still a primary vessel design factor.

2.2. WIND AND WAVES (SEA STATE)

Figure 2 below provides prevailing wind data for Delaware Bay in the vicinity of the CMLF route. Prevailing winds are offshore/down bay and stronger during the winter, and lighter, onshore during the summer months.

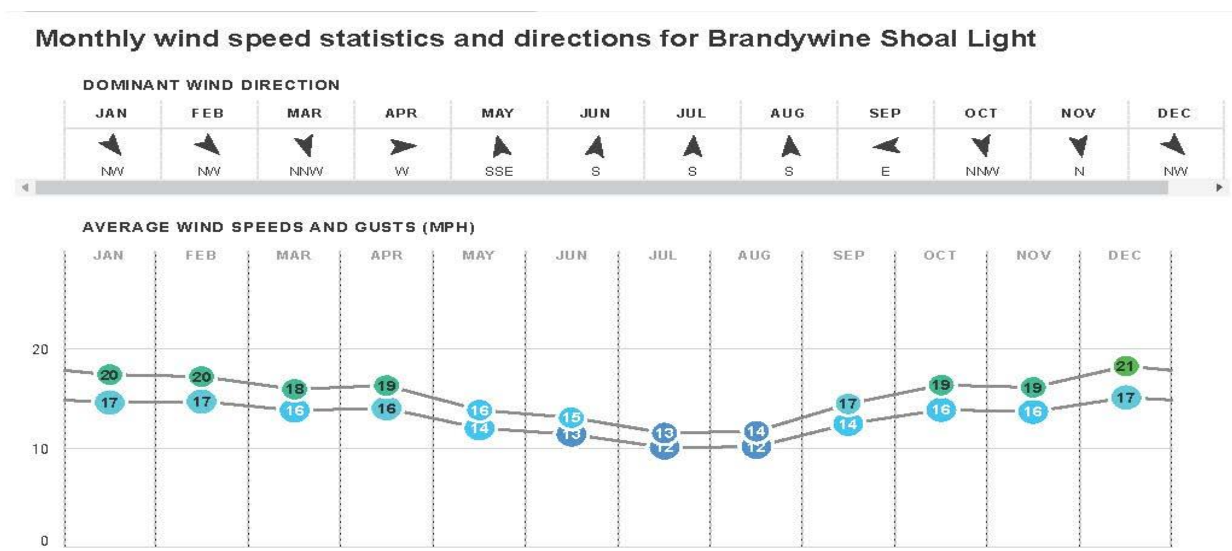


Figure 2: Wind data from Brandywine Shoal Light

Significant wave height history data for station 44009, a weather data buoy located 26 NM southeast of Cape May, are presented in Figure 3. The wave height data parallels the wind speed data, as expected,

[2] "Crossing the Delaware on the New Ferries", John C. Chivvis, Jr., SNAME Paper, Hampton Roads Section, April 18, 1975

with respect to energy content and time of year. While there are very infrequent larger sea states, the predominate significant wave heights range between 0.5 to 2.1 meters (1.6 to 7.0 feet), with an average of about 1.4 meters (4.6 feet) in the winter and just under one meter (3 feet) in the summer.

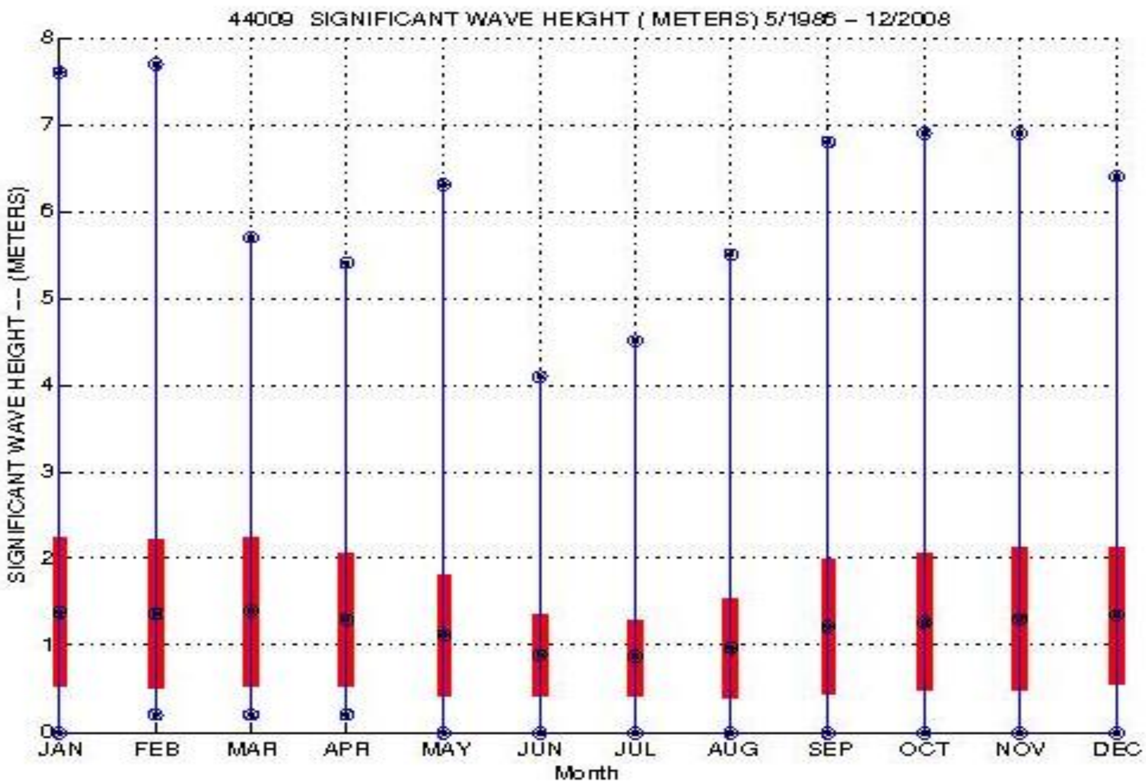


Figure 3: Significant Wave Historical Height Data, Mean and Standard Deviation Plot, Station 44009, 26NM SE of Cape May

Vessel motions due to transit through waves give rise to vertical accelerations that are a primary factor in motion discomfort (sea sickness). For a given sea state and the resulting forces causing motion, a heavier vessel will be more comfortable than a lighter one. And, a shorter vessel will tend to pitch more than a longer vessel, resulting in higher vertical accelerations at the vessel ends.

The anecdotal observation of the existing CMLF vessels is that their ride quality is generally good, with harsher motions in the winter due to encountering higher energy sea states, as expected.

2.3. ICE

Delaware Bay is effectively the terminus of the Delaware River and other smaller rivers in the area, joining up with the Atlantic Ocean between Cape May and Cape Henlopen. As such, much of the bay is a tidal mix of fresh and salt water, with fresh water on the surface. During winter cold periods the rivers will freeze along with portions of the bay surface water, resulting in large areas of floating brash ice, clogging up the terminal areas and making navigation hazardous. At times ferry service has had to be suspended for periods, most recently in 2018 for a few days. In 1977, ferry service was suspended due to ice conditions for over 45 days, basically all of January and half of February[3].

Since these conditions occur only in the depth of the CMLF off-season, shutting down for a short period in the winter is only a minor inconvenience to the ridership. Revenue impact is also minor, and idle vessel crews can be effectively used on winter maintenance tasks. As a result, there is little need to design and build a ferry that can act as its own icebreaker to continue service under all conditions. However, providing the vessel with some level of hull and propeller reinforcements is prudent, and if incorporated into the vessel design at the outset, will result in a negligible increase in capital expenditure.

American Bureau of Shipping's Steel Vessel Rules provide an Ice Class standard for vessels operating in first year ice (non-polar environments). To meet this standard, portions of the vessel's hull structure and propulsion equipment are strengthened in accordance with ABS requirements.

Figure 4: Satellite view of ice in Delaware Bay, January 2018

[3] *A Ferry Tale*, William J. Miller Jr., Delapeake Publishing Co., 1984

2.4. MARINE LIFE

Recently the USCG Captain of the Port, Delaware Bay, imposed a speed restriction on vessel traffic to protect North Atlantic Right Whales[4]. The restriction applies to all vessels 65 Ft. in length or greater in specified locations during certain times of the years along the US Atlantic seaboard, limiting vessel speed to 10 knots in these areas.

As this applies to the CMLF route, the restriction is in place from November 1 to April 30, and extends seaward of the boundary line or COLREGS lines for a 20-mile radius from the center point of the entrance to Delaware Bay.

The current CMLF route, at least on paper, is more than a mile or so inland of the Delaware Bay entrance except when taking the southern end of the Harbor of Refuge break wall, so in general this speed restriction would not apply to the vessels in normal operations. However, wind, other traffic, current and visibility issues may create situations where the vessel's route could perhaps drift into the restricted area for a short period of time. Unlikely, but this information is important for the vessel's captain and navigation crew to be aware of.

3. RECOMMENDATIONS

3.1. VESSEL DRAFT

To suit the shallow water restrictions found on the CMLF route, it is important to maintain the same maximum draft limit of 7'-6" on any new vessel used on the route.

3.2. VESSEL SIZE/DISPLACEMENT – MOTION CONSIDERATIONS

While the CMLF route is not an open ocean route, it is open water, with crossing times of over an hour. The existing size vessels provide reasonable ride quality over the route, with few cancellations in any season due to extreme weather. For the future, a vessel of similar weight/displacement as the existing will respond similarly to the existing vessels in a given sea state. This isn't to say that smaller or lighter vessels would be unsuitable, but ride motions and accelerations will be somewhat larger, and could result in more ride discomfort and perhaps a lower weather and sea state limit for operations. There are several ferry operators on the eastern seaboard that operate vessels of smaller size in all seasons, and CMLF operators taking a ride on some of these vessels is recommended.

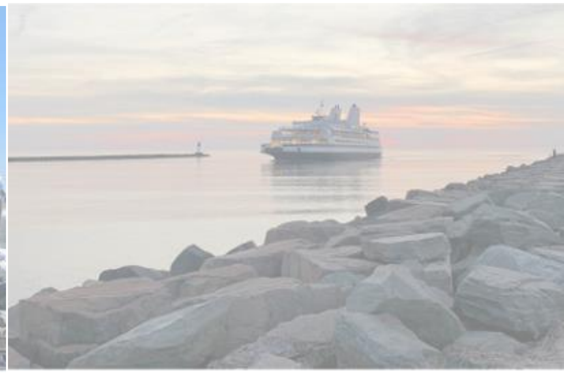
3.3. ABS SCANTLING MINIMUMS – ICE CLASSES

As was done for the existing vessels, the vessel scantlings should be designed to ABS minimums, with increased strength and plate thickness to suit Ice Class standards for vessels operating in ice. The lowest Ice Class requirement, designation E0, for vessels operating in very light first-year drift ice in coastal areas, is appropriate for the Delaware Bay environment.

[4] Marine Safety Information Bulletin 26-20, Oct 29, 2020

APPENDIX F

Phase 2 Task G – Port Fit Analysis


2021 Marine Master Plan

PORT FIT ANALYSIS

Prepared for: Delaware River and Bay Authority

Ref: Phase 2 – Task G: Port Fit Analysis

October 8, 2021

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

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INTRODUCTION

The 2021 Marine Master Plan effort is focused on the identification of the future fleet that will meet Cape May-Lewes Ferry (CMLF) needs into the future. A baseline assumption guiding this work is that any future vessel and its associated fleet of vessels will require minimal-to-no wharf or terminal alterations.

This assumption is in place to respect the investments made as called for in the 2016 CMLF terminal master planning efforts related to the overall visions for both ferry terminals. Following these efforts, significant capital investments were made at both the Cape May and Lewes terminals.

To understand the extent of terminal modifications that might be needed and to eliminate any fleet options that are incompatible with the existing terminal infrastructure, a port fit analysis was conducted. The first stage of this analysis was to identify the existing conditions and constraints of the current terminal operating and overnight mooring slips. These constraints were among the many factors used to narrow down the wide range of fleet configuration options to the three most promising options for more detailed study. Following identification of the top three fleet configurations, a second stage of the port fit analysis was conducted to evaluate how the three fleet options could be accommodated at the existing terminals. The second stage analysis focuses on the structural fit of the vessels with the existing terminal infrastructure and does not address any terminal modifications required to support alternative propulsion or ferry electrification. Future work will involve additional analysis on terminal electrification needs and specific infrastructure layouts and design.

EXISTING TERMINALS

The CMLF operates between two terminals, Cape May and Lewes. Up to three 100-vehicle vessels operate simultaneously during the peak summer season. Each terminal is briefly described below.

CAPE MAY

The existing Cape May terminal has two operating slips. The front of each slip includes a vehicle transfer ramp and wingwall fenders shaped to guide and hold the existing vessel in position during vehicle loading and unloading. All vehicles must be unloaded before vehicles begin loading for the next voyage.

Walk-on passengers can park at the terminal and queue within the terminal building. Passengers board the vessels via passenger tubes that connect directly to the vessel's passenger deck, allowing passengers and vehicles to be loaded and unloaded simultaneously.

In addition to operations, all vessel maintenance and overnight moorage is provided at the Cape May terminal. A large maintenance facility and storage warehouse are present onsite. One moorage slip includes a drive-on access ramp to support vessel maintenance activities.

Figure 1- Aerial View of the Cape May Terminal [Google Earth]

LEWES

The existing Lewes terminal is structured very similarly to the Cape May terminal. It also has two vessel operating slips with the same transfer span and wingwall fending configuration, again requiring all vehicles to disembark prior to vehicles boarding for the next sailing.

Walk-on passengers can park at the terminal and queue within the terminal building. They board the ferry using passenger loading tubes similar to those used at the Cape May terminal.

There are no maintenance or overnight mooring slips at the Lewes terminal.

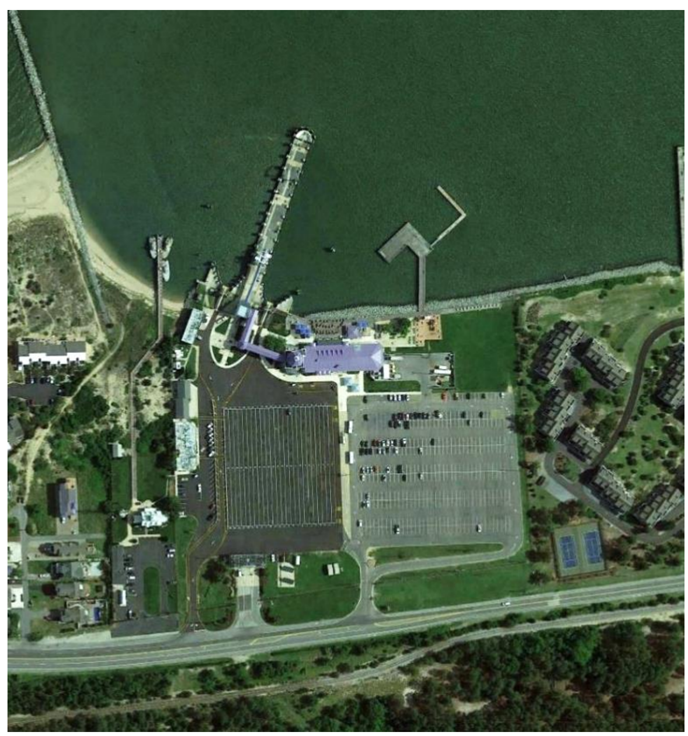


Figure 2 - Aerial View of the Lewes Terminal [Google Earth]

STAGE 1: EXISTING CONDITIONS AND CONSTRAINTS

METHODOLOGY

As the first stage of this analysis was focused on the operating and mooring slips at each terminal, a review of the terminal docking specs and current infrastructure was conducted. Data was collected regarding the shape and size of various terminal components. Following data collection, preliminary constraints were identified and example vessel footprints for the proposed fleet configurations were developed. These footprints were then added to the existing terminal plans to verify feasibility and identify additional constraints.

In parallel, the following fleet configuration options were developed and evaluated:

- **A. Optimized Current Fleet:** Three 100-vehicle ferries
- **B. Larger Vessel Fleet:** Two 150-vehicle ferries
- **C. Mid-size Fleet:** Four 75-vehicle ferries
- **D. Small Vessel Fleet:** Five 55-vehicle ferries
- **E. Mixed Size Fleet:** Two 100-vehicle ferries, two 55-vehicle ferries

ANALYSIS FINDINGS

The existing terminals have a few key constraints that control the size and shape of vessels that can operate and moor at the terminals without the need for significant and costly terminal alterations. The figure below summarizes the key constraints that were identified in the first stage of the Port Fit Analysis.

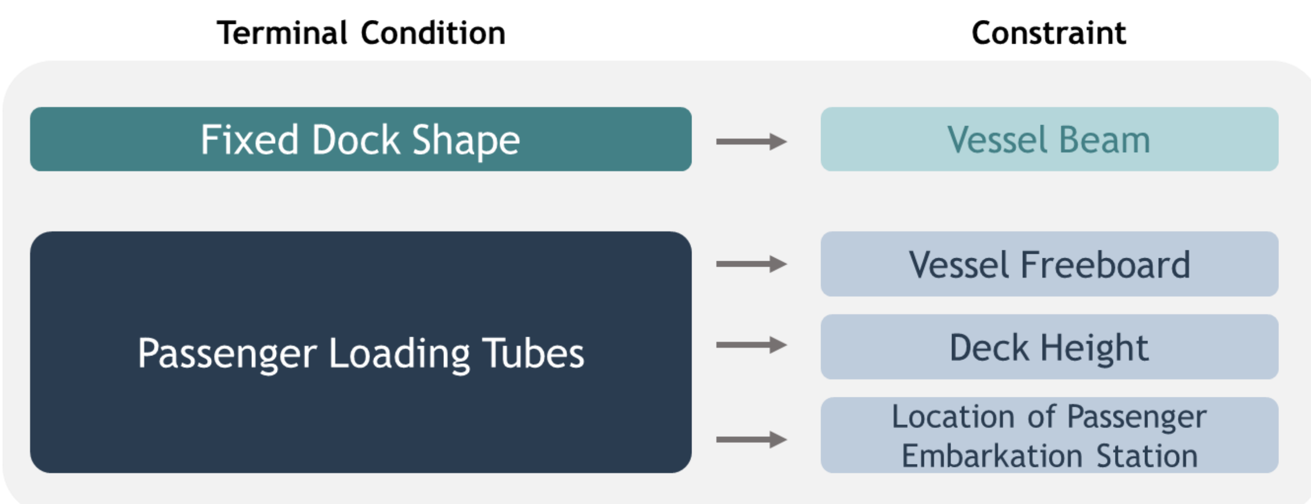


Figure 3 - Summary of Constraints Identified in the First Stage of Analysis

FIXED DOCK SHAPE

The vessel fendering and landing infrastructure is attached to a fixed concrete wharf which would be very difficult and expensive to modify to accommodate vessels with a different beam or bow configuration. The bow fenders and the associated support structure are shaped specifically to match the bow of the existing ferries and align the vessel with the vehicle loading ramp. All four operating slips have the same shape to simplify vessel operations. Due to this fixed shape, the shape of the ends of any new vessels will need to match that of the current fleet to avoid the need for costly modifications.

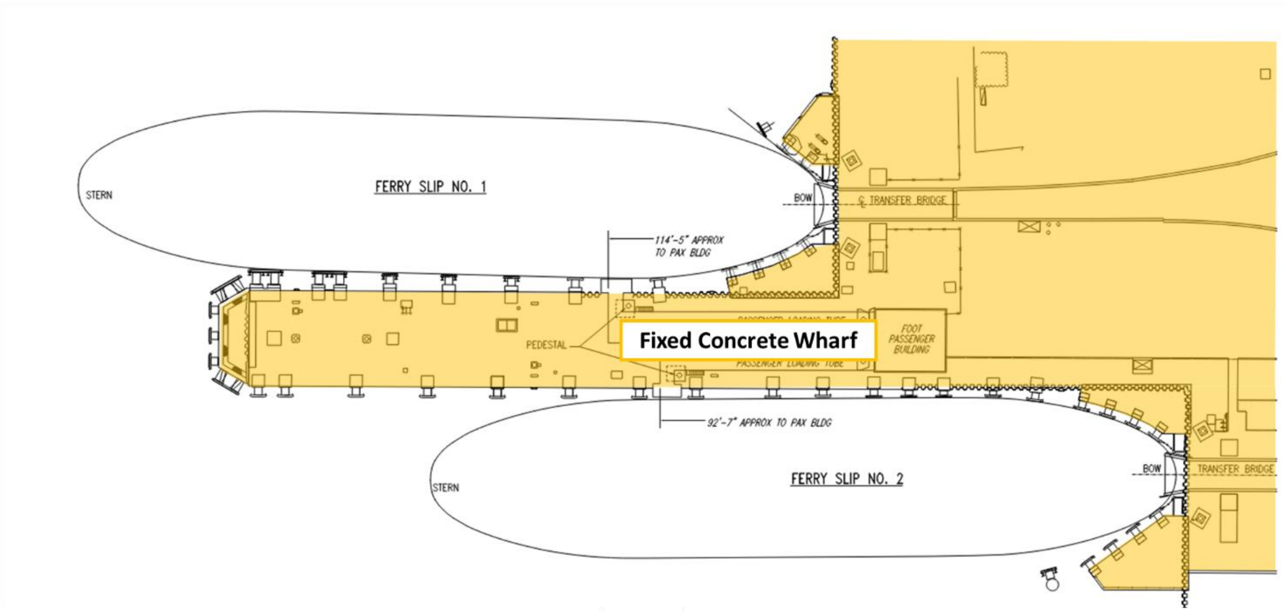


Figure 4- Current Dock Shape

Additionally, vessels with a narrower beam than the current vessels could be made to fit within the bow fender configuration, however the vessels would be misaligned with the centerline of the loading ramp, which could cause maneuvering challenges, particularly for larger vehicles embarking or disembarking from the vessel.

PASSENGER LOADING TUBES

The passenger loading tubes present at the existing terminals are a fixed length and operate with a fixed height range designed to serve the existing vessels throughout the normal range of tides.

Constraints to Vessel Freeboard

The fixed passenger loading tube height ranges differ for each terminal. At the Cape May terminal, the moveable end of the ramps can range in height from 5.42' to 22.42' while for the Lewes terminal this range is between 7.17' and 24.17' above the top of the pier. Though these ranges are large, any new vessels will need to have passenger decks within this range to avoid costly modifications.

Constraints to the Passenger Embarkation Station

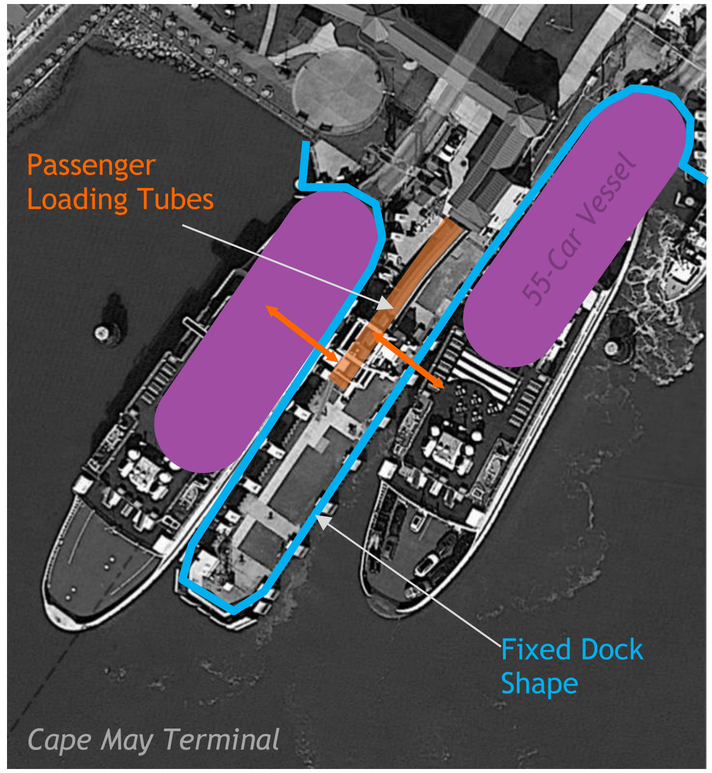


Figure 5- Passenger Loading Tube Challenges at the Cape May for Option 3 Vessels

The passenger tube serving Slip 2 at Cape May will need to be modified to accommodate the 55-vehicle ferries in Option 3, as the superstructure will be too short to reach the end of the loading tube. Figure 5 highlights this challenge. However, one slip operation at Cape May could accommodate the programmed operational tempo for 4 of the 5 vessels, with updates to the passenger tube being needed only upon the receipt of the fifth vessel. However, this would not allow for a second/back-up operating slip on the Cape May side if Slip 1were to be unusable. It would also be possible to have passengers load via the vehicle deck in Slip 2 until the passenger tube modifications are completed.

Constraints to Vessel Deck Height

To operate successfully, the vehicle deck of any new vessels would have to be low enough that the ramp structure would clear the passenger tubes at high tide. At low tide, the vehicle deck would need to be high enough that vehicles with long, low overhangs at either end don't bottom out when going from the vehicle deck up the ramp.

The fixed operational range was of particular concern when evaluating the two 150-vehicle fleet mix option. As the fixed dock limited possibility of adding additional vehicle lanes, a mezzanine deck would be required to support the desired vehicle capacity. Figures 6 and 7 below show the deck ranges possible to align with the passenger tubes and tidal ranges.

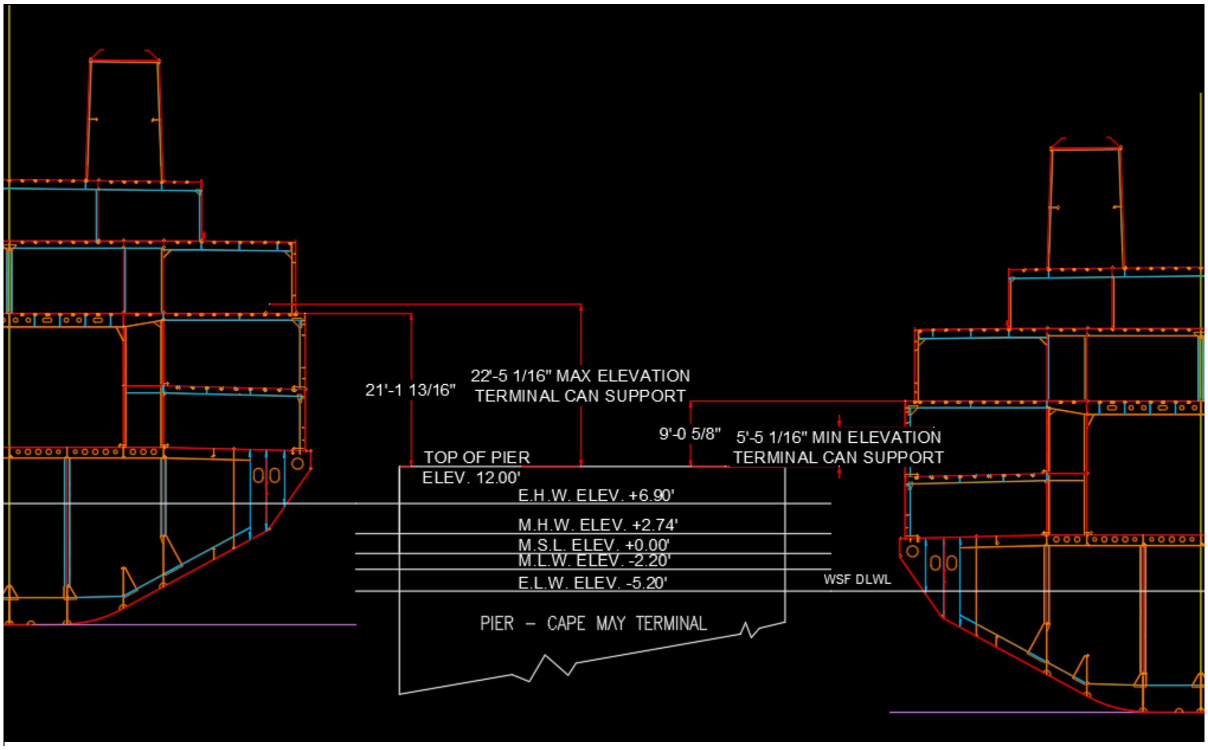


Figure 6- Deck Heights Feasible for the Cape May Terminal

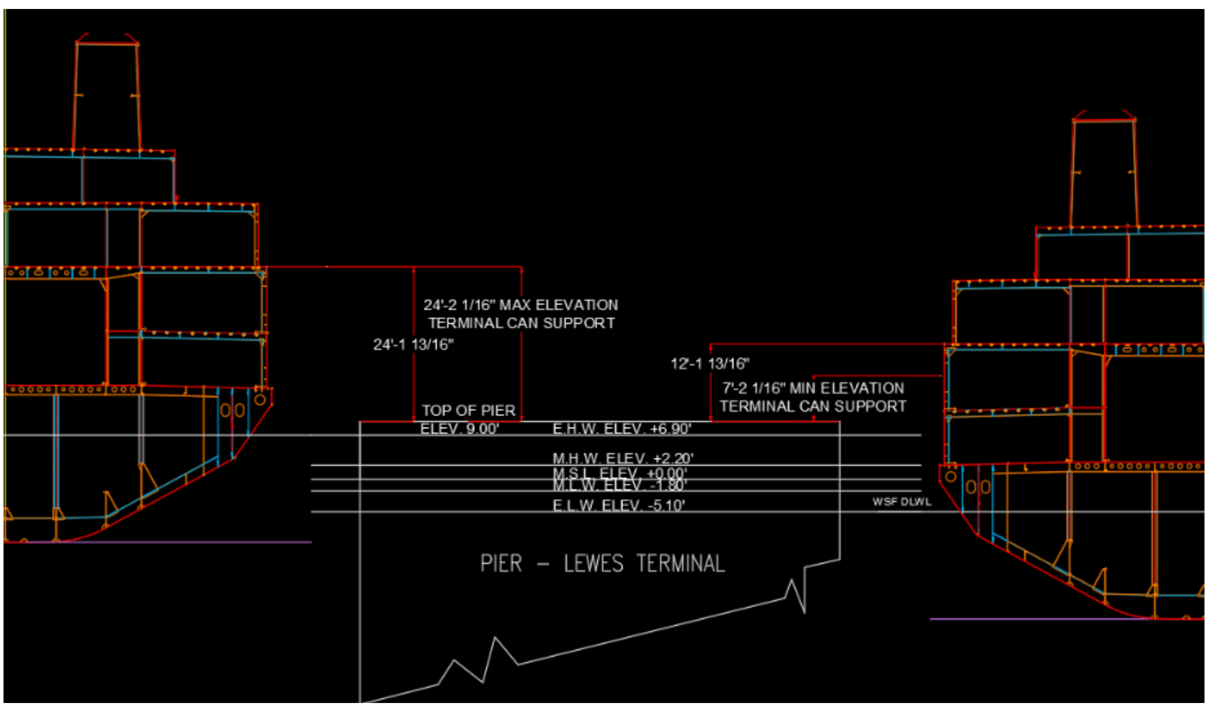


Figure 7- Deck Heights Feasible for the Lewes Terminal

STAGE 2: OVERNIGHT MOORAGE OPTIONS

STAGE 2 METHODOLOGY

Following the selection of the top 3 fleet configurations, the port fit analysis moved into its second stage. This stage focused on identifying a tie-up scheme for each fleet configuration and to determine the extent of capital investment that would be needed to moor the fleet overnight. Currently, CMLF has all vessels tie up at the Cape May terminal, and this will not change for the new fleet, as investments into creating secure tie up at the Lewes terminal could be expensive and will significantly change current operational patterns.

For all options, only one operating slip is used for overnight moorage to allow maintenance of vehicle ramps, passenger tubes, and other slip infrastructure.

STAGE 2 FINDINGS

The modifications needed to the terminal infrastructure at the Cape May terminal for each of the top three fleet configurations are discussed below.

OPTION 1: MOORAGE FOR 3 X 100 CAR CAPACITY FERRIES

This option can utilize existing mooring infrastructure to moor two vessels at maintenance slips. Additional upland maintenance facility improvements should not be necessary.

OPTION 2: MOORAGE FOR 4 X 75 CAR CAPACITY FERRIES

One new dolphin is required at Slip 3 to maintain alignment with the vehicle ramp. Environmental permits will be required for the addition of the dolphin, but the limited amount of in-water work should make the permitting fairly simple. If needed to mitigate environmental impacts, the most southeasterly dolphin at Slip 6 can also be removed.

A condition assessment will be needed at Slip 4 and Slip 5 to determine which can be made available more efficiently for the fourth vessel in this configuration.

Additional crew parking will likely be required during peak season when more total crew members are working (44 max in Option 2 vs current 42 max).

OPTION 3: 5 X 55 CAR CAPACITY FERRIES

To support the overnight moorage of all vessels in this fleet, additional dolphins will be needed at Slips 3, 4, 5, and 6 to provide sufficient mooring points for shorter ferries (half the length of the existing ferries). Due to the shorter vessel length, some existing dolphins will be unnecessary for moorage and can be removed to provide mitigation for the installation of the new dolphins.

Due to the amount of in-water work required in comparison to the other fleet options, permitting for this fleet will require a greater effort.

With two additional vessels in the fleet, more spare parts and supplies will be needed to maintain the fleet. An assessment of the current warehouse utilization is necessary to determine if any additional storage capacity at the Cape May terminal will be needed.

ELECTRIFICATION IMPROVEMENTS

All of the fleet options are assumed to include some terminal modifications to support electrification. Likely electrification improvements include installation of a rapid charging system at the slip, battery storage and power management equipment upland, and new duct banks and electrical infrastructure. Additional detail on potential electrification needs and improvements will be provided as the electrification analysis progresses in Phase 3.

COST OF IMPROVEMENTS

Assumptions for the costs of various terminal improvements are included below. These costs were informed by the costs of previous terminal improvement projects provided by DRBA and by other reference costs such as engineering estimates of similar terminal and electrification improvements. Table 1 represents the cost estimate for each improvement element, while Table 2 represents the final estimate used in the combined capital cost estimates.

- Terminal Electrification: $15M (+/- 25%). Electrification costs depend local utility charges to get power to the terminal and ferry power demands.
- Monopile Dolphin: $900K (+/- 25%). Includes the pile and fender superstructure fabrication and installation.[1]
- Passenger Tube: $3M (+/- 40%). Due to limited references for the specific construction activities needed for the passenger tubes, variation in cost could be more than is shown here.

Table 1- Range of Terminal Capital Costs by Fleet Option

	OPTION 1 100 VEH	**OPTION 2A** 75 VEH	**OPTION 2B** 75 VEH	**OPTION 3** 55 VEH
Electrification Improvements Cost	$10M - $20M	$10M - $20M	$10M - $20M	$10M - $20M
Dolphin Costs	$0	$0.9M - $1.3M	$0.9M - $1.3M	$3.6M - $6.3M
Passenger Tube Costs	$0	$0	$0	$1.8M - $4.2M
Total Estimated Terminal Improvement Costs	**$10M - $20M**	**$10.9M - $21.3M**	**$10.9M - $21.3M**	**$15.4M - $30.5M**

[1] The 2020 project (engineer's estimate $765K) reference for this work only included installation of the steel superstructure; fabrication would likely cost an additional $100K.

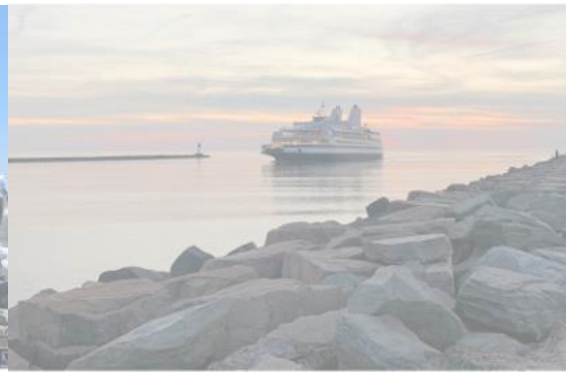
Table 2- Terminal Capital Cost Estimate by Fleet Option

	OPTION 1 100 VEH	OPTION 2A 75 VEH	OPTION 2B 75 VEH	OPTION 3 55 VEH
Electrification Improvements Cost	$15M	$15M	$15M	$15M
Dolphin Costs	$0	$1.1M	$1.1M	$4.3M
Passenger Tube Costs	$0	$0	$0	$3M
Total Estimated Terminal Improvement Costs	**$15M**	**$16.1M**	**$16.1M**	**$22.3M**

Option 3 represents the highest terminal improvements costs of any fleet option.

APPENDIX G

Phase 2 Task H – Identification of Federal State and Local Codes


2021 Marine Master Plan

Identification of Federal, State, and Local Codes

Prepared for: Delaware River and Bay Authority

Ref: Phase 2 – Task H: Identification of Federal, State, and Local Codes

February 1, 2023

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

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1. EXECUTIVE SUMMARY

Marine operations are governed by a wide range of regulations and codes. The new vessels for the Cape May – Lewes Ferry System (CMLF) will be under federal jurisdiction with the United States Coast Guard (USCG) as the primary authority, but also impacted by the American Bureau of Shipping (ABS), Convention on the International Regulations for Preventing Collisions at Sea (COLREGS), Environmental Protection Agency (EPA), American with Disabilities Act (ADA), the Center for Disease Control (CDC), U.S. Food and Drug Administration (FDA), Federal Communication Commission (FCC), and Institute of Electrical and Electronics Engineers (IEEE).

Modifications to the terminals will require compliance with applicable federal, state and local regulations and building codes. In-water work will require environmental permits and regulatory review.

2. INTRODUCTION

To design new vessels for the CMLF system, it is necessary to know what regulations and codes need to be complied with.

Three alternative fleet configurations are being analyzed. Option 1 is three vessel 100-car system, option 2 is a four vessel 75 car system, and option 3 is a five vessel 55-car system. Most regulations will equally apply to all three fleets, but some may not. Additional regulations related to the selected low-emissions propulsion technology may be applicable depending on the final propulsion option selected for the system. Any additional regulations of this kind will be identified and met as vessel design progresses.

3. USCG

All vessels will have to be designed to and comply with the United States Code of Federal Regulations (CFRs) title 33 and title 46. Specific sections in title 46 include Subchapter F, Subchapter G, Subchapter H or K, Subchapter J, Subchapter S, and Subchapter W. The crewing regulations described in Volume III of the Marine Safety Manual will also have to be complied with.

46 CFR Subchapter F- Marine Engineering covers many of the basics of shipbuilding including requirements for pressure vessels, piping systems, machinery, welding and brazing, system automation, and periodic tests and inspections. 46 CFR Subchapter G – Documentation and Measurement of Vessels covers the documentation the vessel requires and the admeasurement.

Fleet options 1 and 2 will be required to comply and be certified under 46 CFR Subchapter H – Passenger Vessels. Fleet option 3 will have to comply and be certified under 46 CFR Subchapter K – Small Passengers Carrying More than 150 passenger or with Overnight Accommodations for More than 49 Passengers. These two subchapters are very similar and cover the general construction and arrangement of the vessel, lifesaving equipment and arrangement, fire protection equipment, machinery installation, electrical installation, vessel control and operations.

All vessels will have to be designed to and comply with 46 CFR Subchapter J – Electrical Engineering, 46 CFR Subchapter S – Subdivision and Stability, and Subchapter W – Lifesaving Appliances and Arrangements.

To ensure compliance with all USCG regulations, the regulations will be regularly consulted during the design. USCG has a list of design documents that must be submitted and approved prior to the vessels being constructed. USCG will also inspect the vessel multiple times while it is being built to ensure regulations and construction standards are being met. Additionally, USCG has specific tests that are done during construction that they are required to witness in person.

4. ABS

The vessels can be designed to and comply with the ABS rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways, but it is not required. The ABS rules will impact everything from the hull construction to the firefighting equipment.

To ensure compliance with the ABS rules, the rules will be regularly consulted during the design. The relevant drawings will be submitted to ABS for approval prior to the vessels being constructed. ABS will also regularly inspect the vessels during construction to ensure their construction standards are being met. Similar to USCG, ABS has specific test that are done during construction that they are required to witness in person.

5. COLREGS

The vessels will be required to follow the regulations set forth in the COLREGS which specify the "rules of the road" or the navigation rules that must be followed by ships to prevent collisions.

6. EPA

The EPA has exhaust emission standards that control the amount of NO_X, SO_X, and particulate matter that can be emitted from marine vessels. The requirements apply to all compression-ignition engines which includes engines powered by natural gas or other gaseous fuels. The requirements vary based on the engine power. Depending on the final HP/kW rating the engines will be either tier 3 or tier 4. Tier 4 engines may require additional equipment for aftertreatment and the addition of urea tanks depending on the type of fuel to be used.

The vessels must comply with the EPA's Clean Water Act which regulates the discharge of pollutants into the water. This act prohibits the discharge of sewage overboard which will require the vessel to have a marine sanitation device (MSD) installed. This may be a sewage holding tank that stores the sewage until it can be discharged shore-side.

The vessels also must comply with the EPA's Vessel's Incidental Discharge Act (VIDA). VIDA establishes the framework for the regulation of discharges incidental to normal operation of a vessel under the Clean Water Act.

7. ADA

The terminals must comply with the ADA Standards for Transportation Facilities. These standards apply to facilities used by state and local governments to provide public transportation. The ADA standards cover many areas of vessel design including parking spaces, stairs, elevators, drinking fountains and toilets. Additionally, there are United States Access Board (USAB) Proposed Passenger Vessel Accessibility Guidelines (PVAG) that should be followed. The marine engineering firm designing the vessel will conduct due diligence to comply with the above standards, but an ADA inspection should be completed with the shipyard prior to outfitting the vessel.

8. CDC

CDC sets the standards for vessel sanitation with regard to potable water systems and food service equipment. With the ongoing pandemic and its unknown duration, it may be prudent to design the new vessel with "social distancing" guidelines in mind for the passenger spaces.

9. FDA

FDA's guidelines for food safety will need to be considered when designing the galley spaces and what equipment and safety protection will be needed for the proper preparation, storage, and display of food and beverages.

10. FCC

All radio equipment will be required to meet the FCC regulations.

11. IEEE

The IEEE Standard 45 will be used to select shipboard electrical and electronic system equipment and will dictate how the equipment is to be installed.

12. TERMINAL IMPROVEMENTS

Terminal improvements will require compliance with federal, state, and local regulations. Projects receiving federal funding through the Federal Transit Administration (FTA) or Federal Highway Administration (FHWA) for capital improvements require National Environmental Policy Act (NEPA) consultation and other federal permits due to the location of improvements in or over the water. Additionally, state and local jurisdictions have separate layers of environmental regulations for projects in or adjacent to the marine shoreline.

Local jurisdictions also administer specific shoreline regulations and building code requirements. The local building department will need to approve the structural design of any improvements before construction.

12.1. IN-WATER WORK

The Marine Master Plan proposes to minimize environmental impacts by using existing terminal infrastructure as much as possible. Terminal modifications required to accommodate the proposed vessel size include modifications at the Cape May terminal to the passenger tubes and relocation of some piles and dolphins. These improvements may require an Environmental Assessment (EA) or Environmental Impact Statement (EIS) through the NEPA process to determine the environmental impacts. Early coordination in the conceptual planning phase with the federal, state, and local agencies will help the design team understand specific environmental and mitigation requirements. During the conceptual design phase, environmental permitting requirements would identify potential environmental impacts and require impact mitigation elements.

The USACE regulates projects within or over navigable waters of the U.S. USACE reviews projects that require in-water or over-water work for consistency with Section 10 of the Rivers and Harbors Act. If a project only includes over-water improvements and would not require formal approval, USACE will make a jurisdictional determination that a permit is not required. This application process begins after initial design work is completed.

Additionally, the USCG requires review of projects that include placement of materials in the water that could impact navigation. Coordination with the USCG should occur after initial design is completed.

12.2. OVERWATER STRUCTURES

Overwater structures require compliance with various building code requirements, building permits, and ADA requirements. Modifications to the existing facility may require compliance with local zoning and jurisdictional requirements. Relevant codes, standards, and guidelines include:

- 2018 International Building Code (IBC), with amendments by the City of Cape May
- 2018 International Fire Code (IFC), with amendments by the City of Cape May
- ASCE 7-16, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers
- ACI 318-14, Building Code Requirements for Structural Concrete, American Concrete Institute
- AISC 360-16, Specification for Structural Steel Buildings, American Institute of Steel Construction
- AWS D1.1, Structural Welding Code - Steel, American Welding Society, 2015
- AWS D1.4, Structural Welding Code - Reinforcing Steel, American Welding Society, 2018
- 2020 National Electrical Code (NEC), with amendments by the City of Cape May
- 2010 ADA Standards for Accessible Design
- Occupational Safety and Health Administration Standards
    - General Industry (Part 1910)
    - Construction (Part 1926)
- AASHTO Green Book, current edition
- NJ Department of Environmental Quality
- United Facilities Criteria (UFC)
- ASCE 61-14, Seismic Design of Piers and Wharves

    - This code is not currently accepted for the design of structures intended for public use. An agreement with the City of Cape May should be reached prior to utilizing this code for structures intended for public use.
- PIANC Guidelines for the Design of Fenders Systems: 2002
- PIANC Port Facilities for Ferries: Practical Guide
- AASHTO Bridge Design Specifications, 7th Edition

U.S. Coast Guard Office of Design and Engineering Standards (CG-ENG)

12.3. BUILDINGS AND UPLAND STRUCTURES

Any modifications to buildings or other upland structures will need to comply with local building ordinances, which typically reference the following codes:

- 2018 International Building Code (IBC), with amendments by the City of Cape May
- 2018 International Fire Code (IFC), with amendments by the City of Cape May
- AISC 341-16, Seismic Provisions for Structural Steel Buildings, American Institute of Steel Construction
- 2018 International Mechanical Code (IMC), with amendments by the City of Cape May
- 2018 International Plumbing Code (IPC), with amendments by the City of Cape May
- ASCE 24-14, Flood Resistant Design and Construction, American Society of Civil Engineers

APPENDIX H

Phase 3 – Statement of Owner's Requirements

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Engineer:	Sarah Nichols, P.E. and John Petersen P.E.
Reference:	20075-070-1 Rev 2
Date:	May 1, 2023
Subject:	DRBA Replacement Ferry Statement of Owner Requirements

Following is a Statement of Owner Requirements (SOR) for the DRBA replacement ferry fleet vessel. These requirements are derived from project meetings with DRBA and outreach meetings with the public and DRBA crew members.

The vessel requirements are generally listed by system. Each requirement is ranked as "Minimum Threshold" or "Objective." "Minimum Threshold" requirements are those that define minimum requirements for the vessel. "Objective" requirements are those that are important to DRBA but may be compromised if it is expected that meeting them will add significant additional cost or complexity to the vessel.

We are at the beginning of a multi-year design process. This initial SOR is intended to contain higher level requirements not smaller details. It is a living document that will continue to be refined throughout the vessel design process.

The areas of owners' requirements that we will cover include:

- Regulatory/Vessel Class
- Vessel Performance
- Geometry
- Spaces and Vessel Arrangements
- Safety Considerations and Features
- Electrical System
- Mechanical/Machinery
- Piping System
- Structural

REGULATORY/CLASS

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
1	US Regulations	46 CFR Subchapter H	X	
2	Classification	ABS		X
3	SOLAS	Not a SOLAS Vessel	X	
4	Specifications	UWILD compliant		X
5	Tonnage	< 1,600 tons gross	X	
6	MARSEC	Meet DRBA Security Requirements	X	
7	Accessibility	ADA compliant components (walkways, etc.)	X	

PERFORMANCE

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
8	Vehicle Payload	Maximize vehicle linear square footage available for vehicles in consideration of hull form, propulsion arrangement, and stability without triggering additional regulations or impeding other SOR criteria. Use 18' for standard automobile weight and dimensions (refer to National Highway Association standards and current vehicle mix.		X
9	Vehicle Capacity	75		X
10	Total Passengers Onboard	≤ 400		X
11	Fuel Capacity	3 days of summer operation		X
12	Fuel Capacity	5 days of summer operation		X
13	Speed	Transit Speed: 18 knots		X
14	Crossing Time	Departure to departure should be ≤ 85 min	X	
15	Maneuvering	Desired improvement over current vessels. More horsepower, better ratio of tonnage / propulsion, larger bow thruster w/follow up control	X	
16	Route	Ferry service between Cape May, NJ and Lewes, DE	X	
17	Design Life	40 years	X	
18	Ice Classification	To be determined		

GEOMETRY

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
19	Hull	Single Ended	X	
20	Hull Shape	Bow and stern to fit with existing port facilities	X	
21	Design	Ability to use existing port infrastructure with minimal modifications	X	
22	Length, Overall	< 320'	X	
23	Beam, Overall	68' Compatible with existing terminals	X	
24	Max Draft	< 7' @ full load	X	
25	Freeboard	Determined by seakeeping, existing infrastructure and compliance with local ADA, high and low tides, and ferry load capacity	X	
26	Service Life Margin	3% of design lightship	X	
27	Decks	All exterior decks cambered	X	
28	Ballast	Permanent, if needed		X

ARRANGEMENTS

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
29	Hold	Lifting eyes and rail for main machinery removal		X
30	Hold	Soft patches with drains for main machinery removal		X
31	Hold	Access to all sides of major machinery		X
32	Hold	Maximize overhead clearance in Engine Room		X
33	Hold	Inclined ladder to access Engine Room compliant with USCG requirements	X	
34	Tanks	Keep fuel tanks below deck (off main deck and bottom)		X
35	Vehicle Deck	Pipe curbing at perimeter of vehicle lanes		X
36	Vehicle Deck	Elevator to all Passenger Deck(s)		X
37	Vehicle Deck	Bicycle Storage (50-60+)		X
38	Not Used			
39	Vehicle Deck	Minimum overhead height is 14’ 6”, would like to see 15' in center portion.	X	
40	Fills and Pump Off Locations	Fills: fuel, oil, and potable water in centralized bunkering station Discharge: sanitary, bilge, waste oil grouped together in one location on both ends of the vessel.		X

41	International Shore Connection (Firefighting)	Meet regulatory requirements (located on the stbd fwd and stbd aft of the vessel)	*X*	
42	Crew Space	Provide space for crew with lockers & restroom. Solid surface floors (no carpet). Lockers big enough for backpacks.	X	
43	Crew Space	Provide space for coffee, sink, couch, television, and table. Ability to access squad locker directly from crew space.		X
44	EOS	Accommodate 4 crew minimum with table and booth seating, enclose ship service switchboard.		X
45	EOS	Soundproof to a higher level than current. Window to look out into engine room.		X
46	EOS	Automation and controls to allow starting / stopping equipment from EOS booth and answer all alarms from booth		X
47	EOS	Cell phone booster in engine room to allow communications below deck.	X	
48	Galley	Galley space for food service, bar space, large windows on bulkheads designed for efficiency	X	
49	Galley	Have food prepared onboard		X
50	Passenger Spaces	Maintain current proportion of indoor and outdoor seats. Include more covered exterior seating some with shade/awnings. Awnings can be retractable with manual operation. Provide options for seating experience including groups of people. Include tables.		X
51	Passenger Spaces	Two decks with seating for passengers with both decks having exterior seating available.		X
52	Passenger Spaces	Clear 3' walkway end-to-end (ADA)	*X*	
53	Passenger Space	Onboard entertainment and information options similar to airlines		X
54	Passenger Space	Similarly-sized to current crow's nest for events. Include AC, bar space/lounge		X
55	Passenger Heads	Men's, women's, and ADA grouped together on each passenger deck		X
56	Passenger Heads	Stainless steel bathrooms, easy clean, hose down (classy prison) If dedicated police space not provided, design handicapped stall to be used as passenger holding space by security.		X

57	Passenger Heads	Minimum of one ADA family restroom	X	
58	Deck Lockers	Minimum of 2 on each deck (one each end)		X
59	Cleaning Gear Locker	On all decks near heads		X
60	Weather Decks	Provide passenger access to all weather decks		X
61	Weather Decks	Outdoor food/beverage area (spaces for families to sit together). Include bar & seating & weather protection. Bar area able to be secured when not in use.		X
62	Weather Decks	Outdoor space for events		X
63	Pilothouse	Sliding windows on sides		X
64	Pilothouse	Eyebrow around perimeter		X
65	Pilothouse	Restroom	X	
66	Pilothouse	Separate chartroom		X
67	Pilothouse	Interior Access		X
68	Pilothouse	inside access from crew room to wheelhouse		X
69	Pilothouse	Angled outward windows on all sides, include tinting and UV blocking		X
70	Pilothouse	Wipers on front windows	X	
71	Pilothouse	All windows heated	*X*	
72	Pilothouse	Bridge Wings, port and starboard enclosed		X
73	Stacks	Location of exhaust stacks to be placed to minimize visibility impacts		X
74	Handrails	Teak Handrails		X
75	Police Area	Dedicated police space for temporary prisoner detention and larger secure weapon storage.		X
76	Electrical outlets	Outlets needed on all decks, including car deck. More outlets than currently provided on vessels.		X

SAFETY

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
77	Life Jackets	Life jackets for adults and children, as required by USCG regulation. Store under seats in cabin and in a limited number of life jacket boxes.	X	
78	MES	at least minimum # of MESs as required by regulatory	X	
79	Lifeboats/Rescue Boats	2 lifeboats or rescue boats with good turn of speed; not fast rescue boats per USCG definition. Including winch for each boat.	X	

80	Fire Suppression	Appropriate suppression system supplied in Engine Rooms and other required spaces.	X	
81	Fire Suppression	High pressure water mist or Ultra Fog fire protection system, No CO_2		X
82	CCTV	CCTV system with onboard storage		X
83	CCTV	Camera locations: access points, machinery spaces, stairwells, passenger areas, crew areas, vehicle deck		X
84	A/V	flatscreen TVs spaced throughout enclosed passenger area for announcements, control from crew-only area		X
85	A/V	Vessel-wide PA system w/ability to play recorded message	X	
86	Noise and Vibration	Controls for noise and vibration – crew, passengers, and animals		X
87	Human Interaction	Consult with Human Factors Engineer/Ergonomist		X
88	Security	Doors that can be secured should be as secured as possible, via key cards or electric doors		X
89	Security	Meet DHS (Department of Homeland Security) previous recommendations and best practices.		X
90	Security	Crew only staircase for secure movement path		X

ELECTRICAL

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
91	AC Electricity	480V, 3 phase	X	
92	DC Electricity	12V, 24V	X	
93	Number of Main Gensets	Extra generator to be able to keep vessel underway in case of generator failure		X
94	Number of Emergency Gensets	1	X	
95	Emergency Gensets	Same make, model as main gensets		X
96	Shore Power Connection	Ensure compatibility with existing infrastructure	X	
97	Car Deck Electrical	Trailer outlets, outlets for events		X
98	Switchboard	Paralleling ship service switchboard	X	
99	Wireways	Wireways and bulkhead penetrations to have 30% additional space for future modifications		X
100	Electronics	Pilothouse instruments on common dimmer circuit		X

101	Lighting	All LED lights		X
102	Lighting	Red lights in Pilothouse for night navigation	X	
103	Lighting	Overhead vehicle deck and vessel perimeter lighting for lighting when passengers are on deck at night	X	
104	Lighting	Remotely operated spotlights for each end	X	
105	Lighting	Gooseneck spotlights in pilothouse		X
106	Outlets	crew spaces, 20A 120V each voids, 20A 120V each passenger areas, 20A 120V each w/USB helm, 120V/USB power outlets		X
107	Power	Power from electric grid, solar, and DRBA windmill		X
108	Power	Combine with backup power supplies for facilities		X
109	Alternative Green Power	Alternate green power on vessels to allow energy mix		X

MECHANICAL/MACHINERY

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
110	Main Machinery	EPA Tier 3 (if under 800hp)	X	
111	Main Machinery	EPA Tier 4 (required if above 800hp engines)	X	
112	Main Machinery	Resilient mounts for all combustion engines and reciprocating equipment	X	
113	Main Machinery	Critical grade, spark arresting silencers on all engines	X	
114	Main Machinery	Have one engine/ electric generator with electric start and the rest of the system on air start		X
115	Main Machinery	All major equipment on skids with ability to lift out and change with package spares		X
116	Propulsion	Diesel battery hybrid propulsion configuration. Final selection based on propulsion study results		X
117	Propulsion	Battery room sized for all-electric battery footprint, including required fire suppression system		X
118	Propulsion	Motor/generator capacity enough for all-electric operation		X
119	Propulsion	Weight / space allocation for shore charging (if necessary)		X

120	Propulsion	Arrangement based on propulsion study results and DRBA input		X
121	Propellers material	NiAlBr		X
122	Thrusters	(2) electric bow thrusters, VFD control, stronger than existing.		X
123	Generators	Generators positioned for stability and sized for optimal load (used during shipyard trips, electrical utility interruptions)	X	
124	Cooling System	Keel coolers, potentially use box coolers		X
125	Fuel System	Fuel Polishing System		X
126	Lube Oil System	Lube oil and waste oil tanks, integral, sized for system demand and DRBA preference	X	
127	Ventilation	Heating and cooling (A/C) in pilothouse, EOS, and passenger areas	X	
128	Ventilation	Ventilation and heat in all below deck voids		X
129	Anchor	As required by regulatory agencies	X	

PIPING

	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
130	Labeling	All piping and valves to be color coded and labeled	X	
131	Seawater Piping	All Cu-Ni	X	
132	Fire main Piping	All Cu-Ni	X	
133	Bilge System	Carbon Steel piping (sch 80)	X	
134	Oily Bilge	Integral tankage, sized to support main engine oil change, Carbon Steel piping (sch 80)	X	
135	Compressed Air	Compressed air - ports on Main Deck, and in Engine Room, air horn	X	
136	Fire Suppression	Structural fire protection on underside of deck	X	
137	Fire Suppression	Minimize fire dampers. Dampers to be crew accessible	X	
138	Fire Fighting on Car Deck	Deluge system, Cu-Ni piping	X	
139	Freeing ports	Freeing ports on Car Deck where possible		X
140	Deck Drains	Drains at rub rail level where freeing ports not possible, provide plenty of deck drains		X
141	Potable Water	Tank sized for # of people onboard	X	
142	Potable Water	CPVC Piping where permitted, copper elsewhere		X
143	Flushing Water	Fresh water	X	

144	Fresh Water	Single system with back-flow preventer, no condensate system, external spigot for wash down on all decks		X
145	Wastewater	Tank sized for # of people onboard,	X	
146	Wastewater	CPVC piping where permitted		X
147	Wastewater	Combine black and grey drains	X	
148	Wastewater	Integral black/gray water holding tank sized for # of people on board	X	

STRUCTURAL

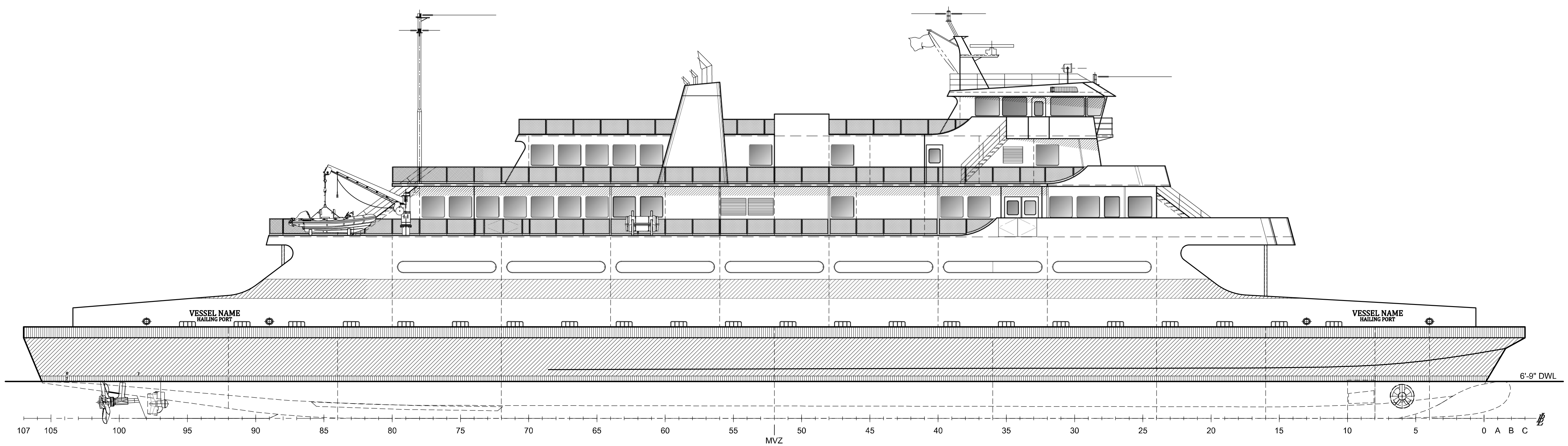
	PARAMETER	REQUIREMENT	MINIMUM THRESHOLD	OBJECTIVE
149	Hull Material	Steel	X	
150	Superstructure Material	Steel		X
151	Pilothouse Material	Steel		X
152	Mast Material	Aluminum		X
153	Hull Design	Overbuilt, reinforced for long life, ice reinforcement on bow.		X
154	Cathodic Protection	Anodes	X	
155	Design Standard	ABS Marine Vessel Rules (latest edition)	X	
156	Corrosion / Painting	Minimize corrosion and painting requirements using non-corrosive (non-metallic) materials on components that don't absolutely require steel use fiberglass and carbon fiber		X
157	Rub Rail/Guard Plate		X	

APPENDIX I

Phase 3 – Notional Design

REVISION HISTORY

REV	ZONE	DESCRIPTION	DWN	DATE	APVD



OUTBOARD PROFILE

1/3/2023
WORK IN PROGRESS

PRELIMINARY

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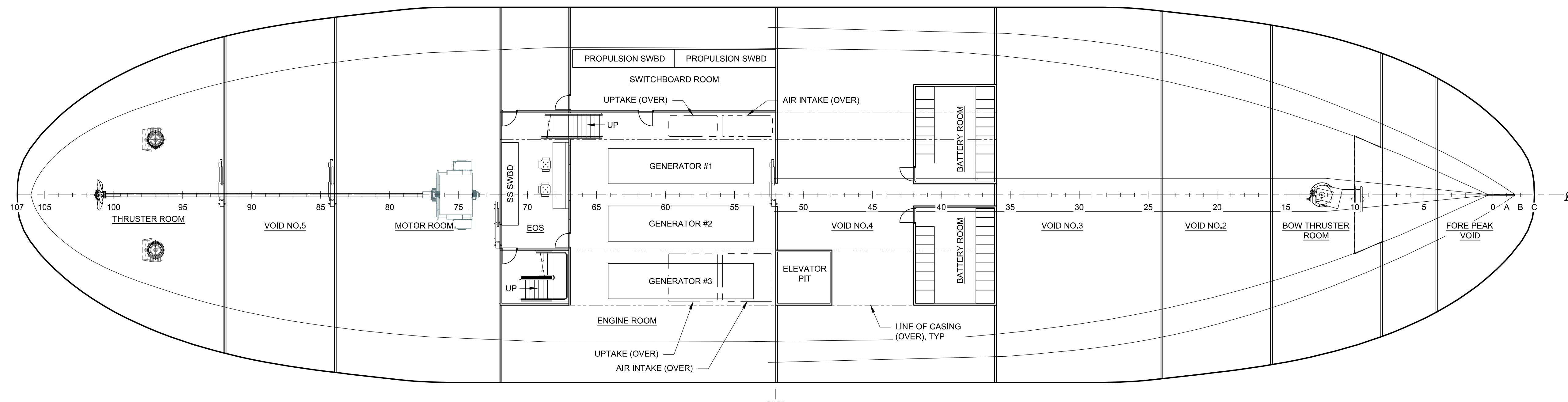
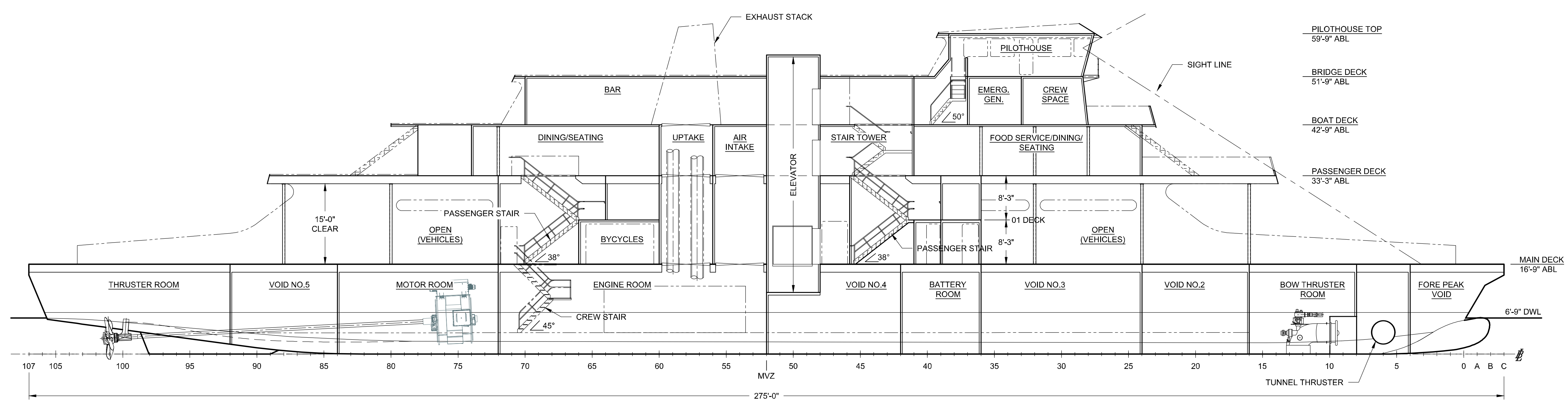
CLIENT	DELAWARE RIVER AND BAY AUTHORITY NEW CASTLE, DELAWARE
PROJECT	75 CAR NEW VESSEL DESIGN
TITLE	PROFILES AND ARRANGEMENTS
SIZE	D
DWG NO.	20075-003-101-0
REV	0
SCALE	3/32" = 1'-0"
APVD DATE	
SHEET	1 OF 4
DWN	ZDL
MOD	
CKD	
APVD	



HOLD PLAN



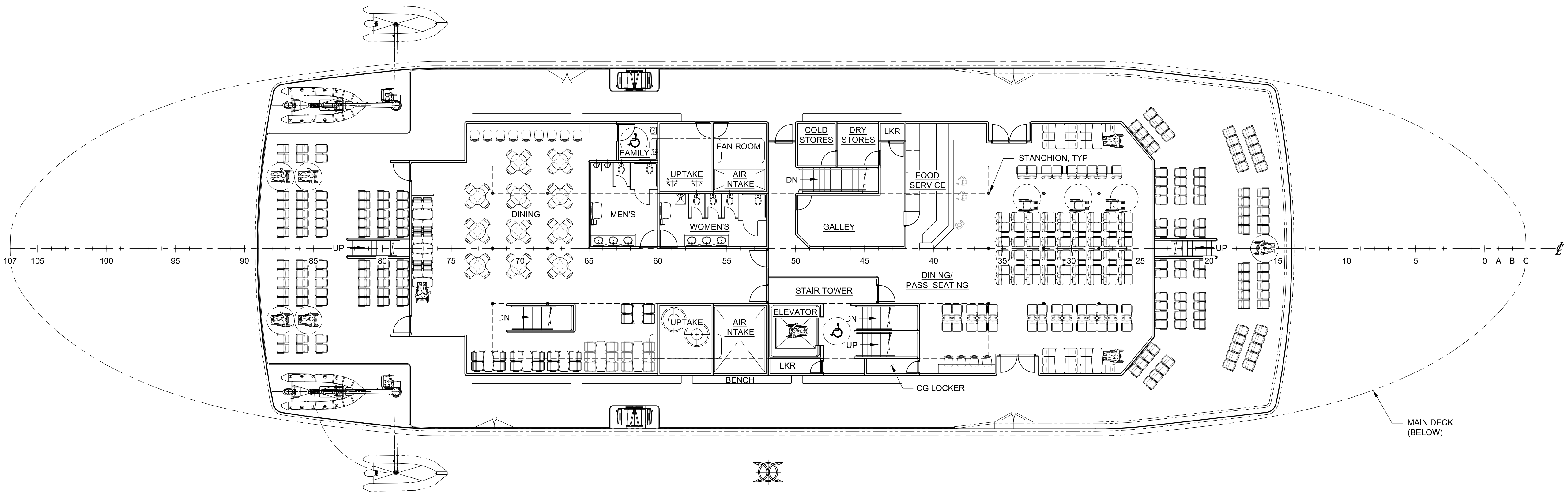
INBOARD PROFILE

FRAME SPACING = 30"

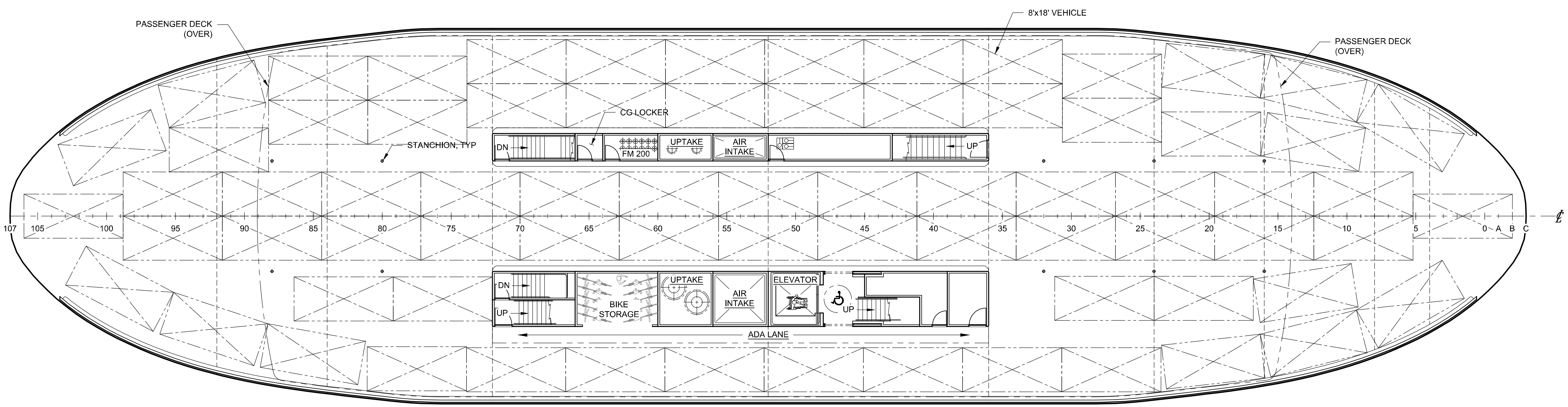
PRELIMINARY

1/3/2023
WORK IN PROGRESS

SIZE	DWG NO.	REV
D	20075-003-101-0	0
SCALE 3/32" = 1'-0"	SHEET 2 OF 4	



PASSENGER DECK

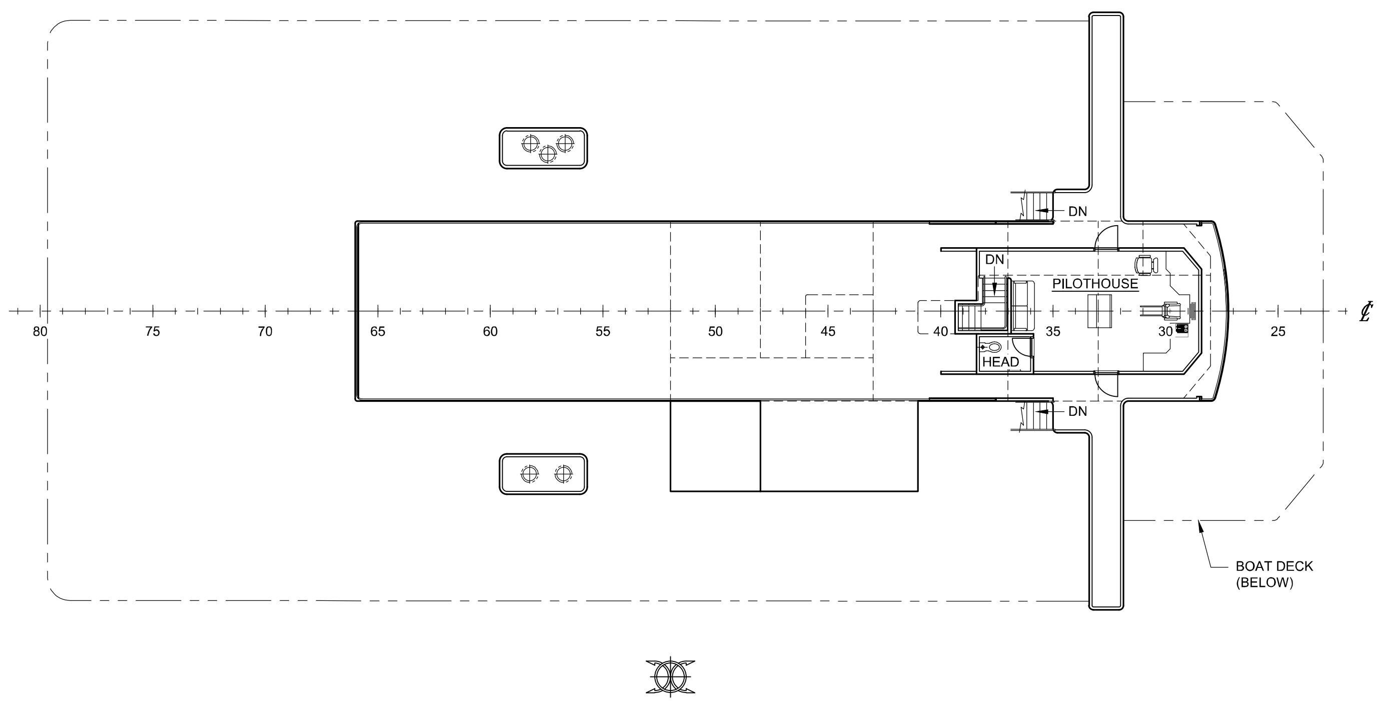


MAIN DECK

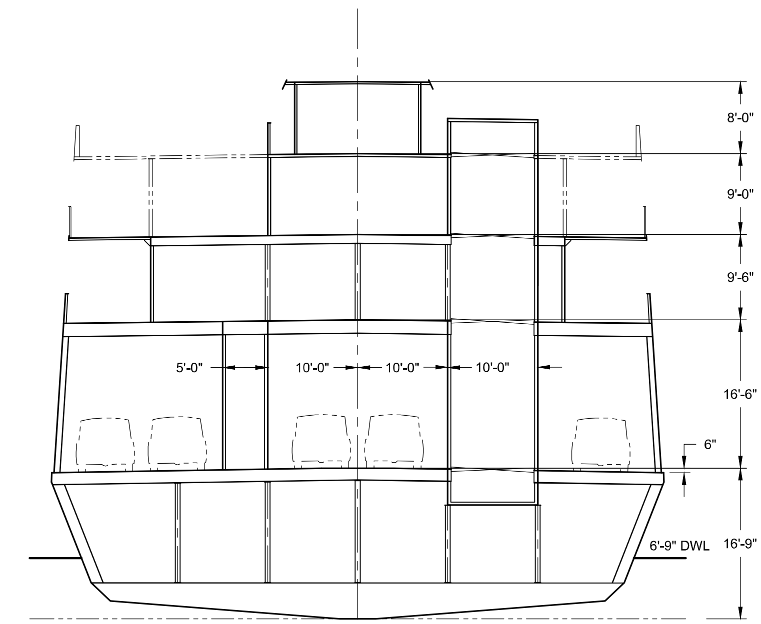
PRELIMINARY

1/3/2023
WORK IN PROGRESS

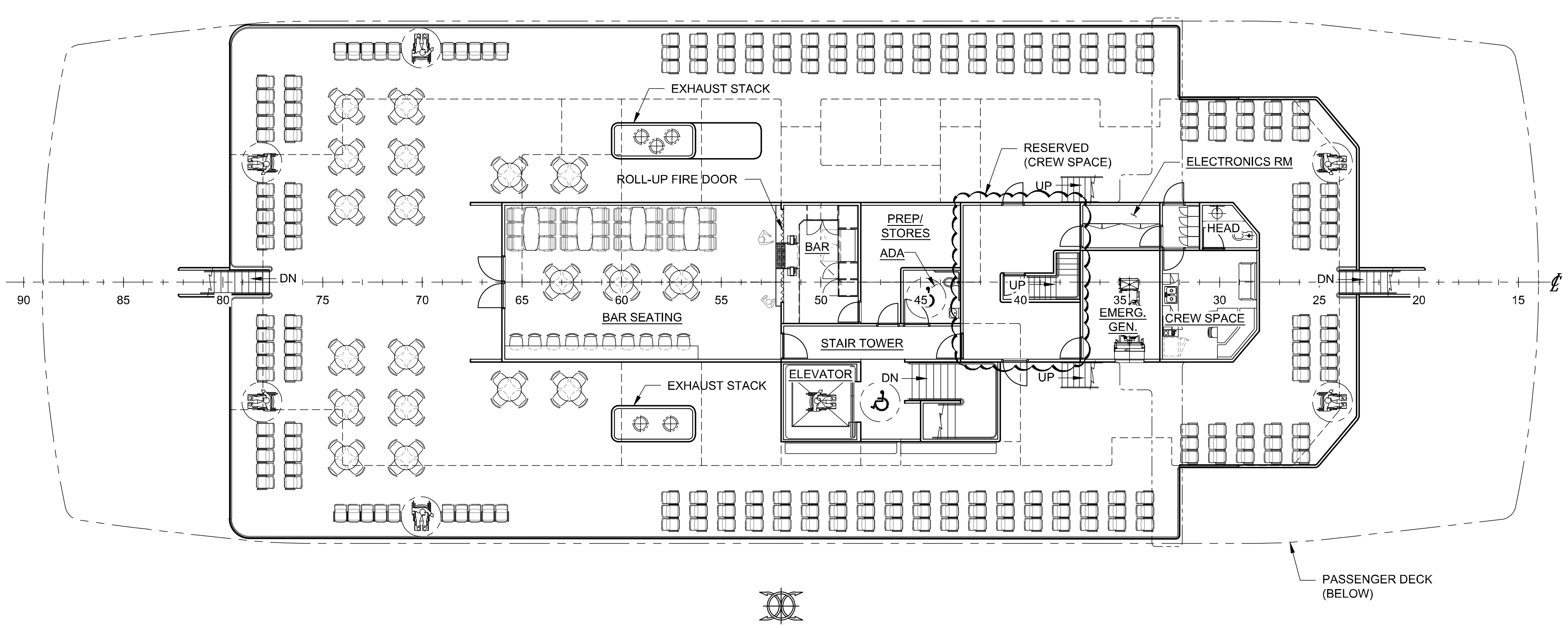
SIZE	DWG NO.	REV
D	20075-003-101-0	0
SCALE 3/32" = 1'-0"	SHEET 3 OF 4	



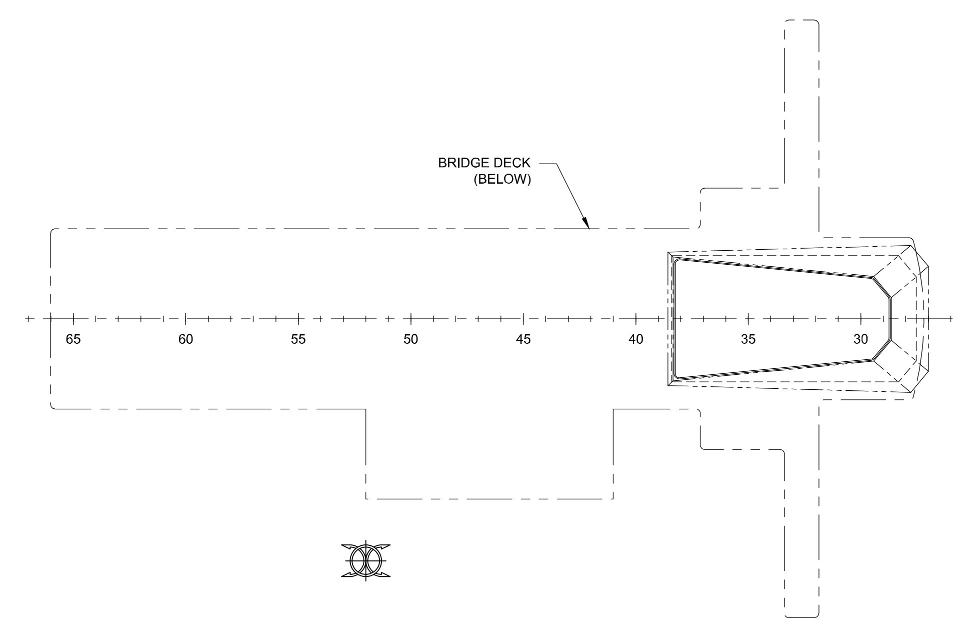
BRIDGE DECK



MIDSHIP SECTION



BOAT DECK



PILOTHOUSE TOP

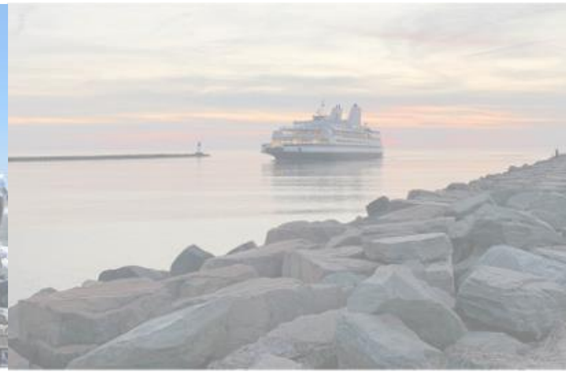
PRELIMINARY

1/3/2023
WORK IN PROGRESS

SIZE	DWG NO.	REV
D	20075-003-101-0	0
SCALE 3/32" = 1'-0"	SHEET 4 OF 4	

APPENDIX J

Outreach & Engagement


2021 Marine Master Plan

STAKEHOLDER AND COMMUNITY OUTREACH

Prepared for: Delaware River Bay Authority

Revision: -

February 1, 2023

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

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INTRODUCTION

The planning process was driven by a series of working groups, meetings, and surveys that contributed to the identification and development of vessel requirements through input from stakeholders. The following appendix items outline how Elliott Bay Design Group (EBDG) and DRBA reached out, educated, and involved internal and external stakeholders related to development of the Marine Master Plan (MMP).

Due to the ongoing COVID-19 pandemic, outreach activities were conducted in accordance with current public health guidance.

GOALS

The following goals guided engagement activities:

- Develop and communicate a meaningful and robust MMP through an informed consent process.
- Enhance relationships and gain support and buy-in for the MMP.
- Implement early, inclusive and continuous outreach throughout the project.
- Generate a sense of ownership over the MMP among crew and other personnel.
- Promote understanding of the purpose of and need for the plan and the challenges and tradeoffs facing the ferry system.
- Deliver comprehensive, coordinated and consistent information.
- Raise awareness and understanding of the engagement process and the opportunities for input to the MMP.

APPROACH

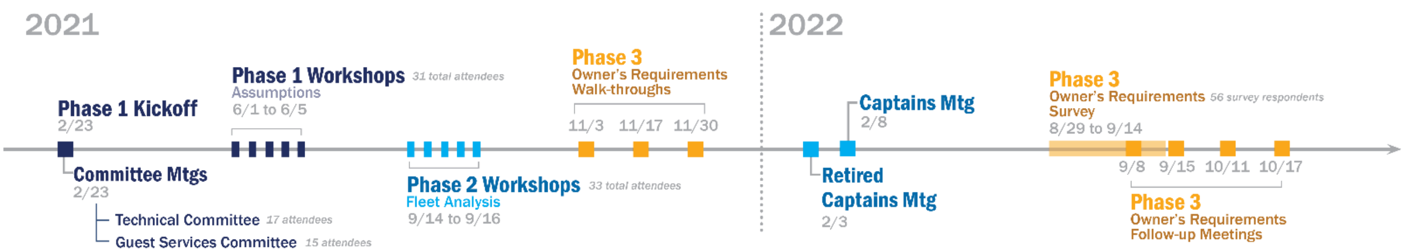
- Phased: Driven by information needed for MMP development and tied to project milestones
- Transparent: Include early and inclusive engagement. Share fact-based, reader-friendly, easy to understand information and visuals that clearly explain the purpose of the plan and provide direction for stakeholders to provide feedback.
- Flexible: Address and respond to evolving COVID-19 restrictions
- Inclusive: Capture insight and feedback from relevant audiences
- Efficient: Include project updates in existing outreach channels/meetings where possible
- Responsive: Ensure appropriate and relevant feedback from stakeholders and the general public influences the final plan.

ENGAGEMENT PROCESS

As the project began, it was crucial to develop and prepare and engagement plan that identified goals for engagement efforts along with resources to fulfill the engagement goals of the study. The engagement plan had four phases, one to align with each phase of the MMP study:

Phase I: Data Gathering
Phase II: Analyses of System and Components
Phase III: Definition of Vessel Requirements
Phase IV: MMP Report

DRBA Engagement Activities
Internal



PHASE I: DATA GATHERING

During this phase, stakeholders were identified, and an initial outreach process was set up while data was being gathered about the existing CMLF system.

INTERNAL ENGAGEMENT

A kickoff was held to provide an introduction and initial information on the master plan. The kickoff also served as an opportunity to get feedback on the proposed MMP goals and on what analysis elements to include in Phase II.

Overall, internal engagement for this phase focused on getting staff on the same page regarding the master plan and its goals and to build excitement about the process and outline the process for further engagement.

Through this phase, a variety of methods of outreach were conducted for stakeholders to provide feedback including:

- Email communications
- Voicemail feedback line

The following internal meetings were held for this phase of engagement:

- Kickoff Meeting (02/23/21)
- Committee Meetings (02/23/21)
  - Guest Experience Committee
  - Technical Committee
- Assumptions Workshops (06/01/21 – 06/05/21)

The feedback from these efforts was gathered to inform the findings that narrowed which issues were of higher concern into the following categories:

- Fleet Mix/ Vessel Types
- Seasonality
- Financial Elements
- Potential Vessel Design Elements
- Potential Vessel Passenger Area Design Elements
- Potential Shoreside Elements

EXTERNAL ENGAGEMENT

External engagement efforts in Phase I were focused on setting the stage for the MMP effort and letting the public know how they would be able to provide feedback as the plan progressed. To do this, a website was developed to inform the public on the process and keep the community and ferry users updated and engaged: https://www.cmlf.com/marine-master-plan. Additionally, targeted emails were sent to key external stakeholders such as state and local politicians, chamber of commerce and other local businesses, and individual community residents, informing them of the launch of the website and the MMP.

PHASE II: ANALYSES OF SYSTEM AND COMPONENTS

Phase II of the MMP involved developing fleet configuration options and conducting detailed analysis to determine the most appropriate future fleet and vessel type. Engagement was focused on getting feedback on the proposed options and the fleet analysis findings.

INTERNAL ENGAGEMENT

Internal engagement for this phase focused on gathering input form the crew on the proposed analyses, the fleet configuration options, and fleet analysis findings. Zoom Meeting Workshops and email updates were prime tools used in this phase to facilitate internal engagement. The email communications and dedicated voicemail lines remained open, and the analysis team continue to receive comments via these forums.

The following internal meetings were held for this phase of engagement:

- Executive Committee Meeting (07/12/21)
- Executive Committee Meeting (08/30/21)
- Fleet Analysis Workshops (09/14/21 – 09/16/21)
- Retired Captains Meeting (02/03/22)
- Captains Meeting (02/08/22)

During this phase of engagement, CMLF personnel expressed concerns about vessel seaworthiness and ride comfort for passengers. Crew feedback has mostly revolved around the seakeeping ability and maneuverability within the shallow channel of a double-ended, smaller 55-vehicle vessel option. As a result, a detailed seaworthiness analysis of the vessels proposed in each fleet option (100-vehicle, 75-vehicle, 55-vehicle) was conducted to get a better understanding of how newer and smaller vessels might handle the operating conditions of the Delaware Bay. A few commenters were also curious about why diesel-electric propulsion was assumed, as opposed to the cheaper pure diesel vessel options

Additional feedback was received regarding accommodating growth and to provide the same level of passenger experience as the current fleet. Customer service representatives inquired about the format and space available for food service while questions and comments were received about how a smaller sized fleet would accommodate growth. The aesthetic of a smaller vessel profile and the ability of smaller vessel to carry long/oversized vehicles.

Key Phase II Internal Feedback

Internal priorities included:

- **Seakeeping** and a smooth passenger ride, especially during rough winter conditions
- **Vessel maneuverability** in the shallow water
- **Maintaining passenger experience** and vessel aesthetic
- Ability for the proposed fleet to **accommodate growth** and large passenger vehicles/campers

Additionally, personnel expressed concerns about how double-ended vessel technologies might interface with the shallow water depths and infrequently dredged channel. To get a better understanding of how these technologies might operate, opportunities were organized for the CMLF captains and crew to travel to discuss these technologies with other operators and to use MITAGS simulators of potential vessel technology options.

EXTERNAL ENGAGEMENT

There were two public meeting webinars held during this phase of engagement on 06/17/21 and 10/07/21 to update the public and receive comments on the progress of the Marine Master Plan. The slide deck for these meetings can be found on the public website established in Phase I: https://www.cmlf.com/marine-master-plan

Engagement activity held during Phase II of this process include:

- Public Webinar (06/17/21)
- Public Webinar (10/07/21)

At these webinars, the public expressed excitement for the MMP effort and for a new fleet and for the opportunity to make CMLF vessels more environmentally friendly and had many questions regarding potential alternative propulsion options for the new vessels. Numerous website comments were also received, often focused on vessel amenities or a desire for service changes, including more service and additional sailing time suggestions.

Key Phase II External Feedback

- The public expressed interest in **alternative vessel propulsion** technologies.
- **Accessibility** for those with disabilities was mentioned.
- A few concerns/ questions were raised regarding the 55-vehicle vessel size meeting commercial traffic and tourism needs.
- Suggestions for **service changes**
- Suggestion regarding **amenities** such as seating, HVAC, and food service.

PHASE III: DEFINITION OF VESSEL REQUIREMENTS

Phase III of the MMP was focused on defining vessel requirements and beginning the development of general arrangements for the selected fleet option.

INTERNAL ENGAGEMENT

The third phase of internal engagement was focused on getting feedback on potential vessel requirements through meetings, discussions, and surveys with vessel crew, terminal engineering staff, and technical expert input.

The following meetings were held as a part of the Phase III internal engagement process:

- Owner’s Requirement Meeting (11/03/21)
- Owner’s Requirement Meeting (11/17/21)
- Owner’s Requirement Meeting (11/30/21)
- Executive Committee Meeting (12/02/21)
- Owner’s Requirements Survey (08/29/22 – 09/14/22)
- Owner's Requirements Follow-up Meetings – Captains (09/08/22)
- Owner's Requirements Follow-up Meetings – Food and Retail (09/15/22)
- Owner's Requirements Follow-up Meetings – Captains (10/11/22)
- Owner's Requirements Follow-up Meetings - Engineers (10/17/22)

To gather as much detailed feedback as possible on the proposed vessel requirements, engagement meetings were supplemented with surveys were developed in this phase to gain feedback on recommendations and requirements.

Phase III employed the use of surveys to gather data on Owner Vessel Requirements from DRBA internal staff and resulted in a list of Top 15 requirements as well as insight into opinions on vessel type, propulsion, and design. The survey was conducted through SurveyMonkey and can be found here: https://www.surveymonkey.com/r/82JGJCP

A list of Top 15 vessel requirements were developed from the survey and discussed in these meetings. This list is shown below.

	Vessel Requirements		
1st	US Regulations - 46 CFR Subchapter H	Tonnage	Meet DRBA Security Requirements
2nd	Vehicle Capacity 75		
3rd	Total Passengers Onboard < 400		
4th	Maneuvering		
5th	ADA compliant components (walkways, etc.)		
6th	Speed		
7th	Crew Space		
8th	Design Life - 40 years		
9th	Hull (Single/Double ended)		
10th	Crossing Time	Lifeboat/ Rescue Boats	
11th	Fire Suppression	Fuel Capacity	MES
12th	Passenger Space		
13th	Propulsion	Fire Fighting on Car Deck	
14th	Corrosion / Painting	Hull Material	Thrusters
15th	Design - Minimal modifications needed	Life Jackets	

EXTERNAL ENGAGEMENT

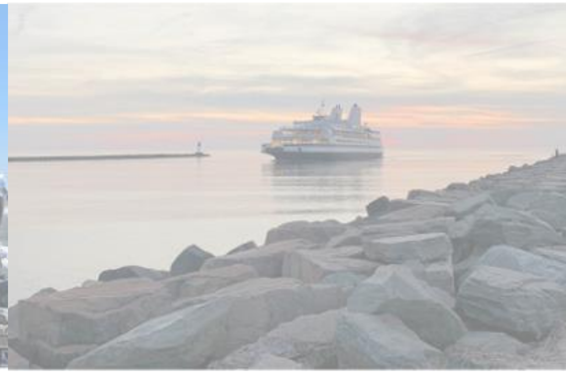
Phase III was engagement was primarily internal in nature, but external efforts were conducted to keep the public informed of the progress to date. A webinar was held on XX date to share the fleet decision from Phase II and the draft general arrangement.

PHASE IV: MARINE MASTER PLAN REPORT

The last phase of the MMP process was to develop a report summarizing the planning process, its key findings, and the fleet decision. Internal and engagement were combined in this phase in the form of a 30-day comment period on the report draft.

APPENDIX K

Phase 5 – Sea Keeping Analysis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2021 Marine Master Plan

Seakeeping Analysis:55-Car Vessel Comparison to Current Fleet

Prepared for: Delaware River and Bay Authority

Ref: Phase 5 - Seakeeping Report

May 1, 2023

DRBA DELAWARE RIVER & BAY AUTHORITY | Elliott Bay Design Group | kpff

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
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1. EXECUTIVE SUMMARY

The purpose of the analysis is to analyze whether Delaware River and Bay Authority (DRBA) operations will be impacted by the seakeeping characteristics of a smaller vessel should DRBA elect to pursue smaller 55-car ferries as a replacement to the existing 100 car ferries. This impact is quantified by looking at the number of additional cancelations that may result from sea state and the corresponding impact on vessel motions.

The number of additional cancelations due to sea state is expected to increase minimally with a smaller 55 car ferry compared to those that have occurred historically for the existing 100 car ferry fleet. DRBA [1] reported cancelations of 35 days due to wind and waves over the past eight and a half years. On average, this equates to weather-based cancelations occurring on roughly 4 days of the year. Over these days, there were 136 total canceled trips. Annual cancelations were between six (2018) and 40 (2016).

DRBA does not have a formalized definition of the sea state that constitutes a no-sail condition. Based on a discussion with DRBA captains, two representative conditions that may prevent the existing fleet from sailing were used as a baseline for the analysis.

Conditions:

1. Bow/Stern Quartering Seas – 10-foot significant wave height (SWH) with an 8-second period with a wave direction of encounter 45 degrees off the bow/stern.
2. Bow/Stern Quartering Seas – 8-foot SWH with a 5-second period with a wave direction of encounter 45 degrees off the bow/stern.

DRBA also identified one additional sea state for analysis.

3. Beam seas driven by northwesterly winds with a 6-foot SWH, which has an associated 5.3 second period.

Note the impact of vessel size on maneuverability in and out of the terminals in high winds and the corresponding impact on cancelations has not been studied, though logically the reduced sail area of a smaller vessel will result in reduced wind-driven forces relative to the 100-car ferry. This is understood to be a common reason for historical cancelations.

The seakeeping analysis was conducted in Aqwa, a panel code hydrodynamic computer program. In general, longer period ocean swells have a comparatively greater impact on vessel motions than shorter period wind waves of the same amplitude and wavelength. This tendency was observed in our analysis, with a peak vessel response for both the existing and 55-car vessels occurring at a wave period between 8-12 seconds. Therefore, Condition 2 did not yield a large response for either vessel, and Condition 1 was used as the assumed threshold at which a cancelation may occur.

Motion Sickness Incidence (MSI) is an estimate of the percentage of people who will experience vomiting when exposed to prolonged whole-body vibrations. MSI calculations were performed for each sea state to quantify the impact operating a smaller vessel on the CMLF route has on passenger comfort. While MSI is not used by DRBA as a basis for canceling a sailing, it is a useful way of measuring passenger comfort that is typical on days when DRBA has historically canceled sailings. MSI was then calculated for the 55-car ferry to find a corresponding sea state that yielded a similar level of passenger comfort. An iterative approach was taken whereby the wave height was reduced until the MSI of the 55-car vessel matched that calculated for the 100-car vessel in the sea states defined by DRBA captains.

The MSI for the existing DRBA ferries in 10-foot waves with an 8 second period is estimated to be equivalent to the 55-car ferry in 7.5-foot waves with a 6 second period.

Data from NOAA Buoy #44009, located 26 nautical miles south-southeast of Cape May, NJ, was analyzed for the years 2011-2020. It was found that over the period from 2013-2021 (which corresponds to the interval for which cancelations were provided), an average daily SWH of 7.5-feet or greater was record 138 times, or approximately 5% of days. An average daily SWH of 10-feet or greater was recorded 44 times, or on 1.2% of days.

Comparing the number of weather-based cancelations (nine over eight and a half years) to the total number of instances a daily average wave height of 10-feet was eclipsed (44), an extreme weather cancelation rate of 20% is assumed. This relatively low rate of actual cancelations in the face of heavy weather is likely due to the fact that the CMLF route is more protected than the NOAA weather buoy from which the wave heights were determined. This is particularly so for waves that are not from SSE-ENE.

Assuming the same cancelation rate in conditions where the cancelation threshold (10-foot waves for the current vessel and 7.5-foot for the 55-car vessel) is eclipsed, the analysis suggests that DRBA may be required to cancel service based on wave height 3.3 days per year on average, or about 2.3 additional days per year.

Historically, 72% of the instances where the daily average wave height recorded at Buoy #44009 exceeds 7.5-Feet occurred in the fall and winter.

1. PURPOSE

This report summarizes a seakeeping analysis performed for DRBA. The analysis considers two vessels:

1. The existing 100 car ferries currently operated by DRBA. These vessels are 320 ft x 68ftx by 16.5 ft.

2. A notional 55 car vessel that is 224 ft x 68 ft x 16.5 ft.

The existing CMLF vessels provide satisfactory ride quality with few cancelations in any season due to extreme weather. As DRBA plans the next generation of vessels, consideration has been given to the impact of a smaller vessel on seakeeping characteristics, passenger comfort, and trip cancelations. It is thought that a vessel of similar dimensions and displacement as the current fleet will respond similarly to the existing vessels in the same sea state. A smaller and lighter vessel's motions and accelerations will likely be larger and could result in a lower weather limit for operations. For example, a shorter vessel will tend to pitch more than a longer vessel, resulting in higher vertical accelerations at each end. Vessel vertical accelerations are a primary factor in motion discomfort.

The purpose of the analysis is to develop a relative comparison of the seakeeping characteristics of the two vessel configurations with the aim of understanding if, and to what degree, DRBA's operations will be impacted by the seakeeping characteristics of a smaller vessel should DRBA elect to pursue smaller 55-car ferries as a replacement to the existing 100 car ferries.

2. BACKGROUND

The following subsections contain discussion of important background information and technical concepts that are referenced throughout the report, as well as their specific applicability to the analysis.

2.1 SEA STATE

A sea state is the general condition of the free surface of a body of water with respect to wind and waves. The sea state of a particular body of water can be ascertained at a particular moment in time by visual observations of the free surface and the corresponding wind speeds. The sea state code is a numerical scale of the severity of wave conditions. For context, a sea state of 0 would be considered calm water, or "glassy" while a sea state of 5 would be considered "rough" – the latter having significant wave heights in the 10-foot range. Significant wave height (SWH) refers to the average wave height, from trough to crest, of the highest one-third of the waves.

The sea state can be approximated mathematically through definition of the SWH, significant wave period, and wave frequency spectrum. Wave frequency spectra describe the distribution of wave energy over wave frequencies and can be used for numerical simulation of a sea state. Two spectra (described below) were used for different portions of this analysis.

The Pierson-Moskowitz spectrum is an idealized wave spectrum that assumes a fully developed sea (produced by steady winds blowing over a long fetch for an extended time). The only parameter affecting this spectrum is windspeed.

The JONSWAP spectrum is similar to the PM spectrum, but incorporates the recognition that waves continue to develop through non-linear, wave-wave interactions even for very long times and distances. Hence an extra factor was added to the Pierson-Moskowitz spectrum to improve the fit to their measurements.

The mouth of the Delaware Bay is a unique operating environment. The ferry route running NE-SW is exposed to the swell of the Atlantic and subject to river and ice flowing from the Delaware River. Prevailing winter winds out of the northwest can build wave spectra with SWH of 6-feet. According to DRBA captains, high winds from the northwest generally result in cancelations before the wind-driven waves accompanying them because the winds make it difficult to maneuver in and out of the terminal [2]. Ocean swells coming from the east can reach up to 12 feet, which results in cancelation of operations. Typical conditions are anecdotally described as 2-4 foot wind-driven waves.

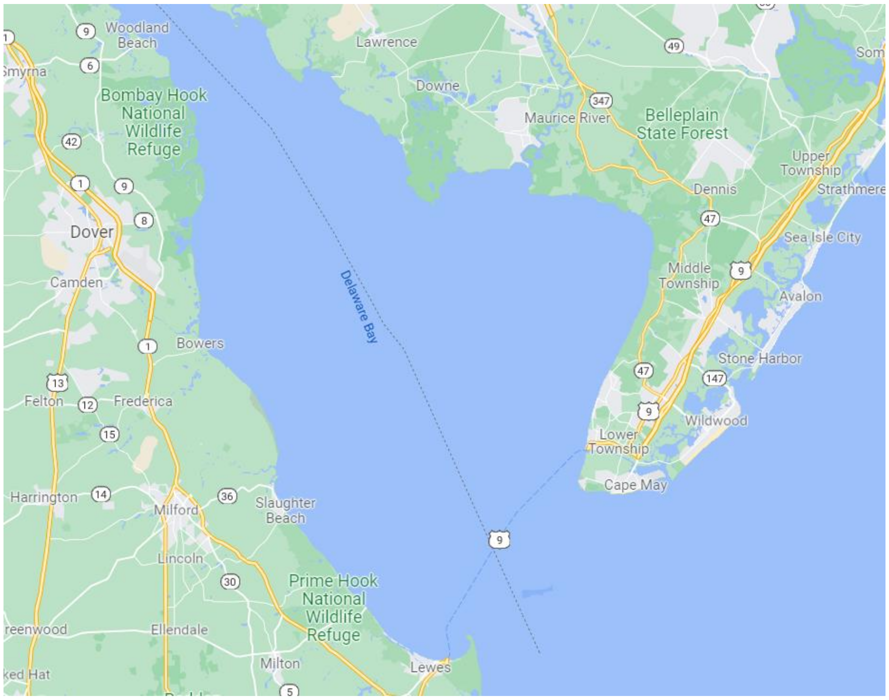

Figure 1: Route and surrounding environment of CMLF

2.2 MOTION SICKNESS INCIDENCE (MSI)

Motion Sickness Incidence (MSI) is an estimate of the percentage of people who will experience vomiting when exposed to prolonged whole-body vibrations. MSI research was conducted by both Wesleyan University in 1945 [3] and picked up in 1974 by Human Factors Research for the Office of Naval Research (ONR) [4]. The intent of the study was to develop a mathematical model that could be used to better understand human tolerance for prolonged accelerations and the implications for the design of transportation vehicles broadly.

MSI is calculated using the exposure duration, sensitivity of the population to motion sickness, and the frequency and magnitude of the vertical accelerations imposed on the body. A two-hour exposure duration is generally the baseline value used to calculate MSI. Because motion sickness is predominantly induced by vertical accelerations, the vertical component of the vessel's response is the focus of this analysis.

While the expected vertical acceleration for a given sea state and wave spectrum can be estimated from analysis, the aggregate tolerance of a population to motion sickness varies. It is common practice to apply a "population sensitivity factor" of 1/3 to the calculation to more accurately estimate the percentage of the vessel's passengers who will experience severe motion sickness.

2.3 SHIP MOTIONS – DEGREES OF FREEDOM

A vessel interacts with a given sea state with movement about six different degrees of freedom (DOFs). Three of these are translational DOFs: heave, sway, and surge. Heave is up and down movement along the z-axis (vertical axis). Surge is fore and aft movement along the x-axis (longitudinal axis along the length of the vessel). Sway is athwartships movement along the y-axis (transverse axis).

The remaining three DOFs are rotational degrees of freedom: roll, pitch, and yaw. Roll refers to rotational motion about the x-axis. Pitching refers to rotation about the y-axis. Lastly, yawing is a rotation around the z-axis.

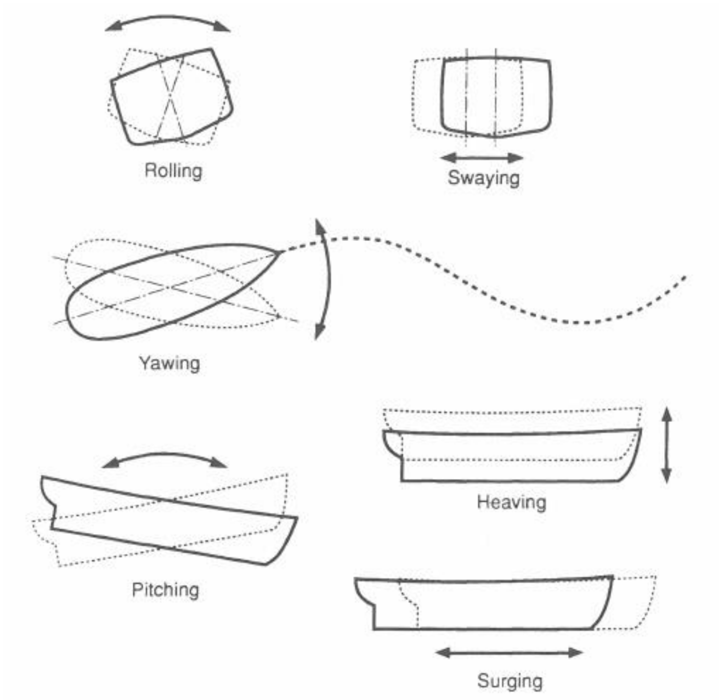

Figure 2: Diagram illustrating the six degrees of freedom for a vessel in a seaway [5].

Note that heave, pitch, and roll motions can all induce local vertical accelerations that impact motion sickness at a point of interest on a vessel as it encounters waves and will be the focal degrees of freedom for this study.

3. PROCEDURE

Vessel motions were predicted using a representative hull model for the existing vessel and another for the notional 55 car ferry. The hydrodynamic analysis was performed in ANSYS Aqwa and the resultant motions data were postprocessed in Microsoft Excel. Aqwa takes as input the vessel geometry, draft, center of gravity, and wave spectrum with a defined significant wave height, period, and direction. Outlined below are the steps used by EBDG to complete the analysis, which the ensuing subsections discuss in detail.

- Environmental conditions for the analysis were selected through conversations with DRBA, with the intent to determine the sea conditions that result in trip cancelations.

- Historical trends in wind and wave data were collected to understand the frequency of the limiting sea states provided by DRBA throughout the year.
- A 3-dimensional model of the existing hull was prepared for Aqwa. A 3-dimensional model of the 55-car notional hull was developed and subsequently prepared for Aqwa analysis.
- EBDG and DRBA agreed on the selection of three locations of interest on the vessel where accelerations would be calculated [1].
- A hydrodynamic analysis was performed with the 3-dimensional model of the existing vessel and the prescribed weather conditions to evaluate the existing vessel's seakeeping characteristics. The analysis was then performed for the notional 55-car vessel under the same conditions.
- MSI calculations were performed for each DRBA defined sea state (see Section 3.1) and at each of the three locations analyzed (see Section 3.3)on the two vessels to quantify the impact of the motions on passenger comfort. To determine whether the smaller 55-car vessels may experience more cancelations than the existing fleet, an iterative approach was taken whereby the wave height was reduced until the MSI of the 55-car vessel matched that calculated for the 100-car ferry in the corresponding DRBA defined sea state.
- An estimate for the relative number of cancelations of the 55-car ferry vs the existing vessel was made based on historical weather data.

3.1 SEA STATE SELECTION

Based on a discussion with DRBA captains, three conditions were identified for comparison in the analysis.

3.1.1 BEAM SEAS

The first wave spectrum represents wind-driven waves from the northwest of 6 feet with an associated 5.3 second period, which encounter the vessel on the beam. The wave height was prescribed by DRBA, and the period was calculated based on guidance from the US Army Corps of Engineers (USACE) [6]. The calculation considers water depth, direction, fetch length, and wind speed to predict the SWH and significant wave period.

The longest fetch runs 48 miles NW-SE from the mouth of the Delaware River down to the opening of the Delaware Bay to the navigation area of the DRBA ferries. The average depth on this fetch was estimated at 39.5 feet. Calculations indicated a windspeed of 31.6 knots is necessary to achieve a SWH of 6 feet, and the resultant significant wave period is about 5.3 seconds.

A Pierson-Moskowitz wave spectrum was used as part of the sea state definition.

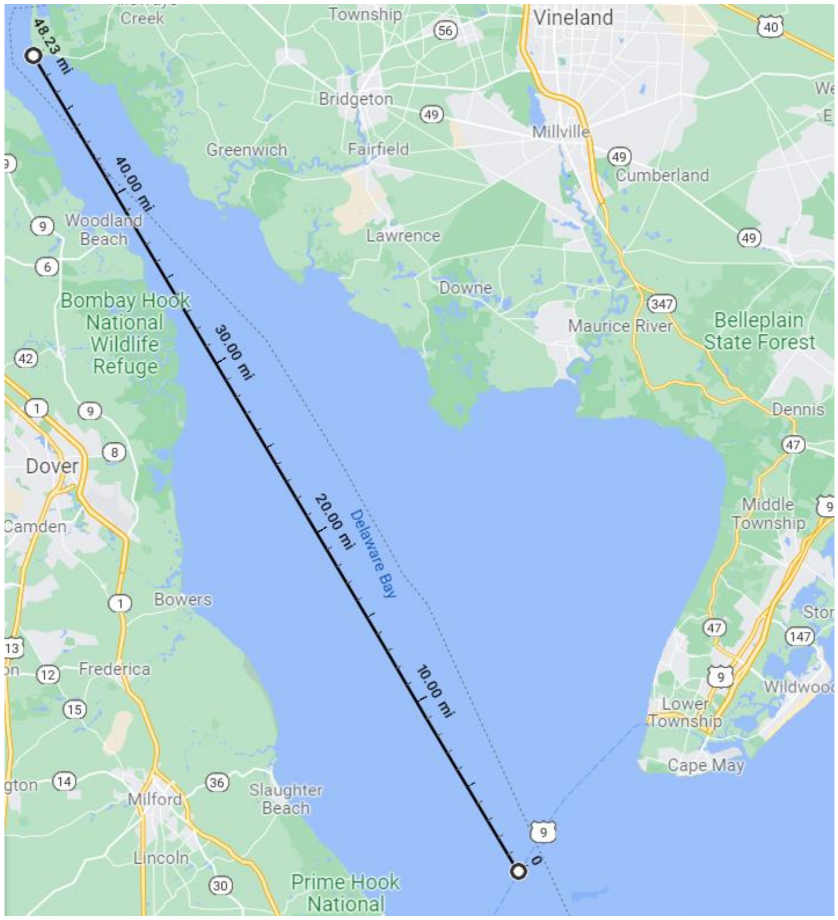

Figure 3. Fetch distance considered in the analysis.

BOW/STERN QUARTERING SEAS: 10 FOOT WAVES

Ocean swells are also encountered, most frequently on either the bow or stern quarter, depending on direction of travel, while the vessel is proceeding on its predominantly NE-SW route. DRBA captains indicated that ocean swells with a SWH of 10 feet and 8-second period are encountered on occasion and may result in a cancelation [2]. This condition is consistent with Sea State 5.

A JONSWAP spectrum was used to model these waves.

BOW/STERN QUARTERING SEAS: 8 FOOT WAVES

Ocean swells with SWH of 8 feet and period of 5 seconds are also encountered [2], and can occasionally result in cancelled service. Like the 10-foot SWH waves previously discussed, these too are most frequently encountered on the bow and stern quarter while the vessel is proceeding on its predominantly NE-SW route. These wave parameters are also consistent with Sea State 5, and were defined using a JONSWAP spectrum

3.2 MODEL GEOMETRY

EXISTING VESSEL

The current ferries operated by DRBA are single-ended propulsion, Roll-on/Roll-off passenger ferries with a length overall of 320 feet, an extreme beam of 68 feet, and a vehicle capacity of 100 cars. The geometry used in the analysis was a 3-dimensional model created for a separate task. The hull geometry is based on the M/V New Jersey.

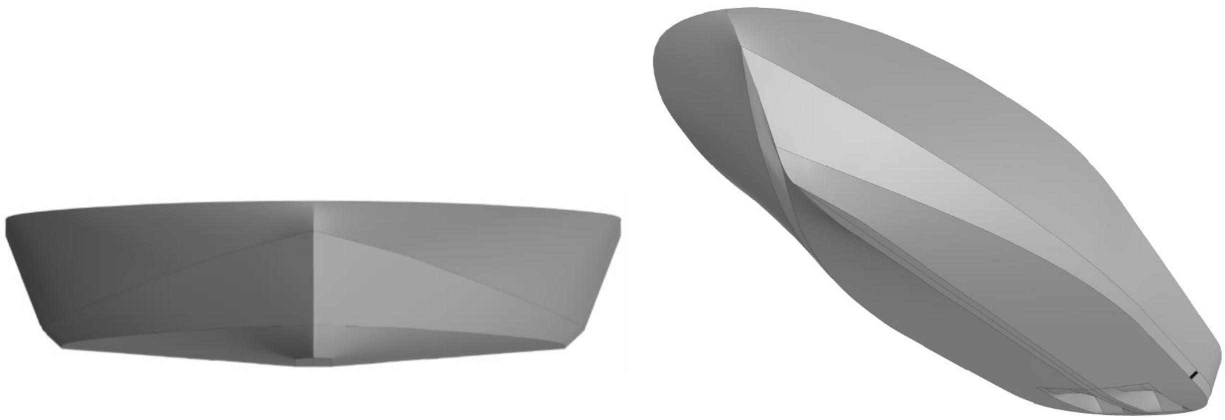

Figure 4. Existing hull model geometry (M/V New Jersey).

NOTIONAL 55-CAR VESSEL

The notional 55-car ferry principal dimensions were based on a regression analysis. The vessel is a double-ended ferry with a deck outline at both ends that matches the bow of the existing M/V New Jersey. The lightweight displacement was estimated using a linear regression model for 12 similar double-ended ferries [7].

The principal characteristics were determined parametrically based on the capacities of other double-ended passenger and vehicle ferries.

Length Overall	224.0	Ft
Beam (Molded)	68.0	Ft
Depth (Amidships, Molded)	16.5	Ft
Full Load Draft	7.5	Ft
Full Load Displacement	1390	LT
Light Ship Displacement	1100	LT
Longitudinal Center of Gravity (LCG)	0.0	Ft fwd of amidships
Vertical Center of Gravity (VCG)	17.5	Ft above Baseline (3/4 load condition)

The hull geometry was developed in Rhinoceros, a 3D modeling software.

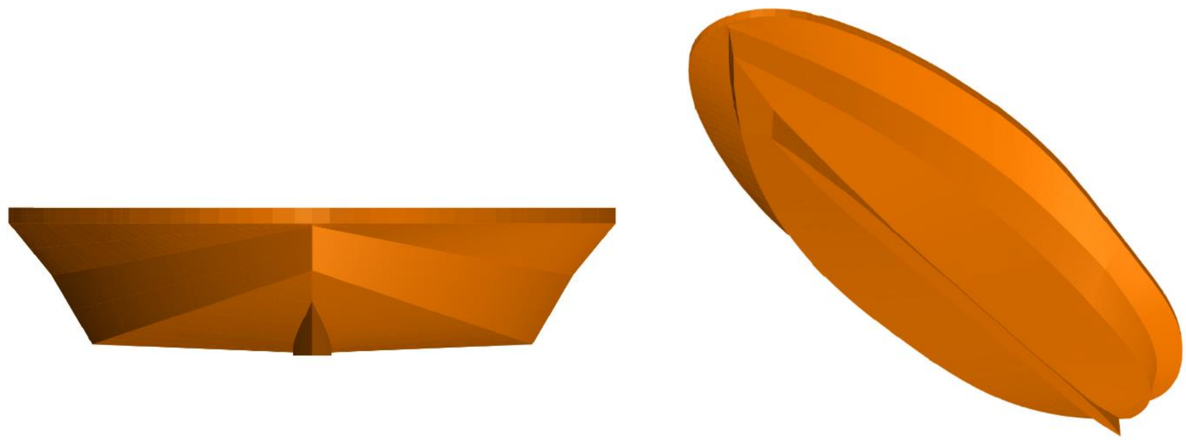

Figure 5. Notional 55-car ferry hull model geometry.

3.3 HYDRODYNAMIC ANALYSIS

MODEL PARAMETERS

A frequency-domain analysis was performed in ANSYS Aqwa, a panel code hydrodynamic analysis tool. This analysis package solves for interactions between the vessel and the environment. A frequency-domain analysis was selected for the analysis, and provides motion response as a function of wave encounter frequency.

The Rhino hullform was imported into Aqwa. A hypothetical ¾ load condition was considered for the displacement condition used in the Aqwa analysis, which accounts for a partial deadweight load and ¾ load of fuel [8]. In this condition, the vessel drafts 6.8 feet and has a vertical center of gravity 17.5 feet above baseline.

Seakeeping characteristics are a function of vessel displacement, among other factors. All else being equal a greater displacement generally results in a reduced vessel response. A 3/4 load condition and its associated displacement was selected to acknowledge seasonal fluctuations in ridership. For example, the most severe wind and sea conditions occur in the winter when ridership (and therefore displacement) is low. Thus, the vessel's motion response in a typical winter trip may be greater compared to a typical summer trip (when ridership is greater). However, because ridership is likely to be less in the winter, a winter cancelation is less impactful. The load condition selected is intended to balance the greater impact of a cancelation with high ridership against the more frequent cancelations that occur during winter periods of relatively lower ridership.

The following table illustrates the weight characteristics of the notional and existing vessel used in the analysis.

Table 1: Characteristics of ¾ Load Condition Used to Define Vessel Weight in AQWA Analysis

VESSEL	NOTIONAL 55-CAR FERRY	EXISTING VESSEL (M/V NEW JERSEY)
Displacement [LT]:	1,220 (-42% relative to existing)	2,097
Draft:	6.75'	7.00'
LCG:	Midships	159.3' Aft FP
VCG [Ft ABL*]:	17.50'	16.36

*ABL = Above Baseline

Three different locations aboard the vessel were chosen for the motion analysis. Analogous locations were selected for both vessels

1. The Pilot House
2. The starboard side of the passenger deck
3. The car deck at the forward end of the vessel

As the notional vessel is shorter than the current vessel, the longitudinal position of the car deck analysis point was shifted aft to a similar percentage of the vessel's overall length forward from midship. The vertical positions were the same for all three points for both vessels.

The passenger deck (amidships and 34' 10" above baseline) and bridge (Frame 60 and 51' 4" above baseline) were selected because these are areas most likely to contain occupants for the duration of the voyage. The bridge monitoring point was positioned on centerline. The passenger deck monitoring point was located to starboard. An off-centerline position tends to increase roll induced accelerations. The pilot house for the smaller notional vessel is assumed to be positioned at midship.

The car deck point was selected because of its distance away from midship. The vessel pitches about its longitudinal center of flotation, which is relatively close to midship. There, this tends to intensify the vertical accelerations caused by pitching of the vessel. For the analysis, a point 20' 8" above baseline centered on Frame 20 of the existing vessel was selected.

The images below depict the positions of the monitoring points for both vessels.

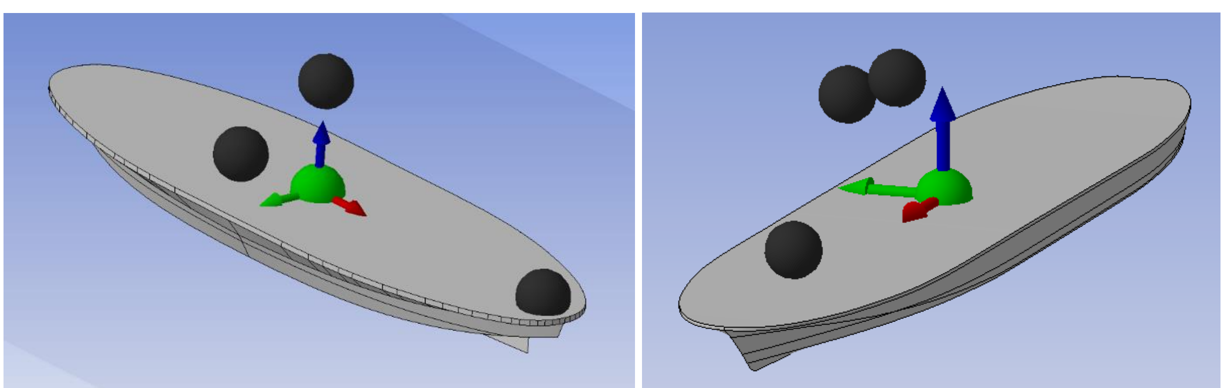

Figure 6. Notional 55-car ferry (left) and existing vessel (right) acceleration monitoring points. The points are represented for the black balls. The green ball depicts the vessel's center of gravity.

Damping coefficients were applied both to the roll and pitch degrees of freedom. Damping coefficients for roll were estimated using guidance provided by the 2009 ASME International Conference on Offshore Engineering [9]. A damping level of approximately 5-10% of critical damping was generally targeted.

A forward vessel speed of ten knots was assumed for all analyses.

BASELINE SIMULATIONS

A set of baseline runs were subsequently performed for both the existing hull and notional 55-car hull based on the various conditions identified. A total of five (5) separate simulations were performed for the *existing* vessel. Note that Condition 5 has been identified for analysis but is not thought to be a cancelation condition.

1. Bow Quartering Seas - 10 foot SWH with 8 second period at 45 degrees off the bow
2. Stern Quartering Seas - 10 foot SWH with 8 second period at 45 degrees off the stern
3. Bow Quartering Seas - 8 foot SWH with 5 second period at 45 degrees off the bow
4. Stern Quartering Seas - 8 foot SWH with 5 second period at 45 degrees off the stern
5. Beam Seas – 6 foot SWH with 5.25 second period

Vessel position, velocity, acceleration for each DOF were calculated for each of the three monitoring points. Aqwa outputs significant values for each of these response characteristics.

MSI CALCULATION

An MSI value corresponding to the no-sail sea states examined was determined for both the existing and notional vessels.

Shown below is an example MSI calculation, including the definition of each variable used.

$$MSI\% = K_m \times MSDV_Z = K_m W_f a_z {T_0}^{1/2}$$

Parameters :

MSI%	12.968434	
K_m :	0.333	
$MSDV_z$:	38.944247	
W_f:	1.006	
a_z:	0.456	m/sec^2
T_0:	7,200	s

Figure 7. Example MSI Calculation.

where:

K_m: *Population Sensitivity Factor*
$MSDV_z = W_f a_z \sqrt{T_0}$
W_f: *ISO Frequency Weighting Factor*

$a_z: Local\ Root\ Mean\ Square\ (RMS)\ Vertical\ Acceleration$
$T_0: Duration\ of\ Exposure\ (2hrs)$

Note that the RMS is the average of the absolute value of the pertinent response output. The MSI values of the two vessels were subsequently compared.

NOTIONAL HULL ITERATION

The intent of the MSI comparison is to understand the relative difference in passenger comfort for the two vessels in an identical sea state. To ascertain an estimate for the increase in cancelations for the smaller vessel, the sea state was reduced for the smaller vessel until the resultant MSI for the smaller vessel matched what was determined for the existing hull in the four cancelation sea conditions identified. This gives a reasonable basis by which to estimate the impact of vessel size on cancelations.

If an appreciable change in SWH was required to achieve an "equivalent" sea state for the 55-car ferry, the wave height and period were reduced proportionately. In the case of heavy seas, it is likely that a passenger located at the forward position on the car deck will seek refuge in a location on the vessel where the response is more moderate and away from sea spray. Therefore, the MSI at the passenger deck location was targeted for convergence.

Iterations were performed both for the beam seas condition as well as the 10-foot bow quartering swell. Rationale for these selections is offered in the Results section.

EVALUATION OF HISTORICAL WEATHER DATA

Historical weather data was consulted with the aim of determining the following.

1. The increased frequency in which the 55-car vessels will encounter a sea state that produces the same passenger deck MSI as the existing 100-car ferry in 6-foot, 5-second period beam waves.

2. The increased frequency in which the 55-car vessels will encounter a sea state that produces the same passenger deck MSI as the existing 100-car ferry in 10-foot waves with an 8-second period on the bow quarter. The delta between the frequency of the 10-foot waves and the reduced sea state determined for the 55-car ferry is representative of the increased cancelations that may result for a fleet of smaller 55-car vessels.

To evaluate the prevalence of ocean swells that exceed 10-feet in the case of the existing fleet and the height that produces the same MSI for the 55-car vessel, data collected by NOAA Buoy #44009 was analyzed for the years 2011-2020. The buoy is located 26NM south-southeast of Cape May, NJ.

To evaluate the prevalence of northwest winds that can drive beam waves of 6-feet in the case of the existing fleet and the height that produces the same MSI for the 55-car vessel, data was collected by NOAA Buoy BRND1 at Brandywine Shoal. Wave height is not collected by the buoy. Therefore, the minimum wind speed required to develop the pertinent beam waves for each vessel was calculated [6] and compared to the buoy data. Data collected by the buoy was analyzed for the years 2011, 2012, 2015-2018, and 2020. Data in the intervening years were not available.

Figure 8. Locations of the NOAA stations from which historical weather data was analyzed.

4. RESULTS

4.1 RESPONSE AMPLITUDE OPERATORS (RAOS)

The Response amplitude operators (RAOs) show the magnitude of the vessel's response relative to the energy contained in waves over a range of wave periods. The actual motion (degrees of pitch and roll and feet of heave) is dependent on the sea state, but these plots provide a concise representation of how the relative motions compare for the two vessel sizes. For the same vessel, the resultant RAOs are identical for conditions where the wave direction is the same. RAOs for each vessel motion condition are shown in the ensuing figures. The results are provided for the bow quartering wave direction and have been taken at the vessel's center of gravity.

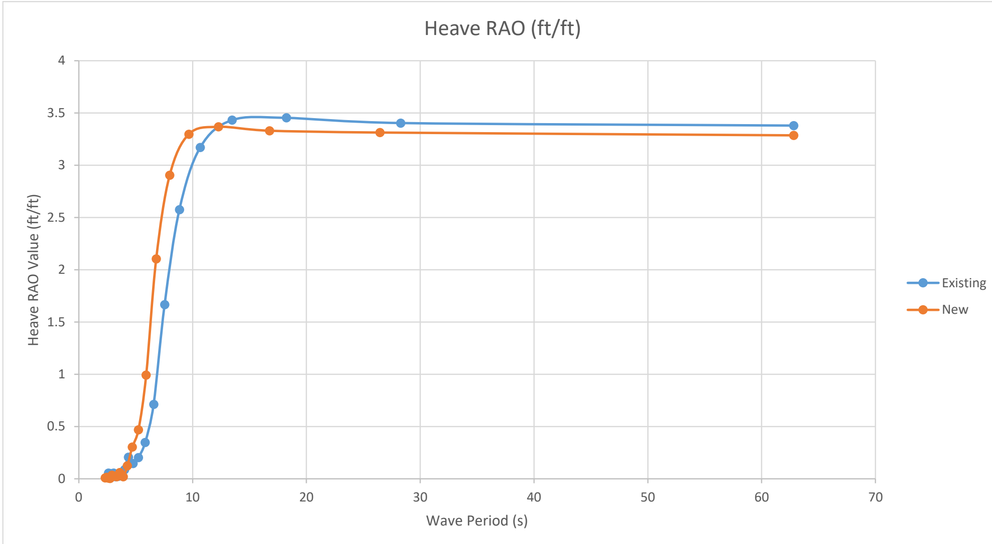

Figure 9: Heave RAOs for the existing and 55-car vessels.

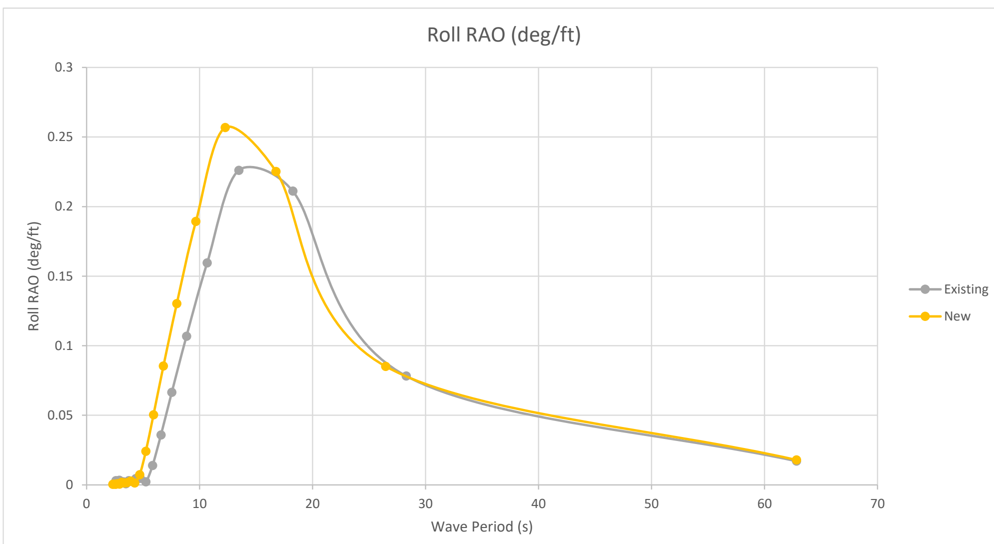

Figure 10: Roll RAOs for the existing and 55-car vessels.

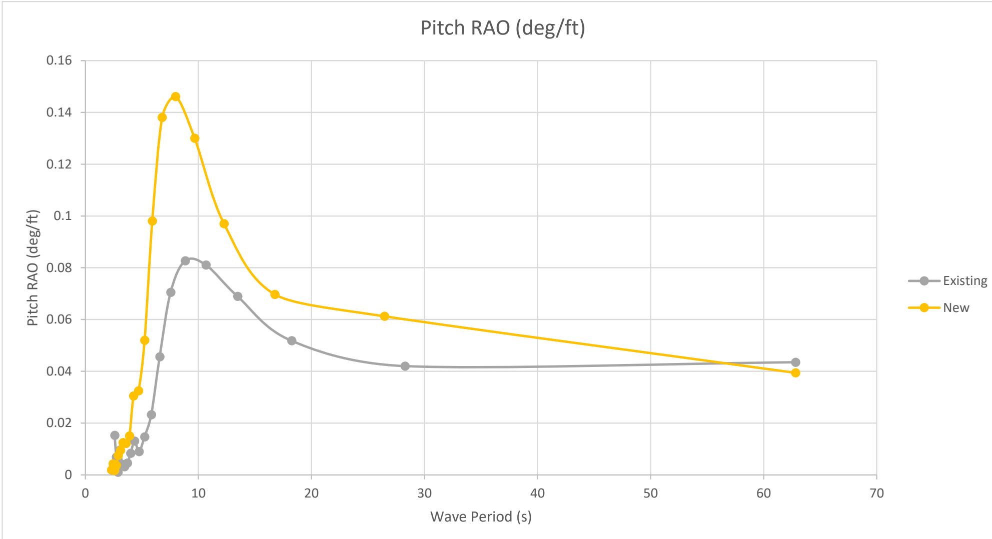

Figure 11: Pitch RAOs for the existing and 55-car vessels.

4.2 ROOT MEAN SQUARE (RMS) VALUES OF BASELINE RESPONSE

Shown below are the tabulated results from the Aqwa analysis for both the existing and 55-car hull forms. The amplitude (position) and acceleration of the response are reported for each of the five sea conditions analyzed, and at each of the three selected monitoring points for the heave (vertical), roll (rotation about the x-axis), and pitch (rotation about the y-axis) degrees of freedom.

Table 2: Comparison of vessel responses in 6-foot beam seas with a 5.3-second period

<table>
<tr><th rowspan="3"></th><th colspan="12">RMS Responses (Beam Seas, Relative to Local Structure Axes)</th></tr>
<tr><th colspan="4">Vertical Direction [Heave]</th><th colspan="4">Rotation About x-Axis [Roll]</th><th colspan="4">Rotation About y-Axis [Pitch]</th></tr>
<tr><th colspan="2">Position [Ft]</th><th colspan="2">Acceleration [Ft/s^2]</th><th colspan="2">Position [Degrees]</th><th colspan="2">Acceleration [Deg/s^2]</th><th colspan="2">Position [Degrees]</th><th colspan="2">Acceleration [Deg/s^2]</th></tr>
<tr><th>Vessel*:
Location</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th></tr>
<tr><td>Pilot House</td><td>1.23</td><td>1.30</td><td>1.27</td><td>1.40</td><td rowspan="3">0.31</td><td rowspan="3">0.42</td><td rowspan="3">0.26</td><td rowspan="3">0.35</td><td rowspan="3">0.06</td><td rowspan="3">0.15</td><td rowspan="3">0.05</td><td rowspan="3">0.14</td></tr>
<tr><td>Car Deck</td><td>1.28</td><td>1.09</td><td>1.23</td><td>1.21</td></tr>
<tr><td>PAX Deck</td><td>1.20</td><td>1.16</td><td>1.19</td><td>1.27</td></tr>
</table>

*Vessel A: Current fleet, Vessel B: Notional 55-Car Ferry

Table 3: Comparison of vessel responses in 10-foot bow quartering seas with an 8-second period

<table>
<tr><th rowspan="3"></th><th colspan="12">RMS Responses (10' SWH, 8-Second Period Bow Quartering Seas, Relative to Local Structure Axes)</th></tr>
<tr><th colspan="4">Vertical Direction [Heave]</th><th colspan="4">Rotation About x-Axis [Roll]</th><th colspan="4">Rotation About y-Axis [Pitch]</th></tr>
<tr><th colspan="2">Position [Ft]</th><th colspan="2">Acceleration [Ft/s²]</th><th colspan="2">Position [Degrees]</th><th colspan="2">Acceleration [Deg/s²]</th><th colspan="2">Position [Degrees]</th><th colspan="2">Acceleration [Deg/s²]</th></tr>
<tr><th>Vessel*:
Location</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th></tr>
<tr><td>Pilot House</td><td>1.37</td><td>1.85</td><td>1.32</td><td>1.99</td><td rowspan="3">0.18</td><td rowspan="3">0.29</td><td rowspan="3">0.17</td><td rowspan="3">0.30</td><td rowspan="3">0.16</td><td rowspan="3">0.31</td><td rowspan="3">0.19</td><td rowspan="3">0.40</td></tr>
<tr><td>Car Deck</td><td>1.47</td><td>2.01</td><td>1.42</td><td>2.01</td></tr>
<tr><td>PAX Deck</td><td>1.39</td><td>1.97</td><td>1.34</td><td>2.12</td></tr>
</table>

*Vessel A: Current fleet, Vessel B: Notional 55-Car Ferry

Table 4: Comparison of vessel responses in 10-foot stern quartering seas with an 8-second period

<table>
<tr><th rowspan="3"></th><th colspan="12">RMS Responses (10' SWH, 8-Second Period Stern Quartering Seas, Relative to Local Structure Axes)</th></tr>
<tr><th colspan="4">Vertical Direction [Heave]</th><th colspan="4">Rotation About x-Axis [Roll]</th><th colspan="4">Rotation About y-Axis [Pitch]</th></tr>
<tr><th colspan="2">Position [Ft]</th><th colspan="2">Acceleration [Ft/s²]</th><th colspan="2">Position [Degrees]</th><th colspan="2">Acceleration [Deg/s²]</th><th colspan="2">Position [Degrees]</th><th colspan="2">Acceleration [Deg/s²]</th></tr>
<tr><th>Vessel*:
Location</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th><th>A</th><th>B</th></tr>
<tr><td>Pilot House</td><td>0.73</td><td>1.22</td><td>0.21</td><td>0.37</td><td rowspan="3">0.70</td><td rowspan="3">1.07</td><td rowspan="3">0.21</td><td rowspan="3">0.35</td><td rowspan="3">0.29</td><td rowspan="3">0.74</td><td rowspan="3">0.09</td><td rowspan="3">0.23</td></tr>
<tr><td>Car Deck</td><td>0.37</td><td>0.44</td><td>0.11</td><td>0.44</td></tr>
<tr><td>PAX Deck</td><td>0.68</td><td>0.78</td><td>0.20</td><td>0.24</td></tr>
</table>

*Vessel A: Current fleet, Vessel B: Notional 55-Car Ferry

Table 5: Comparison of vessel responses in 8-foot bow quartering seas with a 5-second period

	RMS Responses (8' SWH, 5-Second Period Bow Quartering Seas, Relative to Local Structure Axes)											
	Vertical Direction [Heave]				Rotation About x-Axis [Roll]				Rotation About y-Axis [Pitch]			
	Position [Ft]		Acceleration [Ft/s²]		Position [Degrees]		Acceleration [Deg/s²]		Position [Degrees]		Acceleration [Deg/s²]	
Vessel*: Location	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Pilot House	0.15	0.32	0.39	0.75	0.05	0.02	0.11	0.05	0.10	0.03	0.28	0.20
Car Deck	0.17	0.38	0.51	0.94								
PAX Deck	0.14	0.34	0.41	0.78								

*Vessel A: Current fleet, Vessel B: Notional 55-Car Ferry

Table 6: Comparison of vessel responses in 8-foot stern quartering seas with a 5-second period

	RMS Responses (8' SWH, 5-Second Period Stern Quartering Seas, Relative to Local Structure Axes)											
	Vertical Direction [Heave]				Rotation About x-Axis [Roll]				Rotation About y-Axis [Pitch]			
	Position [Ft]		Acceleration [Ft/s²]		Position [Degrees]		Acceleration [Deg/s²]		Position [Degrees]		Acceleration [Deg/s²]	
Vessel*: Location	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Pilot House	0.19	0.26	0.08	0.11	0.15	0.37	0.06	0.16	0.06	0.20	0.02	0.08
Car Deck	0.14	0.23	0.06	0.20								
PAX Deck	0.23	0.36	0.10	0.16								

*Vessel A: Current fleet, Vessel B: Notional 55-Car Ferry

4.3 MSI CALCULATIONS

Using the peak frequency and the RMS value for vertical acceleration attained in Section 4.2, MSI values were calculated for both vessels at each monitoring point for the five wave conditions analyzed.

Note that the bow quartering conditions yield a much greater MSI than the corresponding stern quartering conditions. This is because the encounter frequency drops significantly as the wave celerity (the speed at which an individual wave advances) is near the vessel forward speed.

Table 7: MSI calculation comparison between the existing and notional hullforms

MSI %		Significant Wave Height					
		6 Feet		8 Feet		10 Feet	
		A*	B*	A*	B*	A*	B*
Beam	Pilot House	11.0%	12.1%				
	Car Deck	10.7%	10.5%				
	PAX Lounge	10.3%	11.0%				
Stern	Pilot House			0.7%	0.9%	1.3%	2.8%
	Car Deck			0.5%	0.9%	0.8%	2.1%
	PAX Lounge			0.9%	1.4%	1.6%	1.9%
Bow	Pilot House			3.4%	6.4%	10.1%	15.4%
	Car Deck			4.4%	8.0%	11.0%	17.0%
	PAX Lounge			3.5%	6.7%	10.3%	16.3%

*Vessel A: Current fleet, Vessel B: Notional 55-Car Ferry

4.4 55-CAR FERRY RESPONSE IN REDUCED SEA STATES

Based on the results of Section 4.3, two sea conditions were selected for additional analysis. One notices that the results in Table 7 indicate that the 6-foot beam seas condition yields a greater vertical response and more rider discomfort than the 8-foot, 5-second period ocean swells condition.

Therefore, the beam seas condition was selected to determine at what reduced sea state the 55-car ferry is likely to respond similarly from the standpoint of passenger comfort and vertical response to the current fleet. The second condition was the 10-foot, 8-second period ocean swell condition. This condition was selected to try to understand whether there would be an appreciable impact on the frequency of trip cancelations if the smaller 55-car fleet is pursued.

For these conditions, the sea state was incrementally reduced and the MSI recalculated. This was done iteratively until the passenger lounge MSI matched that calculated for the current vessel in the baseline sea conditions.

Table 8: MSI comparison between the existing and 55-car vessel in the DRBA defined sea conditions and reduced sea conditions, respectively.

MSI %	Current Fleet		55-Car Ferry	
	6', 5.3 Sec Beam Waves	*10', 8 Sec Bow Quartering Waves*	*5.6', 5.3 Sec Beam Waves*	*7.5', 6 Sec Bow Quartering Waves*
Pilot House	11.0%	10.1%	11.3%	10.2%
Car Deck	10.7%	10.3%	9.8%	11.3%
PAX Lounge	**10.3%**	**10.3%**	**10.2%**	**10.6%**

It was found that the 55-car ferry in 5.6-foot, 5.3 seconds period beam waves resulted in a similar passenger lounge MSI as the 6-foot, 5.3 second period beam waves for the current vessel. For the bow quartering condition, the 55-car ferry passenger lounge experiences a similar MSI in 7.5-foot, 6 second period bow quartering waves to the current vessels in 10-foot, 8 second period waves.

Vessel response is impacted by wave energy, and wave energy is a function of the wave height and period, with larger period waves resulting in greater wave energy. To approximate the tendency of the wave period to decrease as wave height decreases for waves with the same steepness, the period and wave height were reduced proportionally for the quartering wave condition.

4.5 COMPARISON TO HISTORICAL WEATHER DATA

Calculations were performed to evaluate the wind speed required to develop the two beam seas conditions discussed in Section 4.4 [6]. The wind speeds were estimated to be 31.6 knots for 6-foot beam seas and 29.1 knots for 5.6-foot beam seas.

Figure 12 illustrates the average daily wind speed at Brandywine Shoal for all available years between 2011-2020. A trendline is provided to illustrate the average daily wind speed over the course of a year. The wind speeds required to generate the pertinent beam seas are indicated by the horizontal lines. Any data point falling above one of these lines indicates the average daily wind speed that day was sufficiently strong and persistent to produce that sea condition.

Wind speed data is provided for approximately 2,300 days over this 10-year period. Figure 12 illustrates that there were 15 days in the 10-year period of 2011-2020 in which an average wind speed of 31.6 knots or greater was recorded. There are 23 days where an average daily wind speed of 29.1 knots or greater was recorded. Consequently, it can be inferred that the smaller 55-car fleet will experience beam seas from northwest winds that produces a response and MSI similar or greater than that of the current fleet approximately 1.3 days more per year. Note that the chart provides *daily* average wind speeds, which may overestimate the wind persistence required to develop the pertinent wave heights. Additionally, through discussions with DRBA it is understood that winds from the northwest that develop beam seas along the route are not sufficient to effect wave-driven cancelations due to the limited available fetch distance over Delaware Bay.

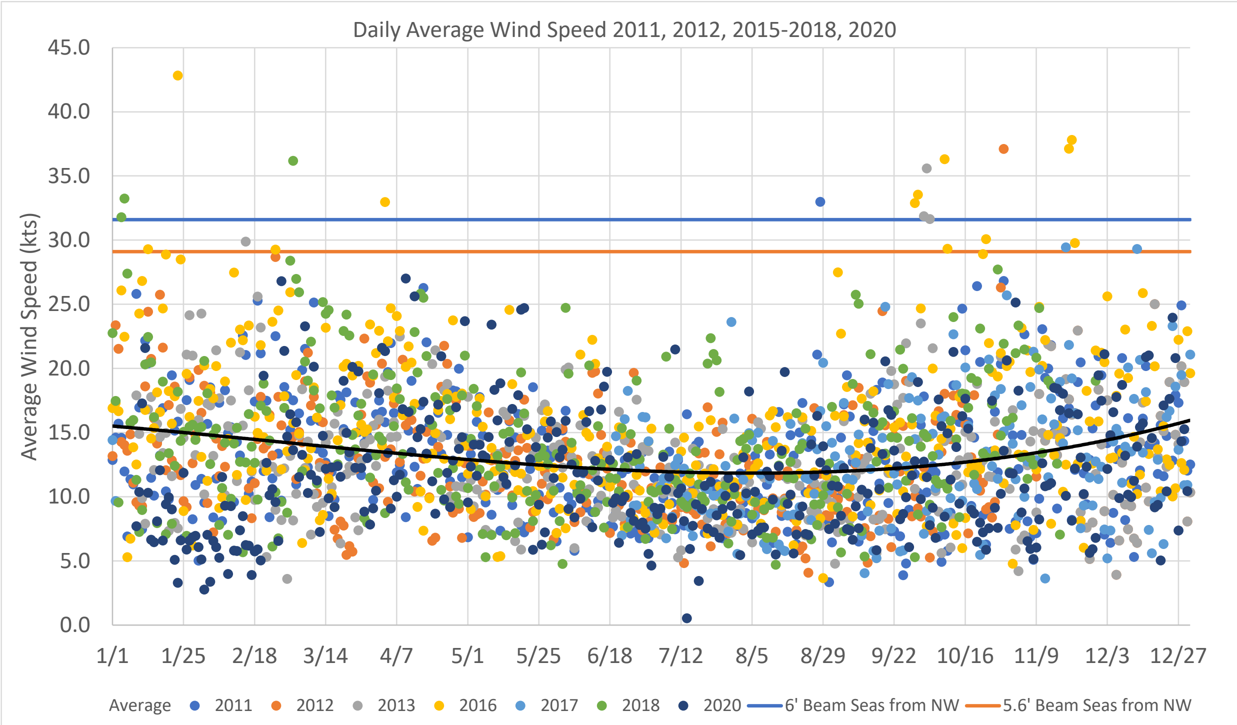

Figure 12: Daily Average Wind Speed at Brandywine Shoal [10]

Similarly, data from NOAA buoy 44009 were analyzed to evaluate the frequency of wave heights that exceed 8-feet and 10-feet, corresponding to the baseline bow quartering sea conditions. A similar analysis was performed for the reduced 7.5-foot seas.

Figure 13 illustrates the average daily average wave height at NOAA station 44009 for the years 2011-2020. A trendline is provided to illustrate the average daily trend in wave height over the course of a year. The wave heights (8 and 10 feet) for the baseline wave heights are indicated by the horizontal lines. A similar line was provided to indicate the reduced 7.5-foot seas. Any data point falling above the line delineating the 7.5-foot seas but below the 8-foot seas indicates a day where a cancelation may have occurred for the 55-car ferry, but not the existing fleet. This is a simplified and somewhat conservative approach that assumes instances of these wave heights occur at a frequency that produces a response similar in magnitude and corresponding MSI that meets or exceeds those determined from the assumed sea conditions in the analysis.

There are approximately 44 days from 2013-2021 where an average daily wave height of 10-feet or greater was recorded. There were 138 days over this period where a wave height of 7.5-foot seas or greater was recorded. The difference between the number of days in which an average wave height of 7.5-feet or greater and 10-feet or greater wave height was recorded (94 days) represents the percentage of additional days over the 10-year period a cancelation may have occurred with the smaller 55-car fleet (about 3.2% of days).

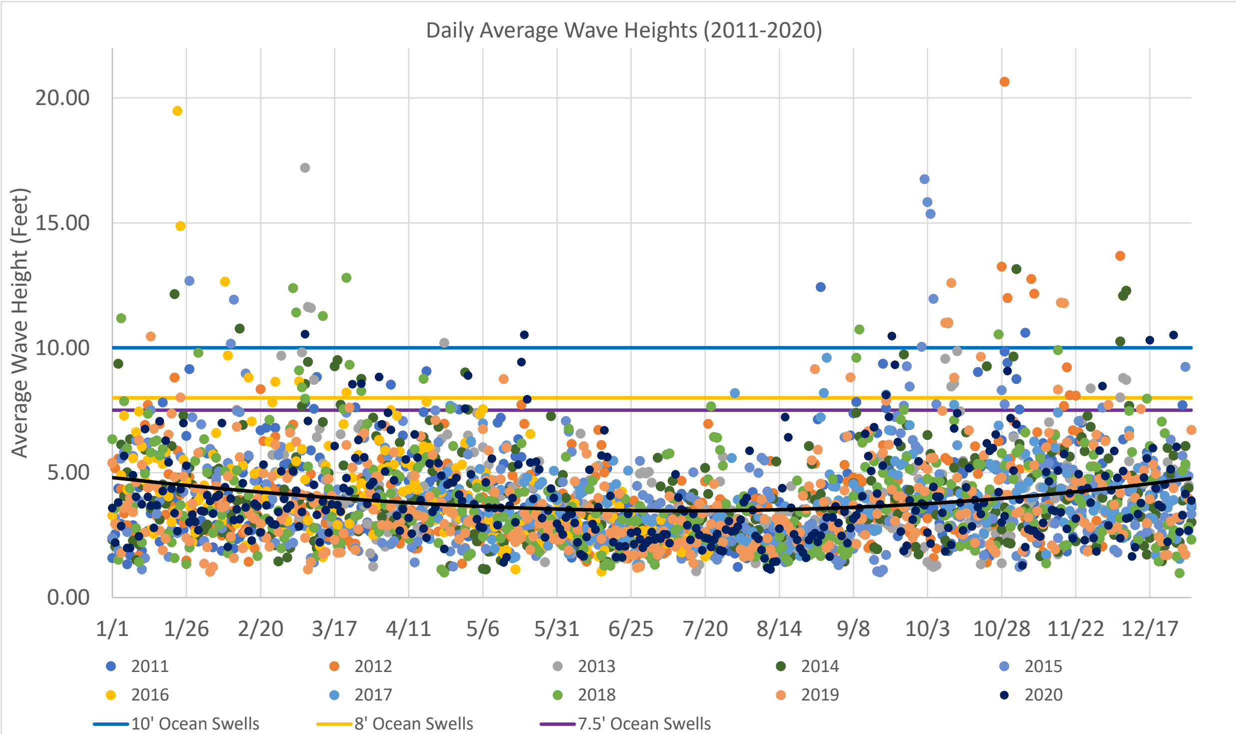

Figure 13: Daily Average Wave Height Speed at Station 44009

5. CANCELATIONS

DRBA provided EBDG cancelation days for the period from 2013 through June of 2021 along with the reasoning for the cancelation. Using the wave data from the NOAA buoy #44009 and the wind data from the Brandywine Shoal buoy, EBDG determined the maximum wave height, the dominate wave period, the direction the waves came from, the average wind speed, the max wind speed, and the direction the maximum wind came from for each of the days that saw canceled service. This information is shown in Table 9. As you can see by the blanks in the table, not all the information was available for all the days.

Table 9: Weather Data for Days with Service Cancelled

Date	Max Wave Height (ft)	Dominate Wave Period (s)	Wave Direction	Average Wind Speed (kts)	Max Wind Speed (kts)	Max Wind Direction	DRBA Reported Reason for Cancelation
3/6/2013	25.6	10.81	NE	-	-	-	Weather
1/3/2014	14.1	10	E	-	-	-	Weather
1/4/2014	8.4	11.43	E	-	-	-	Weather
1/5/2014	5.7	12.9	E	-	-	-	Weather
2/13/2014	15.1	11.43	SE	-	-	-	Weather
7/4/2014	11.5	6.67	N	-	-	-	Hurricane Arthur (several hundred miles offshore)
7/5/2014	7.1	7.14	NE	-	-	-	Hurricane Arthur (several hundred miles offshore)
10/11/2014	6.3	6.67	NE	-	-	-	High winds
10/12/2014	7.1	6.67	NE	-	-	-	High winds
10/13/2014	4.7	12.12	SE	-	-	-	High winds
1/26/2015	12.6	8.33	E	21.1	33.0	NE	Possibly cancelled due to ice
1/27/2015	15.5	9.09	E	24.1	30.9	N	Possibly cancelled due to ice
2/15/2015	11.8	7.14	N	29.9	44.5	NW	Possibly cancelled due to ice
2/19/2015	6.4	5	NW	25.6	34.2	NW	Possibly cancelled due to ice
2/20/2015	7.2	5.88	NW	23.2	34.0	NW	Possibly cancelled due to ice
2/21/2015	4.2	4.76	S	12.5	20.2	S	Possibly cancelled due to ice
2/22/2015	5.3	8.33	SE	5.3	11.3	NW	Possibly cancelled due to ice
2/23/2015	5.4	5.26	NW	14.3	24.9	N	Possibly cancelled due to ice
2/24/2015	5.7	5.26	NW	12.3	23.7	N	Possibly cancelled due to ice
2/25/2015	2.6	10.81	SE	9.0	17.5	S	Possibly cancelled due to ice
1/23/2016	27.6	12.9	NE	37.2	50.7	NE	Weather
5/15/2016	4.4	4.76	NW	21.3	30.7	NW	High Winds
5/20/2016	2.9	7.69	E	9.0	15.6	SE	High Winds
9/3/2016	-	-	-	23.9	36.3	NE	Weather
9/4/2016	-	-	-	19.7	27.2	NE	Weather
9/5/2016	-	-	-	14.1	21.0	N	Weather
1/4/2018	15.8	8.33	N	31.8	48.6	N	Ice
1/5/2018	10.2	11.43	E	33.2	39.1	NW	Ice

1/6/2018	6.7	6.25	NW	27.4	36.2	NW	Ice
1/7/2018	6.3	5.88	N	15.8	25.9	NW	Ice
1/8/2018	5.6	5.26	SW	16.0	21.8	SW	Ice
1/9/2018	4.9	5.56	S	11.3	21.8	SW	Ice
1/10/2018	1.9	3.45	NE	7.3	14.0	N	Ice
1/11/2018	2.8	5.26	SE	9.0	16.3	S	Ice
2/2/2018	6.2	5.88	NW	18.1	27.2	NW	High Winds
3/16/2018	4.5	5	NW	17.9	32.1	N	Low Tide
3/22/2019	10.5	10.81	SE	-	-	-	Wind
10/17/2019	8.0	6.25	NW	-	-	-	Wind
11/1/2019	10.6	8.33	SE	-	-	-	Wind
11/12/2019	8.2	6.25	N	-	-	-	Wind & Low Tide
11/13/2019	8.7	6.25	N	-	-	-	Wind & Low Tide
4/13/2020	11.4	10.81	SE	25.6	59.5	S	Wind
8/4/2020	14.1	9.09	S	19.0	53.8	W	Hurricane Isaias
11/18/2020	7.9	5.88	N	20.8	32.9	NW	Wind
11/23/2020	7.2	6.25	N	17.0	30.3	NW	Wind
12/5/2020	10.0	6.25	N	19.3	35.0	N	Wind
12/6/2020	7.1	5.56	N	17.9	24.5	NW	Wind
12/17/2020	14.0	10.81	E	21.9	40.2	NW	Wind
12/24/2020	7.8	6.67	SE	18.6	25.5	S	Wind
1/29/2021	8.6	6.67	N	-	-	-	High winds & low tides
2/1/2021	15.4	10	E	-	-	-	Winter Storm Orlena/h-winds
3/1/2021	5.1	6.67	E	-	-	-	Winds
3/2/2021	7.6	6.25	N	-	-	-	Low Tide
3/29/2021	6.5	7.14	S	-	-	-	Winds
4/30/2021	5.5	7.14	S	-	-	-	Winds and Low Tide

DRBA reported there were thirty-five (35) days with cancelations over eight and a half (8.5) years due to weather or wind. This means that on average there are about (4) cancelations a year due to wind or weather. From the table, it is noted that twenty-three (23) out of the thirty-five (35) days were specifically identified as cancelled due to wind. Of those twenty-three (23) days, wind information was available for ten (10) and seven (7) were from offshore wind. Offshore wind is defined as wind that blows from the land towards the sea which in this case would be wind from the N, NE, NW, and W.

Table 9 indicates that a substantial portion of cancelations are due to excessive winds and ice. A smaller vessel will be equally affected by these as the current fleet. Extreme weather events (i.e. hurricanes and winter storms) will also cancel sailings at the same frequency for both size vessels.

6. CONCLUSIONS

As motion sickness is produced by sustained sea conditions and exposure over long periods of time, the average wave height is a better indicator of limiting conditions than the maximum wave height. Using data collected by NOAA Buoy #44009, Figure 14 shows the average wave heights greater than 8 feet (outlined by DRBA as limiting sea conditions) occur on less than 4% of days annually. These conditions are likely more severe than those experienced along the Cape May to Lewes route, which is located further inshore on the Delaware Bay. It is likely that extreme weather conditions will overlap a portion of this time and would cancel operations regardless of vessel size.

	Average WVHT (ft)											
WVHT (ft)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**TOTAL**	**Percent**
0-2	26	41	30	31	45	20	21	50	42	29	335	10%
2-4	192	201	176	198	182	148	143	172	187	202	1801	52%
4-6	102	78	73	88	93	102	78	95	88	92	889	26%
6-8	34	28	18	32	32	29	15	33	35	28	284	8%
8-10	9	5	11	10	5	5	4	8	7	9	73	2%
10-12	1	1	4	2	4	1		5	5	5	28	1%
12-14	1	6		4	1	1		2	1		16	0%
14-16					2	1					3	0%
16-18			1								1	0%
18-20					1	1					2	0%
20-22		1									1	0%
Grand Total	**365**	**361**	**313**	**365**	**365**	**308**	**261**	**365**	**365**	**365**	**3433**	

Figure 14: Average Wave Height between 2011-2020. Waves heights were taken as the SWH.

There are only nine instances over the 8.5-year period for which cancelation data is provided where weather is listed as the predominant reason for the cancelation. On average, this equates to approximately 1.1 cancelations per year. Over the course of roughly this same period, there were only 44 instances where the average daily wave height exceeded 10-feet. There were 138 instances where the average daily wave height exceeded 7.5-feet.

The analysis demonstrates that both vessels experience a relatively modest response in 8-Foot, 5-second period waves. It can also be observed that most cancelations from weather occurred on days with an average daily wave height exceeding 10-Feet. Therefore, 10-feet is considered a more reliable threshold for predicting cancelations. We see that cancelations occur on about 20% of the days where the average significant wave height recorded by Station 44009 exceeds 10-feet.

With the notional 55-car vessel, the notional cancelation threshold of 7.5-foot SWH may be eclipsed about 3.3 times as frequently as the 10-foot threshold for the current vessels. Therefore, the analysis suggests that DRBA may be required to cancel service based on wave height about 2.3 additional days per year on average. In addition to the other assumptions defined herein, this assumes that historical weather trends from the past ten years can be extrapolated out across the life of the vessel and does not consider the possibility for increased extreme weather events.

Apart from the wave parameters, a vessel's motion and acceleration response in a seaway is a function of many parameters, including the underwater hull form shape, the weight distribution of the ship, and the location where accelerations are being measured. The weight of the vessel impacts vessel acceleration to the extent that it impacts the underwater hull form shape and the weight distribution and corresponding radius of gyration. Therefore, the impact of displacement on the vertical accelerations and MSI calculations for the 55-car ferry relative to the 100-car ferry is not proportional to the change in displacement between the two vessels.

Historically, 72% of the instances where the daily average wave height exceeds 7.5-Feet occurred in the fall and winter.

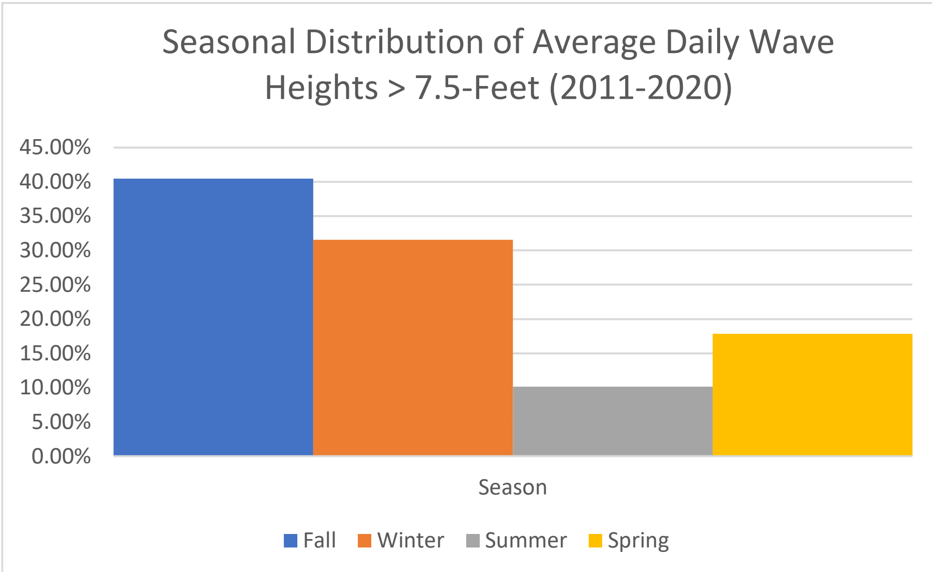

Figure 15: Seasonal distribution of average daily wave heights recorded by Station 44009 from 2011-2020

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APPENDIX L

Phased Electrification Memo

MEMO

Date: February 17, 2023

To: Heath Gehrke, DRBA

From: Andy Bennett

Subject: Cape May – Lewes Ferry Phased Electrification

1 Overview

A goal of the Delaware River and Bay Authority's (DRBA) Marine Master Plan (MMP) for the Cape May Lewes Ferry (CMLF) is to strive for enhanced environmental efficiencies. This phased ferry electrification plan explores the transition of the CMLF to low and then zero-emission operations. Although the amount of power currently available at Cape May is not sufficient to support fully electric ferry operations, by installing energy storage, management, and charging infrastructure, the process of reducing emissions can begin as soon as new, plug-in hybrid vessels are available. Designing the initial infrastructure elements with future expansion in mind allows additional power to be readily integrated into the ferry charging system, including renewable energy sources, thereby reducing greenhouse gas emissions in a stepwise manner.

1.1 Vessel Energy Requirements

During the development of the 2021/22 MMP, three different sized vessels were analyzed. During this process, DRBA selected a 75-vehicle ferry for its future fleet. Energy requirements and potential emissions reductions for this vessel are shown in Table 1 below:

Table 1: Energy Requirements and Emissions Reductions

75 Car Ferry Round Trip Energy & Emissions		
Fuel Consumption (100% diesel)	278	gallons per R/T
Local CO2 Emissions (100% diesel)	6,244	pounds per R/T
Energy Required (100% electric)	4,372	kWh per R/T
Diesel Cost	$973.00	per R/T
Electric Cost	$524.64	per R/T
Energy Cost Savings	$448.36	per R/T
Cost Assumptions		
Diesel Fuel (per gallon)	$3.50	per gallon
Electric Cost (per kilowatt-hour)	$0.12	per kWh

1.2 Current Utility Power

The electricity grid in Cape May currently has more spare capacity than in Lewes so this initial analysis is based on charging each vessel at Cape May for a complete round trip. For this analysis, 1 MW[1] is assumed to be currently available at the Cape May terminal. Possible layouts for the shoreside charging equipment are provided for Lewes, but deeper analysis should be conducted as additional grid capacity in Lewes becomes more likely.

[1] This assumption has been confirmed by Atlantic City Electric

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<u>Emission Reductions</u>

Emission reductions are achieved by replacing the energy produced by burning diesel fuel with energy provided by the electrical grid, which is generated in a manner that produces less emission. A shoreside battery energy storage system (BESS) will use the time between sailings to accumulate power from the grid and store it until a ferry arrives and is ready to charge. During winter operations, there are relatively few sailings per day without ample stretches of time to charge between each sailing. The long charging time and lower overall energy need in winter allows a substantial portion of the daily energy demand to be met with grid power currently available. However, there is not much time between sailings during summer peak operations, so the ability of shoreside BESS to accumulate energy during this season is limited. Consequently, the percentage of daily energy demand that can provided by shoreside power is much smaller during the summer season. Table 3, near the end of this paper explores this more thoroughly.

It should be noted that this analysis only addresses local emission reductions. Emissions generated in the process of providing energy to the electric grid are not considered.

2 Implementation Phasing

The installation of the infrastructure necessary to transition to operating on 100% renewable energy can be done in phases, to both manage capital costs and take advantage of new power supplies as they become available. The following implementation phases are recommended:

- Phase 0: No changes to electrical infrastructure; plug-in ready hybrid vessels delivered.
- Phase 1: Infrastructure installed to take maximum advantage of existing 1 MW power supply utilizing BESS.
- Phase 2: Additional infrastructure added to take advantage of increased availability of grid power at the current voltage, using existing duct banks and distribution lines.
- Phase 3: Grid capacity supply increased by ACE to allow all vessels to operate on 100% electric power in normal operations. This could be achieved by either increasing the grid power supplied and continuing to use BESS to limit peak demands or ACE providing a new 69 KV line
- Phase 4: On-site renewable power incorporated into available power supply.

All phases will require close coordination with the local utility provider. Additional discussion of the improvements associated with each phase follow.

2.1 Phase 1

In Phase 1, infrastructure will be put in place to charge the plug-in hybrid ferries using utility power currently available at the Cape May terminal to partially reduce the use of diesel fuel. In this phase, the ferries will use shore power to charge onboard batteries as much as practicable and use diesel fuel whenever the power in the onboard batteries drops below a pre-set threshold. For this phase, the BESS is assumed to have a working capacity of 110% of the round-trip energy demand and a normal depth of discharge of 40%. For the 75-vehicle ferry, Phase 1 BESS capacities are as follows:

Table 2: Phase 1 BESS Capacities

	75 Car Ferry
BESS Working Capacity (kW-hr)	4,900
BESS Total Capacity (kW-hr)	12,300

In addition to the BESS, Phase 1 improvements would include new switchgear and a new meter for a dedicated circuit, primary switchgear near the operating slips with expansion panels for Phases 2, 3, and 4, a new charging arm at the primary operating slip, and transformers between the new BESS and the primary switchgear.

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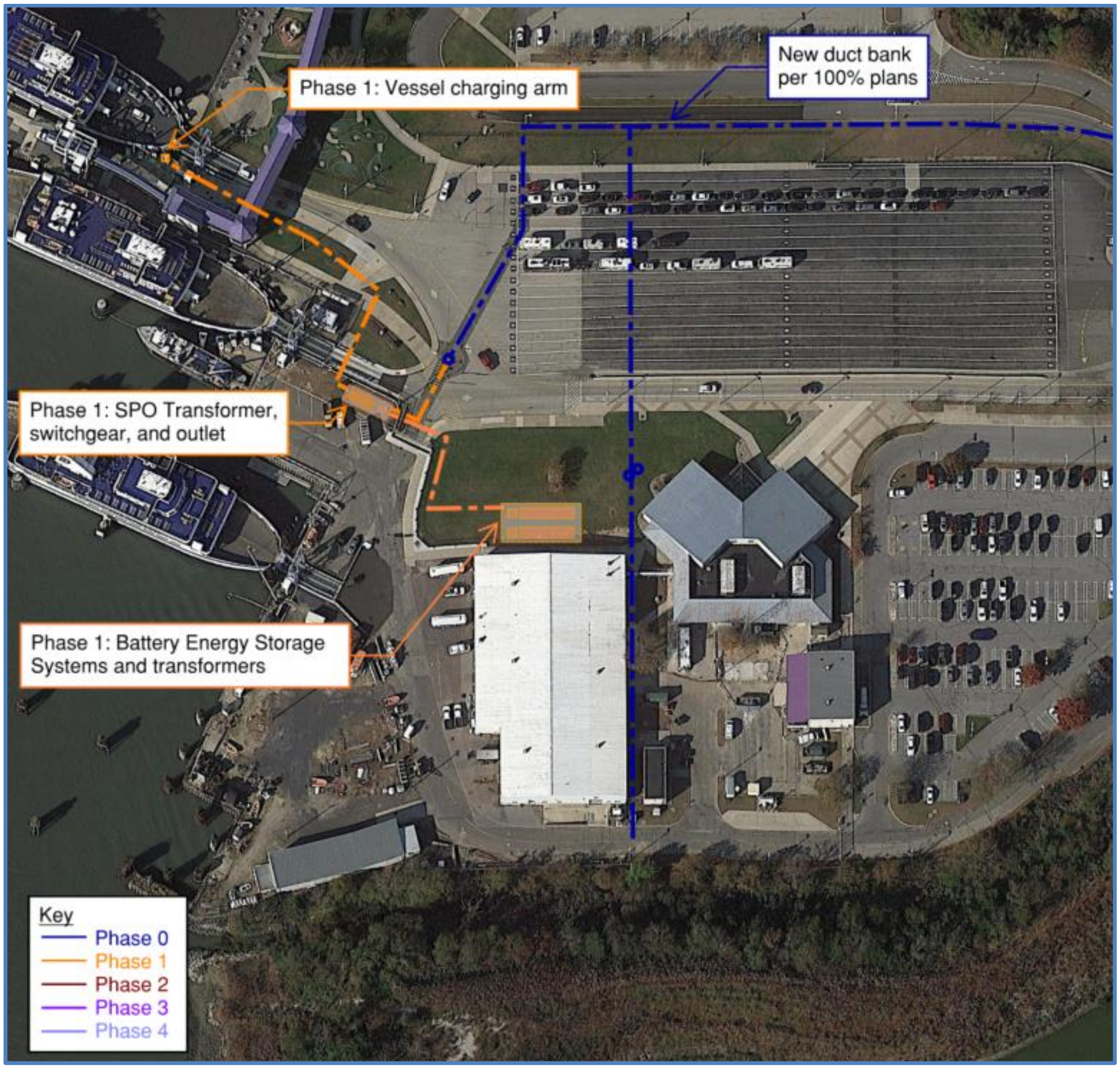

Figure 1: Phase 1 Improvements

2.2 Phase 2: Marginal Grid Capacity Improvements

If marginal improvements are made to the grid capacity at Cape May, the additional energy available could be captured and stored in on-site BESS to increase the percentage of total energy provided. To take advantage of this capacity, additional BESS units would be required and a second charging arm could be installed at the second operating slip so two vessels could be charged overnight.

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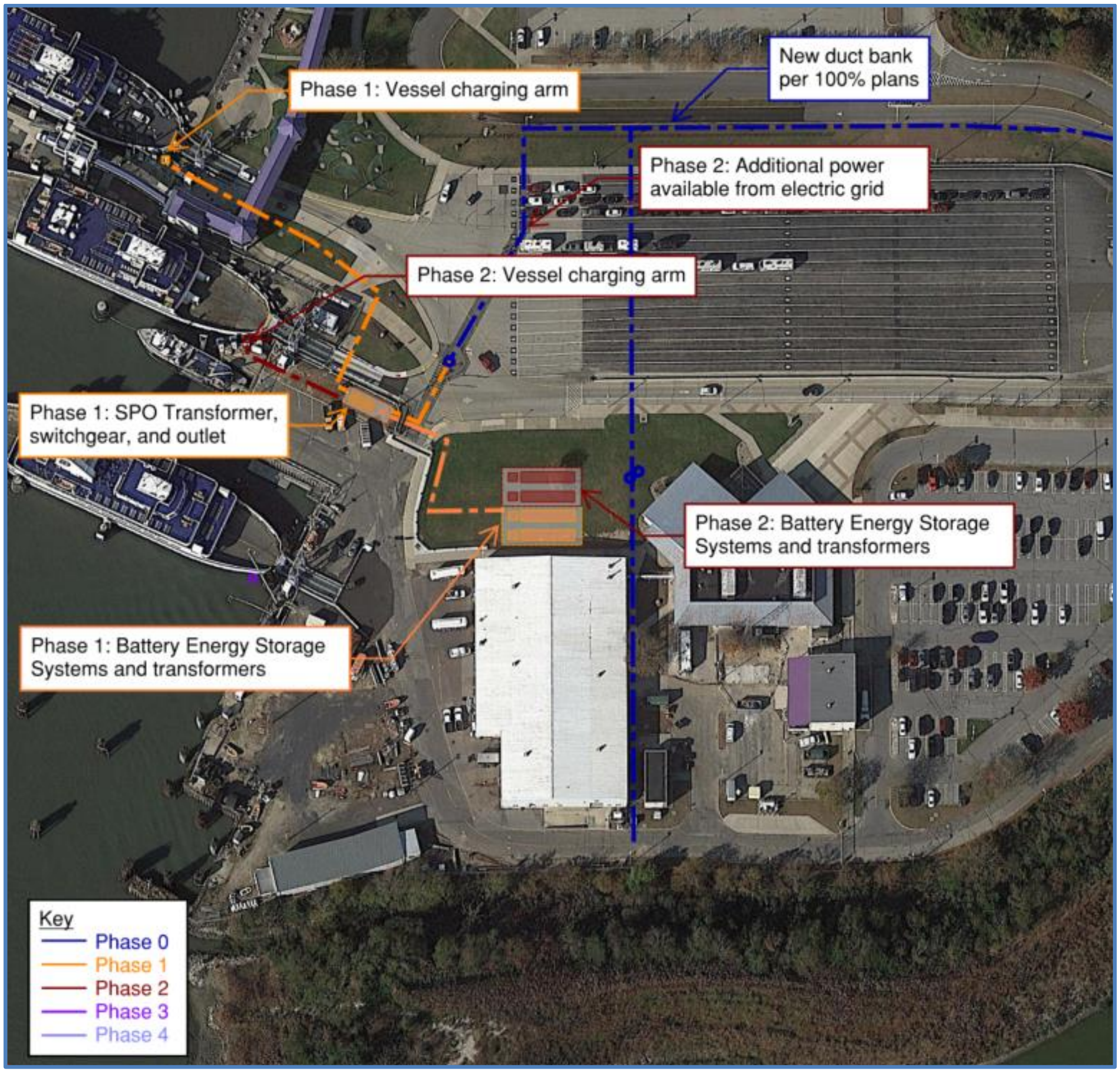

Figure 2: Phase 2 Improvements

2.3 Phase 3: Ferry Operations 100% Electric

The Phase 3 system will include all the renewable energy power supplies and storage capacity needed to support 100% electric ferry operations, as well as a third charging arm at an overnight mooring slip since all ferries will be electric. This phase assumes that there is enough power available to accommodate the demand created with all ferries operating on 100% electric power.

2.3.1 With BESS

If a BESS system will be used to stabilize power demand by accumulating energy between sailings, the Phase 3 grid demand for a fleet of 75 car ferries would be approximately 6.3 MW and the BESS storage capacity would be 7,300 kW-hours. In this scenario, the only improvements necessary at Cape May would be the installation of an additional charging arm at one of the overnight moorage and maintenance slips. With the additional charging arm, three vessels could be charged overnight when electric rates are lower.

2.3.2 Direct Charging from Grid

If the ferries were to be rapid charged directly from the grid, the demand would be approximately 16 MW, which would require ACE to increase the supply voltage to the terminal from 12.47 KV to 69 KV. A new substation would be required on-site to step down the grid voltage to that required by the vessel charging system. Due to the cost of such an initiative, this scenario may not be implemented, particularly if 6.3 MW can be supplied and the use of a BESS can adequately buffer the local grid against the peaks and drop-off in demand during the start and end of vessel charging cycles.

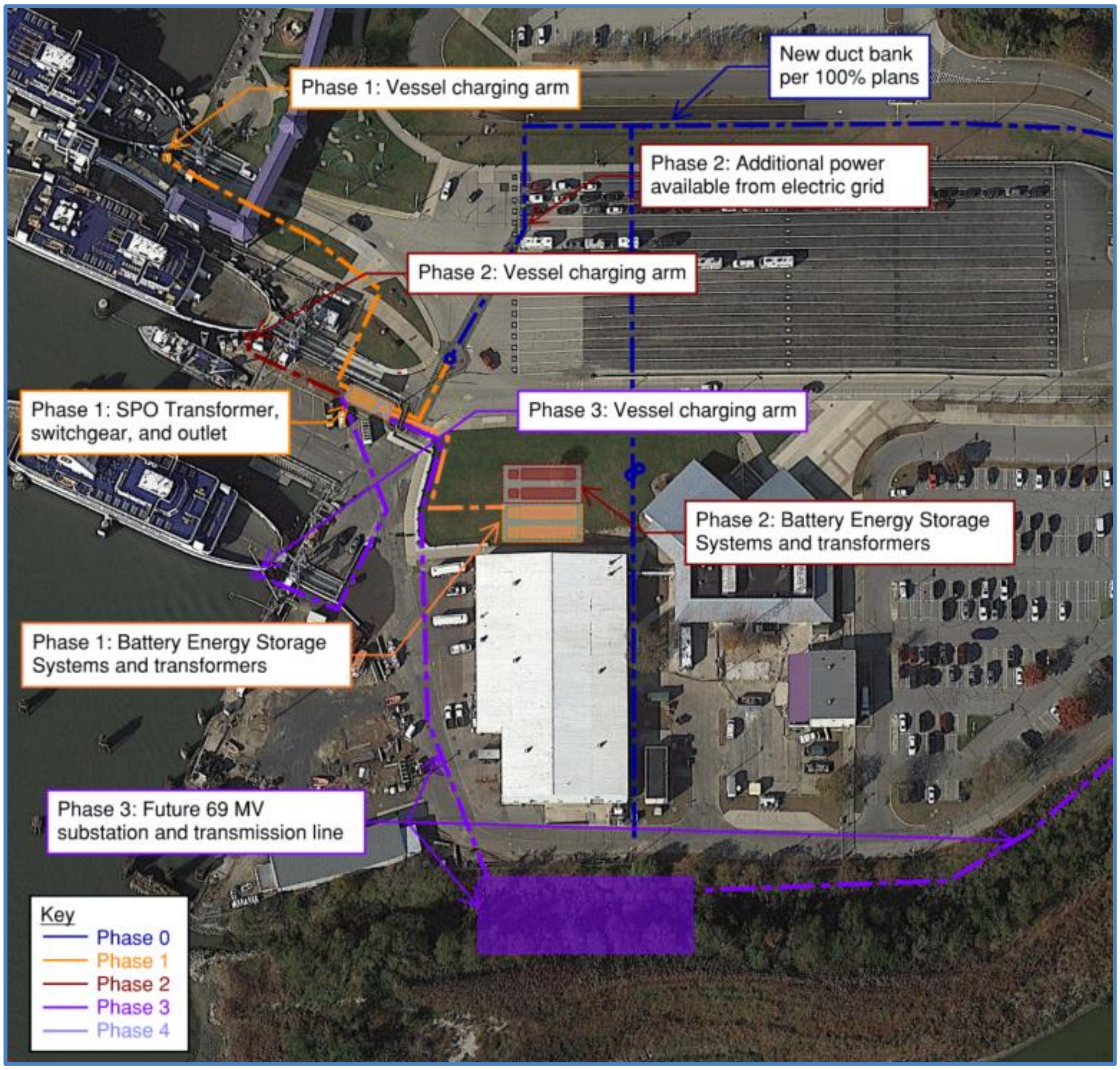

Figure 3: Phase 3 Improvements

2.4 Phase 4: Use On-site Renewable Energy

Because renewable energy sources currently provide less than 10% of the power generated in New Jersey, the installation of on-site green energy generation systems is proposed to further reduce system-wide total greenhouse gas emissions from the CMLF. The viability of wind and solar systems is being assessed as part of the development of the DRBA Green Master Plan. Further study is required to determine feasibility of wind turbine or solar panel systems in Phase 4.

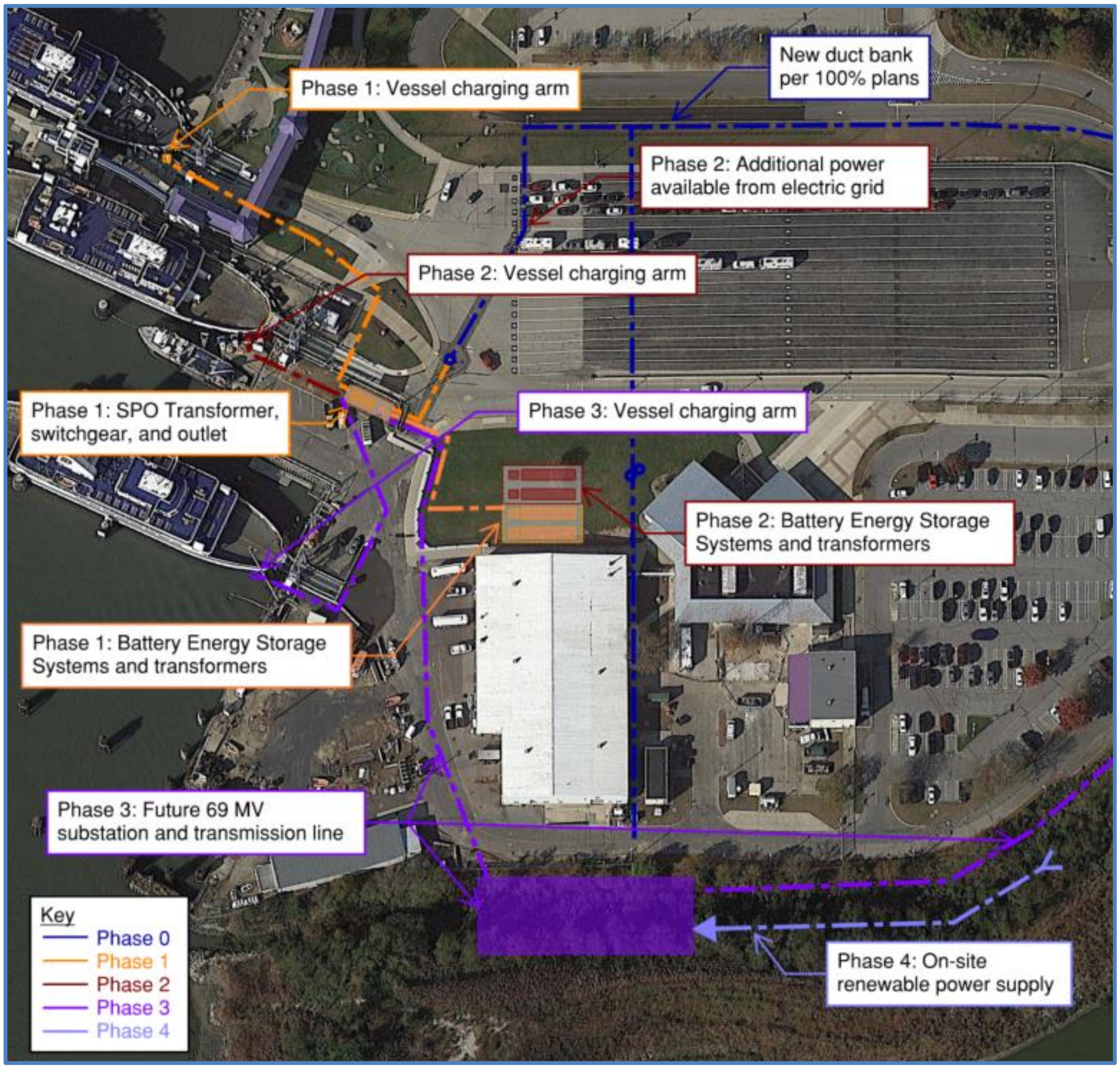

Figure 4: Phase 4 Improvements

The additional Phase 4 equipment could include transformers, circuit breakers, and control systems to convert the type and voltage of the supplied power to match that of the vessel charging system and to protect the rest of the system from potential issues with generating systems.

The Phase 4 on-site renewable energy systems are most likely to be installed on the eastern portion of the Cape May terminal property, in the area currently used for dredge spoils disposal. As part of the Phase 4 construction efforts, it will likely be more efficient to install additional BESS and other infrastructure in this portion of the site rather than expanding the footprint of the charging system within the operating terminal and maintenance facility. Atlantic City Electric (ACE) may also require an upgraded connection to the local utility grid to accept any excess power generated as part of a buy-back agreement.

3 Charging System Components

The infrastructure elements that will be required include shoreside power conversion and management systems, shoreside Battery Energy Storage System (BESS), vessel rapid charging system (RCS), and the associated duct banks, distribution cables, and support systems.

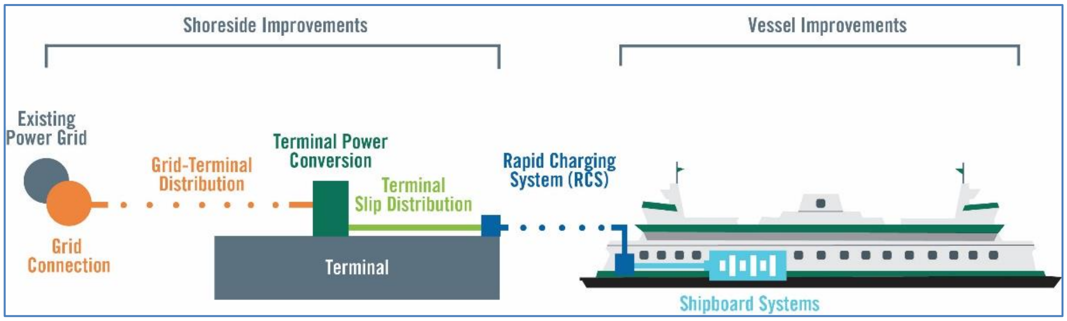

Figure 5: Ferry Electrification System Components

3.1 Substation and Switchgear

The power conversion and management systems would include a utility connection (ideally sized to support Phase 3 demand for full electric operations), primary circuit breaker, isolation transformer, distribution panel for connection to the vessel charging system and BESS, auxiliary panel(s), and spare panels for additional charging arms and connections to the local renewable energy sources to be developed in Phases 2 and 3.

3.2 Battery Energy Storage System (BESS)

Energy provided by the utility at lower power levels can be accumulated in a shoreside BESS at the grid supplied power level and then discharged at a higher power level into the vessel batteries. The BESS units include power management and conversion equipment, batteries, firefighting systems, and monitoring, control, and alarm systems. Because power from the grid is alternating current and batteries operate on direct current, an inverter is required for both charging and discharging the battery. A transformer is also required to change the voltage to that required by the vessel charging system.

Figure 6: Kokam 40' Container BESS

Figure 7: SAFT 20' Container BESS

3.3 Vessel Rapid Charging System (RCS)

The automated vessel rapid charging system would be mounted adjacent to the operating slip to connect the shoreside systems to the vessel batteries. Vessel charging systems typically consist of an active, automated plug mechanism and a matching, passive receptacle. For most of the systems in operation now, the active element is mounted on shore or fixed mooring structures, like wingwalls or dolphins. Regardless of whether the passive or active element is installed on the vessel, the charging mechanism will need to be integrated into the vessel's structural, electrical, and control systems design.

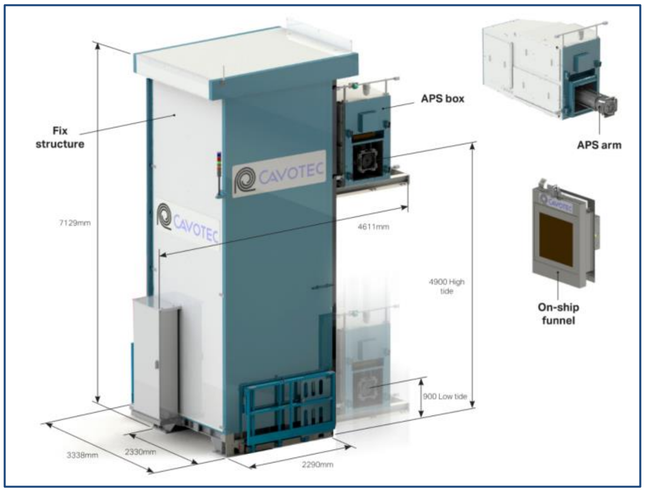

Figure 8: Cavotech PowerReach System

Figure 9: Stemmann Technik FerryCHARGER

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Figure 10: Wabtec FerryCharger

3.4 Duct Banks, Cabling, and Support Systems

The power and control cabling connecting the utility, the local substation, and the rapid charging system would be run in an underground duct bank rather than overhead cables to maximize reliability. Depending on the length and routing of the duct bank, manholes and vaults or hand holes will be required to support cable installation and maintenance. Where practicable, the substation, BESS, and transformers would be located adjacent to each other within a secure fenced and lighted enclosure. Each piece of equipment would need a foundation and stormwater drainage would be required to prevent ponding in the area. Each piece of equipment has required maintenance and safety clearance requirements that will need to be accommodated. For Phase 1, the enclosure could be sized for just the Phase 1 equipment, but it should be located such that it could be expanded to accommodate Phase 2 and 3 equipment as well. The voltages typically used to charge vessel batteries are high enough that the BESS and any associated transformers can be separated from the substation by several hundred feet without incurring substantial line losses.

4 Sample Energy Cost Profile and Emission Reductions

Estimates of the energy costs and emission reductions were developed for Phase 1, current electric power supply, and Phase 3, 100% electric daily operations. These estimates only account for normal operations and do not include any repositioning or other non-revenue trips. To address the minimum and maximum daily energy requirements, operations were analyzed for winter weekday service with five round-trips per day and summer weekend service with 18 round trips per day. In all cases, new vessels with a capacity of 75 cars were assumed.

4.1 Phase 1 Energy Costs and Emission Reductions

During winter operations, a single vessel is assumed to be in service and it is charged upon its arrival at the end of the service day. Once the vessel batteries are fully charged, the shoreside batteries are charged so they will have enough energy stored to completely charge the second sailing of the day. This allows the first two sailings each day to make complete round trips on all electric power. Subsequent departures are charged as much as possible but will be required to make part of the trip on diesel power.

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On summer weekends with 18 departures (one every 40 minutes), it would be possible to charge a specific vessel during each Cape May landing, which would result in fewer but deeper discharge cycles, or charge every vessel, which would require more, shallower charge cycles. The preferred operating approach will depend on the battery chemistry used in the shoreside batteries. Both scenarios are summarized below.

In each scenario, the first departure of the day is assumed to charge overnight and once the vessel batteries have been charged, the shoreside batteries are charged so that a full charge is available for the second departure.

In Phase 1, the total energy assumed to be available from the grid on a given day is of a similar order of magnitude as the winter demand and is only a fraction of total summer demand. The recommended Phase 1 BESS capacity is set to store enough energy for one round-trip with a 10% margin, which makes efficient use of the energy available.

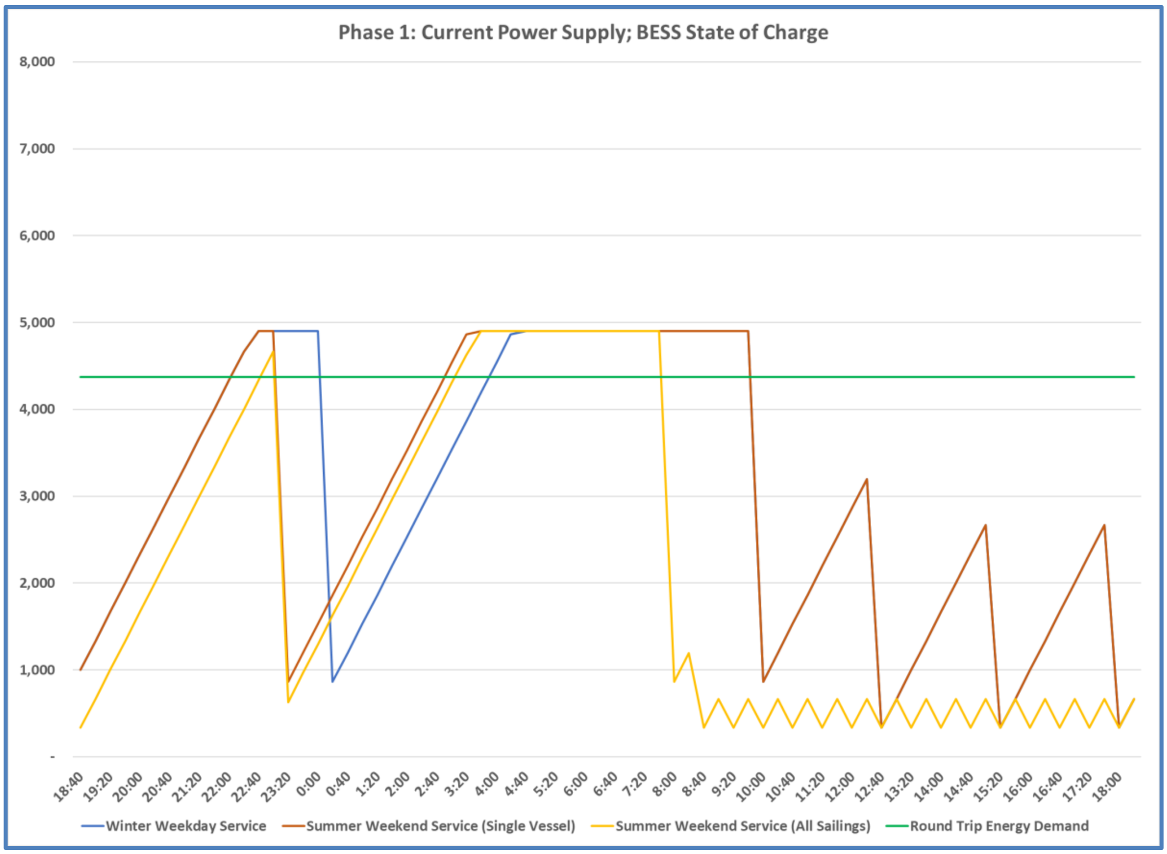

Figure 11: Phase 1 BESS State of Charge

Table 3: Phase 1 Operating Cost Savings and Local Emission Reductions

Phase 1: Currently Available Grid Power Supply (1 MW total)				
	Winter Weekday	Summer Weekend (1 vessel) Deeper Charge Cycles	Summer Weekend (all vessels) Shallower Charge Cycles	
Winter Weekdays (Sched A)				
Daily Round-trips	5	18	18	
Daily Fuel Consumption	1,390	5,004	5,004	gal
Daily Fuel Cost (100% diesel)	$ 6,255	$ 22,518	$ 22,518	
Daily Emissions (100% diesel)	31,219	112,390	112,390	lbs CO2
Daily Energy Demand	21,860	78,696	78,696	kW-hrs
Charge Cycles	5	5	18	
% of trips charged	100%	28%	100%	
Daily Electric Energy Used	17,272	17,272	19,939	kW-hrs
% of Total Energy Required	79%	22%	25%	
Daily Fuel Used (Hybrid)	292	3,906	3,736	gal
Daily Fuel+Electric Cost	$ 3,371	$ 19,634	$ 19,189	
Energy Cost Saving (Hybrid)	$ 2,884	$ 2,884	$ 3,329	
Emission Reduction	(24,667)	(24,667)	(28,475)	lbs CO2
Approximate Annual Savings		$ 1,053,000	$ 1,134,000	
Approximate Annual Reduction		(9,003,000)	(9,699,000)	lbs CO2

4.2 Phase 2 Energy Costs and Emission Reductions

In Phase 2, an additional RCS at the second operating slip and additional BESS capacity would be added to take advantage of an assumed increase in the power available from the gird. For this analysis, an increase of 1 MW in the available power at Cape May, for a total of 2 MW, was assumed, along with a 50% increase in BESS capacity. If additional power does become available, the actual scope of improvements will need to be reviewed based on the actual power provided.

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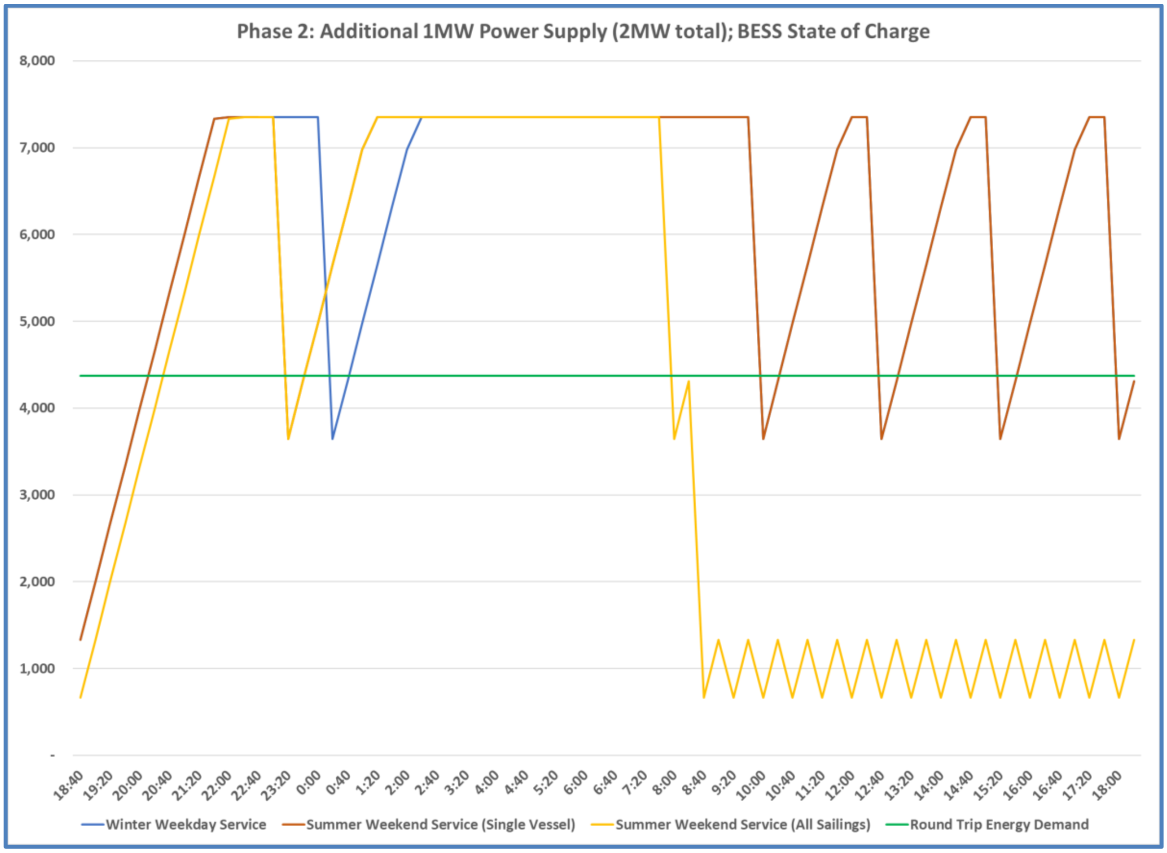

Figure 12: Phase 2 BESS State of Charge

Table 4: Phase 2 Operating Cost Savings and Emission Reductions

Phase 2: Additional 1MW Grid Power Supply (2 MW total)				
	Winter Weekday	Summer Weekend (1 vessel)	Summer Weekend (all vessels)	
Winter Weekdays (Sched A)				
Daily Round-trips	5	18	18	
Daily Fuel Consumption	1,390	5,004	5,004	gal
Daily Fuel Cost (100% diesel)	$ 6,255	$ 22,518	$ 22,518	
Daily Emissions (100% diesel)	31,219	112,390	112,390	lbs CO2
Daily Energy Demand	21,860	78,696	78,696	kW-hrs
Charge Cycles	5	5	18	
% of trips charged	100%	28%	100%	
Daily Electric Energy Used	21,860	21,860	33,055	kW-hrs
% of Total Energy Required	100%	28%	42%	
Daily Fuel Used (Hybrid)	-	3,614	2,902	gal
Daily Fuel+Electric Cost	$ 2,605	$ 18,868	$ 16,999	
Energy Cost Saving (Hybrid)	$ 3,650	$ 3,650	$ 5,519	
Emission Reduction	(31,219)	(31,219)	(47,208)	lbs CO2
Approximate Annual Savings		$ 1,333,000	$ 1,674,000	
Approximate Annual Reduction		(11,395,000)	(14,313,000)	lbs CO2

4.3 Phase 3 Energy Costs and Emission Reductions

In Phase 3, the combination of grid power and BESS storage will be enough to provide all of the power needed for daily operations, even during summer peak season weekends. Because the vessels will be plug-in hybrids, they will be able to operate on diesel when shore power is unavailable, either due to power outages or equipment maintenance or repairs.

As discussed in Section 2.3, getting to all-electric regular operations can be achieved one of two ways, expanded use of BESS with additional power provided to the terminal at the existing line voltage or direct charging from the grid.

The analysis below assumes the shoreside BESS has the capacity required in Phase 2 (18,400 kWh total, 7,350 kWh usable) and the available power supply is increased to 6.3 MW. As part of the design of the Phase 3 system, the combination of BESS capacity and charging power provided should be reanalyzed to account for battery and energy costs at the time.

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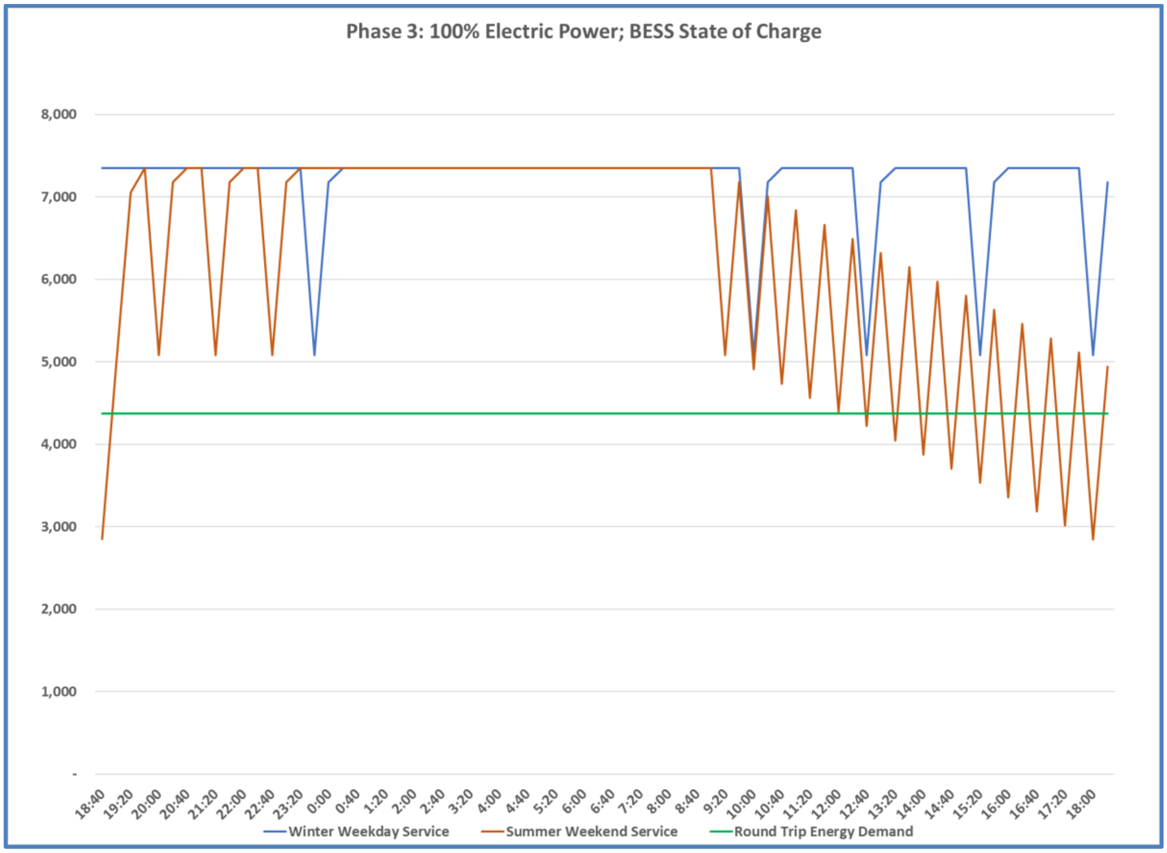

Figure 13: Phase 3a BESS State of Charge

Table 5: Phase 3a Operating Cost Savings and Emission Reductions

Phase 3: 100% Electric Daily Operations			
	Winter Weekday	Summer Weekend	
Winter Weekdays (Sched A)			
Daily Round-trips	5	18	
Daily Fuel Consumption	1,390	5,004	gal
Daily Fuel Cost (100% diesel)	$ 6,255	$ 22,518	
Daily Emissions (100% diesel)	31,219	112,390	lbs CO2
Daily Energy Demand	21,860	78,696	kW-hrs
Charge Cycles	5	18	
% of trips charged	100%	100%	
Daily Electric Energy Used	21,860	78,696	kW-hrs
% of Total Energy Required	100%	100%	
Daily Fuel Used (Hybrid)	-	-	gal
Daily Fuel+Electric Cost	$ 2,605	$ 9,379	
Energy Cost Saving (Hybrid)	$ 3,650	$ 13,139	
Local Emission Reduction	(31,219)	(112,390)	lbs CO2
Approximate Annual Savings		$ 3,064,000	
Approximate Annual Reduction		(26,209,000)	lbs CO2

If a new 69 KV feeder is provided to the Cape May terminal, 100% electric operations can be achieved by providing 16 MW directly to an RCS at each operating slip. In this option, the spikes in demand may be difficult to manage to prevent voltage drops and surges. This option would have the same operating cost savings as using the Phase 2 BESS with a total of 6.3 MW available power.

4.4 Phase 4 Energy Costs and Emission Reductions

The Phase 4 energy and emission savings will be the same as Phase 3, with the difference being the greenhouse gas emissions created during power generation.

5 Capital Cost

The capital costs below are based on the infrastructure for each phase as described in Sections 2.1 through 2.3 to support round-trip charging of a 75-car ferry fleet at the Cape May Terminal.

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Table 6: Estimated Capital Costs

	Phase 1	Phase 2	Phase 3
Charging Arm	$ 1,000,000	$ 1,000,000	$ 1,000,000
Primary Electrical Equipment	$ 3,350,000	$ 335,000	$ 335,000
BESS	$ 4,920,000	$ 2,460,000	$ -
BESS to Switchgear Duct Bank	$ 120,000	$ -	$ -
Switchgear to Charging Arm Duct Bank	$ 400,000	$ 400,000	$ 400,000
Misc. Site Improvements	$ 130,000	$ 43,333	$ 32,500
Baseline Construction Cost	**$ 9,920,000**	**$ 4,238,333**	**$ 1,767,500**
Mobilization/Contingency/Design & Permitting/CM Costs	$ 6,150,400	$ 2,627,767	$ 1,095,850
Total Program Cost	**$ 16,070,400**	**$ 6,866,100**	**$ 2,863,350**

A detailed cost estimate is provided in Attachment 2.

In Phase 2, some additional equipment will be needed in the reserved sections of the main switchgear to make the connection to the new power source and additional BESS units and transformers will likely be required. Phase 2 would also include the installation of an RCS at the second operating slip to allow two vessels to be charged overnight.

Phase 3 would see the full build-out of the system, which would include completing the final reserved section of the switchgear and an additional RCS at an overnight mooring and maintenance slip. The Phase 3 costs to upgrade the utility service are not included as they would need to be developed by ACE.

The Phase 4 capital costs would be included in the cost of the new wind or solar generating system.