103115-01-RPT-0001
Revision 0

Port of Lake Charles

Calcasieu Ship Channel Traffic Study – 2018 Update

Final Report

June 12, 2019

Revision Status

Revision	Date	Description	Author		Approver	
A	2019-03-22	Draft Report	Tyler Beames-Canivet	Simulation Engineer	Joel Shirriff	Project Sponsor
0	2019-06-12	Final Report	Tyler Beames-Canivet	Simulation Engineer	Stephen Wong	Simulation Consultant

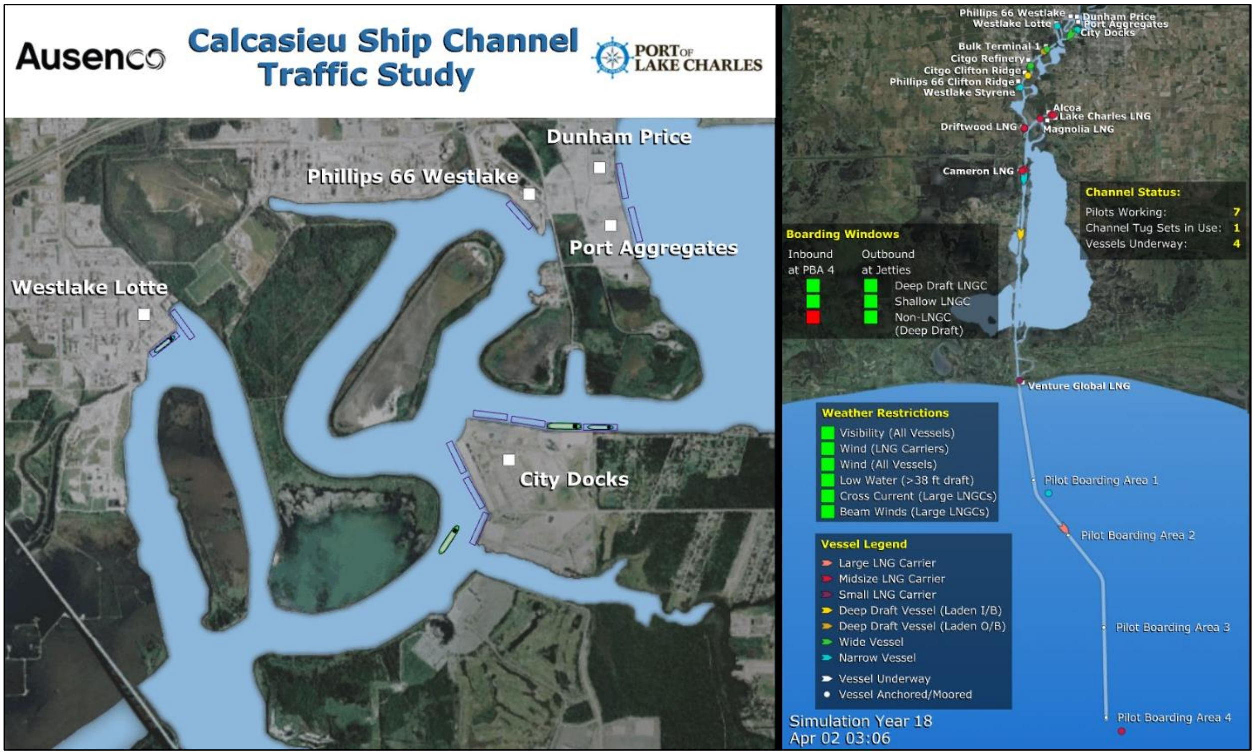
Table of Contents

Executive Summary

Traffic in the Calcasieu Ship Channel is expected to increase significantly over the next decade due to the expanded operations of the present channel users and the construction of several proposed terminals. By 2025, the traffic in the channel is forecasted to more than double from 2018 levels. Ausenco was engaged by the Port of Lake Charles in 2015 to conduct a simulation study to investigate the impact of this traffic on the operations of the channel and to assess the need for changes to the channel infrastructure and regulations. This study was commissioned in late 2018 to reassess the channel's capabilities, regulatory needs, and infrastructural needs.

In the 2015 study, Ausenco developed a detailed model of the Calcasieu Ship Channel. This model included the existing and proposed terminals, present and forecasted traffic levels, different vessel types, the four pilot boarding areas, rules and restrictions for transits, boarding windows, and weather closures. Figure 1 shows a screenshot of the Calcasieu Ship Channel simulation model. In this study, the changes to terminal infrastructure and plans were incorporated into the model, along with updated pilot regulations and weather data.

Figure 1 Screenshot of the Calcasieu Ship Channel Simulation Model



The Base Case of the simulation model investigated how the channel is expected to operate in the future, assuming the channel maintains its present infrastructure and operational rules and is dredged to congressionally authorized dimensions. Five Infrastructure Cases were investigated to test the sensitivity of how the channel would be impacted by changes to its infrastructure or regulations, including the effect of insufficient dredging.

Each traffic year from 2017 to 2033 was simulated for each case, although the majority of the discussions focused on three key traffic years: 2018, 2023, and 2028. These traffic years provide an overview of the conclusions of the study because they represent the channel at the present and at key points over the next 10 years when traffic is expected to increase significantly. Based on the changes observed in terminal investment from the 2015 study to this study, data beyond 2023 was subject to a large amount of variability due to, for example, future market conditions, and was not analyzed in detail.

The outputs from the simulation model were analyzed to determine statistics and draw conclusions about the channel performance. The key performance indicators calculated from the model outputs and used to assess the channel included the number of vessels handled, the vessel wait times, the number of vessel Pilots required, the number of tugs required, and – for the Infrastructure Cases – the increase or decrease in vessel charter costs.

Base Case Results

Table 1 shows the forecasted traffic levels and the key results for the Base Case simulation runs in the three key traffic years, as well as for 2033.

Table 1 Overall Channel Performance in 2018, 2023, 2028, and 2033

Year	Number of Vessels Scheduled	Number of Vessels Handled	Median Wait Time
2018	1,098	1,098	3.5 h/vessel
2023	1,769	1,769	6.3 h/vessel
2028	2,527	2,527	10.7 h/vessel
2033	2,607	2,607	11.0 h/vessel

The match between the number of vessels scheduled and the number of vessels handled shows that the channel, with the existing infrastructure and operations, has the capacity to handle the forecasted traffic increases in each year, provided it is maintained at congressionally authorized dimensions. However, the traffic was subject to longer wait times: between 2018 and 2023, the median wait time for a vessel increased by 2.8 hours (an 80% increase). The increase in median wait time was largely driven by LNG vessels, which began arriving in 2019 and which experienced longer wait times than non-LNG-carrying vessels.

An analysis of the wait times showed that the Large and Midsize LNG carriers (expected at the majority of the proposed LNG terminals) experienced the highest wait times out of all vessel categories. Due to the increased stringency of the pilot regulations on LNG carriers, wait times were larger than those in the 2015 study, despite a lower traffic volume.

Weather closures and boarding windows were major contributors to the wait time and although these cannot be minimized directly, their secondary effects can be mitigated. Any changes to the channel that would allow vessels to begin moving sooner, after either a closure ends or a boarding window opens, should improve operations – such changes were investigated in the Infrastructure Cases.

The model also showed that additional Pilots are necessary to meet the demands of the increased traffic. By 2023, the channel will need up to 33 Pilots (the channel had 17 Pilots as of 2018).

Infrastructure Cases Results

Table 2 summarizes the change in vessel charter costs (for all vessels) due to the change in vessel wait times for each of the Infrastructure Case simulation runs for the 2023 traffic year (which was representative of the impact in any given year).

Table 2 Estimated Economic Impact of Infrastructure Cases in 2023

Case	Change to Channel Operations	Estimated Change in Annual Charter Costs (M$/y)
1A	Insufficient dredging (moderate)	$1.6M
1B	Insufficient dredging (more severe)	$5.6M
2	Increased Pilot requirements for LNG carriers	-
3	LNG carrier passing on the Outer Bar	($9.3M)
4	Inner Channel anchorages	$0.2M
5	Inner Channel passing lane	$0.6M

* Values in parentheses ( ) reflect a reduction in annual charter costs.

Insufficient dredging, especially in the more severe scenario, significantly increased the vessel charter costs for the channel users. In addition to these charter costs, insufficient dredging would result in delayed deliveries and shipments at the terminals (as evidenced by the increase in vessel wait times) and could impact the ability of the channel to handle fully laden vessels. Although the economic assessment of these additional effects was beyond the scope of the study, they would only further increase the costs to the channel. These cases demonstrate the significant economic benefit and importance of continued dredging and maintenance of the channel.

Changing the passing restrictions for LNG carriers on the Outer Bar resulted in significant charter cost savings. These savings were the result of decreased wait times for all vessels, since this change allowed all traffic to move more easily in the channel. This result is in line with one of the conclusions from the Base Case: a change that allowed vessels to more easily enter after a weather event would provide the greatest benefit to the channel operations.

The costs and savings of the infrastructure cases were less than in the 2015 study due to the lower traffic volume in 2023 compared to the 2015 study and because LNG carriers had a stringent schedule for transiting the channel due to increased weather restrictions.

Since the 2015 study, the addition of either anchorages or a passing lane were reviewed and decided to be impractical. The cases were included in this study for continuity with the 2015 study.

The addition of anchorages to the channel did not have a significant impact on either vessel wait times or charter costs. The anchorages had little impact because the majority of vessels in the modeled channel did not use them – either because they were unable to, due to the location of their terminal relative to the anchorages, or because they already had an available berth when they entered the channel.

The addition of a passing lane on the Inner Channel improved vessel wait times but resulted in a modest increase in charter costs. Since the passing lane did not substantially improve the channel operations and would likely involve significant additional expenses and difficulties (such as dredging costs and environmental regulations), it was not considered a cost-effective improvement for the channel.

1 Introduction

1.1 Background

The Calcasieu Ship Channel, shown in Figure 1-1, is located in southwestern Louisiana and connects the Port of Lake Charles to the Gulf of Mexico. In recent years, approximately 1,000 vessels per year have called at the numerous terminals located on the channel.

Figure 1-1 Location of Calcasieu Ship Channel

Traffic in the channel is expected to increase due to the expanded operations of the present channel users and the construction of several proposed terminals. It is forecasted that traffic will increase significantly over the next decade, with the number of vessels expected to more than double by 2025. This increased traffic could have a significant impact on the operations of the Calcasieu Ship Channel, and changes to channel infrastructure may be necessary to avoid congestion and delays.

Ausenco was engaged by the Port of Lake Charles in late 2013 to conduct a simulation study of the Calcasieu Ship Channel. The purpose of the study at the time was to investigate the present and future channel capacity and assess the need for, and impact of, changes to the channel infrastructure. The results from this study were issued to the Port of Lake Charles in a report in early 2015.[1]

In late 2018, Ausenco were contracted by the Port of Lake Charles to update the study and the report to reflect up-to-date expectations of the future traffic and proposed terminals for the channel.

---

[1] Ausenco, *Calcasieu Ship Channel Traffic Study*, Final Report, Revision 0, January 15 2015

1.2 Study Scope

For this study, Ausenco updated a detailed simulation model of the Calcasieu Ship Channel. The model was built in 2015 for the Port of Lake Charles and was based on a previous version originally developed for BG over the course of three simulation studies conducted between 2011 and 2013. The simulation model of the channel developed for this updated study included the existing and proposed terminals (based on information as of late 2018), present and forecasted traffic levels, different vessel types, the four pilot boarding areas, rules and restrictions for transits, boarding windows, and weather closures. Ausenco's Transportation Logistics Simulation (TLS) software was used to create the model. The scope limits of the model were the arrival and departure of vessels at the pilot boarding areas and the loading or unloading of vessels at the terminals.

One of the significant aspects of the study was the participation of the channel users. A total of eighteen terminal operators provided data for use in the simulation model, which represented 94% of the traffic in the channel over the past five years. The data from each user included present and forecasted traffic and terminal operations for the 17 year period (from 2017 to 2033). The participation of the channel users in the study ensured that the model was based on the best available forecasts for future traffic levels. The user participants included both existing operations as well as future terminal developments that have filed an application with the Federal Energy Regulatory Commission (FERC) to locate an LNG export facility on the channel.

1.3 Confidentiality

The data provided by the channel users was confidential, since it described both their present operations and future plans which would be considered commercially sensitive. To preserve this confidentiality, the channel user's data is only presented in this report in a compiled format so that the information for a single user could not be identified. However, in the simulation model each terminal was implemented individually using the specific data from the appropriate channel user.

2 Inputs and Assumptions

This section details the inputs and assumptions used in the simulation model of the Calcasieu Ship Channel, as well as the data sources and analysis that provided these inputs.

Many of the inputs and assumptions remain the same as in the 2015 study and are reiterated below for completeness.

In some cases, historical data for the channel was available from different sources, but the model inputs could only use data from only a single source. Appendix A discusses the justification and validation for the selected data sources that were used in the model.

2.1 Sources of Data

Ausenco gathered a number of data files that detailed the present and future operations of the Calcasieu Ship Channel. The following sources provided the majority of the inputs used in the simulation model:

- <u>Historical channel traffic</u>: data for 2006 to 2018, from the Lake Charles Pilots (also referred to as “the Pilots”)
- <u>Forecasted channel traffic and terminal operations</u>: data for 2017 to 2033, from channel users
- <u>Channel navigational rules and procedures</u>: ‘*Standards of Care Practiced by the Lake Charles Pilots*’ dated April 28, 2017
- <u>Boarding windows</u>: current and tide data for January 2013 to December 2017 at the Cameron Fishing Pier, from NOAA PORTS at http://tidesandcurrents.noaa.gov/cdata/DataPlot?id=lc0201 and current data from NOAA CO-OPS at lighted buoy #36 (lc0101) at http://tidesandcurrents.noaa.gov/cdata/DataPlot?id=lc0101
- <u>Historical boarding windows</u>: predicted boarding windows for 11 months in 2017, from the Pilots
- <u>Wind and visibility closures</u>: wind data for 2005 to 2017 at Calcasieu Pass (USAF 997337) and wind and visibility data for 1973 to 2017 at the Lake Charles Regional Airport (USAF 722400), both from NCDC at http://www7.ncdc.noaa.gov/CDO/cdo
- <u>Historical channel closures</u>: data for 2001 to 2018, from the Pilots

Wind and visibility closure data was the most recent full years of data available at the time of the study. Additional inputs and assumptions for the study were determined through correspondence with the Port of Lake Charles and the Lake Charles Pilots.

2.2 General Channel Information

The Calcasieu Ship Channel consists of two sections:

- The Outer Bar, which extends from the Cameron jetties (at Mile Marker 0) seaward to the CC buoy and has an overall length of 31.8 statute miles (27.6 nmi)
- The Inner Channel, which extends from the Cameron jetties inland to Mile Marker 36 and has an overall length of 36.0 statute miles (31.3 nmi) along the main channel

The channel is crossed by the Intracoastal Waterway (ICWW) at Mile Marker 22, at a location known as Devil's Elbow (or the Calcasieu Intersection). Devil's Elbow is also the location at which vessels transiting to terminals in the Industrial Canal Basin leave the main channel.

There are several turning areas located on the Inner Channel, which are used for maneuvering and for bunkering. The expansion of these turning areas into anchorages was investigated as an Infrastructure Case.

For the simulation model, it was assumed that the channel will be properly maintained in the future and dredged to its congressionally authorized width and depth along its entire length. The impact of insufficient dredging was investigated as an Infrastructure Case.

2.3 Terminals

This section details the terminals that were implemented in the simulation model of the Calcasieu Ship Channel. Both the existing terminals that presently operate on the channel and the proposed terminals that are planned for construction are described.

2.3.1 List of Terminals and Locations

As in the 2015 study, the existing terminals on the channel were identified from the historical vessel data provided by the Lake Charles Pilots. These identified terminals had at least one vessel call that required a Pilot over the 13 years covered by the data.

A total of 30 terminals were identified in the historical data, but only 12 of these terminals were included in the simulation model. The other 18 terminals[2] were excluded because they had very low traffic levels that were not expected to increase in the future or because they were no longer active (that is, they had no vessel calls in the past 3 years). The traffic from these terminals, even combined, would have little impact on either the other terminals or on the channel capacity (discussed in Section 2.4.1).

The Technip terminal was present in the historical data and received vessel traffic in 2014; however, the terminal was not expected to be in operation in the future and was not modelled. As in the 2015 study, Rain CII traffic used the Westlake Styrene terminal's berths. In the 2015 study, Dunham Price and Port Aggregates were modelled as one terminal, Bulk Terminal 4; in this study, the two terminals were modelled separately.

The Port of Lake Charles identified five terminals which filed applications with the Federal Energy Regulatory Commission (FERC) to construct and operate LNG export facilities along the Calcasieu channel. These terminals were included in the simulation model as they have a high likelihood of implementation but future LNG projects without FERC approval were not included in the model inputs.

Figure 2-1 shows the location of each of the 16 modeled terminals (both existing and proposed) on a map of the channel and a table of the terminals and their nearest Mile Marker. The proposed terminals are shown in the table in italics and in the figure in orange. The five LNG terminals were considered new since they had not begun exporting LNG as of this study.

---

[2] The 18 existing terminals that were excluded from the simulation model were: A.B. Dock Services, Asco Logistics, Baroid Drilling Fluids, BJ Completion Services, Bollinger Shipyard, Cameron, Dehyco Docks, Dynamic Industries, Falcon, Haliburton, Holnam, L&L Oil and Gas Services, LEEVAC Shipyard, Martin Midstream, R.P.S., Talens Marine & Fuel, Technip, and TMT.

Figure 2-1 Location of Terminals on the Modeled Calcasieu Ship Channel

Terminal	Nearest Mile Marker	Number on Map
Venture Global LNG	*0*	*1*
Cameron LNG	*19*	*2*
Alcoa	22	3
Lake Charles LNG	*22*	*4*
Magnolia LNG	*22*	*5*
Driftwood LNG	*23*	*6*
Westlake Styrene (and Rain CII)	26	7
Phillips 66 Clifton Ridge	27	8
Citgo Clifton Ridge	27	9
Citgo Refinery	28	10
Bulk Terminal 1	30	11
Westlake Lotte	32	12
City Docks	34	13
Phillips 66 Westlake	34	14
Dunham Price	36	15
Port Aggregates	36	16

Five of the modeled terminals are located off the main channel, at an additional distance from the nearest Mile Marker: Alcoa, Lake Charles LNG, and Magnolia LNG are located on the Industrial Canal Basin 3.1 miles from Devil's Elbow (at Mile Marker 22), Westlake Lotte is located 1.2 miles from Mile Marker 32, and Phillips 66 Westlake is located 0.7 miles from Mile Marker 34.

2.3.2 Terminal Operations

The data from the channel users was used to represent the operations of the terminals in the model. Each modeled terminal had the appropriate number of berths, with each vessel spending a variable amount of time at berth based on the provided values and distributions. The terminals for which data was not provided were modeled with an estimated number of berths based on available information and each vessel spent an average of 24 hours at berth.

In addition to the time at berth, each vessel was assumed to require 1.0 hour for docking and mooring operations and 0.5 hours for undocking and unmooring operations. Since the vessel was maneuvering to or from the berth during these times, the vessel blocked the channel for other traffic – that is, other vessels could not meet or pass the docking/undocking vessel. Vessels bound for a terminal in the Industrial Canal basin were modelled with a longer docking time of 2.5 hours.

The Westlake Lotte and Phillips 66 Westlake terminals are located far enough off the main channel that a docking or undocking vessel did not block the main channel. Similarly, a vessel docking or undocking at one of the terminals in the Industrial Canal Basin only blocked other traffic in the basin.

The onshore facilities and infrastructure for each terminal (such as storage tanks or stockpiles) were not modeled since they were beyond the scope of the study (as they were not expected to impact the capacity of the channel).

2.4 Traffic

This section details the historical and forecasted traffic to each terminal on the modeled Calcasieu Ship Channel.

2.4.1 Historical Traffic

The historical vessel data was analyzed to determine the number of vessel calls at each existing terminal between 2006 and 2018. The historical traffic levels provided a reference for the traffic in the channel and were used to identify "low traffic" terminals for exclusion from the model (discussed in Section 2.3.1).

Table 2-1 lists the number of vessel calls per year to each of the existing terminals over the 13 years of data. The traffic to the terminals excluded from the model was grouped together.

Table 2-1 Historical Vessel Traffic for Terminals in the Calcasieu Ship Channel

Modeled Terminal	Inbound Vessel Calls Per Year													Average
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Cameron LNG*	0	0	0	3	2	7	2	0	0	0	0	0	0	1.1
Alcoa	16	21	29	28	26	26	26	24	24	24	0	8	30	21.7
Lake Charles LNG*†	51	85	4	11	14	1	1	0	0	0	0	0	0	12.8
Westlake Styrene	30	29	45	43	56	49	35	61	41	58	46	56	45	45.7
Phillips 66 Clifton Ridge	123	140	113	113	103	113	112	135	167	165	121	76	85	120.5
Citgo Clifton Ridge	132	128	112	118	130	127	136	128	112	119	125	98	112	121.3
Citgo Refinery	205	215	147	170	201	228	251	279	250	187	221	202	189	211.2
Bulk Terminal 1	90	84	82	85	99	105	101	99	101	90	96	103	97	94.8
Westlake Lotte‡	95	118	107	96	95	100	100	91	68	67	70	99	92	92.2
Phillips 66 Westlake	84	81	50	44	41	51	62	72	71	60	56	75	78	63.5
City Docks	114	102	124	100	116	83	67	75	116	77	98	74	86	94.8
Bulk Terminal 4‖	37	34	34	27	25	26	25	30	27	59	53	39	26	34.0
Total	**977**	**1,037**	**847**	**838**	**908**	**916**	**918**	**994**	**977**	**906**	**886**	**830**	**840**	**913.4**

Terminals Not Modelled	133	52	59	62	87	70	51	40	71	66	62	53	48	65.7

* These terminals had no recent vessel calls but were modelled as they are proposed LNG export terminals with FERC approval

† 'Lake Charles LNG' was present in the historical data as 'Trunkline LNG'

‡ 'Westlake Lotte' was present in the historical data as 'Axiall'

‖ 'Port Aggregates' and 'Dunham Price' were present in the historical data as 'Bulk Terminal 4'

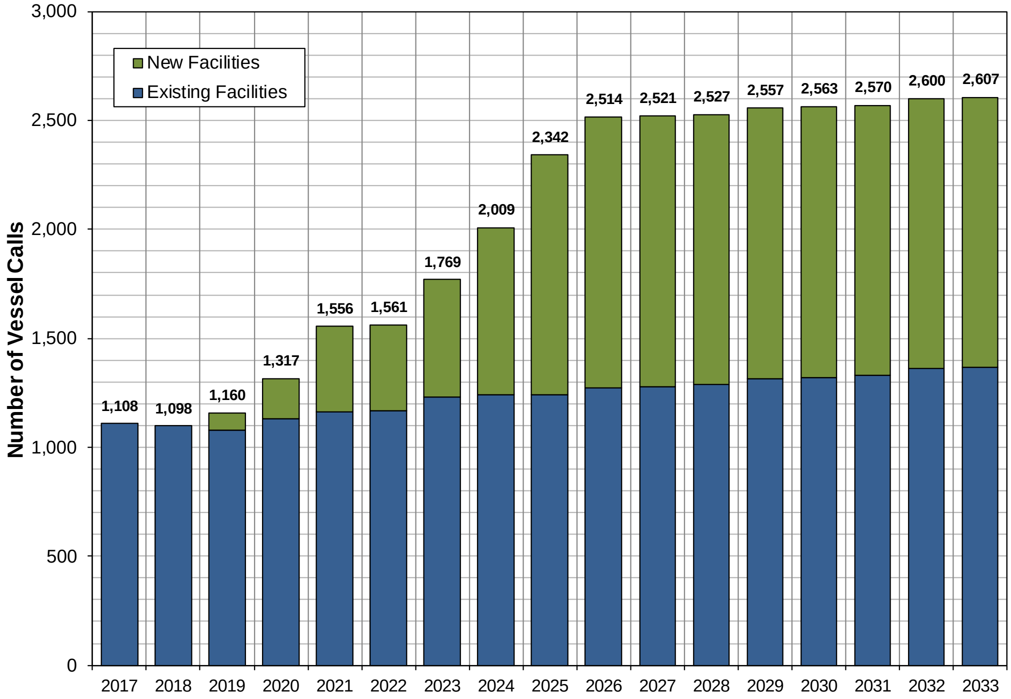
An overall average of 913.4 vessels per year called at the 12 modeled existing terminals between 2006 and 2018. Although an overall average of 65.7 vessels per year called at the 18 excluded terminals, the traffic to these terminals has been decreasing in the final 4 years of the data and was expected to continue decreasing. As such, the exclusion of these terminals from the model was considered to be a valid assumption.

2.4.2 Modeled Traffic

The data from the channel users detailed the expected traffic levels to the existing and proposed terminals for a 17-year period (from 2017 to 2033). Over this period, traffic was forecasted to increase on account of both the increased operations of the present users and the new traffic from the proposed terminals.

Figure 2-2 shows the combined traffic to all the modeled terminals on the channel for each year from 2017 to 2033.

Figure 2-2 Combined Traffic to the Modeled Terminals for 2017 to 2033



Traffic in the channel is forecasted to reach a peak in 2026 with 2,514 vessel calls, representing an increase of 129% from the 2018 traffic level. In the simulation model, each year's traffic was evaluated independently to determine when possible improvements to the channel might be required.

2.4.3 Vessel Categories

The traffic on the channel is composed of a variety of different vessel sizes and classes. In the simulation model, the vessel traffic to each terminal was grouped into categories that were based on how vessels were impacted by the rules and restrictions of the channel (discussed in Section 2.5 and 2.6) instead of specific sizes and classes.

Category Definitions

In the channel, vessels are categorized based on rules from the Standards of Care:

- Draft: vessels with a draft in excess of 34 feet are considered "deep draft"; all other vessels are considered "shallow draft"

- Ability to pass on the Inner Channel: vessels with a beam less than 100 ft and a draft of less than 30 ft can meet or pass certain other non-LNG vessels on the Inner Channel, and are referred to as “narrow” vessels; all other vessels are considered “wide”

- Type of Ship: LNG carriers are subject to a number of additional restrictions; all other vessels are considered “non-LNG” and are not subject to restrictions due to their ship type

Based on these rules, the modeled vessels were grouped into six categories:

1) **Large LNG carriers**: LNG vessels with a windage greater than 8,000 m^2; these vessels were assumed to have a draft >38 ft. Examples include Q-Flex LNG carriers.

2) **Midsize LNG carriers**: LNG vessels with contents greater than 155,000 m^3 and a windage less than 8,000 m^2. Examples include Moss-Type LNG carriers.

3) **Small LNG carriers**: LNG vessels with contents less than 155,000 m^3 and a windage less than 8,000 m^2. These carriers had capacities on the order of 145,000 m^3.

4) **Deep Draft vessels**: non-LNG vessels with a draft greater than 34 ft and any beam

5) **Narrow vessels**: non-LNG vessels with a draft less than 30 ft and a beam less than 100 ft

6) **Wide vessels**: non-LNG vessels that did not fit into the other categories (that is, vessels with a draft between 30 and 34 ft and any beam, along with vessels with a draft less than 34 ft and a beam greater than 100 ft)

The Lake Charles pilots advised that all LNG carriers are expected to have a draft greater than 34 ft.

Historical Vessel Mix

The historical vessel data was analyzed to determine how the individual vessels that called at the existing terminals between 2006 and 2018 fit into the modeled categories. Table 2-2 lists the vessel category mix for the overall traffic to each of the modeled existing terminals. Note that the historical traffic only included import Midsize LNG carriers.

Table 2-2 Historical Vessel Mix for Terminals in the Calcasieu Ship Channel

Modelled Terminal	Vessel Mix			
	LNG	Deep-Draft	Non-Passing	Passing
Cameron LNG	92.9%	7.1%	0.0%	0.0%
Alcoa	0.0%	0.4%	16.7%	83.0%
Lake Charles LNG	99.4%	0.6%	0.0%	0.0%
Westlake Styrene	0.0%	3.2%	35.9%	60.9%
Phillips 66 Clifton Ridge	0.0%	83.8%	8.5%	7.7%
Citgo Clifton Ridge	0.0%	79.8%	19.5%	0.6%
Citgo Refinery	0.0%	17.2%	54.4%	28.4%
Bulk Terminal 1	0.0%	11.0%	57.2%	31.8%
Westlake Lotte	0.0%	2.4%	41.0%	56.6%
Phillips 66 Westlake	0.0%	2.7%	64.4%	33.0%
City Docks	0.0%	4.0%	32.6%	63.4%
Dunham Price	0.0%	92.6%	7.4%	0.0%
All Terminals	**1.5%**	**30.4%**	**36.2%**	**31.9%**

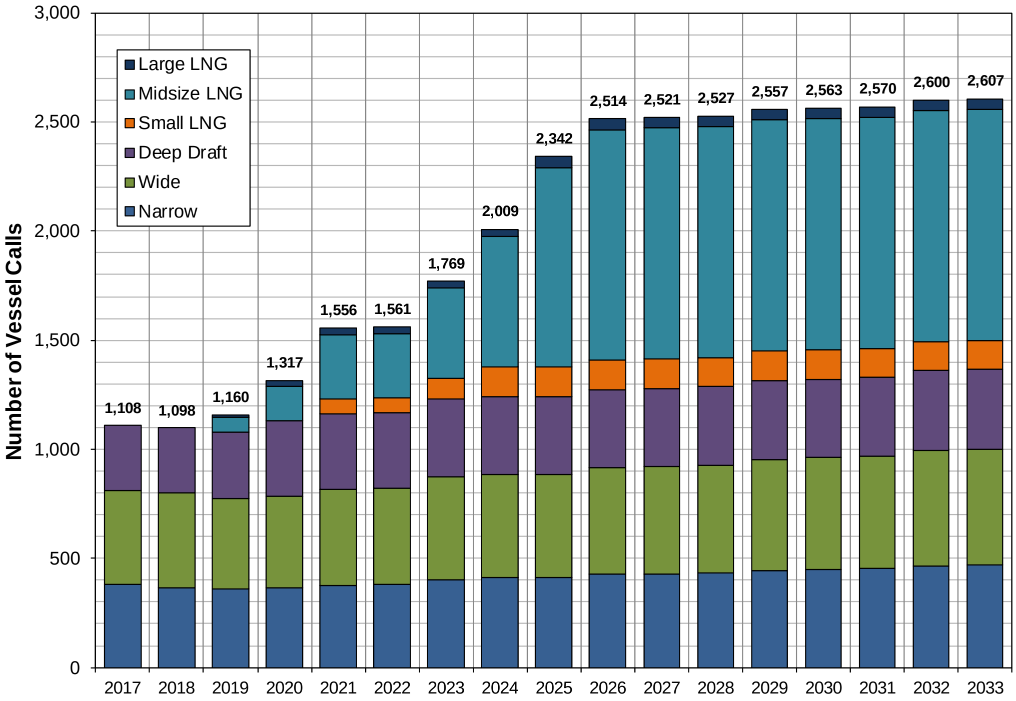
Modeled Vessel Mix

The data from the channel users detailed the specific vessel sizes and types that were expected to comprise the forecasted traffic to the terminals over a 17 year period. Using the vessel sizes and types, the traffic to each modeled terminal was split into the six categories.

For the modeled terminals for which neither expected vessel sizes nor types were provided, the historical vessel mix listed in Table 2-2 was applied to the terminal's forecasted traffic.

Figure 2-3 shows how the combined traffic to the modeled terminals was split into the six vessel categories for each year from 2017 to 2033.

Figure 2-3 Vessel Mix for Combined Traffic to the Modeled Terminals for 2017 to 2033



Although the forecasted traffic in each category was expected to increase in the future, the majority of the additional vessel traffic in the channel will consist of LNG carriers.

2.4.4 Non-Piloted Barges

In addition to the piloted vessel traffic discussed in Sections 2.4.1 and 2.4.2, which included ocean-going barges, ATBs and ITBs, the channel is transited by a number of non-piloted barges (that is, barges that are not piloted by a Lake Charles Pilot). These barges enter the channel via the ICWW and either transit to one of the terminals further upstream or cross the channel and continue along the ICWW.

Non-piloted barges are subject to fewer restrictions than piloted vessels, so these barges have lower priority for using the channel – a barge will wait for a piloted vessel, but a piloted vessel will not be delayed for a barge. Additionally, the Pilots have advised that these barges can be maneuvered in between the piloted vessels, so the barges themselves are not significantly delayed by the piloted vessel traffic. As such, the barge traffic was not included in the simulation model since, based on these assumptions, it would not impact the capacity of the channel.

Any barge traffic (with the exception of ocean-going barges) indicated in the forecasted traffic data from the channel users was assumed to behave as discussed above, and was not included in the modeled traffic to the terminals (shown in Figure 2-3).

2.4.5 Arrival Distribution

Vessels to each terminal were scheduled to arrive at the pilot boarding areas at regular intervals. Each modeled vessel arrived within 1 day of its scheduled arrival: 10% of vessels arrived 1 day early, 80% arrived on time (within 24 hours of their scheduled arrival), and 10% arrived 1 day after their scheduled arrival. This arrival distribution was included in the simulation model to provide a degree of variability in the arrivals but was not a significant factor for the channel capacity.

2.5 Channel Operations

This section details the rules and restrictions that vessels transiting the Calcasieu Ship Channel are subject to.

2.5.1 Pilot Boarding Areas

Vessels enter and exit the channel at one of four pilot boarding areas[3] on the Outer Bar. Each modeled vessel waited at anchor at one of the four pilot boarding areas until a berth was available at their destination terminal, conditions in the channel were suitable for transit, and sufficient Pilots and tugs were available.

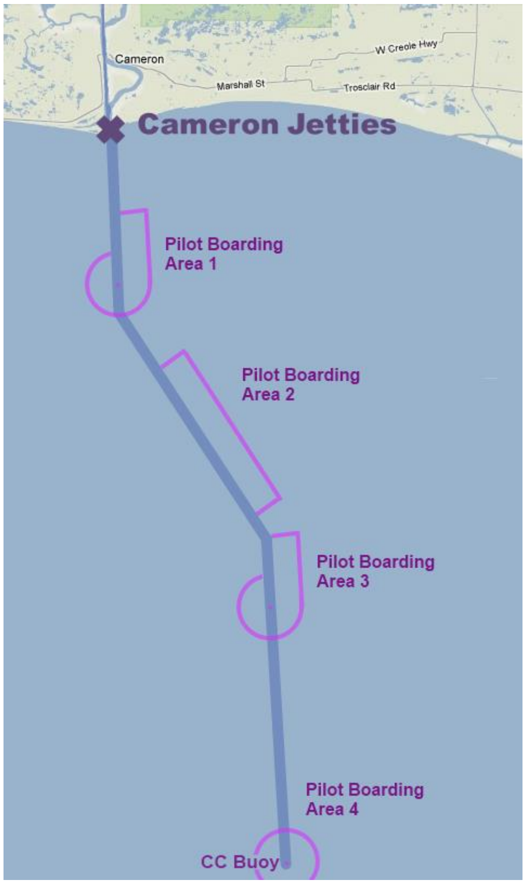
---

[3] Certain vessels can enter the channel at the Cameron jetties instead of at a pilot boarding area. Since an analysis of the historical data showed that relatively few vessels entered at the jetties, for the simulation model any vessel that would have entered the channel at the jetties entered instead at Pilot Boarding Area 1.

Figure 2-4 shows the location of the four pilot boarding areas on the Outer Bar, their designated buoys, and their distances from the Cameron jetties. Note that “Pilot Boarding Area 4” and “CC buoy” refer to the same location.

Figure 2-4 Location of Pilot Boarding Areas on the Outer Bar

Pilot Boarding Area	Buoy	Distance from Jetties (nmi)
1	30	7.5
2	18	12.8
3	2B	20.6
4	CC	27.5



The historical vessel data was analyzed to determine at which pilot boarding areas the different vessel categories (discussed in Section 2.4.3) entered and exited the channel. The percent of each vessel category that entered and exited the channel at each pilot boarding area was calculated, and from these percentages a simplified set of usage rules was determined.

Table 2-3 and Table 2-4 list the pilot boarding areas at which each modeled vessel category entered and exited the channel, respectively.

Table 2-3 General Pilot Boarding Area Usage – Entering Vessels

Vessel Category	Pilot Boarding Area	Percent of Vessels
All LNG Carriers	4	100%
Deep Draft	4	100%
Wide	1	40%
	2	40%
	4	20%
Narrow	1	90%
	2	10%

Table 2-4 General Pilot Boarding Area Usage – Exiting Vessels

Vessel Category	Pilot Boarding Area	Percent of Vessels
All LNG Carriers	4	100%
Deep Draft	2	50%
	3	20%
	4	30%
Wide	1	30%
	2	60%
	3	10%
Narrow	1	90%
	2	10%

Note that since Large LNG carriers were not present in the historical vessel data, the pilot boarding area at which they entered and exited the channel was assumed based on the size of the vessels in the category. Small LNG carriers were not significantly smaller than midsize LNG carriers; therefore, they were assumed to use Pilot Boarding Area 4 also.

2.5.2 Speeds

Vessel speeds on the channel are variable. In the simulation model, fixed speeds were used since vessels typically transited the channel as part of a convoy (discussed in Section 2.5.4) and it was assumed that all vessels in a convoy traveled at the same average speed.

All vessels on the Outer Bar traveled at an assumed speed of 12 knots, regardless of their direction of travel. Transit speeds on the Inner Channel were calculated from the transit times in the historical vessel data.[4] All inbound and outbound vessels on the Inner Channel traveled at a speed of 7 knots.

---

[4] The historical "transit times" covered all time that a Pilot was on board a vessel, which included docking and undocking time. The actual transit times were calculated by adjusting the historical times to account for 1.0 h of docking and 0.5 h of undocking time (discussed in Section 2.3.2).

2.5.3 Passing

Non-LNG vessels are able to meet and pass other non-LNG vessels in the channel depending on the beam and draft of the two vessels and the location at which they meet. On the Outer Bar, two non-LNG vessels are able to meet and pass if:

- The combined beam of the two vessels is less than 400 ft
- The vessels do not meet within 0.5 nmi of the Cameron jetties

None of the vessels in the historical data had a beam greater than 200 ft and it was assumed that this would be the case for all future traffic. As such, the combined beam of two vessels could not be greater than 400 ft and thus all modeled non-LNG vessels were able to meet and pass on the Outer Bar as long as the passing was 0.5 nmi from the Cameron jetties.

On the Inner Channel, two non-LNG vessels are able to meet and pass if:

- The combined beam of the two vessels is less than 200 ft
- The combined draft of the two vessels is less than 60 ft

The Narrow vessel category (discussed in Section 2.4.3) was used to implement the meeting and passing restriction on the Inner Channel. Since every Narrow vessel had, by definition, a beam less than 100 ft and a draft less than 30 ft, any Narrow vessel could meet another Narrow vessel on the Inner Channel.

No other vessel combinations were allowed to meet and pass on the Inner Channel in the simulation model. In reality, a Narrow vessel and a Wide vessel could meet and pass if the exact dimensions of the two satisfied the conditions above; however, for conservatism in the model, no Wide vessels could pass on the Inner Channel.

LNG carriers may pass another vessel if one of the vessels exits the buoyed channel. The ability to exit the buoyed channel is determined by vessel draft. In the base case, it was assumed that no vessels passed LNG carriers in the Outer Bar to ensure strict adherence to the moving safety zone (discussed in Section 2.5.5) and as a conservative estimate of ship draft. An Infrastructure Case reinvestigated the impact of allowing LNG vessels unrestricted passing on the Outer Bar.

2.5.4 Convoys and Priorities

With increased traffic in the channel, it is expected that vessels will be organized in convoys to be handled in the most efficient manner for the channel. A convoy would specify the order in which queued vessels would enter the channel rather than allowing the vessels to enter the channel based on their order of arrival.

In the model, an inbound convoy was organized from the vessels that were queued at the pilot boarding areas and waiting to enter the channel. The convoy order prioritized vessels transiting the furthest upstream. This order avoided delays caused by a docking vessel blocking the channel for other transits. For example, if a Citgo vessel entered the channel before a Bulk Terminal 1 (BT-1) vessel, the BT-1 vessel would be delayed by the 1-hour docking time for the Citgo vessel; however, if the BT-1 vessel entered the channel first, neither the BT-1 vessel nor the Citgo vessel would be delayed.

A vessel that arrived “late” for a convoy (that is, one that arrived after the convoy had started its transit) was still allowed to enter the channel if the conditions permitted; however, the vessel may have been subject to additional delays if vessels to downstream terminals (relative to the destination of the late vessel) were already in the convoy.

Outbound convoys were not typically prioritized. The distance between the terminals created a natural spacing and vessels were not subject to additional delays to exit the channel, so priorities would not provide a benefit to outbound vessels.

After a long closure of the channel (discussed in Section 2.6) during which both inbound and outbound vessels were queued, priority was given to the outbound convoy. The outbound convoy had priority so that berths were made available for inbound vessels, as advised by the Pilots in the 2015 study.

2.5.5 Separation Distances/Times and Safety Zones

A minimum separation distance of approximately 2 miles is maintained between any two vessels in transit in the same direction on the entire channel. This distance is equivalent to a minimum separation time of 15 minutes.

LNG carriers have a moving safety zone (mandated by the US Coast Guard) that extends 2 miles ahead and 1 mile astern, and encompasses the full width of the channel. This safety zone was not modeled explicitly, since the former conditions were accounted for by the minimum separation distance between vessels, and the latter was accounted for by the restriction on passing or meeting LNG carriers (discussed in Section 2.5.3).

In addition to the 15 minute minimum separation time between vessels, the separation between two inbound vessels transiting to the same destination – either different berths at the same terminal or different terminals located at the same Mile Marker – was greater. A separation time of 1.0 hour was required between most vessels transiting to the same destination, although 2.5 hours was required between vessels transiting to terminals in the Industrial Canal Basin. These separation times allowed the first vessel to complete docking maneuvers (discussed in Section 2.3.2) without requiring the second vessel to stop and wait in the channel.

2.5.6 Nighttime Operations

All vessels were able to transit the channel at night, with no further restrictions and no preference given to either day or night transits.

2.6 Channel Restrictions and Closures

The Calcasieu Ship Channel can be effectively “closed” for vessel transits due to the environmental conditions on the channel. During a closure[5], vessels remain anchored at the pilot boarding areas or moored at berth while waiting for conditions to improve.

2.6.1 Boarding Windows

Certain vessels require suitable currents and tide levels during their transit through the Cameron jetties and within the Inner Channel. These vessels are restricted to entering the channel at certain

---

[5] Technically, the Calcasieu Ship Channel can only be closed by the US Coast Guard during severe weather events. However, for clarity in this report, any weather event that suspends Pilot services and thus stops vessel transits is referred to as a “closure”.

times – referred to as boarding windows – which ensure the currents and tides at the Cameron jetties are suitable.

The inbound and outbound boarding windows restrict different vessel categories, and open and close according to different thresholds.

A time series of inbound and outbound boarding windows was implemented in the simulation model by applying the rules described in this section to one year of historical current and tide data (from January 2013 to December 2016) obtained from NOAA PORTS. A subset of the available data was chosen due to large gaps in the data before January 2013 and after December 2016. The validation of this historical data for use in the model is discussed in Appendix A, Section A.1.

Inbound Boarding Windows

Inbound Deep Draft vessels and Large LNG carriers are restricted to boarding windows by the currents at the jetties.

The windows open and close before the current thresholds are exceeded to ensure that vessels have sufficient time to transit from the CC buoy to the Calcasieu Pass (the restricted vessel categories enter the channel at the CC buoy) and arrive while the current is suitable.

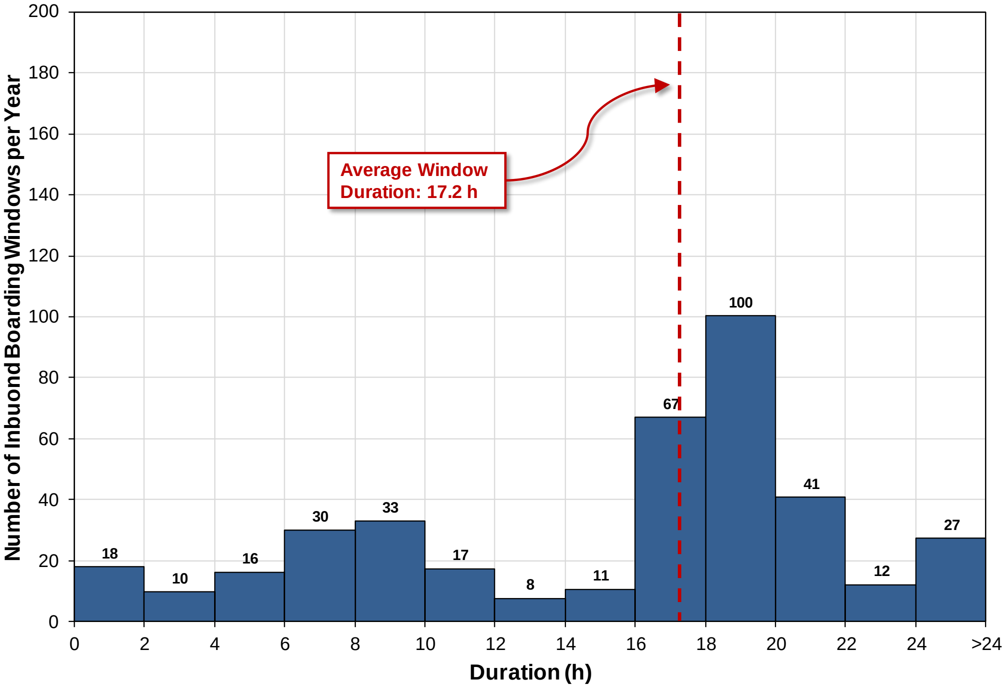
The rules that govern the opening and closing of the inbound boarding windows are described below.

LNG Carriers:

- A window opens at the CC buoy 2.5 hours before the current is less than or equal to 1.5 knots ebb at Calcasieu Pass
- A window closes at the CC buoy 3.5 hours before a 1.5 knot ebb current at the Calcasieu Pass

Based on the historical tide data, a window was open in the simulation model for 76.6% of the year. Figure 2-5 shows a histogram of the durations of the LNG carrier inbound boarding windows used in the model.

Figure 2-5 Histogram of Inbound Boarding Windows for LNG Carriers



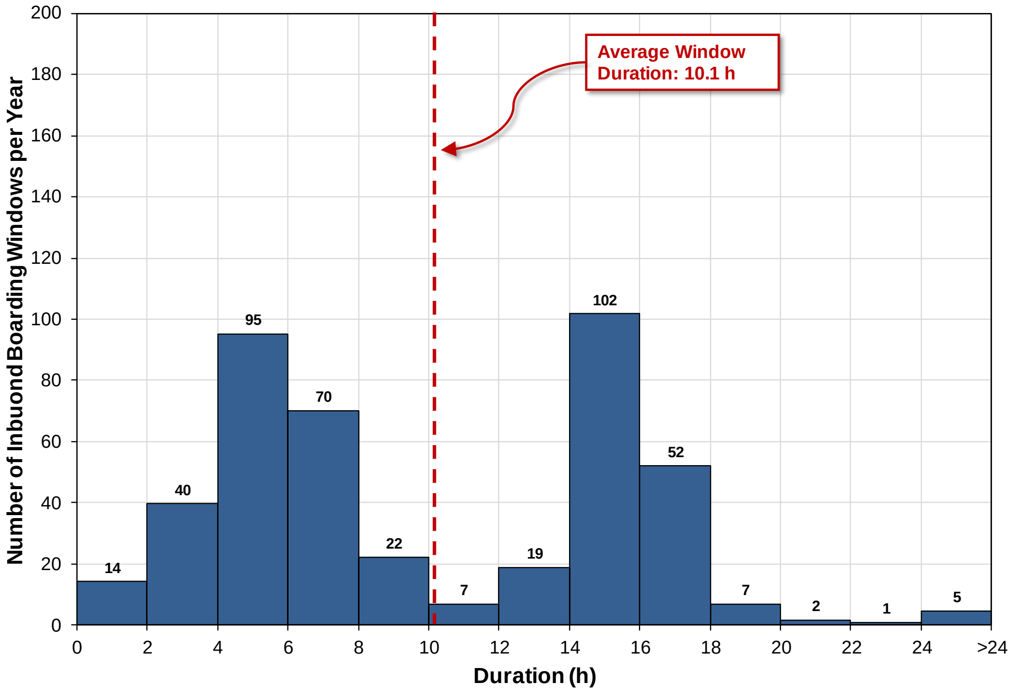
Deep Draft Non-LNG Carriers:

- A window opens at the CC buoy 2.0 hours before slack water going to flood
- A window closes at the CC buoy 3.5 hours before a 1.0 knot ebb current

Based on the historical tide data, a window was open in the simulation model for 50.2% of the year. Figure 2-6 shows a histogram of the durations of the Deep Draft inbound boarding windows used in the model.

The current limits for Deep Draft Non-LNG carriers are more stringent than for LNG carriers; hence, the windows for Deep Draft vessels are shorter than for LNG carriers. These boarding windows became shorter since 2015, when windows were open for 61.0% of the year.

Figure 2-6 Histogram of Inbound Boarding Windows for Deep Draft (Loaded Inbound) Vessels



Outbound Boarding Windows

Outbound laden Deep Draft vessels and all LNG carriers are restricted to boarding windows by the currents and tide levels at the jetties.

Since the restricted vessels depart from different locations, different offset times were used in the model to account for the transit time from each terminal to the jetties. Each vessel departed from its terminal with sufficient time to ensure it could clear the jetties while the window was open (which meant that some vessels departed before the window had opened at the jetties).

The rules that govern the opening and closing of the outbound boarding windows are described below.

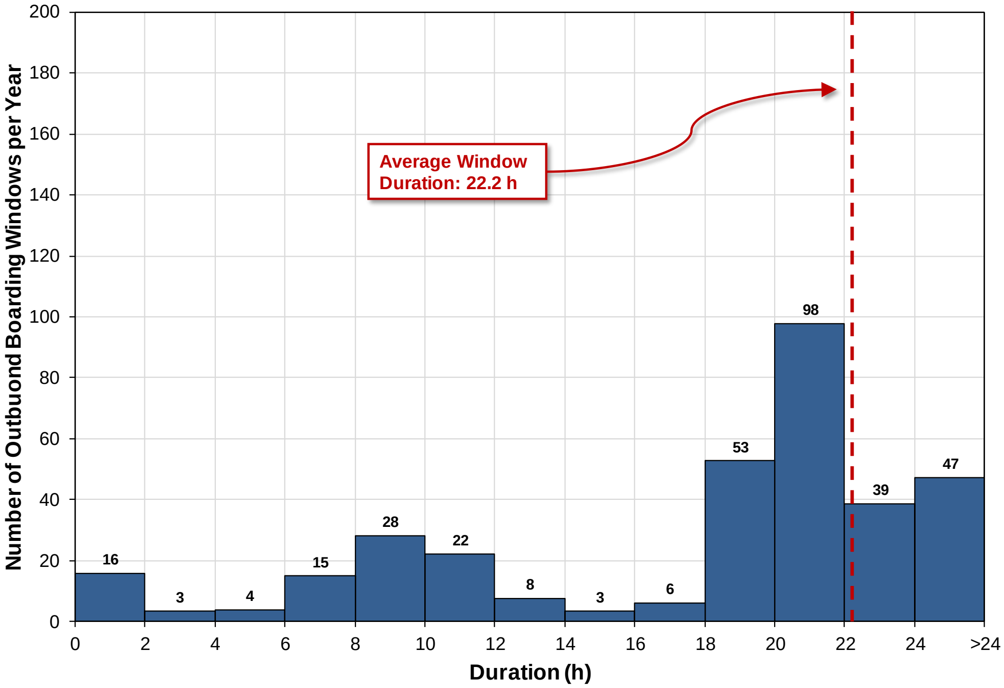
LNG Carriers with Draft < 38 Feet:

- A window opens at the Cameron jetties when the current is less than or equal to 1.5 knots flood at Calcasieu Pass
- A window closes at the Cameron jetties when the current is greater than 1.5 knots flood at Calcasieu Pass

Based on the historical tide data, a window was open in the simulation model for 86.9% of the year. Figure 2-7 shows a histogram of the durations of the LNG carrier (draft < 38 ft) outbound boarding windows used in the model.

The outbound boarding windows for LNG carriers (draft < 38 feet) are longer and open for 35% more of the year than in the 2015 study.

Figure 2-7 Histogram of Outbound Boarding Windows for LNG Carriers with Draft <38 ft



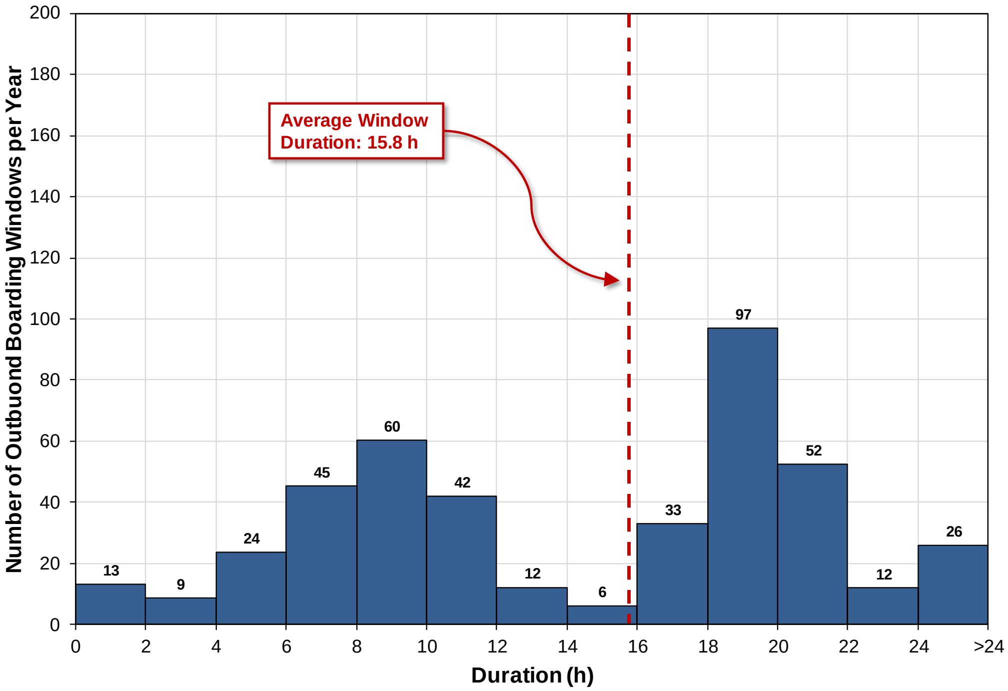
LNG Carriers with Draft > 38 Feet:

- A window opens at the Cameron jetties when the current is less than or equal to 1.0 knot flood at Calcasieu Pass and when tide level is greater than Mean Lower Low Water
- A window closes at the Cameron jetties when the current is greater than 1.0 knot flood at Calcasieu Pass or when tide level is less than Mean Lower Low Water

Based on the historical tide data, a window was open in the simulation model for 78.1% of the year. Figure 2-8 shows a histogram of the durations of the LNG carrier (draft >38 feet) outbound boarding windows used in the model.

The outbound boarding windows for LNG carriers (draft >38 feet) vessels are longer and open for 26% more of the year than in the 2015 study.

Figure 2-8 Histogram of Outbound Boarding Windows for LNG Vessels with Draft >38 ft



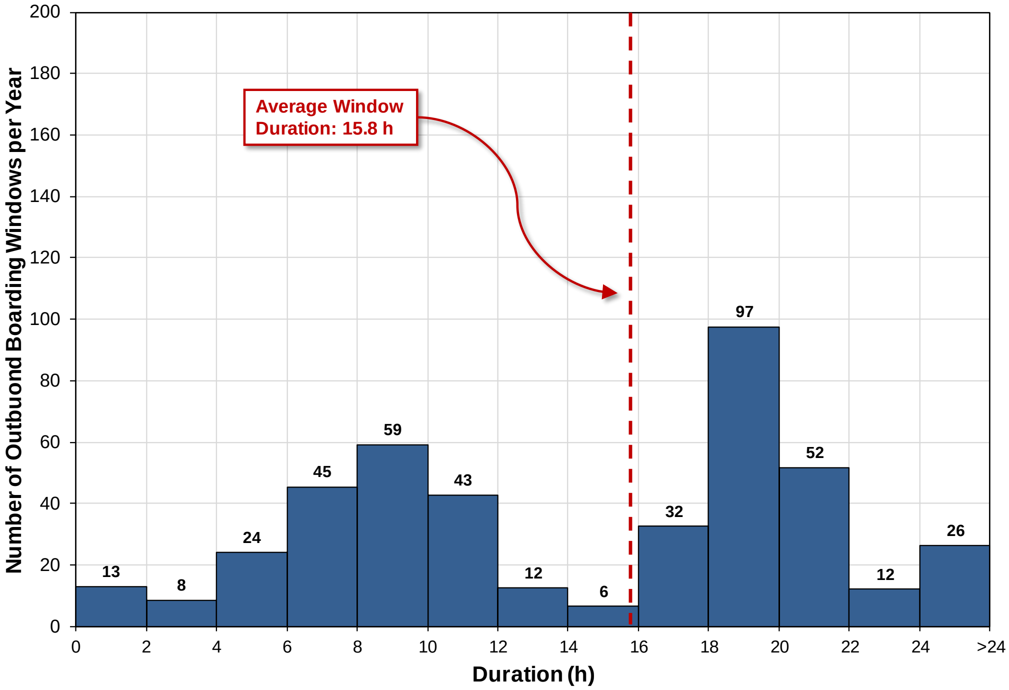
Deep Draft Non-LNG Carriers:

- Outbound boarding windows for Deep Draft vessels are the same as for LNG carriers except that windows open and close 2 hours earlier

Based on the historical tide data, a window was open in the simulation model for 78% of the year. Figure 2-9 shows a histogram of the durations of Deep Draft (Loaded Outbound) boarding windows used in the model.

The outbound boarding windows for Deep Draft vessels are longer and open for 26% more of the year than in the 2015 study.

Figure 2-9 Histogram of Outbound Boarding Windows for Deep-Draft (Loaded Outbound) Vessels



2.6.2 Wind

Pilot services are suspended when sustained wind speeds exceed certain thresholds. LNG carriers are unable to transit the channel if wind speeds exceed 20 knots, and all other vessels are unable to transit if wind speeds exceed 25 knots. Large LNG carriers are unable to transit the channel if beam winds (defined as winds within 45° of east or west) exceed 15 knots. A time series of wind closures – that is, times when vessels were unable to transit the channel – was implemented in the model by applying the wind thresholds to historical data from 1973 to 2017 obtained from the NCDC. This data was the most recent full-year data available at the time of the study. The validation of this data for use in the simulation model is discussed in Appendix A, Section A.2.

To ensure that the modeled channel was only closed due to sustained wind speeds and not gusts, all wind closures in the historical data with a duration of less than 1 hour were omitted from the time series.

A 6-hour lookahead was applied to the modeled wind closures to ensure that a vessel beginning transit had sufficient time to reach its destination while conditions were still suitable. A vessel only departed from the pilot boarding area or berth if wind speeds in the channel were below the thresholds for the next 6 hours after departure (due to the lookahead).

Figure 2-10 and Figure 2-11 show the percent of time in each month of the historical data that the wind speeds in the channel exceeded the closure limit for LNG carriers (20 knots) and for all other vessels (25 knots), respectively. The figures show how the percent of closure time varied for each of the 45 months in the historical data, with the best and worst months, as well as the 25th, 50th (median) and 75th percentile months shown explicitly. The closure time included the 6-hour lookahead when vessel transits were stopped in advance of high wind speeds.

Figure 2-10 Monthly Channel Closures for LNG Vessels due to Wind

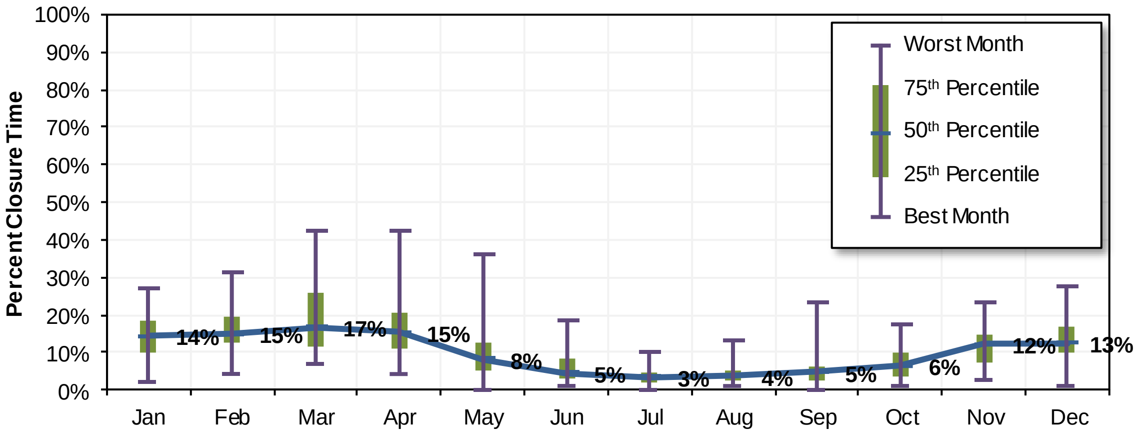
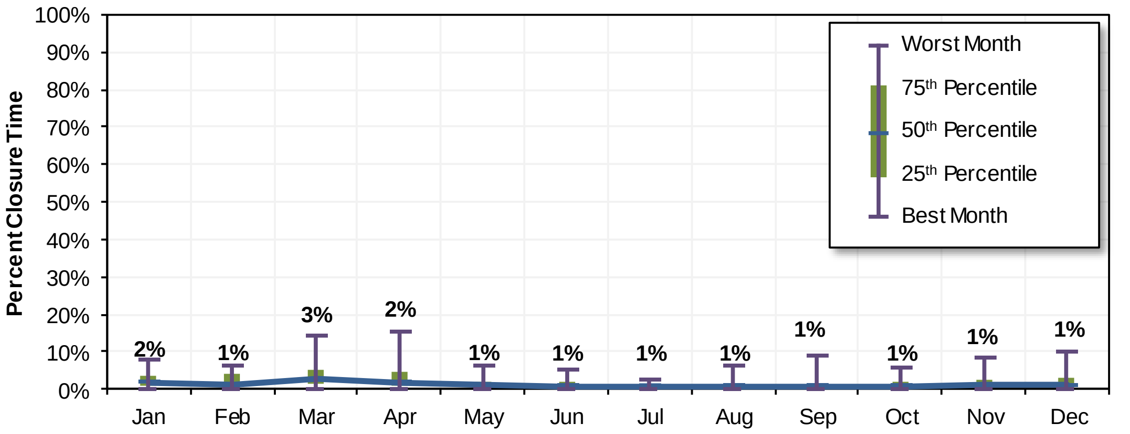


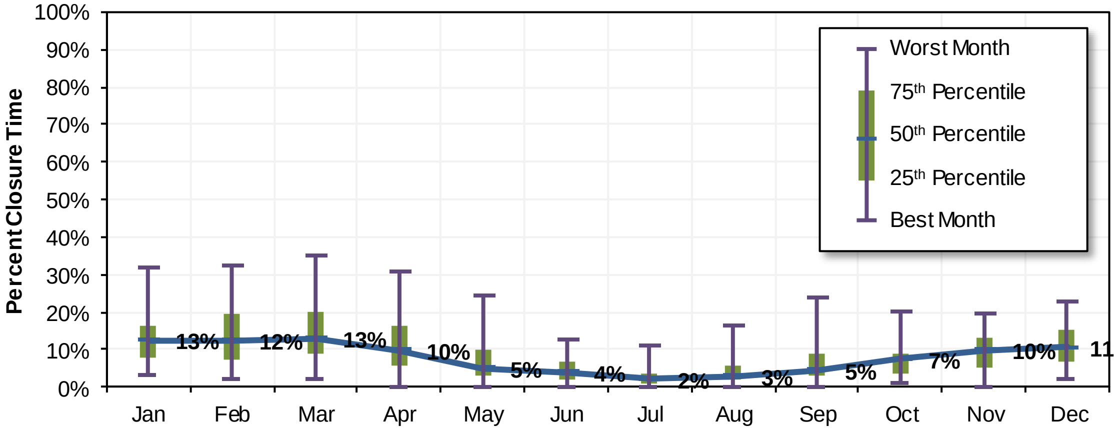
Figure 2-11 Monthly Channel Closures for Non-LNG Vessels due to Wind



The average annual percent closure time of the channel due to wind was 10.8% for LNG carriers, and 1.8% for all other vessels. The average duration for a wind closure was 10.8 hours for LNG carriers, and 8.6 hours for all other vessels. The updated wind closures represented a slight decrease over the closure time in the 2015 study.

Figure 2-12 shows the percent of time in each month of the historical data that the beam wind speeds in the channel exceeded the closure limit for Large LNG carriers (15 knots). The figures show how the percent of closure time varied for each of the 45 months in the historical data, with the best and worst months, as well as the 25th, 50th (median) and 75th percentile months shown explicitly. The average annual percent closure time of the channel due to beam wind was 7.8%. The average duration for a beam wind closure was 10.7 hours.

Figure 2-12 Monthly Channel Closures for Large LNG Vessels due to Beam Wind

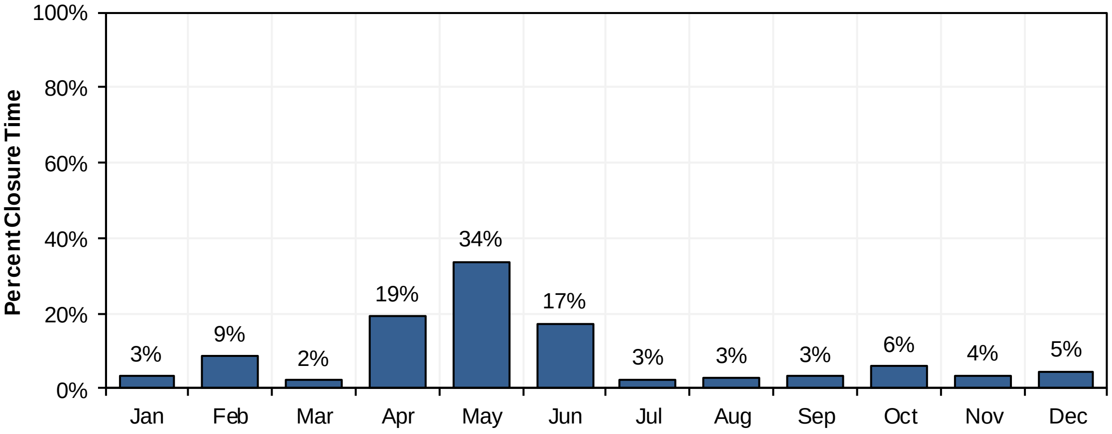


2.6.3 Outer Bar Cross-Current

As of 2017, LNG carriers are restricted to a maximum of 1.0 knots of cross-current along the Outer Bar. A time series of closures was modelled using four years of historical data from 2013 to 2016 from the NOAA data at lighted buoy #36. This data was the most recent full-year data available; large gaps were present before 2013 and after 2016. As with the wind closures, only cross-current closures that lasted longer than 1 hour were used to ensure that vessel transits were only stopped due to sustained poor current conditions. A 6-hour lookahead was also applied to the cross-current closures to prevent conditions changing while a vessel was in transit.

Figure 2-13 shows the percent of time in each month of the time series that the channel was closed for the restricted LNG vessels due to cross-current events.

Figure 2-13 Monthly Channel Closures for LNG Vessels due to Cross-Current



The average annual percent closure time of the channel due to cross-current events was 7.7% and the average durations for a cross-current closure was 13.9 hours.

LNG Carrier Wind and Current Channel Closures

Figure 2-14 shows the percent of time in each month of the simulation model that the channel was closed for Large LNG Carriers due to wind, beam wind, and cross-current.

Figure 2-14 Monthly Channel Closures for Large LNG Vessels due to Wind and Cross-Current

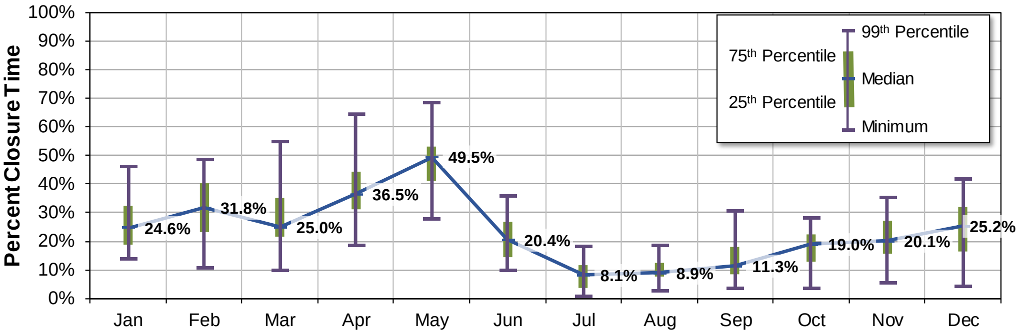
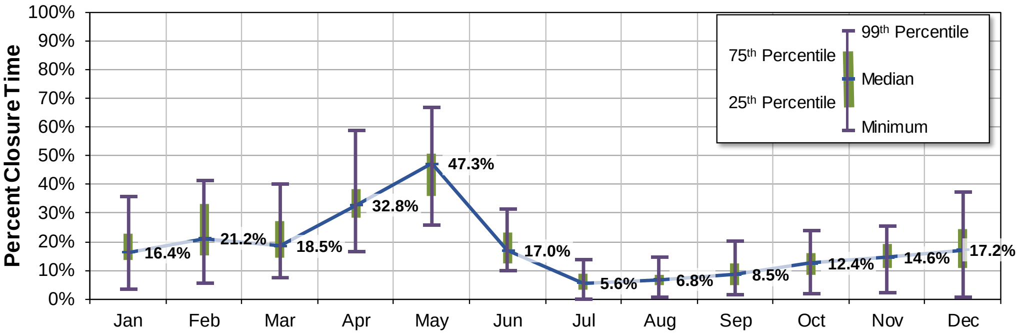


Figure 2-15 shows the percent of time in each month of the simulation model that the channel was closed for Small and Midsize LNG Carriers due to wind and cross-current (beam wind restrictions did not affect these vessels).

Figure 2-15 Monthly Channel Closures for Small and Midsize LNG Vessels due to Wind and Cross-Current



The overall closure time was less than the sum of the individual closure times due to overlap in the closures. The closure time included the 6-hour lookahead when vessel transits were stopped in advance of high wind speeds. The increase in restrictions on LNG Carriers was the main cause in the longer channel closures in this study compared to the 2015 study.

2.6.4 Visibility

Pilot services are suspended when visibility in the channel is less than 1 nmi.[6] A time series of visibility closures was implemented in the simulation model by applying this 1-nmi limit to historical data from 1973 to 2018 obtained from the NCDC. The validation of this data for use in the simulation model is discussed in Appendix A, Section A.3.

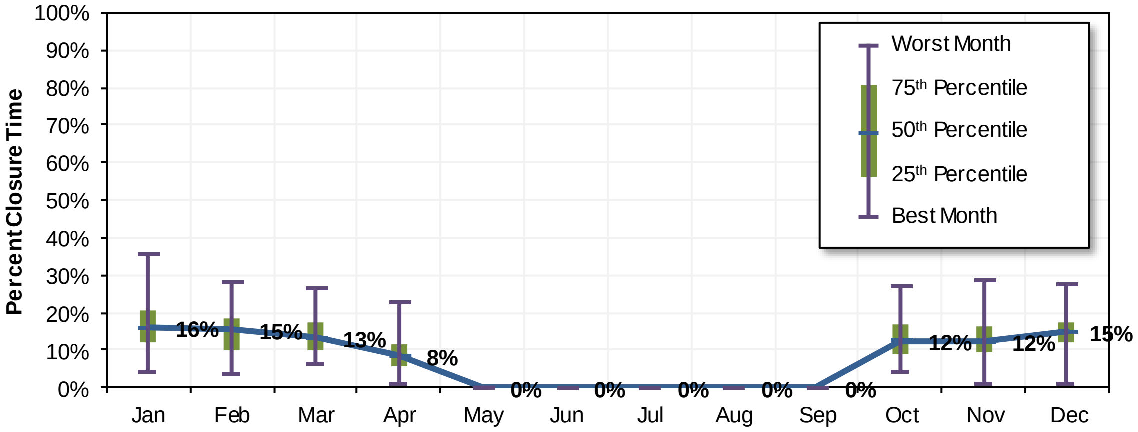
---

[6] The visibility closure limit of 1 nmi was specified during the March 11, 2014 Harbor Safety Committee meeting. This limit was used for the simulation model and superseded the 2-nmi limit specified in the Standards of Care.

As with the wind closures, only visibility closures that lasted longer than 1 hour were used to ensure that vessel transits were only stopped due to sustained poor visibility conditions. A 6-hour lookahead was also applied to the visibility closures to prevent conditions changing while a vessel was in transit.

Figure 2-16 shows the percent of time in each month of the data that the visibility in the channel was below the 1-nmi limit required for vessel transits.

Figure 2-16 Monthly Channel Closures due to Visibility



The average annual percent closure time of the channel due to visibility was 7.4% and the average duration for a visibility closure was 10.8 hours. However, visibility closures only occurred between October and April – and the average percent closure time during these months was 13.5%. The updated visibility closures increased closure time by 1.3% of the year compared to the 2015 study (a 21% increase over the 2015 study's visibility data).

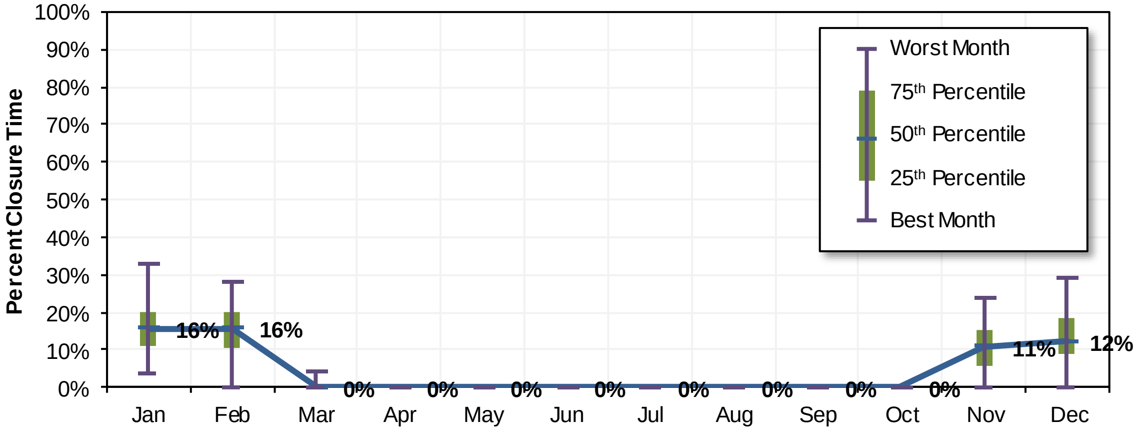
2.6.5 Low Water

The water level in the upper portion of the channel can be lower than normal due to continuous north winds. The low water events caused by these north winds prevent certain Deep Draft vessels from docking due to their draft. A time series of low water closures caused by north winds was implemented in the simulation model using the historical wind data obtained from the NCDC. The analysis that produced this time series is detailed in Appendix A, Section A.4.

Low water closures prevented vessels with drafts of 38 ft or greater from entering the channel. An analysis of the historical vessel data showed that approximately 50% of inbound Deep Draft vessels had a draft of 38 ft or greater. To ensure that this proportion of Deep Draft vessels was impacted by low water closures in the model, only the modeled Deep Draft vessels that exit the channel at either Pilot Boarding Area 3 or 4 were subject to low water restrictions – these vessels, as shown in Table 2-4, comprised 50% of all Deep Draft vessels.

Figure 2-17 shows the percent of time in each month of the time series that the channel was closed for the restricted Deep Draft vessels due to low water events.

Figure 2-17 Monthly Channel Closures due to Low Water Events



The average annual percent closure time of the channel due to low water events was 4.2% and the average duration for a low water closure was 35.9 hours. However, low water closures only occurred between November and February – and the average percent closure time during these months was 13.9%.

2.6.6 Force Majeure Events

Force majeure events – such as hurricanes, oil spills, or accidents – can have a significant impact on the operations of the channel. During such events, the channel may be closed to all vessel traffic, terminals themselves may be closed, and vessels may be diverted or significantly delayed. Force majeure events are infrequent and do not represent "typical" channel operations. Since the study is investigating the capacity during normal operations, force majeure events were not included in the simulation model.

2.7 Pilots and Tugs

Vessels that transit the Calcasieu Ship Channel require at least one Pilot on board and require assist tugs for maneuvering. If sufficient Pilots or tugs are not available, vessels wait at either the pilot boarding areas or the berths.

2.7.1 Pilots

Each of the modeled vessels required either one or two Pilots on board to transit the channel. An inbound vessel required one Pilot from the time it entered the channel at the pilot boarding area until it finished docking at the destination terminal. An outbound vessel required one Pilot from the start of undocking until it exited the channel on the Outer Bar.

A second pilot was required for:

1. All Large LNG carriers, between the CC buoy and the terminal,
2. Inbound LNG carriers when the outer bar cross-current was greater than 0.7 knots, and
3. Any LNG carrier transiting the Inner Channel at night.

The pilot requirements for LNG carriers require a second pilot more often than was required in the 2015 study. Consequently, Infrastructure Case 2 was modified to investigate requiring a second pilot on LNG ships at all times.

The second Pilot boarded the inbound LNG carrier at the CC buoy and, similarly, departed from the outbound Large LNG carrier at the CC buoy. All non-LNG vessels only required one Pilot during transit.[7]

The time when a Pilot is on board a vessel is referred to as the “bridge hours”. To evaluate potential Pilot staffing requirements, 700, 800 and 900 bridge hours per year were evaluated in this study.

2.7.2 Tugs

Tugs assist vessels with maneuvering along certain portions of the channel to help mitigate the risks of allisions. Inbound non-LNG vessels require tug assistance from Devil’s Elbow until they are all fast at their terminal, while outbound vessels require tug assistance 15 minutes before undocking until they pass Devil’s Elbow.

The channel had access to 7 tugs. Considering that each vessel requires the assistance of 2 tugs at a time, these 7 tugs were equivalent to 3 tug “sets”.

The number of tugs (or tug sets) required by the channel was determined from the results of the simulation model. Fueling and breakdowns for tugs were not modeled, since it was assumed that a replacement tug would be available when necessary.

Per the Lake Charles Pilots Standards of Care, inbound LNG carriers will require one escort tug from buoy #36 until the terminal and outbound LNGCs will similarly require one escort tug from the terminal to buoy #36. Each LNG terminal is expected to provide their own dedicated tugs – as an estimate, if each terminal will provide an average of four dedicated tugs, the number of tugs dedicated to LNG terminals would be projected to reach 20 by 2026. Since it was assumed that the LNG terminals would have sufficient tugs to assist the LNG carriers visiting these terminals – and since the rules for potential shared usage were not known at the time of the study – these dedicated tugs were not included in the simulation model.

---

[7] According to the Standards of Care, certain large vessels (such as those with a length overall greater than 984 ft) require two Pilots during transit. This requirement was not implemented in the simulation model since only two of the vessels in the historical data, and none of the vessel sizes in the channel user’s data, were large enough to require two Pilots.

3 Methodology

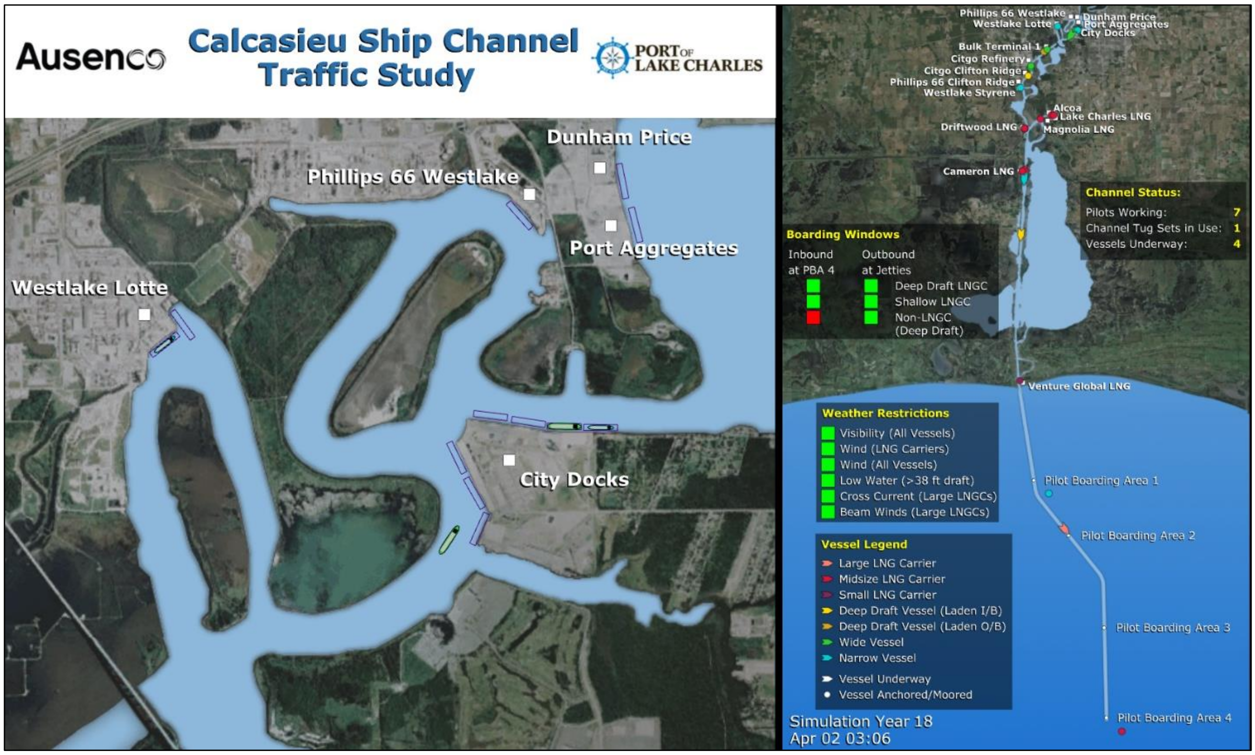
This section describes the simulation model developed for the Calcasieu Ship Channel Traffic Study, the methodology used to perform the simulation runs for the study, and the key performance indicators used to assess the channel.

3.1 Simulation Model

Ausenco updated the simulation model of the Calcasieu Ship Channel using our proprietary Transportation Logistics Simulator (TLS) software[8] and the inputs and assumptions described in Section 2. This version of the model is referred to as the "Base Case". A number of Infrastructure Cases, in which inputs were altered to observe the impact of changes to the channel operations, were also prepared.

Figure 3-1 shows a screenshot of the Calcasieu Ship Channel Base Case simulation model.

Figure 3-1 Screenshot of the Calcasieu Ship Channel Base Case Simulation Model



The right window shows the entire Calcasieu Ship Channel, with the four pilot boarding areas on the Outer Bar and the 16 modeled terminals on the Inner Channel. The right window also shows red and green indicators which show whether the environmental conditions (boarding windows, wind, visibility, and low water events) are suitable for vessels to enter the channel. The left window shows a close-up view of the upper channel, with vessels at berth at two of the modeled terminals.

---

[8] TLS is a software package built upon JaamSim (http://www.jaamsim.com), an open-source discrete-event simulation platform developed by Ausenco.

3.2 Simulation Run Methodology

For every case (Base Case or Infrastructure Case), each traffic year from 2017 to 2033 was modeled independently as a unique "simulation run". Within each simulation run, the total traffic for that specific year was repeated 46 times – which was equivalent to 46 simulated years. Each simulated year in a given run had a unique pattern of weather closures, boarding windows, and vessel arrivals, so the 46 simulated years produced model outputs with a sufficient amount of variability.

The outputs from each simulation run were analyzed to determine statistics and draw conclusions about the channel performance for each traffic year. The two primary key performance indicators (KPIs) calculated from the model outputs and used to assess the channel were:

- **Number of vessels handled**: The number of vessels handled by the channel in each traffic year indicated whether or not the channel had the capacity for the forecasted traffic. If all of the scheduled vessels for the given traffic year could enter the channel and load or unload, then the channel had sufficient capacity for that year.

- **Vessel wait time**: The vessel wait time indicated how much vessels were delayed when waiting to enter the channel and represented the effect of congestion on channel operations. The wait time for an individual vessel had two components:

    - Inbound wait time: Counted from the time the vessel was assigned a berth and was ready to enter the channel. Included all the time the vessel waited at the pilot boarding area due to opposing traffic, government regulations, boarding windows, wind, visibility, low water events, Pilots, and tugs.

    - Outbound wait time: Counted from the time the vessel had finished all activities at berth and was ready to depart. Included all the time the vessel waited at berth for the conditions noted above.

  The sum of a vessel's inbound and outbound wait times is the combined wait time. The majority of the discussions in Sections 4 and 5 focus on the combined wait time (also referred to as just "wait time"). Unlike the number of vessels handled, there was not a threshold for wait time that identified excessive congestion in the channel. As such, the wait time was most useful for comparisons (such as between traffic years to see the impact of additional traffic) and to identify causes of delays.

  However, it is somewhat difficult to assign an exact cause to the wait times experienced by vessels because delays often compounded or had multiple causes. For example, a vessel may have been initially delayed due to opposing traffic, and then further delayed by a missed boarding window or weather. Inferences about the causes of delays were thus made through the analysis of the wait times.

Other KPIs for the channel – the number of Pilots required, the number of tugs required, and the recovery time after a weather closure – were also assessed as part of the Base Case simulation runs.

4 Base Case Results

This section details the results from the Base Case simulation runs for the Calcasieu Ship Channel Traffic Study. These results demonstrate how the channel is expected to operate without any changes to its infrastructure (albeit with sufficient dredging to maintain the channel width and depth).

A number of discussions focus on three key traffic years: 2018, 2023, and 2028. These traffic years provide a general overview of the results of the study because they represent the channel at the present and at key points over the next 10 years when traffic is expected to increase significantly.

4.1 Overall Channel Performance

The two primary KPIs for the study – number of vessels handled and vessel wait time – were analyzed to determine the overall performance of the Calcasieu Ship Channel. Table 4-1 shows the number of vessels scheduled and handled in the three key traffic years, as well as for 2033.

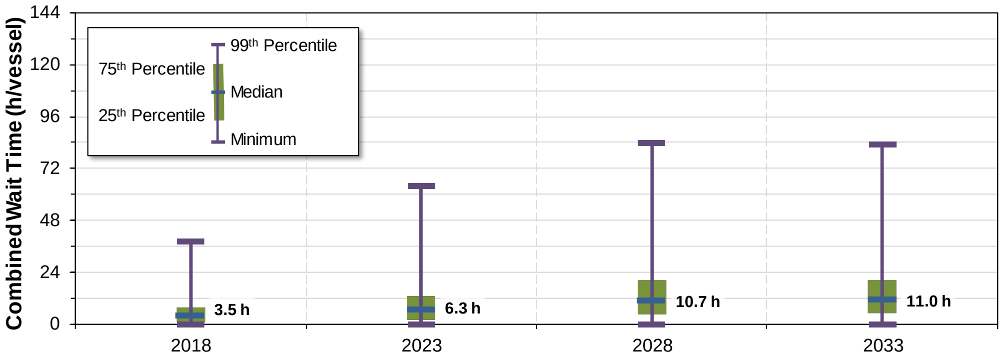
Table 4-1 Number of Vessels Scheduled and Handled in 2018, 2023, 2028, and 2033

Year	Number of Vessels Scheduled	Number of Vessels Handled
2018	1,098	1,098
2023	1,769	1,769
2028	2,527	2,527
2033	2,607	2,607

In each of the four traffic years, the channel handled all the scheduled vessel traffic. This shows that the channel has sufficient capacity to receive and handle the additional traffic forecasted by 2028 (over 1,400 additional vessels per year). The combined vessel traffic to the modeled terminals from 2028 to 2033 is forecasted to remain nearly flat and as such, these traffic years will not have any greater impact to the channel operations than the selected key traffic year of 2028.

Figure 4-1 shows the combined wait time statistics for all vessels in 2033 and the three traffic years.

Figure 4-1 Combined Wait Time in 2018, 2023, 2028, and 2033



The figure above is a “box-and-whisker” diagram that shows the wait time statistics from all vessels in the three traffic years. The diagram shows the minimum, 25th, 50th, 75th, and 99th percentile wait times.[9] The median (50th percentile) wait time value is highlighted since it represents the delays experienced by a typical vessel.

The median wait time for all vessels in the channel increased by 2.8 hours between 2018 and 2023 – from 3.5 hours in 2018 to 6.3 hours in 2023. The increase in median wait time was largely due to LNG carriers, which experienced long wait times and which began arriving in 2019. The wait times were longer than in the 2015 study largely due to the increased restrictions on LNG carriers.

Overall, these results indicate that the Calcasieu Ship Channel is capable of handling the forecasted additional traffic, although vessels will typically experience moderately higher wait times in future years. If this expected increase in wait times is considered acceptable to the channel users, changes to the channel infrastructure or regulations may not be necessary.

Subsequent sections of the Base Case results discuss the wait times in greater detail to identify the key drivers of the increase.

4.2 Vessel Wait Times by Category

The modeled vessel traffic was grouped into six categories (discussed in Section 2.4.3): Large LNG, Midsize LNG, Small LNG, Deep Draft (laden inbound and laden outbound), Wide, and Narrow. Each category was subject to a different set of rules and restrictions for transiting the channel and was expected to encounter different amounts of wait time.

---

[9] The 99th percentile is shown throughout the report as the peak value instead of the 100th percentile (the absolute maximum). Each simulation run had a few vessels that experienced excessively long delays, which would have skewed the results if presented. Such wait times were not considered representative since in practice they could be reasonably managed and mitigated by the Pilots.

Figures 4-2 and 4-3 show the wait time for the vessels in each category in 2018 and 2023 respectively. No LNG carriers arrived in 2018.

Figure 4-2 Wait Time by Category in 2018

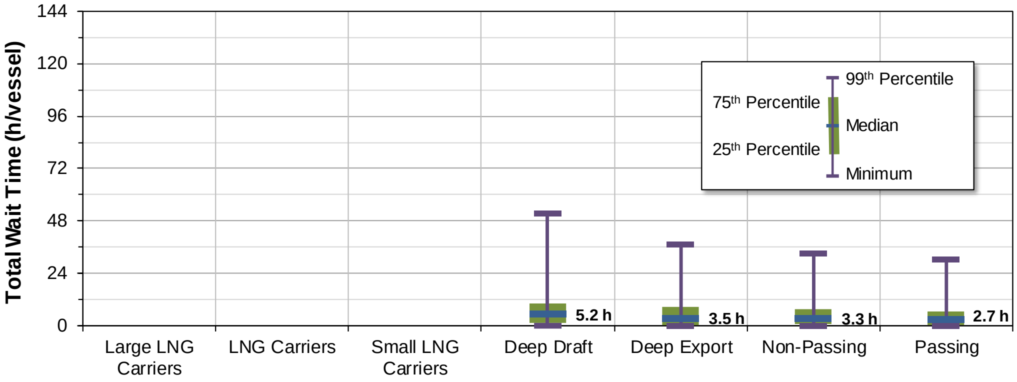
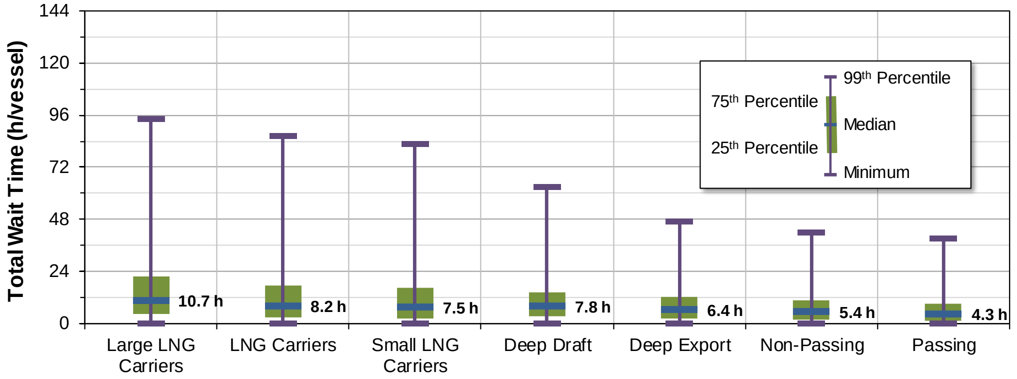


Figure 4-3 Wait Time by Category in 2023



The wait times for all vessel categories increased as traffic in the channel increased – no vessel category was immune to the impact of additional traffic. However, the various vessel categories experienced significantly different wait times.

Vessels in a more restricted category typically experienced higher wait times in a given traffic year and their wait time statistics increased more significantly with additional traffic. For example, Large LNG carriers, which were subject to boarding windows, a moving safety zone, an outer bar cross-current limit, a beam wind limit, and a more restrictive wind speed limit, had the highest median wait times in a given year (10.7 hours in 2023); whereas Narrow vessels, which were less restricted, had lower median wait times (4.3 hours in 2023).

The wait times in Figures 4-2 and 4-3 demonstrate that the most restricted vessel categories –LNG carriers and Deep Draft vessels – were the major driver of the increased wait times seen by all vessels as traffic in the channel increased. This suggests that any changes intended to improve the overall wait times in the channel should focus on allowing the more restricted vessel categories to transit the channel more easily.

4.3 Vessel Wait Times by Month

To determine which aspects of the channel operations were the primary drivers of vessel wait time, the statistics for each vessel category were analyzed in detail. This section provides the wait time statistics for each vessel category in 2023 for each month and direction (inbound and outbound).

Figures 4-4 to 4-7 show the inbound and outbound wait time statistics for each vessel category and for each month in 2023.

Figure 4-4 Inbound Wait Times By Month for LNG Vessels in 2023

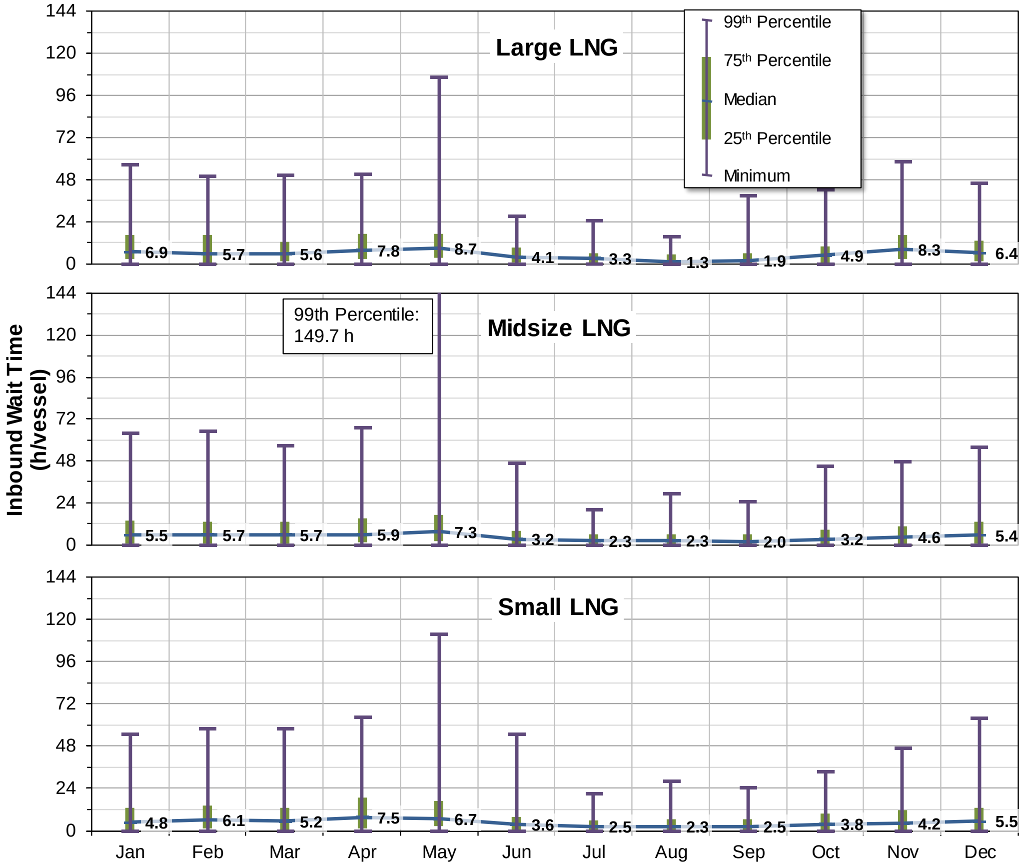


Figure 4-5 Inbound Wait Times by Month for Non-LNG Vessels in 2023

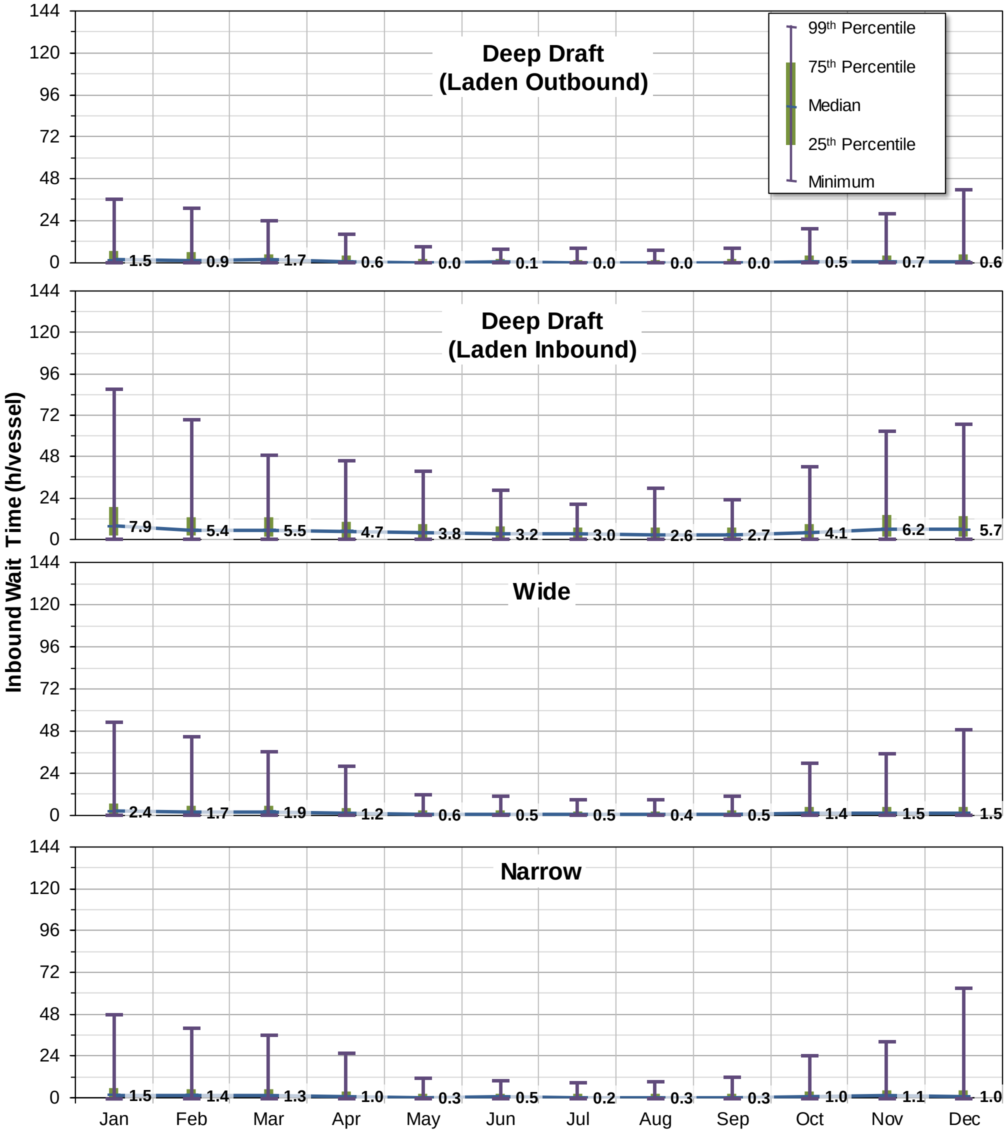


Figure 4-6 Outbound Wait Times for LNG Vessels in 2023

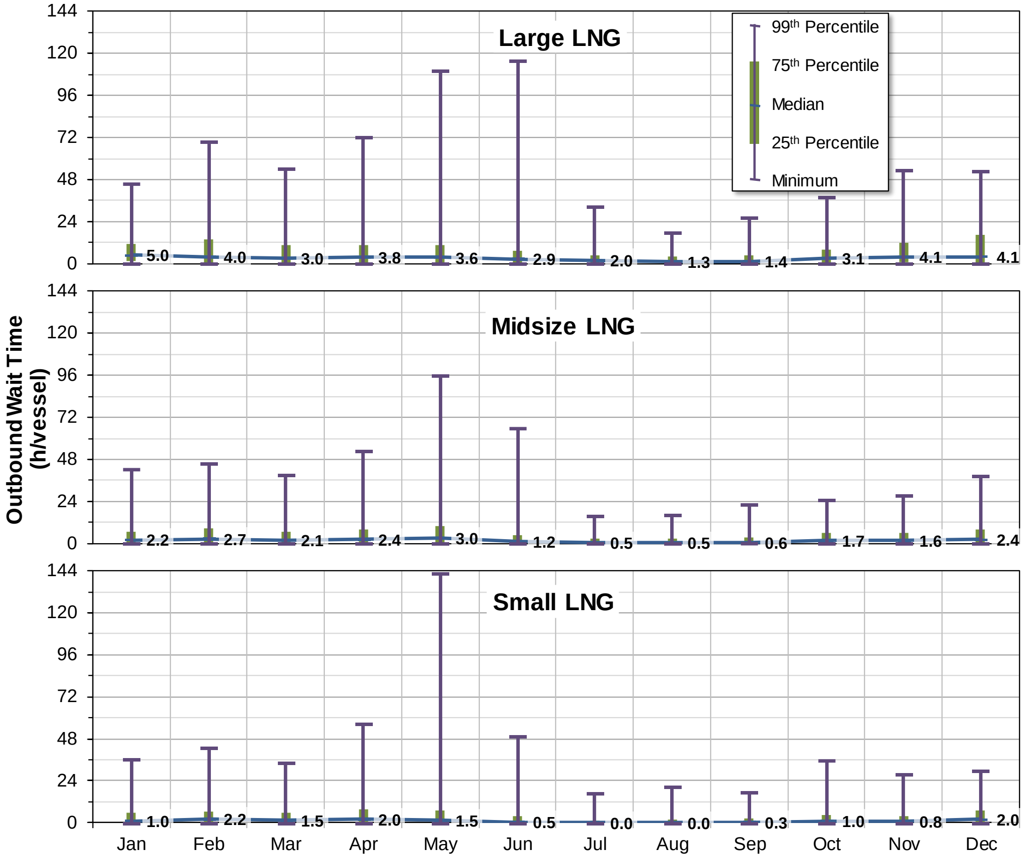
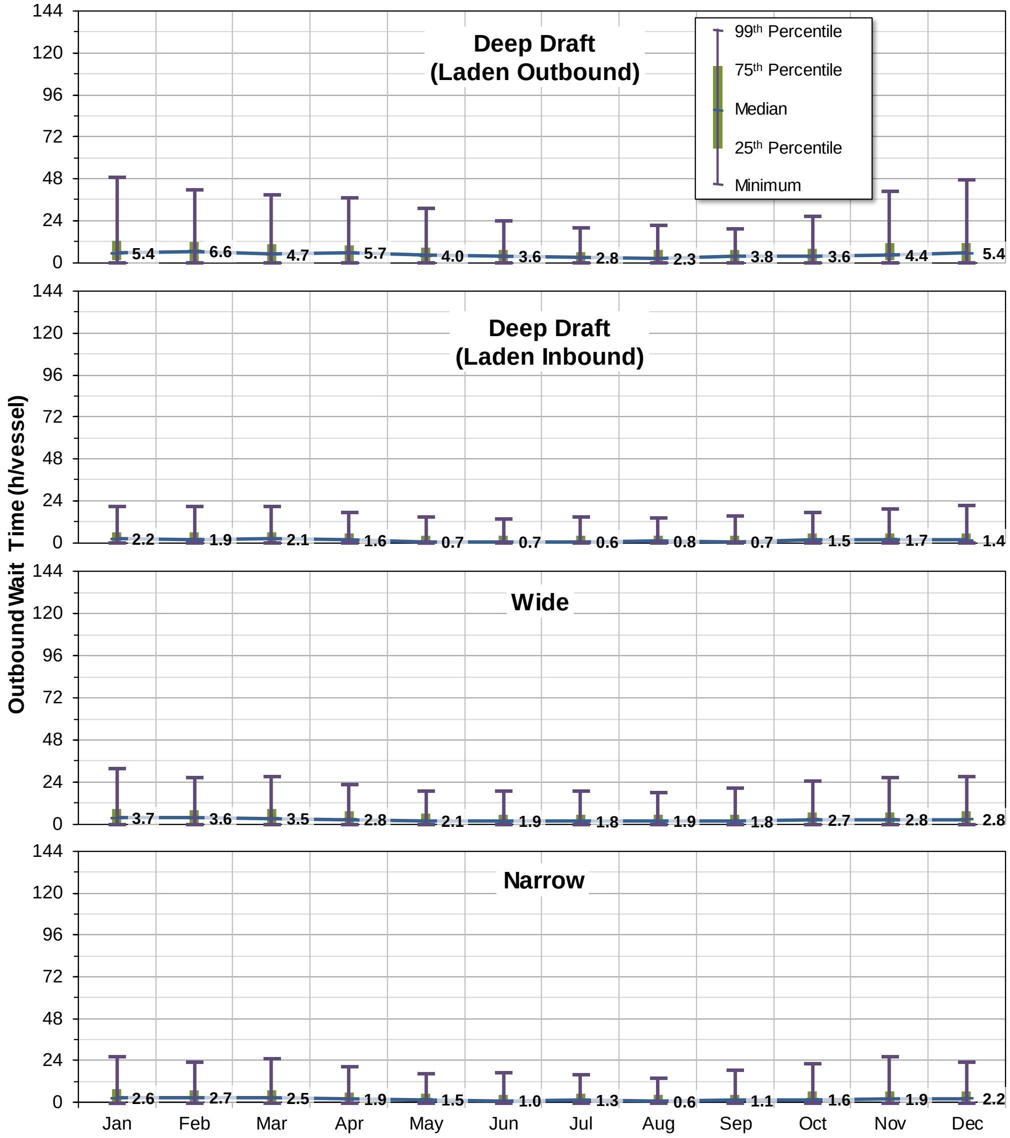


Figure 4-7 Outbound Wait Times for Non-LNG Vessels in 2023



The wait time statistics for all vessel categories varied seasonally – wait times were lower in the summer months and higher in the winter months. Seasonality was most clearly represented with the 99th percentile of wait times since these were the times for the vessels that encountered the longest weather closures. The difference between the summer and winter wait times demonstrates the impact that weather has on the wait times. The high wait times for LNG carriers between April and June were predominantly due to channel closures due to cross-current in these months.

Although the weather closures were a definite cause of wait time and are not possible to mitigate, the impact of weather closures can be decreased indirectly by minimizing any knock-on effects. After a weather closure in the model ended, there was typically a queue of vessels waiting to enter or exit the channel. Any additional restrictions on the queued vessels – such as boarding windows or passing rules – caused further delays and increased the time before the queue could be cleared. Therefore, any change to the channel regulations that would allow vessels to enter the channel more easily would decrease overall wait times.

As seen in previous sections, the vessel categories that required a boarding window to enter the channel and had the highest annual wait times –LNG carriers and Deep Draft vessels – experienced higher wait times in every month and in each direction than other vessel categories.

Although inbound LNG carriers and Deep Draft (laden inbound) vessels were restricted by the same boarding windows, LNG carriers had consistently higher inbound wait time statistics. The inbound wait times were higher because LNG carriers were subject to passing restrictions on the Outer Bar, Outer Bar cross-current limits, a more restrictive wind limit, and, for Large LNG carriers, a beam wind limit.

Overall, inbound wait times were generally longer than outbound wait times for a given vessel category. This was because outbound vessels generally faced less opposing traffic than inbound vessels and because they had priority after a weather closure. Combined with the seasonality, this suggests that any improvement to the channel that would allow vessels to more easily enter would have the largest impact. Based on all of the factors, one change that may offer the most significant benefit would be to modify the passing rules for LNG carriers on the Outer Bar; this is investigated in Section 5.

4.4 KPIs for All Traffic Years

This section details the wait time statistics for every traffic year from 2017 to 2033 – the conclusions are the same as those from the previous analyses.

Table 4-2 shows the number of vessels scheduled and handled in each year from 2017 to 2033. Despite there being fewer terminals in this study than in the 2015 study, the projected number of vessel calls by 2033 was higher for the terminals in this study than in 2015.

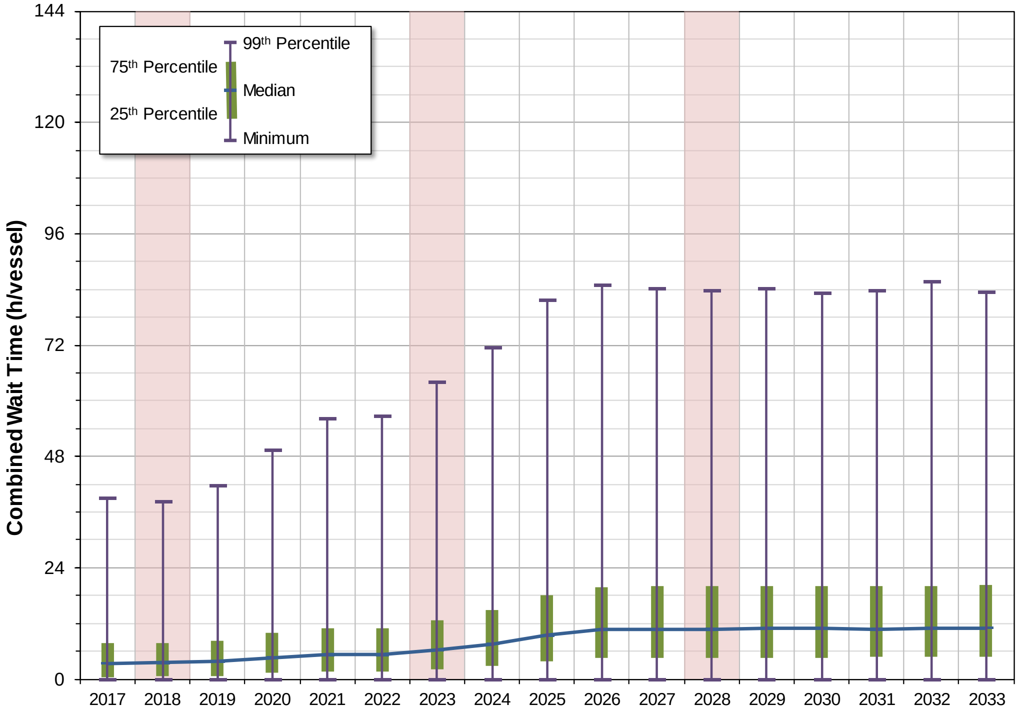
Table 4-2 Number of Vessels Scheduled and Handled from 2017 to 2033

Year	Number of Vessels Scheduled	Number of Vessels Handled
2017	1,108	1,108
2018	1,098	1,098
2019	1,160	1,160
2020	1,317	1,317
2021	1,556	1,556
2022	1,561	1,561
2023	1,769	1,769
2024	2,009	2,009
2025	2,342	2,342
2026	2,514	2,514
2027	2,521	2,521
2028	2,527	2,527
2029	2,557	2,557
2030	2,563	2,563
2031	2,570	2,570
2032	2,600	2,600
2033	2,607	2,607

In every traffic year, the channel had the capacity to handle all the scheduled vessel traffic.

Figure 4-8 shows the wait time statistics for all vessels in each year from 2017 to 2033.

Figure 4-8 Wait Times for All Vessels from 2017 to 2033

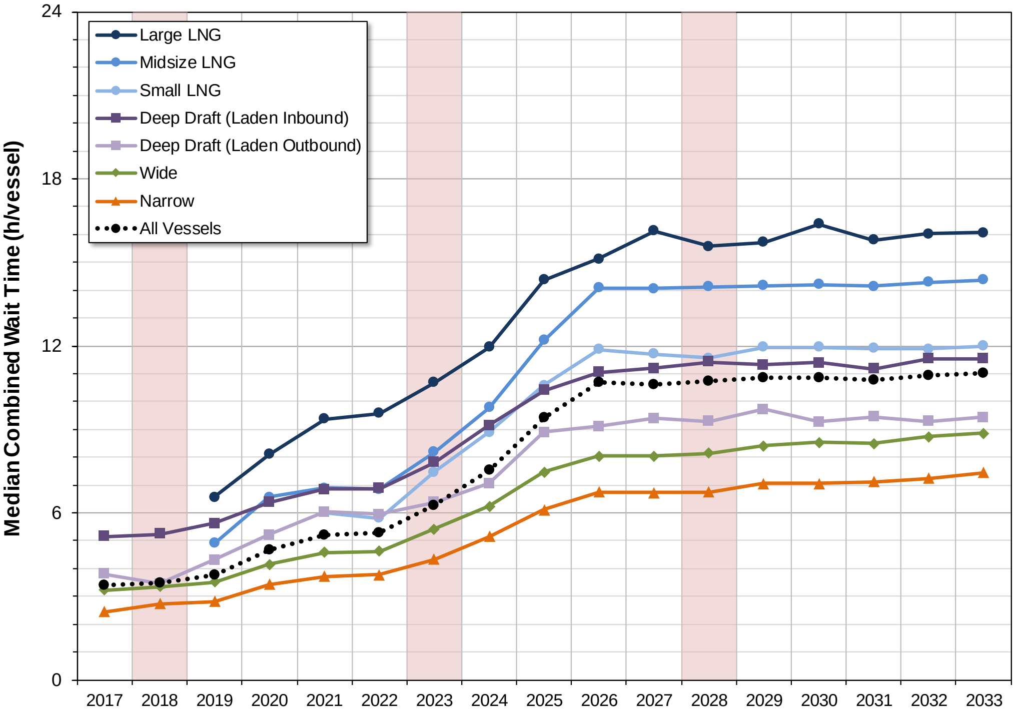


The median wait time increased from 3.4 hours in 2017 to 10.8 hours in 2029, when the median wait times in the channel reached its peak. In general, the increase in wait time statistics for all vessels followed the same trend as the forecasted increases in traffic (shown in Figure 2-2) – that is, the wait times increased in the same years and in similar proportions as the traffic.

The increase in wait times for non-LNG vessels compared to the 2015 study was due to increased visibility closures and due to less open windows for inbound Deep Draft vessel transit. The increase in wait time for LNG vessels compared to the 2015 study was due to the more restrictive weather transit limits and due to shorter inbound boarding windows.

Figure 4-9 shows the median wait times for each vessel category in each year from 2017 to 2033.

Figure 4-9 Median Wait Times by Vessel Category from 2017 to 2033



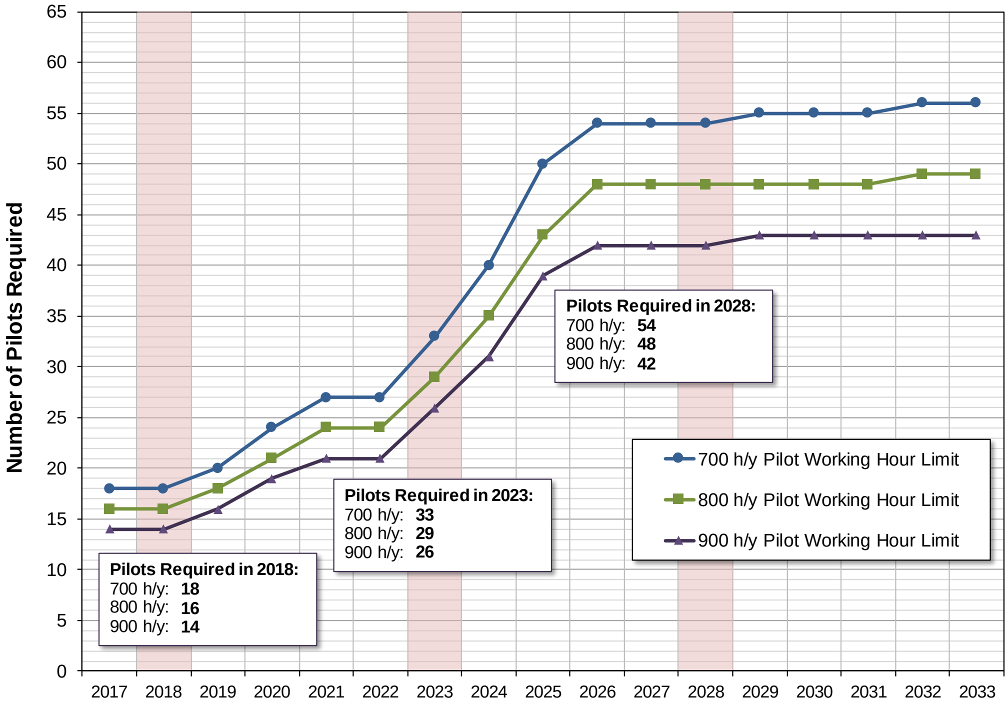
The median wait time in a given traffic year was highest for the most restricted vessel categories – LNG carriers and Deep Draft vessels. Midsize LNG carriers had the largest increase – from 4.9 hours in 2019 (the first year these vessels were expected in the channel) to 14.2 hours in 2028 and thereafter.

4.5 Pilot Requirements

The number of Pilots required for a given traffic year was calculated from the total bridge hours (based on the rules detailed in Section 2.7.1) for all vessels and for each of the three potential bridge hours limits (700, 800, and 900 bridge hours per year).

Figure 4-10 shows the number of Pilots required for each traffic year and for the three bridge hour limits.

Figure 4-10 Pilot Requirements for 2017 to 2033



The modeled channel required between 14 and 18 Pilots to handle the vessel traffic in 2018. This result is in line with reality, as 17 Pilots were employed in 2018. The number of Pilots required increased significantly with the additional traffic: in 2023, between 26 and 33 Pilots were required and in 2028, between 42 and 54 Pilots were required, triple the number employed in 2018.

The Pilot requirements shown in Figure 4-10 are the minimum numbers given the assumption that the bridge hour limits cannot be exceeded. If the modeled channel did not have at least the number of Pilots listed for a given traffic year, it was unable to handle every scheduled vessel as there were not enough available bridge hours.

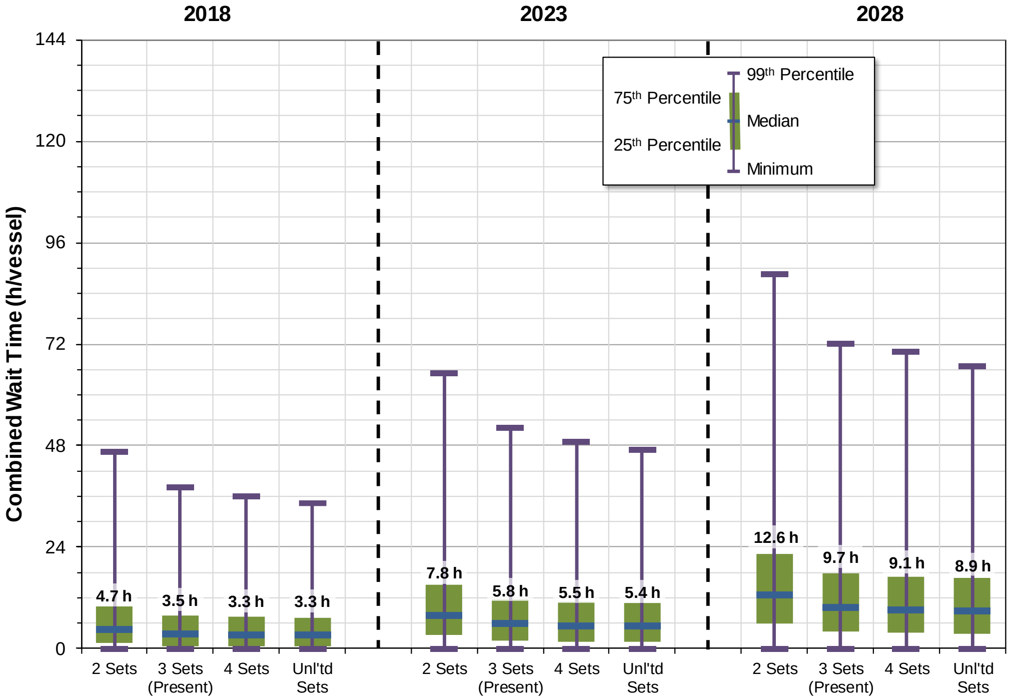
Pilot requirements in 2023 were increased compared to the 2015 study due to LNG carriers requiring two pilots more often than in the 2015 study.

4.6 Channel Tug Requirements

Unlike the Pilots, the channel tugs did not have a limit to the number of hours they could operate in a given year. To determine how many channel tugs were necessary to handle the forecasted traffic, simulation runs were performed with 2, 3, and 4 channel tug pairs, or tug sets, as well as with an unlimited number of channel tugs. The wait times from these simulation runs were compared to observe the impact of additional tug sets.

Figure 4-11 shows the wait time statistics for all non-LNG vessels with different numbers of channel tug sets in 2018, 2023, and 2028. Channel tugs only escorted non-LNG vessels.

Figure 4-11 Wait Time with Different Numbers of Channel Tug Sets in 2018, 2023, and 2028



In each year, adding channel tug sets decreased the wait times. For example, in 2023, one additional tug set decreased the median wait time from 5.8 hours to 5.5 hours. More than one additional tug set did not provide a significant improvement – even with unlimited tug sets, the median wait time only decreased to 5.4 hours per non-LNG vessel. Non-LNG traffic did not increase significantly so channel tug requirements were not expected to increase.

Since non-LNG vessels did not have significantly lower wait times when the channel had 4 tug sets instead of 3 tug sets, it was assumed that the channel continued using 3 dedicated tug sets.[10] Note that regardless of the number of channel tug sets, the channel was able to handle all of the scheduled traffic in each year – the number of tug sets only impacted the wait times of non-LNG vessels.

4.7 Weather Closure Recovery Time

An analysis was performed with the Base Case model to determine how long it takes the channel to "recover" – that is, how long it takes to return to normal operations – after a weather closure stops traffic.

To perform this analysis, the historical weather data (discussed in Section 2.6) was removed from the Base Case model and was replaced with a series of closures of a fixed duration occurring at set intervals. The model recorded the number of vessels waiting to enter the channel before, during, and after each weather closure at 1 hour intervals. A total of 72 weather events for each duration were

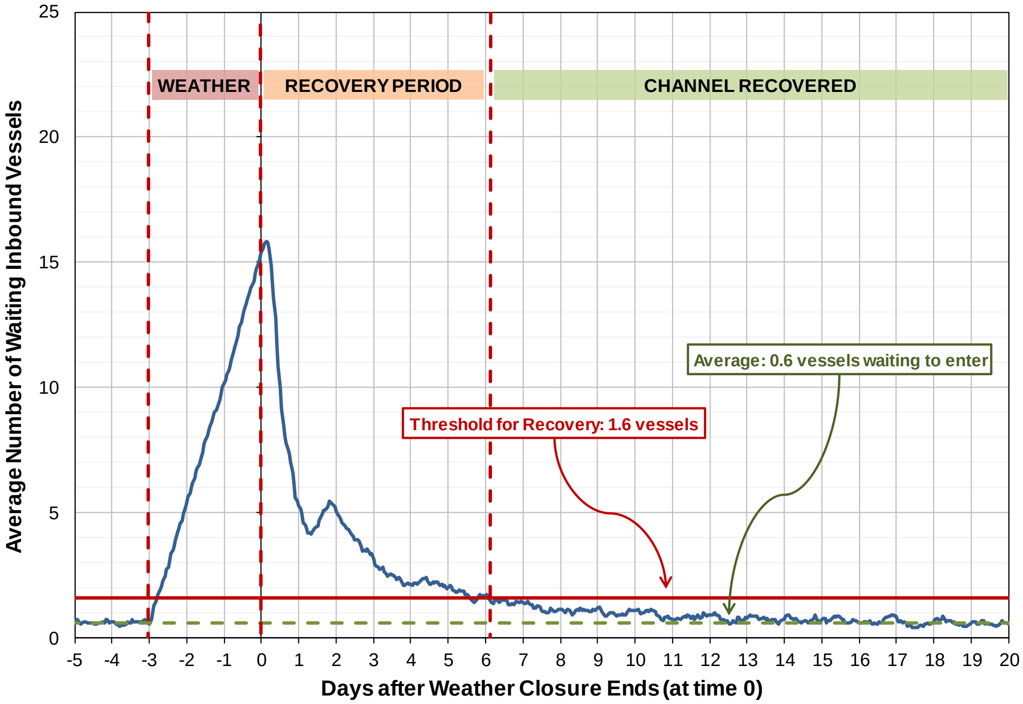
---

[10] Note that the simulation runs and results in previous sections were based on the modeled channel having 3 tug sets.

simulated, and the average number of waiting vessels at each hour was calculated. This averaging highlighted the effect of the channel rules and infrastructure on the recovery time, as opposed to the effects of the specific vessel arrivals or boarding windows at the time of the closure.

Figure 4-12 shows an example of the average number of waiting vessels before, during, and after a 3-day weather closure in the 2023 traffic year.

Figure 4-12 Average Vessels Waiting for a 3-day Closure in 2023

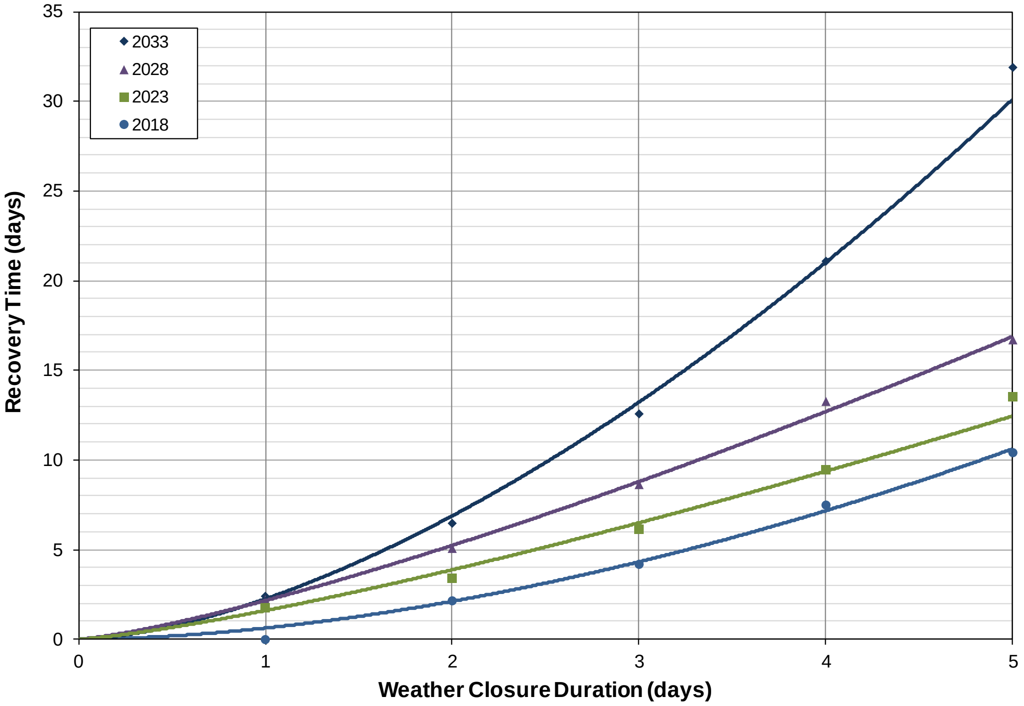


The green dashed line represents normal channel operations and shows the average number of vessels waiting when there were no weather closures. The recovery time was how long after the weather closure had ended that it took for the average number of waiting vessels to return to within 1 vessel of the average from before the closure (in this example, there was an average of 0.6 vessels in queue before the closure).

During the recovery period (i.e. after the closure ended), there was a brief period of time during which the number of waiting vessels increased because the outbound vessels were being cleared. After the outbound vessels were cleared, the inbound queue quickly decreased as vessels were brought into the channel. However, the recovery continued at a slower pace as berths became unavailable and additional vessels needed to undock and exit the channel. In this example, the total recovery time was 6.2 days – the lower traffic volume for 2023 in this study compared to the 2015 study resulted in a decreased recovery time.

The analysis was performed for weather closures of 1, 2, 3, 4, and 5 days and for each traffic year from 2018 to 2033. Figure 4-13 shows the recovery time for the channel for four traffic years (2018, 2023, 2028, and 2033) for the different closure durations.

Figure 4-13 Recovery Time versus Closure Duration in 2018, 2023, 2028, and 2033



The channel was able to recover almost immediately after a 1-day weather closure in 2018 and required 2.4 days to recover from the same closure in 2033. For a 3-day weather closure, the channel required 4.2 days to recover in 2018 and 13.0 days in 2033. For a 5-day weather closure – a very infrequent occurrence – the channel required significantly more time to return to normal operations: 10.8 days in 2018 and 32.5 days in 2033. As discussed in previous sections, the increased weather restrictions on LNG carriers, the more restrictive inbound boarding windows, and the increase in visibility closures contributed to closure durations increasing compared to the 2015 study.

5 Infrastructure Cases Results

This section details the results from sensitivity analyses of five Infrastructure Cases as part of the Calcasieu Ship Channel Traffic Study. These results demonstrate how the channel would be impacted by changes to its infrastructure or regulations.

5.1 Overview of Infrastructure Cases

Five Infrastructure Cases were simulated with the model:

- **Case 1**: Insufficient dredging
- **Case 2**: Increased Pilot requirements for LNG carriers
- **Case 3**: LNG carrier passing on the Outer Bar
- **Case 4**: Inner Channel anchorages
- **Case 5**: Inner Channel passing lane

Each Infrastructure Case was implemented by modifying the inputs of the Base Case simulation model described in Section 2. The input changes for each case are discussed in the subsections below.

None of the infrastructure cases affected the channel's ability to accommodate the increased vessel traffic; therefore, the impact of each change to the channel was determined by comparing the vessel wait times for the case to the wait times for the Base Case. This comparison indicated whether the change had a positive or a negative effect on the channel, as well as the magnitude of the impact.

The wait times were also used to estimate the economic impact of each change by calculating the increase or decrease in vessel time charter costs (relative to the Base Case). Table 5-1 shows the assumed daily charter costs for each modeled vessel category that were used in this calculation.

- Wide and Narrow charter costs are estimated 1-year charter rates from April 2017, averaged over Atlantic and Pacific charter rates.
  (source: www.hellenicshippingnews.com/weekly-dry-time-charter-estimates-april-12-2017)
- Deep Draft charter costs are estimated using 2017-2018 charter costs.
  (source: www.teekay.com/investors/teekay-tankers-ltd/market-insights)
- LNG charter costs are the approximate average charter costs between 2012 and 2014 – this was a period with high LNG carrier demand which appeared to be similar to the high demand experienced at the end of 2018 and beginning of 2019.
  (source: blogs.platts.com/2018/10/19/lng-shipping-spot-rates-hit-250000-day)

Table 5-1 Daily Charter Costs for Each Vessel Category

Vessel Type	Example Vessel Class	Assumed Daily Charter Cost ($/d)
LNG Carriers	Q-Flex LNG Carrier, Moss-type LNG carrier	$100,000
Deep Draft	Aframax	$12,000
Wide	Panamax	$11,750
Narrow	Handysize	$8,250

The economic impact was estimated by multiplying the daily charter costs by the change in average wait time for each vessel category (relative to the Base Case wait times). The actual economic impact of each change would likely be much greater than these estimates. These estimates only accounted for additional direct vessel time charter costs. Other factors such as construction cost of the change or additional terminal operating costs were not included in the calculation; estimating such costs was beyond the scope of this study. These calculations still provide a useful indication of the potential economic impact.

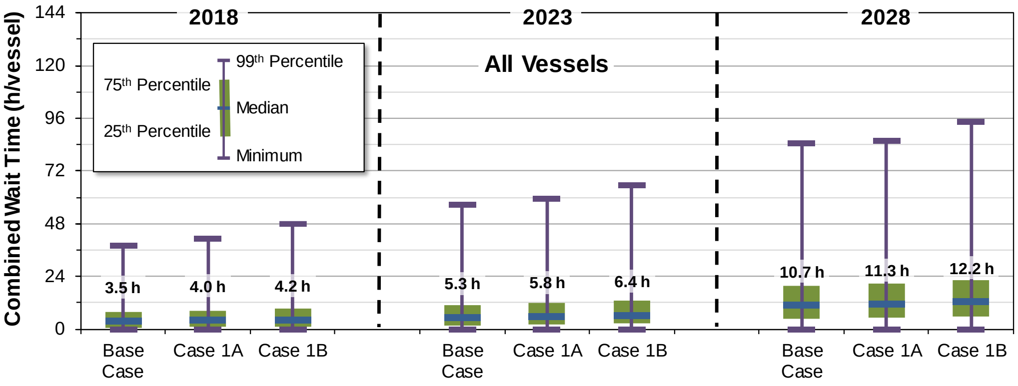
5.2 Case 1: Insufficient Dredging

In the Base Case, the channel was assumed to be properly maintained and dredged to its congressionally authorized dimensions. In Case 1, the channel was insufficiently dredged, which reduced its width and depth. The impact of insufficient dredging was investigated in two scenarios:

- **Case 1A**: the moderate scenario. The channel width was reduced to 250 ft or less (such that no vessels were able to pass on the Inner Channel) and the depth was reduced by roughly 1 ft (such that the boarding windows closed at the jetties 1 hour earlier than normal).
- **Case 1B**: the more severe scenario. The channel width was reduced to 250 ft or less (such that no vessels were able to pass on the Inner Channel) and the depth was reduced by roughly 2 ft (such that the boarding windows opened at the jetties 2 hours later and closed 1 hour earlier than normal).

Figure 5-1 compares the wait time statistics for all vessels between the Base Case, Case 1A, and Case 1B in the three key traffic years.

Figure 5-1 Comparison of Wait Times between the Base Case, Case 1A, and Case 1B



When the channel was insufficiently dredged, the wait time for all vessels increased: the median wait time in 2023 increased from 5.3 h to 5.8 h in Case 1A (a 9% increase) and to 6.4 h in Case 1B (a 21% increase).

The lack of sufficient dredging impacted the various vessel categories differently. Figure 5-2 and Figure 5-3 compare the wait time statistics between the Base Case, Case 1A, and Case 1B for each vessel category. No data is shown for LNG carriers in 2018 since none were scheduled.

Figure 5-2 Comparison of Wait Times between the Base Case, Case 1A, and Case 1B by Vessel Category

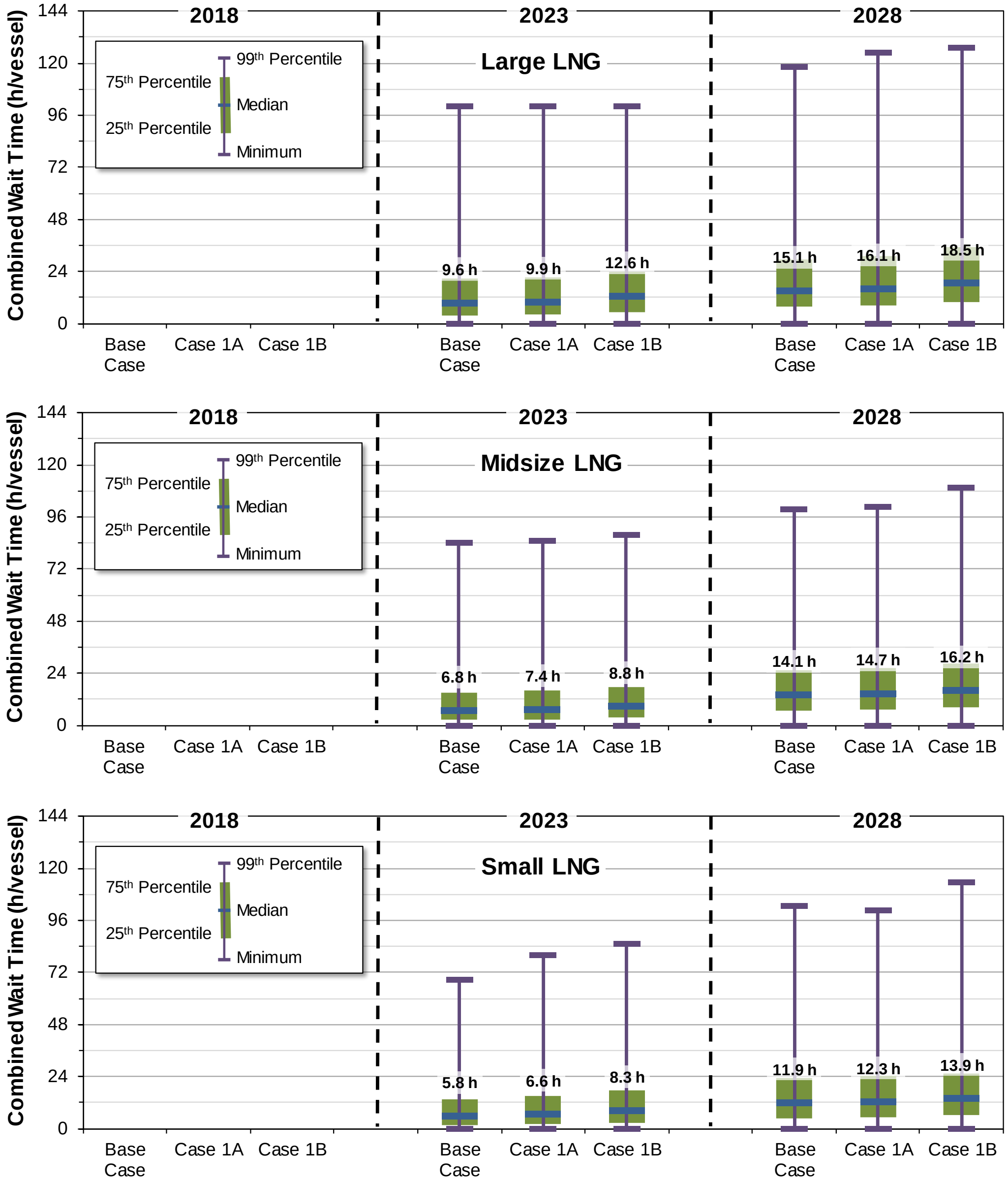
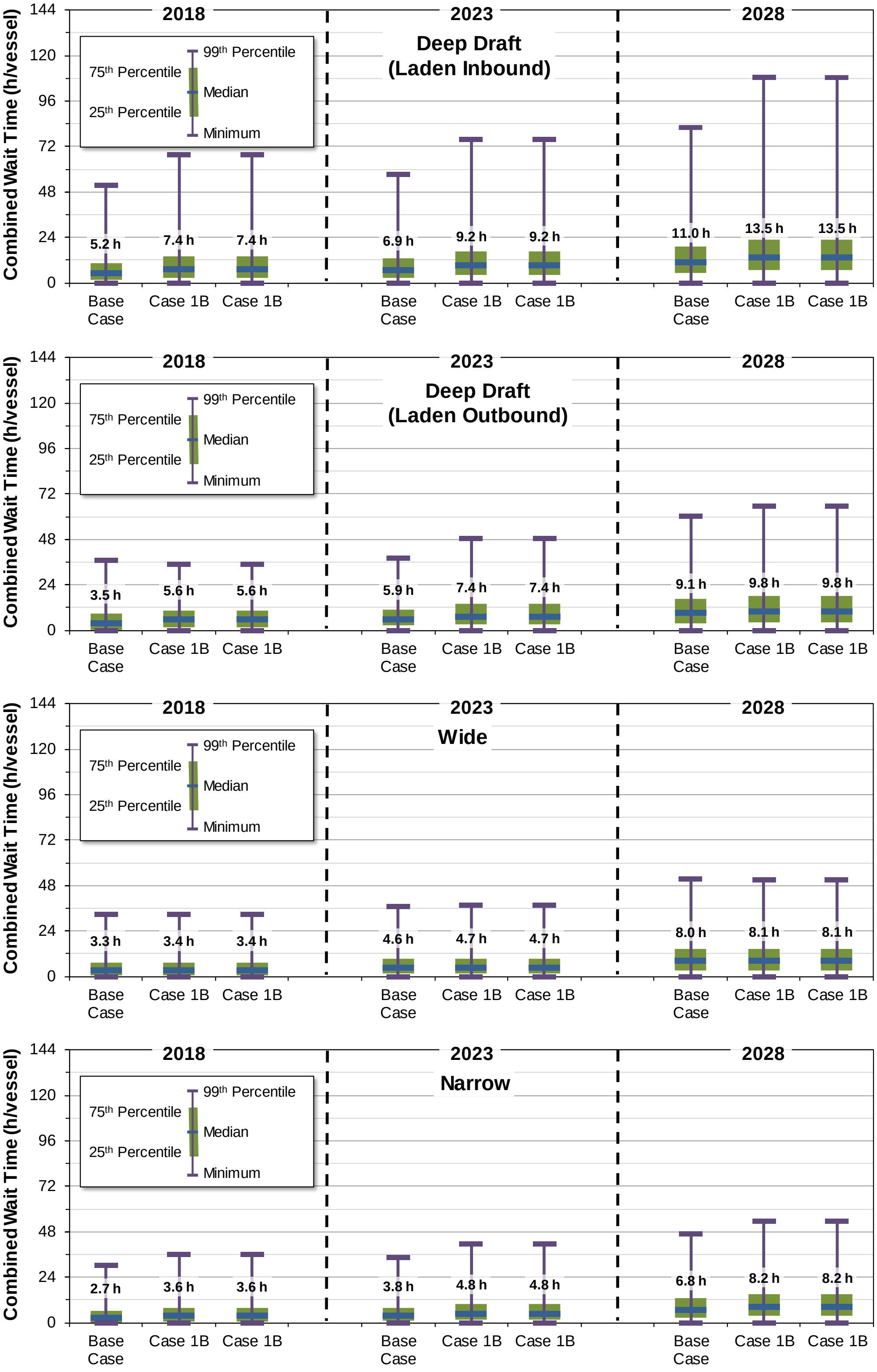


Figure 5-3 Comparison of Wait Times between the Base Case, Case 1A, and Case 1B by Vessel Category, continued



LNG carriers and Deep Draft vessels were impacted most significantly by insufficient dredging because of the direct impact on the boarding windows. For example, the median wait times for Deep Draft vessels increased by 25% from the Base Case to Case 1B. Such increases indicate that insufficient dredging dramatically affected the ability of the channel to handle large vessel traffic when it experienced heavy weather events.

These results also indicate that proper dredging of the channel is essential to maintain the present performance and to ensure that future traffic will not experience significant delays that could prevent the terminals from meeting their targets.

Economic Impact

Table 5-2 shows the estimated additional charter costs in 2023 for Case 1A and Case 1B for each vessel category, as well as the overall charter cost increase.

Table 5-2 Estimated Change in Vessel Charter Costs for Case 1A and Case 1B in 2023

		Average Change in Wait Time (h/vessel)		Estimated Change in Charter Cost (M$/y)	
Vessel Type	**Number of Vessel Calls**	**Case 1A**	**Case 1B**	**Case 1A**	**Case 1B**
All LNG Carriers	539	0.6	2.2	$1.3 M	$4.8 M
Deep Draft (Laden Inbound)	310	0.7	3.3	$0.1 M	$0.5 M
Deep Draft (Laden Outbound)	48	0.4	1.6	<$0.1 M	<$0.1 M
Wide	467	0.1	0.2	<$0.1 M	<$0.1 M
Narrow	405	1.3	1.5	$0.2 M	$0.2 M
Total	1,769			$1.6 M	$5.6 M

* Note that “<$0.1M” signifies a negligible increase or decrease to charter costs.

As a result of insufficient dredging, the overall charter costs increased, by $1.6M per year in Case 1A and by $5.6M per year in Case 1B. This increase was primarily driven by the additional delays imposed on LNG Carriers, although almost all vessel categories were negatively impacted.

The impact of insufficient dredging in this study was significantly lower than in the 2015 study. In this study the transit windows were more restricted than in the 2015 study, so dredging limitations overlapped with base case weather and boarding window restrictions.

The overall economic impact of insufficient dredging on the future channel operations would likely be much greater than just these charter costs – for example, the terminals would have additional costs due to delayed deliveries or shipments. Since the charter cost increases alone are already high, this case emphasizes the economic importance of sufficient dredging to the channel operations.

5.3 Case 2: Increased Pilot Requirements for LNG Carriers

In the Base Case, Large LNG carriers always required two Pilots on board, whereas Small and Midsize LNG carriers required two pilots on board only when their transit occurred at night or when outer bar cross current exceeded 0.7 knots. Midsize and small LNG carriers transiting during daytime and when outer bar cross current remained below 0.7 knots required only one Pilot on board. All other vessels required one Pilot on board at any time while transiting the channel.

In Case 2, all LNG carriers required two Pilots on board at all times during their transit (either day or night and on both the Outer Bar and the Inner Channel). This change only impacted Small and Midsize LNG carriers. The changes in Case 2 were relatively minimal, but Case 2 was always included to show the impact of requiring two pilots on LNG carriers.

Figure 5-4 compares the number of Pilots required in the Base Case and in Case 2 for each traffic year and for the three bridge hour limits.

Figure 5-4 Comparison of Pilot Requirements between the Base Case and Case 2

With the increased Pilot requirements for Small and Midsize LNG carriers, up to 2 additional Pilots were necessary in 2023 and between 5 to 7 additional Pilots were necessary in 2028, depending on the bridge hour limit. The Pilot requirements from 2017 to 2019 were not impacted by this change since there were no LNG carriers forecasted for these years.

Case 2 differs from the Case 2 investigated in the 2015 study; hence, the pilot requirements in this study varied less than in the 2015 study.

Vessel wait times were not impacted by the increased Pilot requirements. The pilot requirements did not affect the channel's ability to meet the forecasted vessel calls.

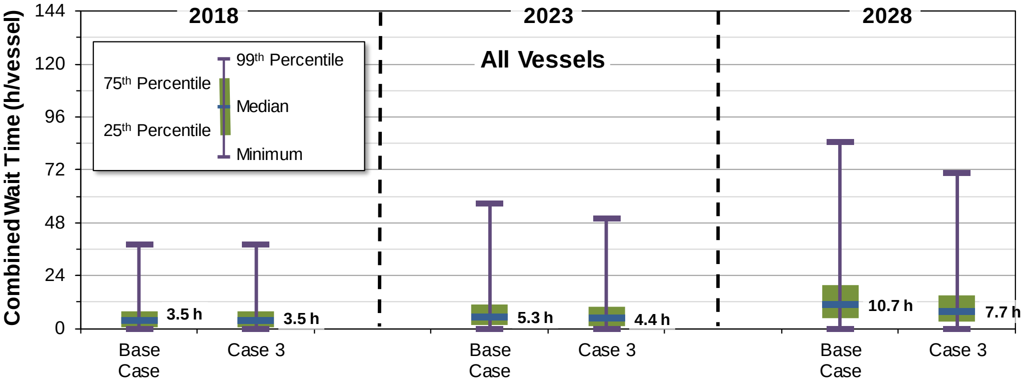
5.4 Case 3: LNG Carrier Passing on the Outer Bar

In the Base Case, Large and Small LNG carriers were not allowed to pass other vessels at any location along the channel because of the moving safety zone around LNG carriers.

In Case 3, the safety zone restrictions were lifted for the Outer Bar, which allowed any LNG carrier (loaded or ballasted) to pass any other vessel along the Outer Bar. The safety zone restrictions remained in place on the Inner Channel, which meant that LNG carriers were still unable to pass any other vessel on the Inner Channel.

Figure 5-5 compares the wait time statistics for all vessels between the Base Case and Case 3 in the three key traffic years.

Figure 5-5 Comparison of Wait Times between the Base Case and Case 3



When LNG carriers were allowed to pass on the Outer Bar, the wait time for all vessels decreased: the median wait time decreased from 5.3 h to 4.4 h in 2023. The wait times in 2018 were not impacted by this change since there were no LNG carriers in the traffic for that year.

Figure 5-6 and Figure 5-7 compare the wait time statistics between the Base Case and Case 3 for each vessel category.

Figure 5-6 Comparison of Wait Times between the Base Case and Case 3 by Vessel Category

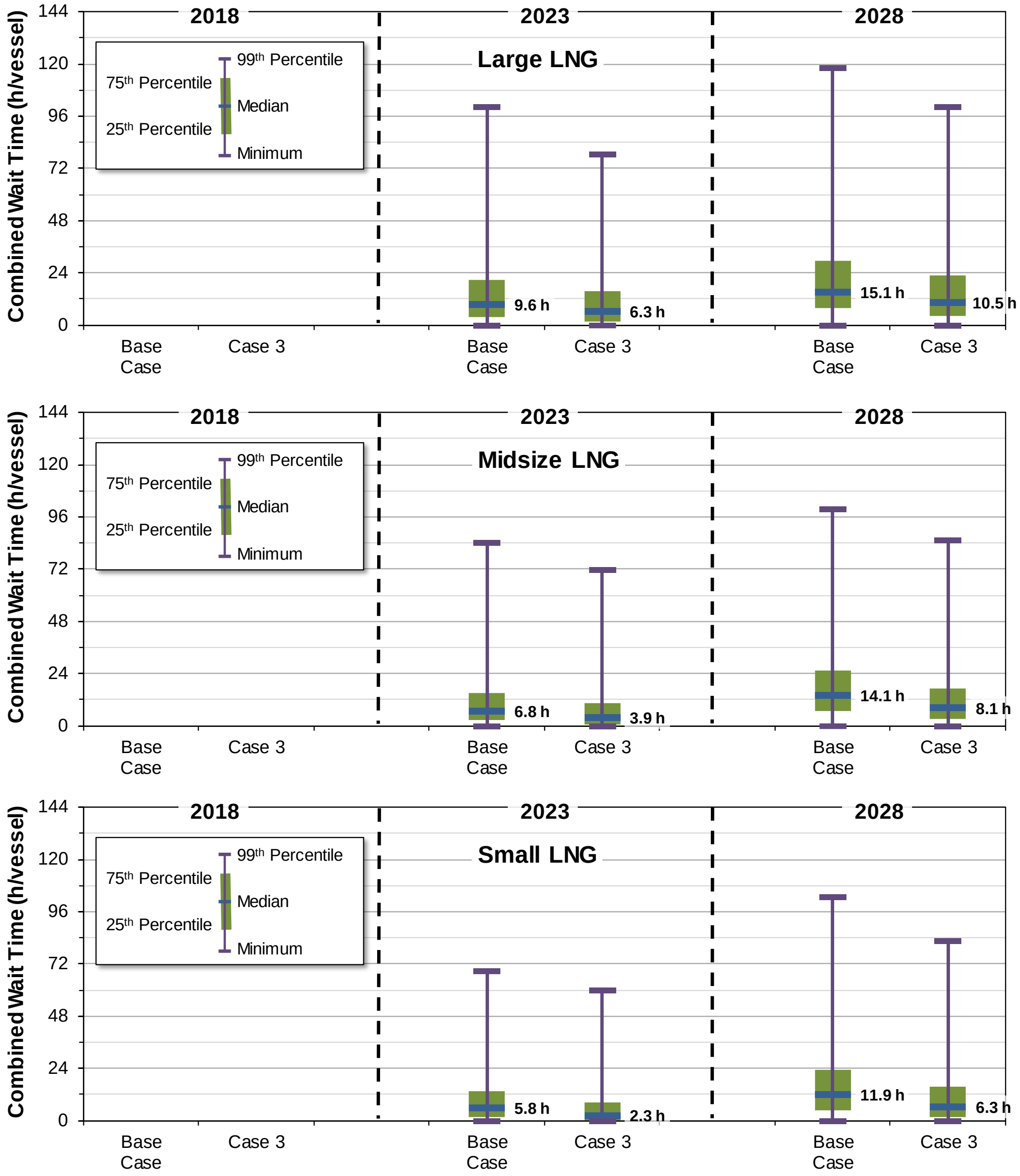
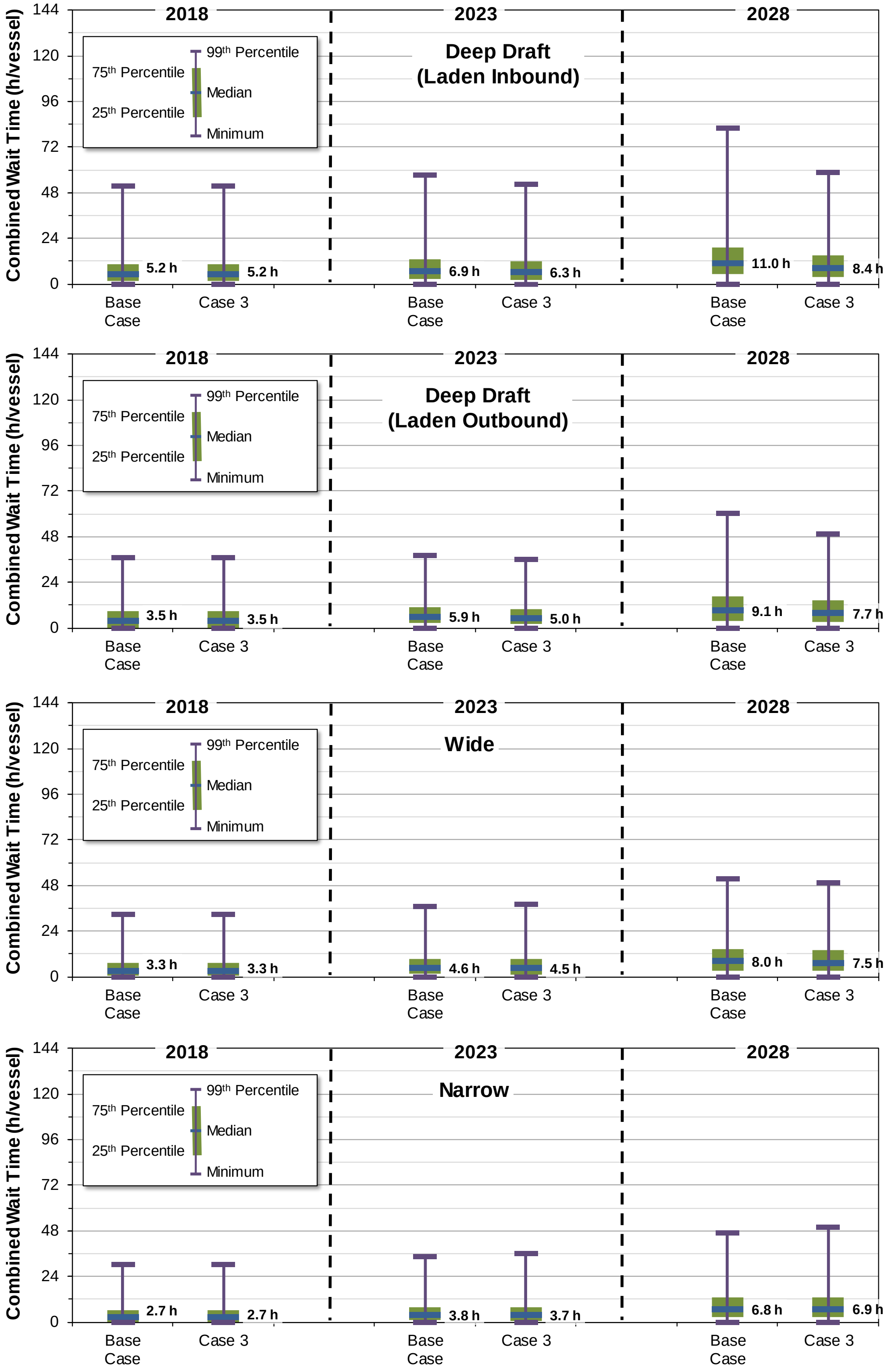


Figure 5-7 Comparison of Wait Times between the Base Case and Case 3 by Vessel Category, continued



LNG carriers were directly impacted by the change to the Outer Bar passing restrictions and as a result, Midsize LNG carriers had the most significant decrease in wait times. For example, in 2023 the median wait times for Midsize LNG carriers decreased from 6.8 h to 3.9 h. However, wait times for almost all vessel categories decreased with this change (in 2023 and 2028, when there was LNG traffic in the channel) since all vessels were able to move more easily. Narrow vessels in 2028 saw a moderate increase in median wait times, from 6.8 h to 6.9 h, due to waiting longer for LNG carriers along the Inner Channel.

Economic Impact

Table 5-3 shows the estimated charter cost savings in 2023 for Case 3 for each vessel category, as well as the overall charter cost decrease.

Table 5-3 Estimated Change in Vessel Charter Costs for Case 3 in 2023

Vessel Type	Number of Vessel Calls	Average Change in Wait Time (h/vessel)	Estimated Change in Charter Cost (M$/y)
LNG Carrier	539	-4.0	($8.9 M)
Deep Draft (Laden Inbound)	310	-1.6	($0.3 M)
Deep Draft (Laden Outbound)	48	-1.2	<$0.1 M
Wide	467	-0.2	($0.1 M)
Narrow	405	0.0	<$0.1 M
Total	1,769		($9.3 M)

As a result of the change to LNG carrier passing restrictions on the Outer Bar, the overall charter costs in the channel decreased by $9.3M per year. These cost savings were primarily driven by the reduced wait times for LNG carriers, although all vessel types benefited because they could typically enter the channel earlier (and pass LNG vessels in transit). This effect was especially apparent following weather closures when LNG carriers were able to begin transit as vessels were exiting the channel.

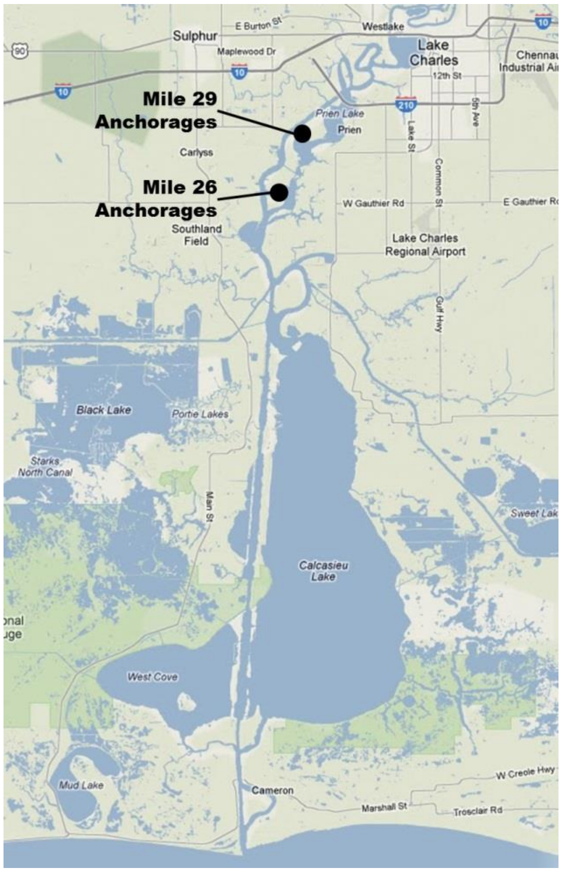
The increased weather restrictions on LNG carriers in this study left less time for LNG carriers to transit than in the 2015 study; hence the economic impact unrestricted Outer Bar passing was lower than in the 2015 study.

5.5 Case 4: Inner Channel Anchorages

In the Base Case, there were no anchorages along the channel. Once a vessel began its inbound transit from the Pilot Boarding Area, it did not stop until it reached its berth.

In Case 4, four anchorages were set up on the upper portion of the Inner Channel – two at Mile Marker 26 and two at Mile Marker 29 – as shown in Figure 5-8. Since the 2015 study, this case was reviewed and decided to be impractical. This case is included here for continuity with the 2015 study.

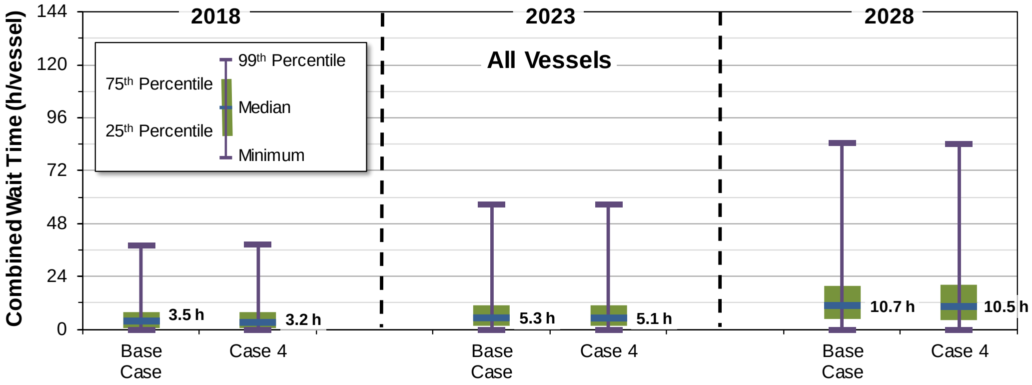
Figure 5-8 Location of Anchorages on the Modeled Calcasieu Ship Channel



Vessels were able to travel to these anchorages without having an assigned berth, and then travel to their berth once it became available. The anchorages were only used by inbound vessels destined for terminals nearby or upstream of the anchorages – as a result, they were not used by any of the LNG carriers. Up to four vessels could be anchored at a time.

Figure 5-9 compares the wait time statistics for all vessels between the Base Case and Case 4 in the three key traffic years.

Figure 5-9 Comparison of Wait Times between the Base Case and Case 4



The addition of anchorages had very little impact on vessel wait times in the channel. In 2018 the median wait time decreased from 3.5 h to 3.2 h and in 2023 the median wait time decreased slightly from 5.3 h to 5.1 h. The effect on wait times for the individual vessel categories was similar and no individual category saw a significant change in wait times.

Anchorages generally only provide a benefit when there are terminals without enough berth capacity. Since the majority of terminals had sufficient berth capacity, the addition of anchorages had little impact on wait times. The anchorages did help to minimize delays for some vessels calling at certain terminals but, as a whole, the anchorages did not help vessels move more easily in the channel and thus had a minimal impact on the overall channel.

Economic Impact

Table 5-4 shows the estimated additional charter costs in 2023 for Case 4 for each vessel category, as well as the overall charter cost increase.

Table 5-4 Estimated Change in Vessel Charter Costs for Case 4 in 2023

Vessel Type	Number of Vessels Calls	Average Change in Wait Time (h/vessel)	Estimated Change in Charter Cost (M$/y)
LNG Carrier	539	0.1	$0.1 M
Deep Draft (Laden Inbound)	310	0.1	<$0.1 M
Deep Draft (Laden Outbound)	48	-0.2	<$0.1 M
Wide	467	0.0	<$0.1 M
Narrow	405	0.0	<$0.1 M
Total	1,769		$0.2 M

The wait times did not change significantly with the introduction of anchorages, and as such the overall charter costs were minimally impacted in Case 4. The anchorages could have a direct impact on the operations of specific terminals, but such analysis was beyond the scope of the study.

5.6 Case 5: Inner Channel Passing Lane

In the Base Case, only Narrow vessels were able to pass on the Inner Channel – all other vessel categories were unable to meet and pass anywhere along the Inner Channel.

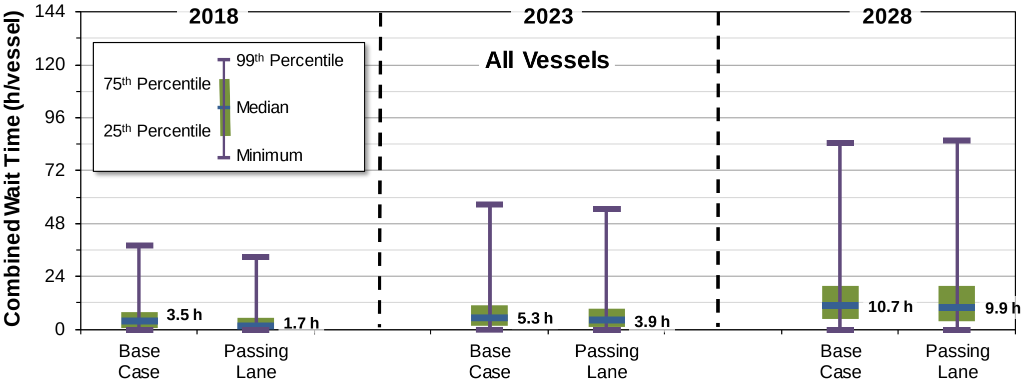
In Case 5, a 10-mile long passing lane was added to the Inner Channel between Mile Marker 7 and Mile Marker 17, as shown in Figure 5-10. Since the 2015 study, this case was reviewed and decided to be impractical; however, it is included here for continuity with the 2015 study.

Figure 5-10 Location of Passing Lane on the Modeled Calcasieu Ship Channel

Modeled vessels were not allowed to stop once they began their transit, so vessels did not queue at the entrance to the passing lane. The safety zone for LNG carriers remained in place for this case, so LNG carriers were unable to pass, either in the passing lane or anywhere else along the channel.

Figure 5-11 compares the wait time statistics for all vessels between the Base Case and Case 5 in the three key traffic years.

Figure 5-11 Comparison of Wait Times between the Base Case and Case 5



When a passing lane was added to the Inner Channel, the wait times for all vessels decreased: the median wait time decreased from 3.5 h to 1.7 h in 2018 and from 5.3 h to 3.9 h in 2023. The effect of the passing lane was more pronounced in 2018 than in 2023 since the influx of LNG carriers reduced the opportunities for the passing lane to be used.

Figure 5-12 and Figure 5-13 compare the wait time statistics between the Base Case and Case 5 for each vessel category.

Figure 5-12 Comparison of Wait Times between the Base Case and Case 5 by Vessel Category

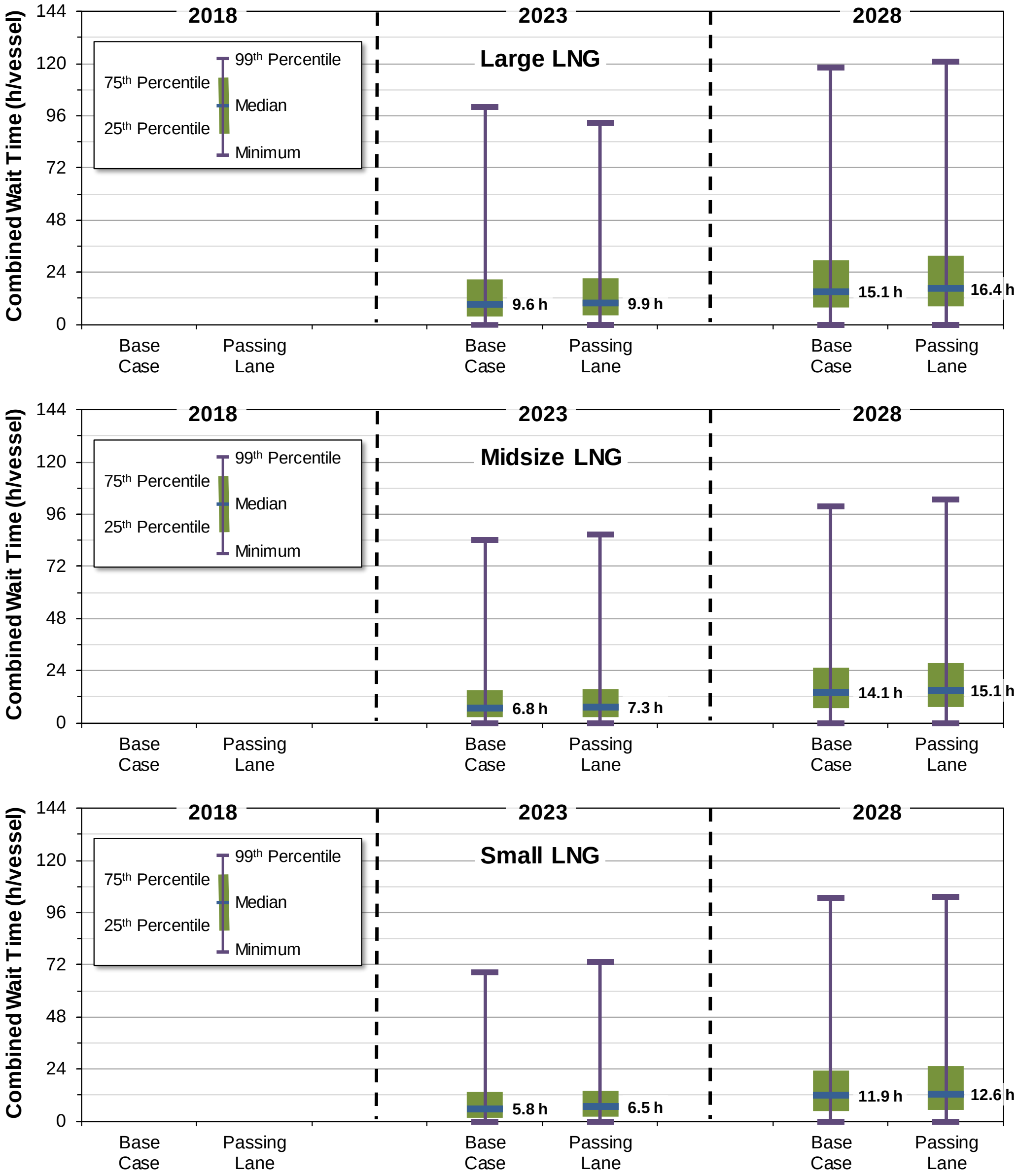
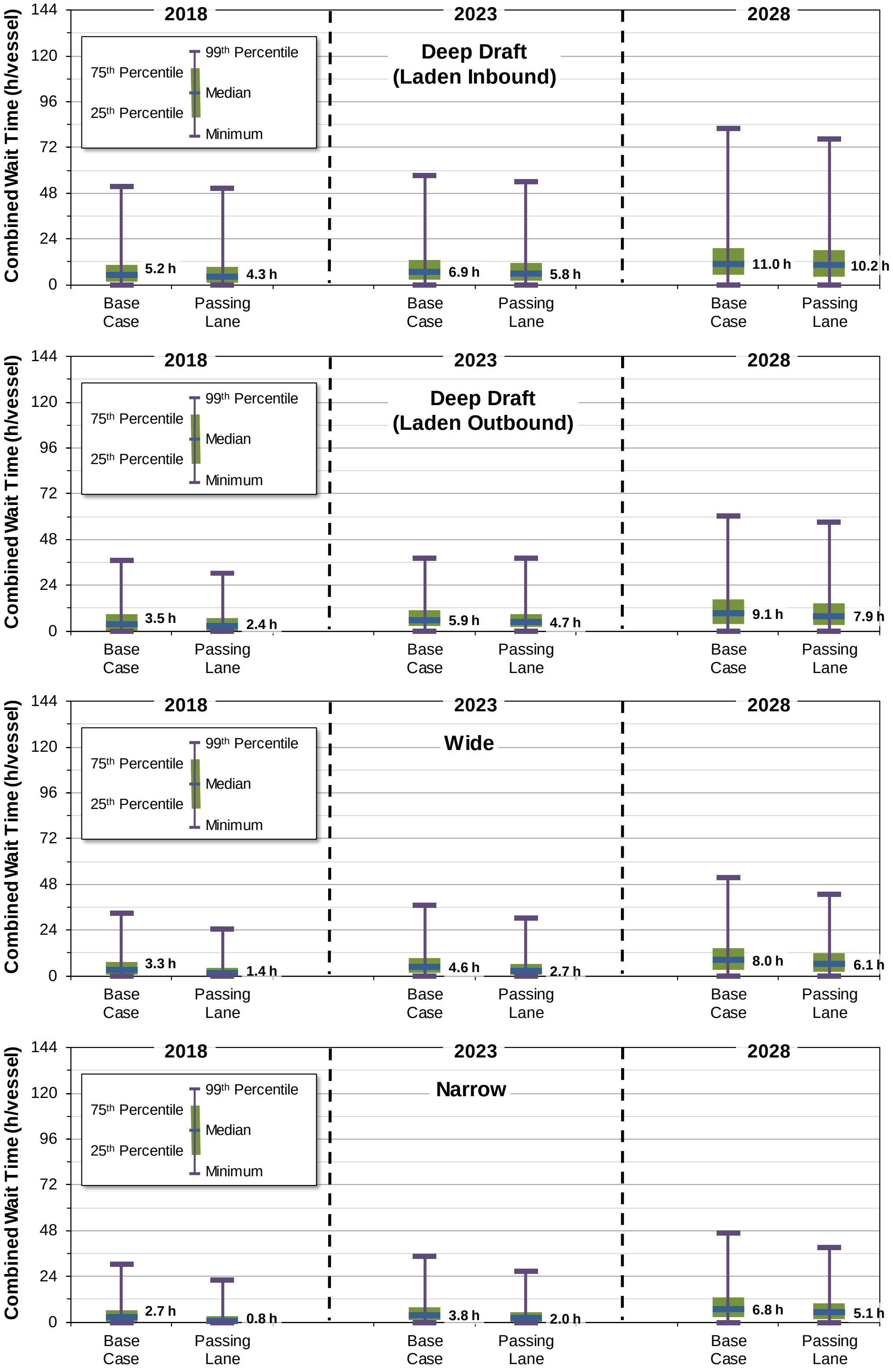


Figure 5-13 Comparison of Wait Times between the Base Case and Case 5 by Vessel Category, continued



The wait times for all non-LNG vessel categories decreased when the passing lane was added to the channel. The LNG carriers had a minor increase in wait times because, with a passing lane, the channel had a greater tendency to have both inbound and outbound vessels moving at the same time and this decreased the opportunities for modeled LNG carriers to move.

Economic Impact

Table 5-5 shows the estimated additional charter costs in 2023 for Case 5 for each vessel category, as well as the overall charter cost increase.

Table 5-5 Estimated Change in Vessel Charter Costs for Case 5 in 2023

Vessel Type	Number of Vessel Calls	Average Change in Wait Time (h/vessel)	Estimated Change in Charter Cost (M$/y)
LNG Carrier	539	0.7	$1.4 M
Deep Draft (Laden Inbound)	310	-1.0	($0.2 M)
Deep Draft (Laden Outbound)	48	-1.2	<$0.1 M
Wide	467	-2.0	($0.5 M)
Narrow	405	-1.9	($0.3 M)
Total	1,769		$0.6 M

Despite the reduced wait times for the majority of vessel categories, the overall charter costs increased in Case 5 in 2023 due to the higher cost for the LNG carriers.

5.7 Comparison of Infrastructure Cases

Each Infrastructure Case had a different impact on vessel wait times, as well as a different economic impact on the channel. Figure 5-14 compares the median wait times for the Base Case and the Infrastructure Cases for all vessels in each traffic year and Figure 5-15 compares the charter costs or savings for each Infrastructure Case in 2023.

Figure 5-14 Comparison of Median Wait Times between the Base Case and Infrastructure Cases

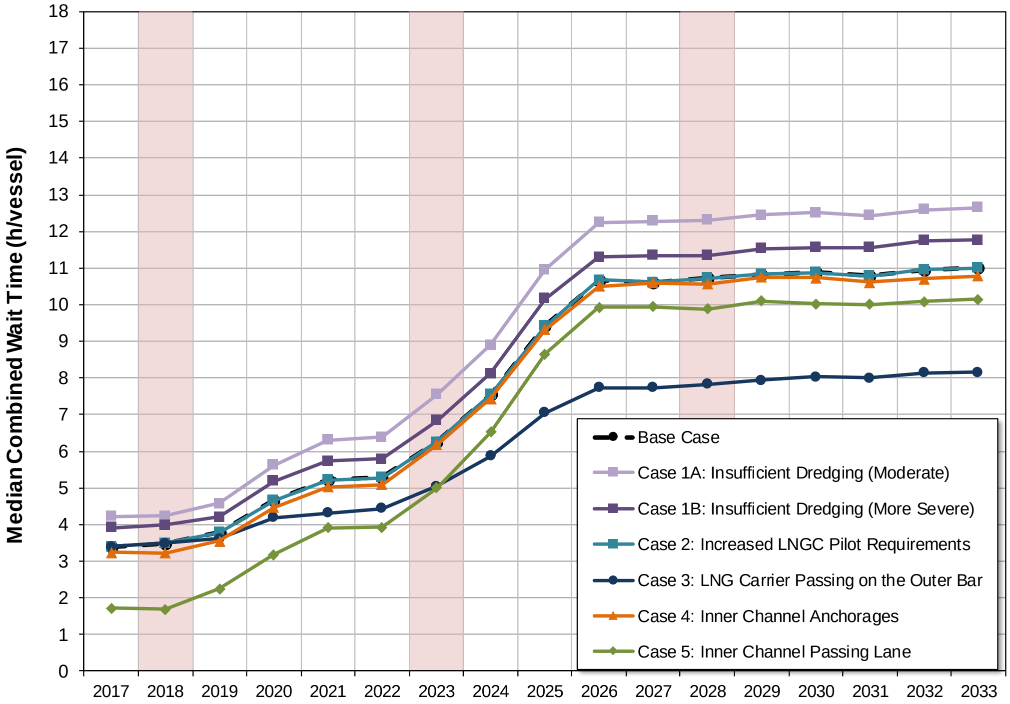
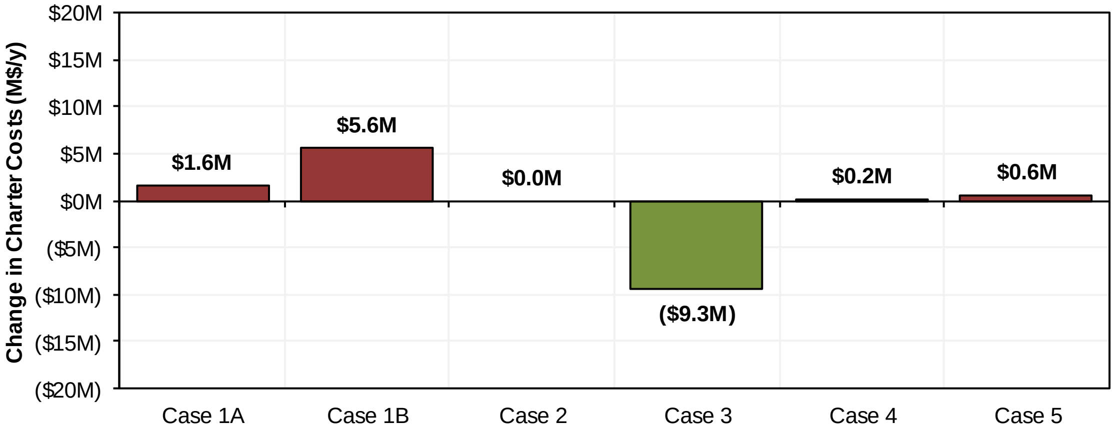


Figure 5-15 Comparison of Change in Charter Costs between the Infrastructure Cases



Case 1A and Case 1B had higher median wait times than the Base Case, and Case 1B had the highest costs for the channel of any Infrastructure Case. Of the five cases, only Case 3 provided a noticeable benefit to the channel in terms of decreased total charter costs to all terminal customers.

The increased weather restrictions on LNG carriers and the stricter inbound boarding windows left less time for the sensitivity cases to impact vessel transits than in the 2015 study – it was more likely for Infrastructure Case changes to occur during a time when transits were not allowed due to weather or boarding window restrictions. Hence, the economic impacts were lower in this study than in the 2015 study.

6 Conclusions

This section details the conclusions from the Calcasieu Ship Channel Traffic Study.

6.1 Base Case Conclusions

The Base Case simulation model was used to investigate the operations of the Calcasieu Ship Channel from 2017 to 2033, assuming the channel maintains the present infrastructure and operational rules and is dredged to congressionally authorized dimensions.

Table 6-1 shows the forecasted traffic levels in three traffic years (2018, 2023, and 2028) as well as the key performance indicators from the simulation runs for these years.

Table 6-1 Overall Channel Performance in Three Key Traffic Years

Year	Number of Vessels Scheduled	Number of Vessels Handled	Median Wait Time
2018	1,098	1,098	3.5 h/vessel
2023	1,769	1,769	6.3 h/vessel
2028	2,527	2,527	10.7 h/vessel

The match between the number of vessels scheduled and the number of vessels handled shows that the existing channel has the capacity to handle the forecasted traffic increases in each year, provided it is maintained at congressionally authorized dimensions. However, the traffic was subject to longer wait times: between 2018 and 2023, the median wait time for a vessel increased by 2.8 hours. The increase in median wait time was largely due to LNG carriers, which experienced longer delays and which began arriving in 2019. Wait times in this study were longer than in the 2015 study due to additional weather restrictions on LNG carriers and because inbound boarding windows were closed more frequently than in the 2015 study.

Weather closures and boarding windows were major contributors to the wait time and although these cannot be minimized directly, their secondary effects can be mitigated. Any changes to the channel that would allow vessels to begin moving sooner, after either a closure ends or a boarding window opens, should improve operations – such changes were investigated in the Infrastructure Cases.

The model also showed that additional Pilots are necessary to meet the demands of the increased traffic. By 2023, the channel will need between 26 and 33 Pilots (the channel had 17 Pilots and as of 2018).

6.2 Infrastructure Cases Conclusions

The Infrastructure Cases were used to investigate how the channel would be impacted by changes to its infrastructure or regulations. Table 6-2 summarizes the change in vessel charter costs for each of the Infrastructure Cases for the 2023 traffic year (which was representative of the impact in any given year).

Table 6-2 Estimated Economic Impact of Infrastructure Cases in 2023

Case	Change to Channel Operations	Estimated Change in Annual Charter Costs (M$/y)
1A	Insufficient dredging (moderate)	$1.6M
1B	Insufficient dredging (more severe)	$5.6M
2	Increased Pilot requirements for LNG carriers	-
3	LNG carrier passing on the Outer Bar	($9.3M)
4	Inner Channel anchorages	$0.2M
5	Inner Channel passing lane	$0.6M

* Values in parentheses ( ) reflect a reduction in annual charter costs.

Insufficient dredging, especially in the more severe scenario, significantly increased the vessel charter costs for the channel users. In addition to these charter costs, insufficient dredging would result in delayed deliveries and shipments at the terminals (as evidenced by the increase in vessel wait times) and could impact the ability of the channel to handle fully laden vessels. Although the economic assessment of these additional effects was beyond the scope of the study, they would only further increase the costs to the channel. These cases demonstrate the significant economic benefit and importance of continued dredging and maintenance of the channel.

Changing the passing restrictions for LNG carriers on the Outer Bar resulted in significant charter cost savings. These savings were the result of decreased wait times for all vessels, since this change allowed all traffic to move more easily in the channel. This result is in line with one of the conclusions from the Base Case: a change that allowed vessels to more easily enter after a weather event would provide the greatest benefit to the channel operations.

The addition of anchorages to the channel did not have a significant impact on either vessel wait times or charter costs. The anchorages had little impact because most vessels in the modeled channel did not use them – either because they were unable to due to the location of their terminal relative to the anchorages, or because they already had an available berth when they entered the channel. It is possible that anchorages may have a benefit to the operations of individual terminals but such an assessment was beyond the scope of the study.

The addition of a passing lane on the Inner Channel improved vessel wait times but resulted in a modest increase in charter costs. Since the passing lane did not substantially improve the channel operations and would likely involve significant additional expenses and difficulties (such as dredging costs and environmental regulations), it was not considered a cost-effective improvement for the channel.

Appendix A Validation of Historical Data

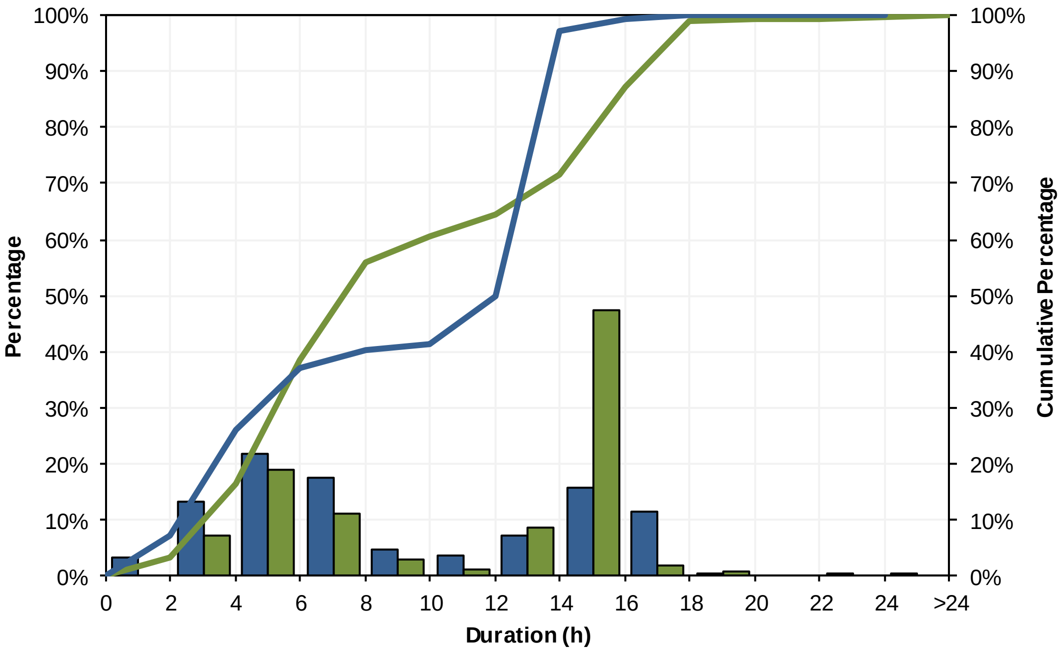
A.1 Current and Tide Data

Two data sources provided historical records for the boarding windows: current and tide data from NOAA PORTS (from which boarding windows were calculated using the conditions provided by the Pilots) and predicted boarding windows from the Pilots. The current and tide data was used in the simulation model because the predicted windows only provided inbound boarding windows for deep draft non-LNG vessels. The inbound windows for LNG carriers and the outbound boarding windows could not be easily calculated from that source.

To confirm that the boarding windows calculated from the current and tide data accurately represented the boarding windows observed by the Pilots, a comparison was performed between the windows from the two sources. The inbound boarding windows for February to December 2017 were used for comparison, since this was the only overlap period between the two data sets.

Figure A-6-1 shows a histogram of the duration of the inbound boarding windows from the current and tide data and from the predicted windows.

Figure A-6-1 Comparison of Inbound Boarding Window Durations



Over the comparison period, an inbound boarding window was open 52% according to the current and tide calculated boarding windows and 54% according to the Pilot's predicted boarding windows. The average boarding window from the current and tide data was open for 9.1 hours and the average boarding window from the Pilot's data was open for 10.9 hours.

The boarding windows from the two data sources were considered to reasonably match, so the boarding windows calculated from the NOAA PORTS current and tide data were valid for use in the simulation model. The historical data used in the simulation model covered a different period of time – January 2013 to December 2016 – which provided a continuous year of data without discontinuities.

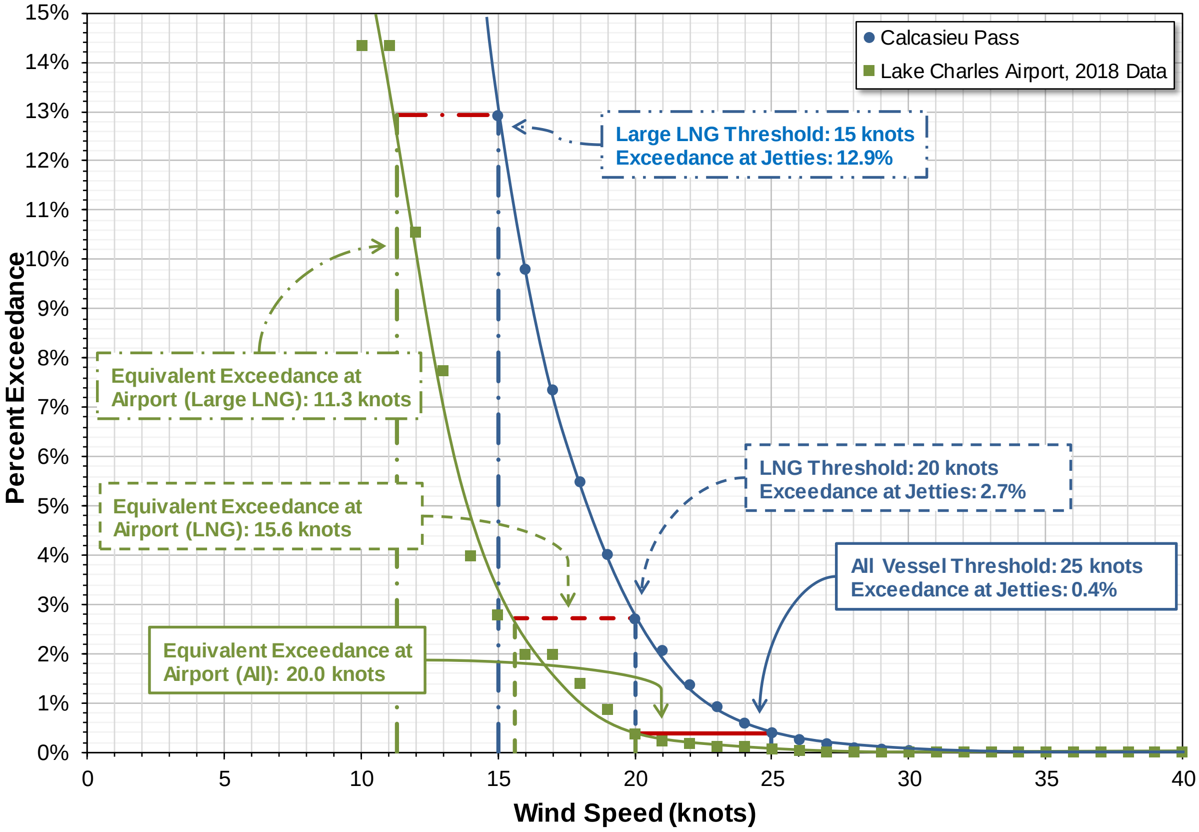
A.2 Wind Data

Historical wind data for the simulation model was obtained from the NCDC from two locations: the Calcasieu Pass measuring station and the Lake Charles Regional Airport.

Since the Calcasieu Pass measuring station is located near the entrance to the channel, its wind speeds more accurately reflect conditions in the channel; however, due to gaps in its historical data, it was not suitable for use as a time series. The data from the Lake Charles Regional Airport was used in the model, but it was calibrated against the Calcasieu Pass data to account for the differences in wind speeds between the two locations.

Figure A-6-2 shows a comparison of the wind speed exceedance (the percent of time the winds exceeded certain speeds) for the two locations.

Figure A-6-2 Comparison of Wind Speed Exceedance

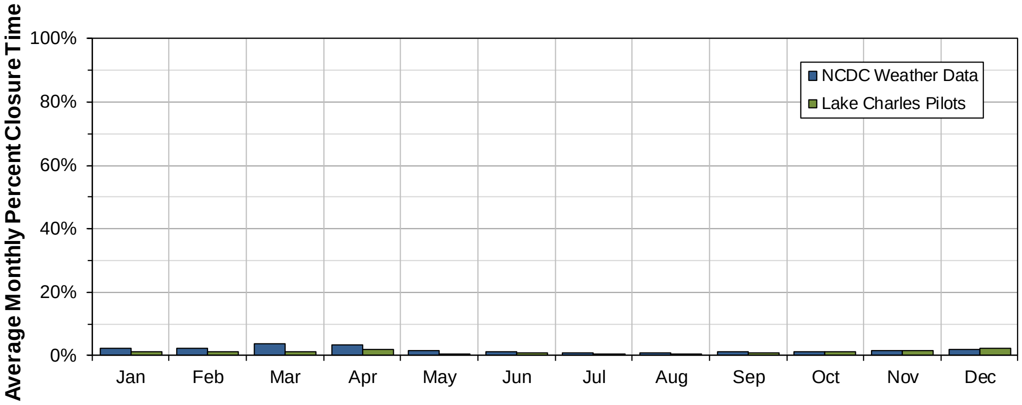


The 25 knot wind speed threshold for all vessels was exceeded 0.4% of the time at the Calcasieu Pass. The same percent exceedance was reached at 20.0 knots at the Lake Charles Regional Airport – that is, a wind speed threshold of 20.0 knots at the airport was equivalent to a threshold of 25 knots at the entrance to the channel. Similarly, the 20 knot LNG carrier threshold at the Calcasieu Pass was equivalent to a 15.6 knot threshold at the airport. Finally, the 15 knot Large LNG carrier threshold at the Calcasieu Pass was equivalent to an 11.3 knot threshold at the airport. These equivalent thresholds were applied to the airport data to produce the time series of historical channel closures used in the simulation model (discussed in Section 2.6.2).

The historical channel closures data for 2001 to 2012 from the Pilots documented the times when vessel transits were stopped due to high winds or rough seas. These historical closures could not be used directly in the simulation model since only closures for all vessels were listed – that is, specific closures for Large LNG carriers only were not listed.

To confirm that the closures calculated from the calibrated airport data accurately represented the closures recorded by the Pilots, a comparison was performed between the two data sources. Figure A-6-3 shows a comparison of the average percent closure time for all vessel transits in each month from both sources (the time series from Section 2.6.2 and the historical channel events).

Figure A-6-3 Comparison of Channel Closures due to Wind



Since closures are only recorded by the Pilots if a vessel was delayed, it was expected that the amount of closures from the time series would be slightly greater than the closures recorded by the Pilots. The average annual percent closure of the channel for all vessel transits due to wind was 1.8% from the calibrated historical airport data and was 1.1% from the historical channel closures from the Pilots. Since there was a close match between the closure times from the two sources, the calibrated airport wind data was considered valid for use in the simulation model.

A.3 Visibility Data

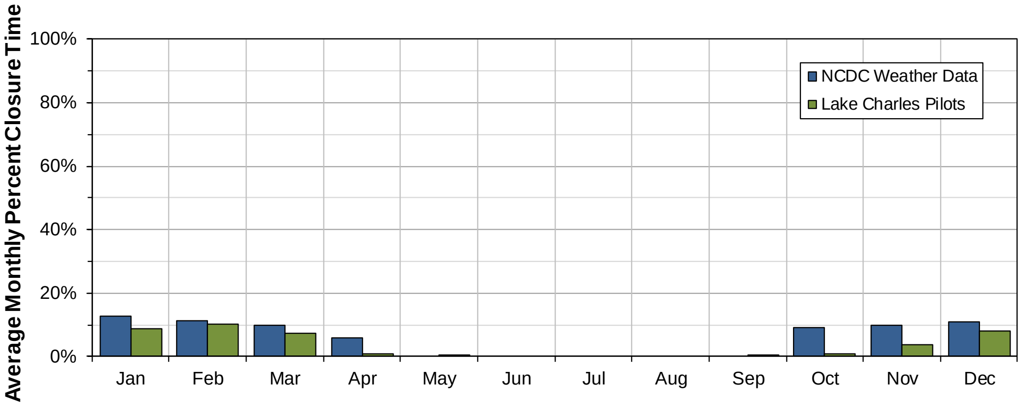
Visibility data for the simulation study was obtained from the NCDC from the Lake Charles Regional Airport. Unlike the wind data (discussed in Section A.2), a second source of visibility data closer to the entrance of the channel was not available for calibration.

The NCDC airport data had a significant number of visibility closures in the summer months (May to September). The Pilots anecdotally noted that visibility downtime does not occur in the summer. To better align the NCDC data with the conditions encountered on the channel, any visibility closures in the summer months of the data were removed.

The historical channel closure data for 2001 to 2012 from the Pilots included closures due to visibility; however, a time series was preferred for the simulation model since it covered a longer time period and allowed for more variability. The historical visibility closures were used to provide a comparison point for the time series of visibility closures created from the 1-nmi threshold and the historical airport visibility data (discussed in Section 2.6.3).

Figure A-6-4 shows a comparison of the average percent closure time for vessel transits in each month due to visibility from both data sources.

Figure A-6-4 Comparison of Channel Closures due to Visibility



The average annual percent closure of the channel due to visibility was 6.1% from the time series and was 3.3% from the historical channel closures from the Pilots. As expected, the amount of closures from the time series used in the model was greater than the closures recorded by the Pilots. Although there was not a close match between the closures from the two sources, the amount of annual closure time from the airport visibility data was reasonable and the airport data was considered valid for use in the simulation model.

A.4 Low Water Data

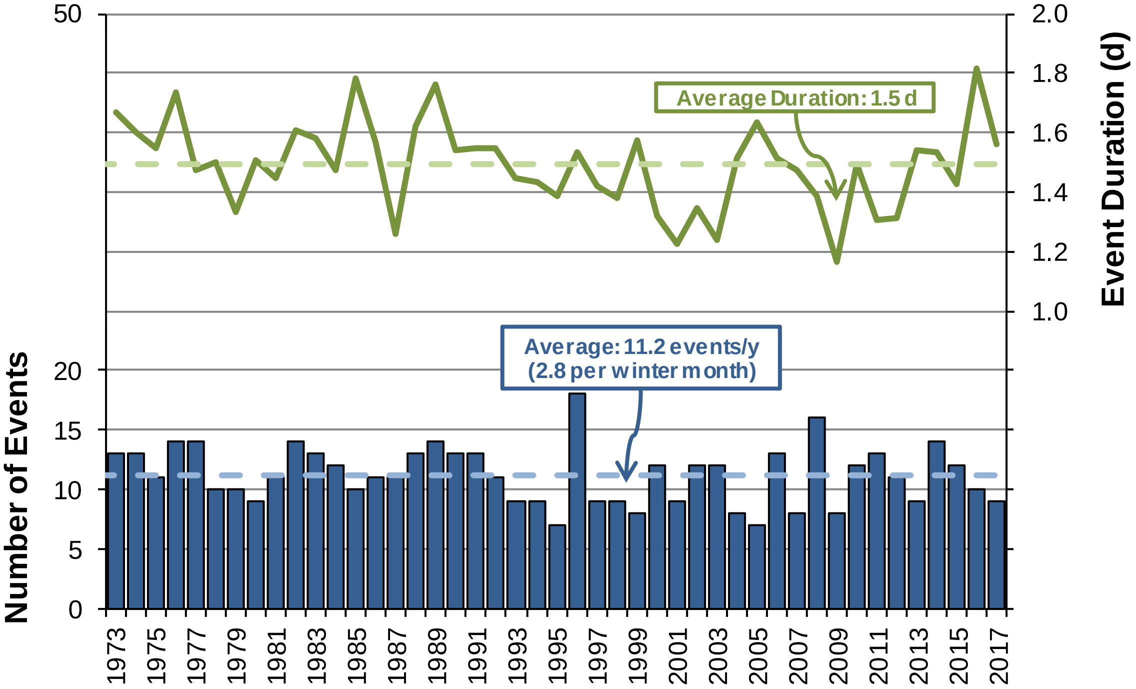
A time series of low water events caused by north winds was produced for the simulation model from the historical wind data from the NCDC.

The Pilots advised that north winds of 20 knots or greater in November to February will cause water levels in the channel to decrease. For the analysis, it was assumed that north winds in excess of 20 knots had to persist for at least 1 hour to have an effect on the water levels. It was also assumed that low water would persist for 1 day after the north winds ceased.

Limited water level data was available for the channel from 2009 to 2017 from NOAA, which was used to validate these assumptions. It was found that the low water events from the historical wind data correlated with lower than normal water levels in the NOAA data, so the parameters for calculating low water events were considered valid.

Figure A-6-5 shows the number and total duration of low water events calculated in each year of the NCDC data based on the criteria above.

Figure A-6-5 Number and Average Duration of Low Water Events in Each Data Year



The analysis showed that there were on average 11.2 low water events in a year and that the average duration was 1.5 days. The Pilots estimated that there are on average 12 low water events in a year and that each event would delay vessels by 1-2 days. Since there was a close match between the low water events from the time series and the Pilot's estimates, the time series of low water events produced from the airport wind data was considered valid for use in the simulation model.

Ausenco Engineering Canada Inc.
855 Homer Street
Vancouver, BC V6B 2W2
Canada

T +1 604 684 9311
F +1 604 688 5913
W www.ausenco.com

Memorandum

Attention	Channing Hayden Regan Brown
From	Tyler Beames-Canivet Stephen Wong
Subject	103115-01 Calcasieu Traffic Study: Wait Time Statistical Analysis Methods
Date	June 13, 2019
Page	Page 1 of 27

1 Summary

This memorandum summarizes information on three methods of analyzing wait time in the Calcasieu Channel Traffic Study.

2 Comparison Methodology

Each simulation run consisted of 45 modelled years with variations in ship arrival patterns and weather effects. Vessel wait times were aggregated by vessel type and analyzed using three statistical methods to show a comparison between the median, mode, and mean.

The median wait time was defined as the wait time experienced by the 50th percentile of the vessels. The mean wait time was the total amount of wait time divided by the total number of vessels. The mode wait time was the most frequently-occurring wait time. To calculate the mode, wait times were rounded to the nearest 0.2 hours – this resolution offered reasonable coarseness for the wait time histograms while preserving the integrity of the result.

3 Traffic Year Results

The three statistical methods are shown for passing and non-passing vessels in Figure 1, for deep draft vessels in Figure 2, and for LNG Carriers in Figure 3. In each of these graphs, the median is shown as a darker shade with square markers, the mean is shown as a lighter shade with circular markers, and the mode is nearly always zero. The results for traffic years 2018, 2023, and 2028 were summarized in Table 1. The mean was always larger than the median, since the distributions were centred towards zero wait time. The mode was zero in nearly every scenario because many ships – not the majority of ships – experienced no delays entering and exiting the channel.

Figure 1 Total Wait Times for Passing and Non-Passing Vessels

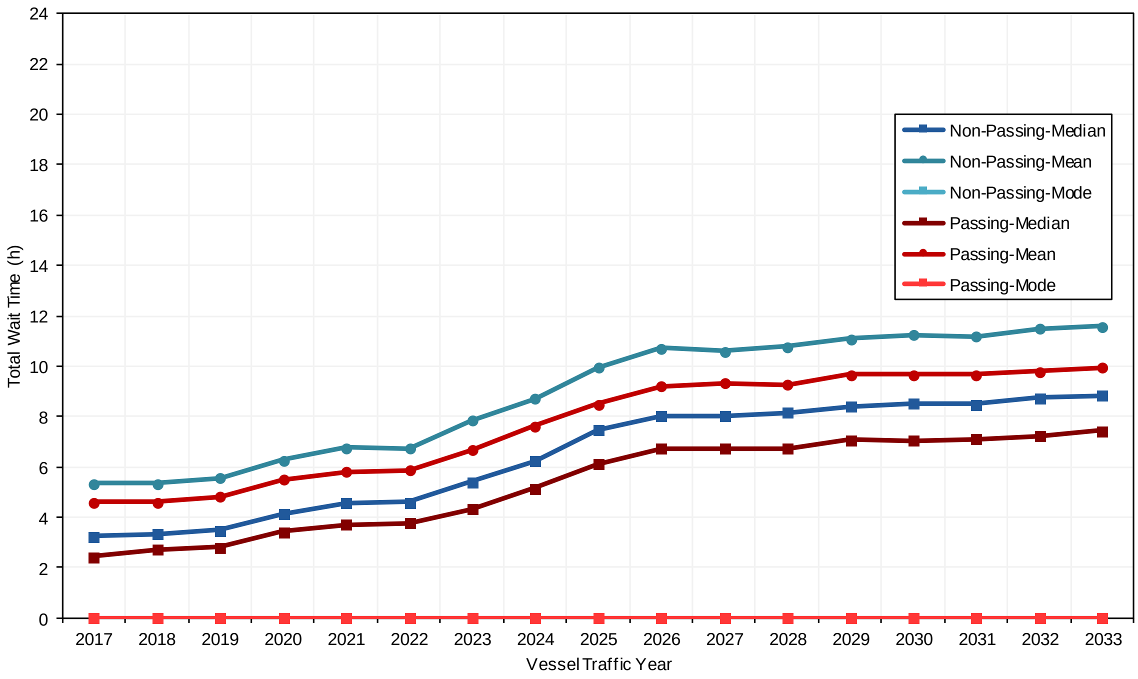


Figure 2 Total Wait Times for Deep Draft Vessels

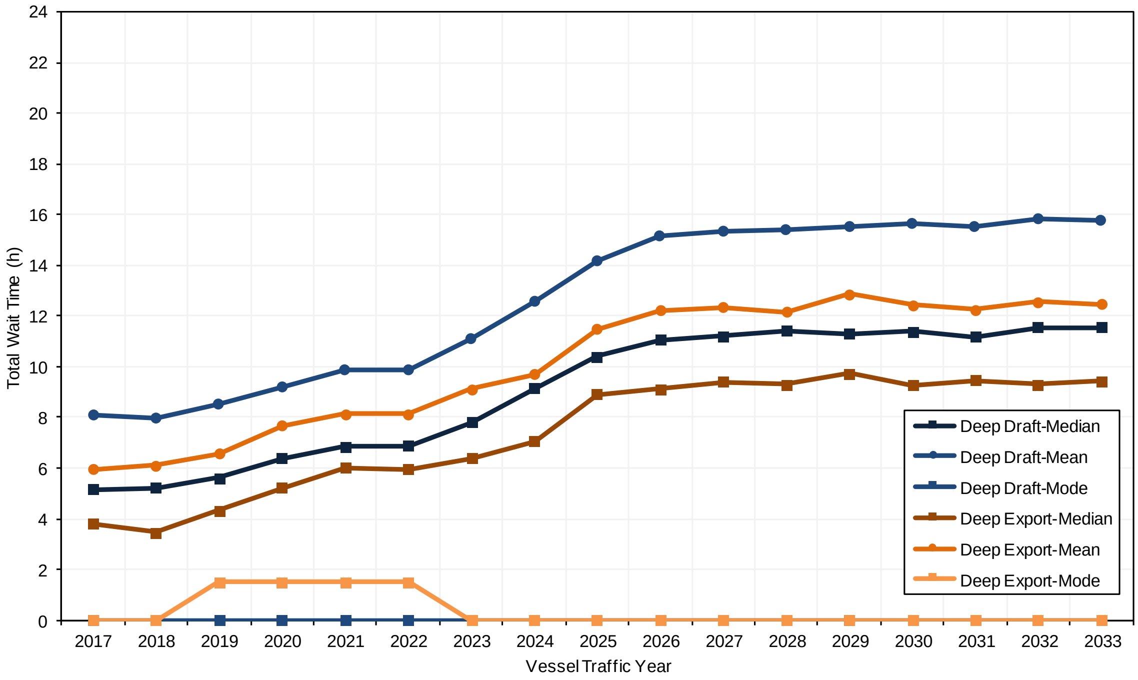


Figure 3 Total Wait Times for LNG Carriers

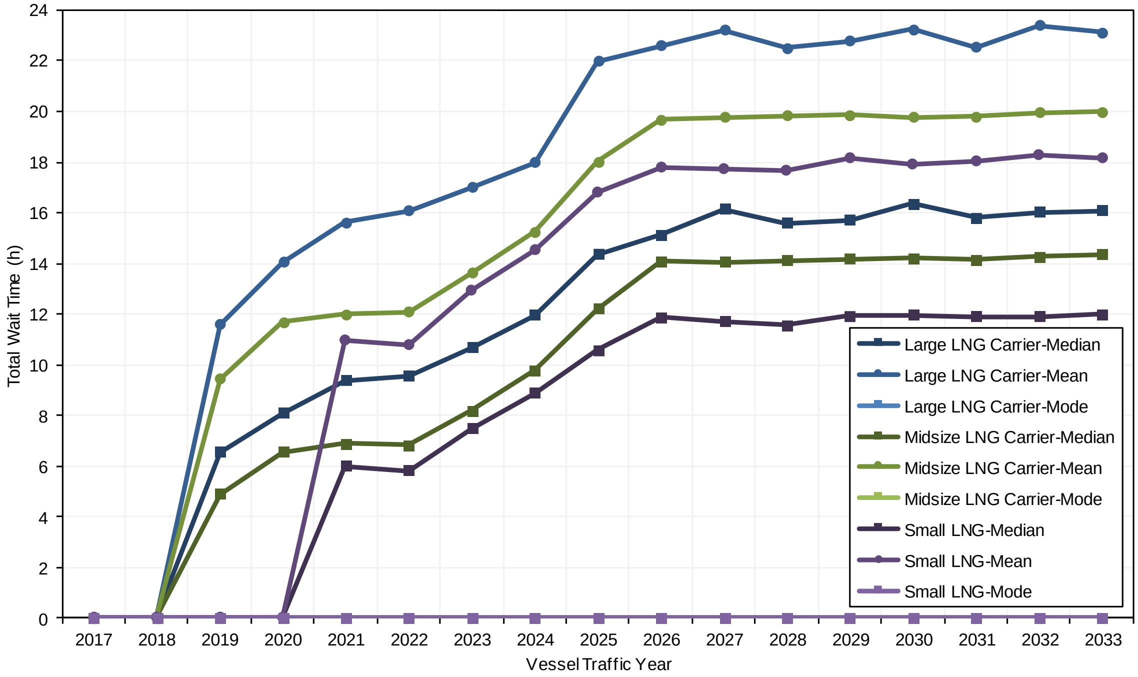


Table 1 Summary of Total Wait Times for Three Traffic Years

Traffic Year	2018			2023			2028		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode
Large LNG Carrier	0.0	0.0	0.0	17.0	10.7	0.0	22.5	15.6	0.0
Midsize LNG Carrier	0.0	0.0	0.0	13.6	8.2	0.0	19.8	14.1	0.0
Small LNG Carrier	0.0	0.0	0.0	13.0	7.5	0.0	17.7	11.6	0.0
Deep Draft (Laden Inbound)	8.0	5.2	0.0	11.1	7.8	0.0	15.4	11.4	0.0
Deep Draft (Laden Outbound)	6.1	3.5	0.0	9.1	6.4	0.0	12.2	9.3	0.0
Wide	5.3	3.3	0.0	7.8	5.4	0.0	10.8	8.1	0.0
Narrow	4.6	2.7	0.0	6.7	4.3	0.0	9.3	6.7	0.0
All Vessels	**5.8**	**3.5**	**0.0**	**10.0**	**6.3**	**0.0**	**15.5**	**10.7**	**0.0**

4 Wait Time Histograms

Histograms of wait times by vessel type are shown in the figures below for traffic years 2018, 2023, and 2028. Few Deep Draft (Laden Outbound) vessels arrived in 2018 so the histogram is sparse. No LNG carriers arrived in 2018 so the histograms are empty.

Traffic Year 2018

Figure 4 Histogram of Total Wait Times for All Vessels in 2018

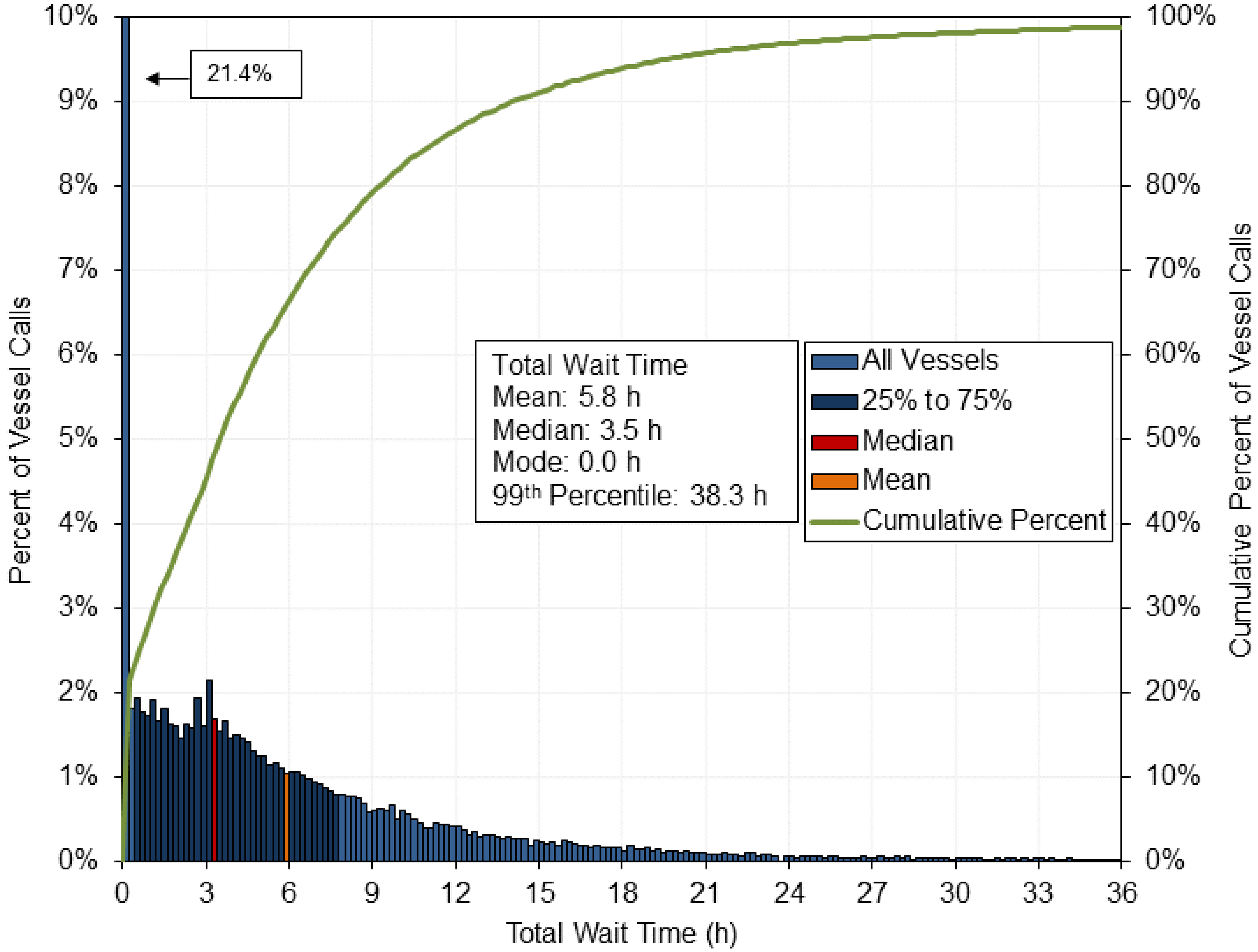


Figure 5 Histogram of Total Wait Times for Narrow Vessels in 2018

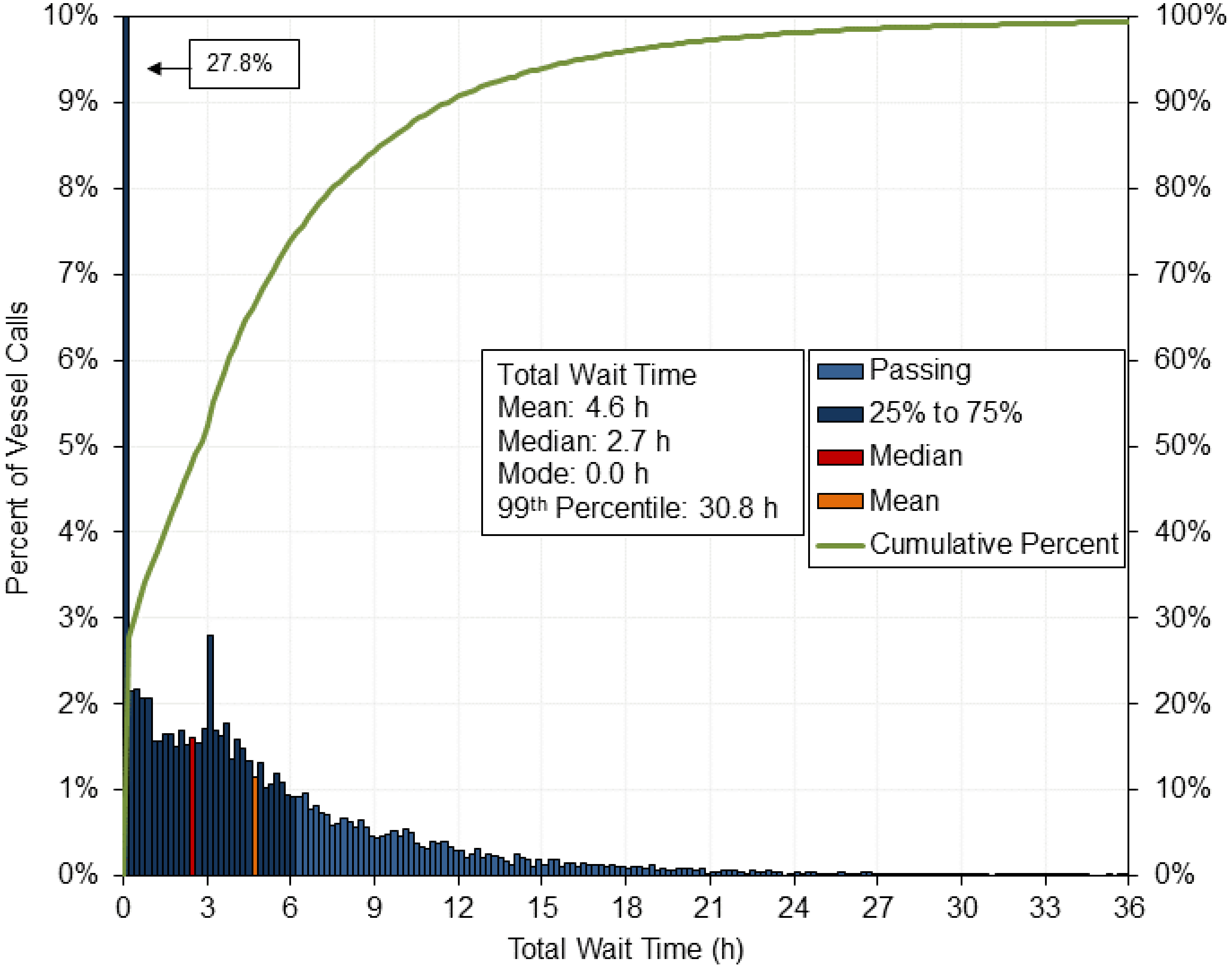


Figure 6 Histogram of Total Wait Times for Wide Vessels in 2018

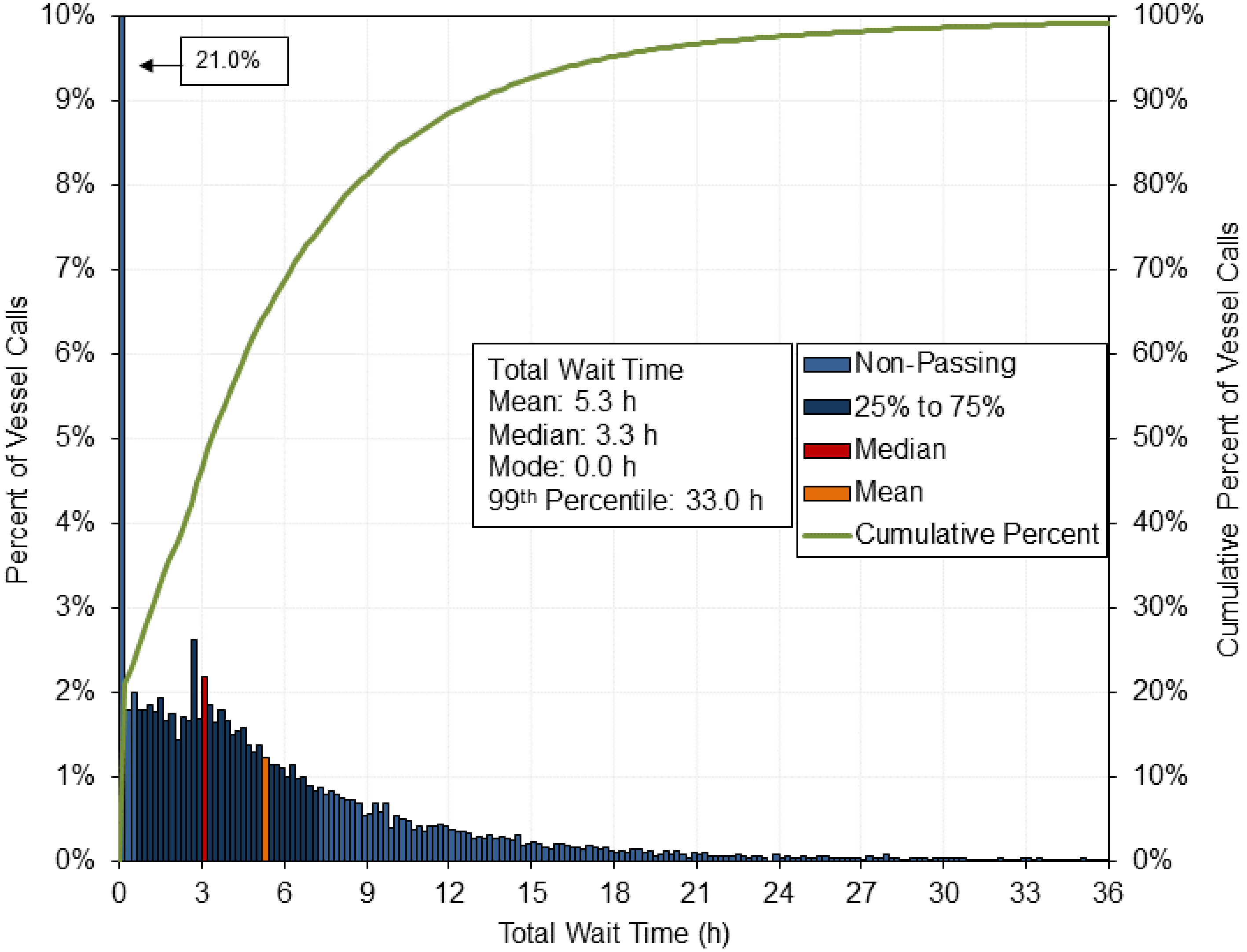


Figure 7 Histogram of Total Wait Times for Deep Draft (Loaded Inbound) Vessels in 2018

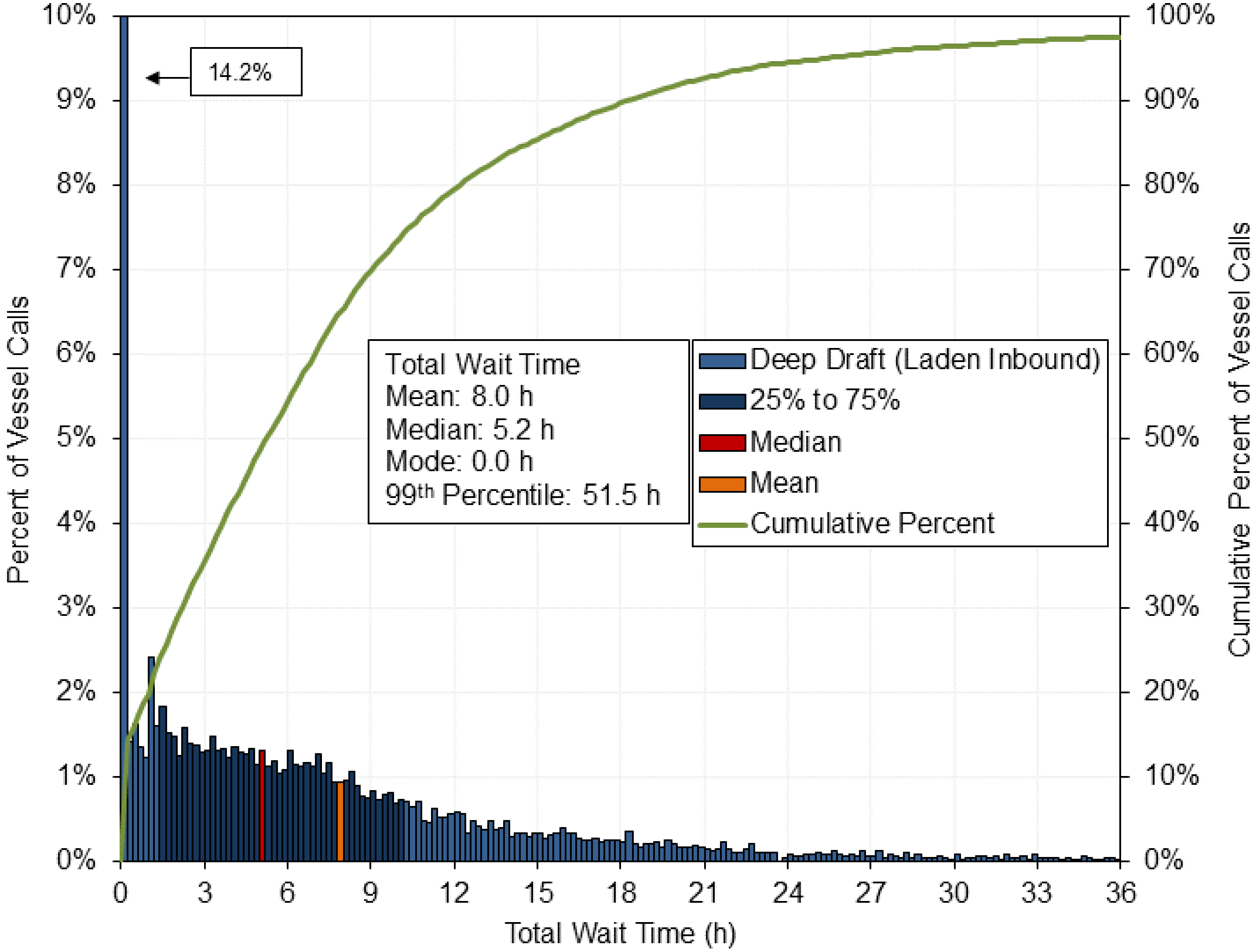


Figure 8 Histogram of Total Wait Times for Deep Draft (Loaded Outbound) Vessels in 2018

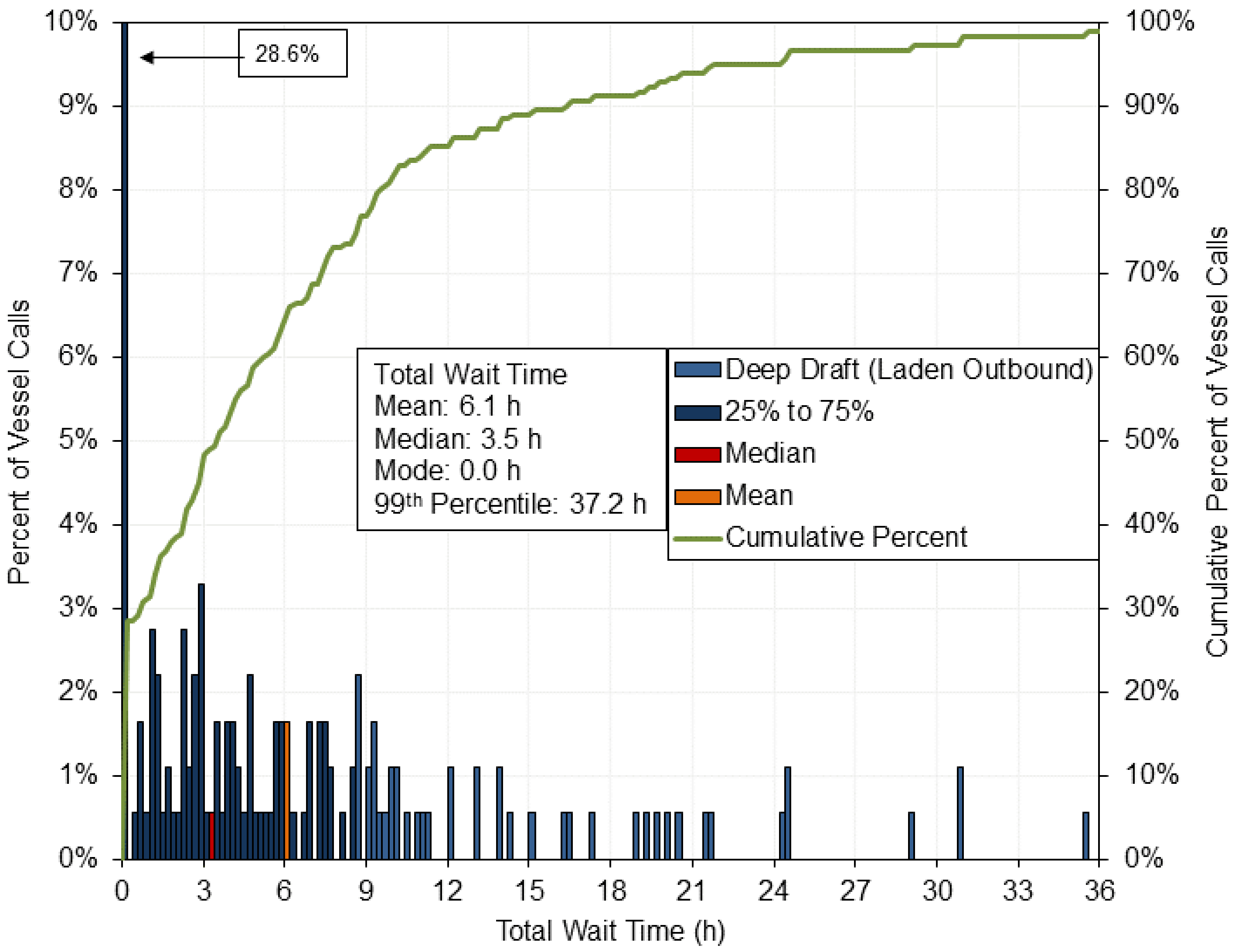


Figure 9 Histogram of Total Wait Times for Small LNG Carriers in Small LNG Carriers in 2018

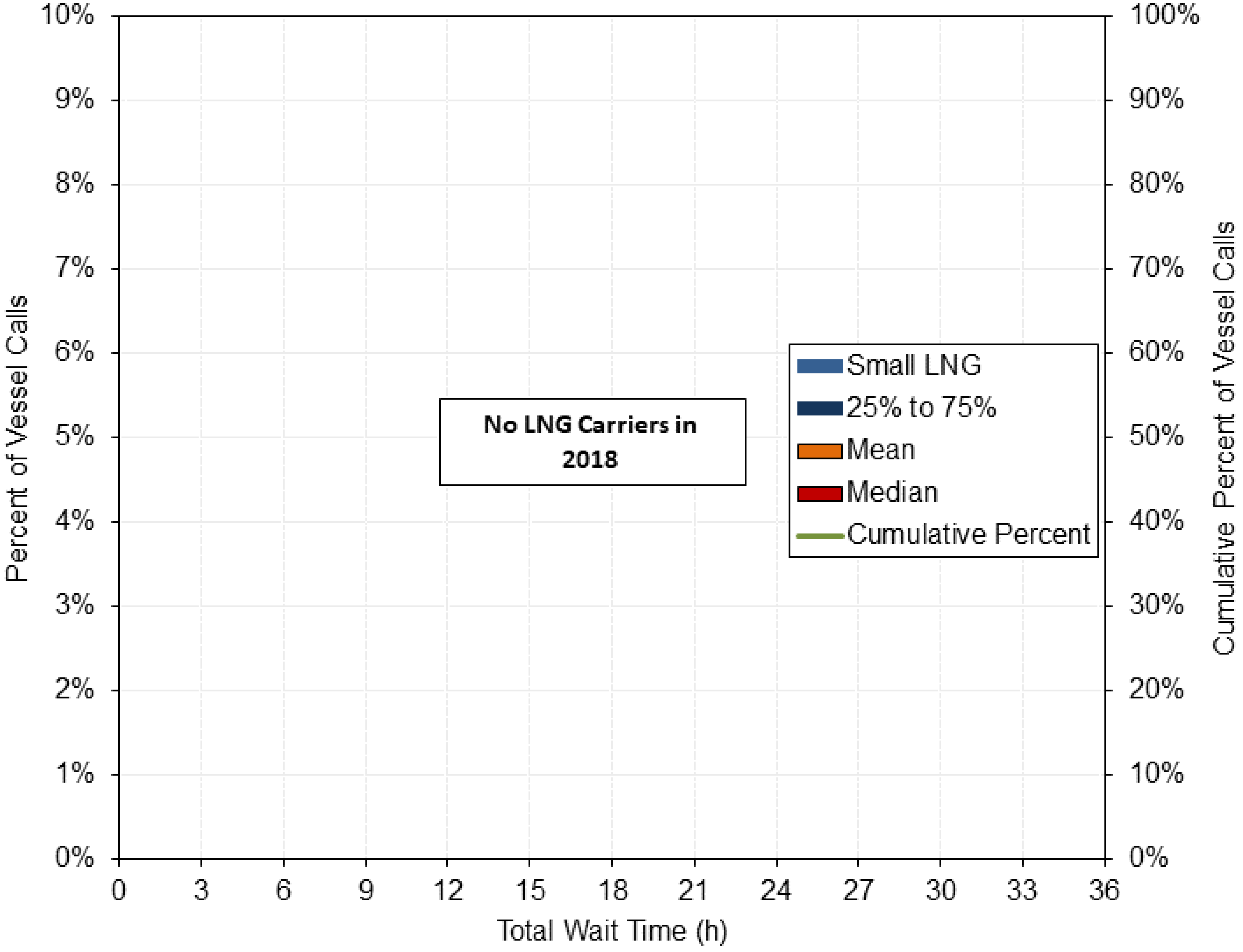


Figure 10 Histogram of Total Wait Times for Midsize LNG Carriers in Large LNG Carriers in 2018

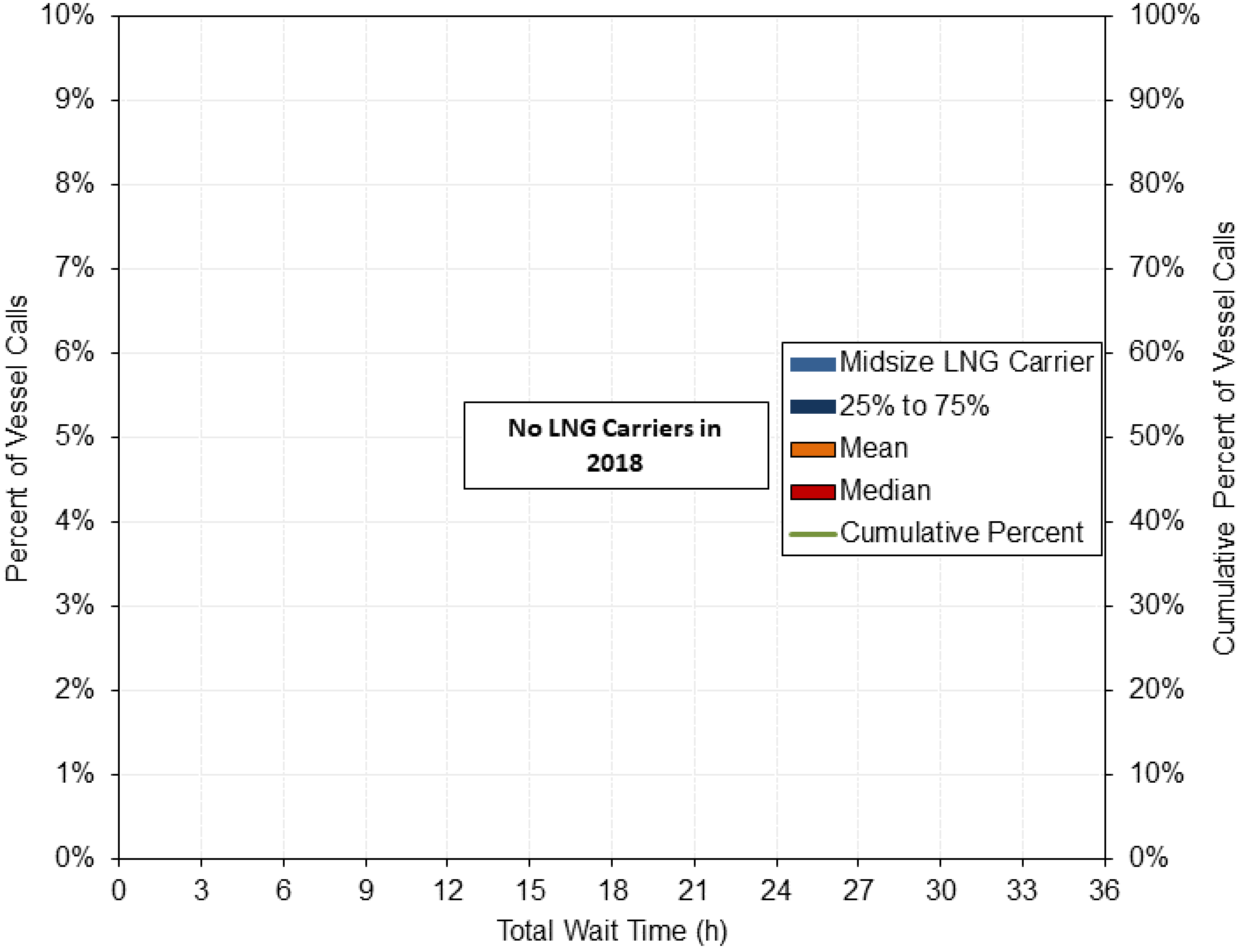
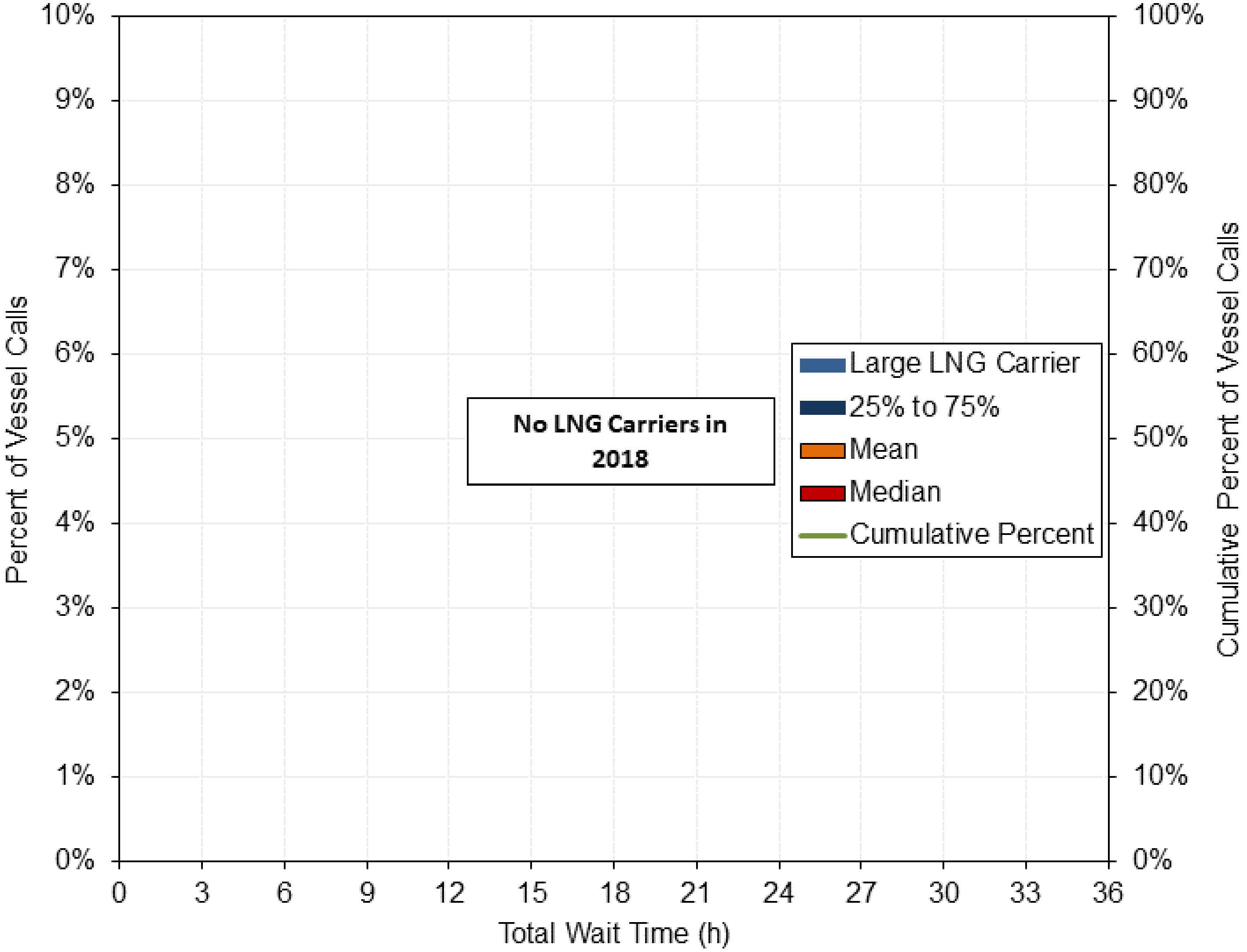


Figure 11 Histogram of Total Wait Times for 2018



Traffic Year 2023

Figure 12 Histogram of Total Wait Times for All Vessels in 2023

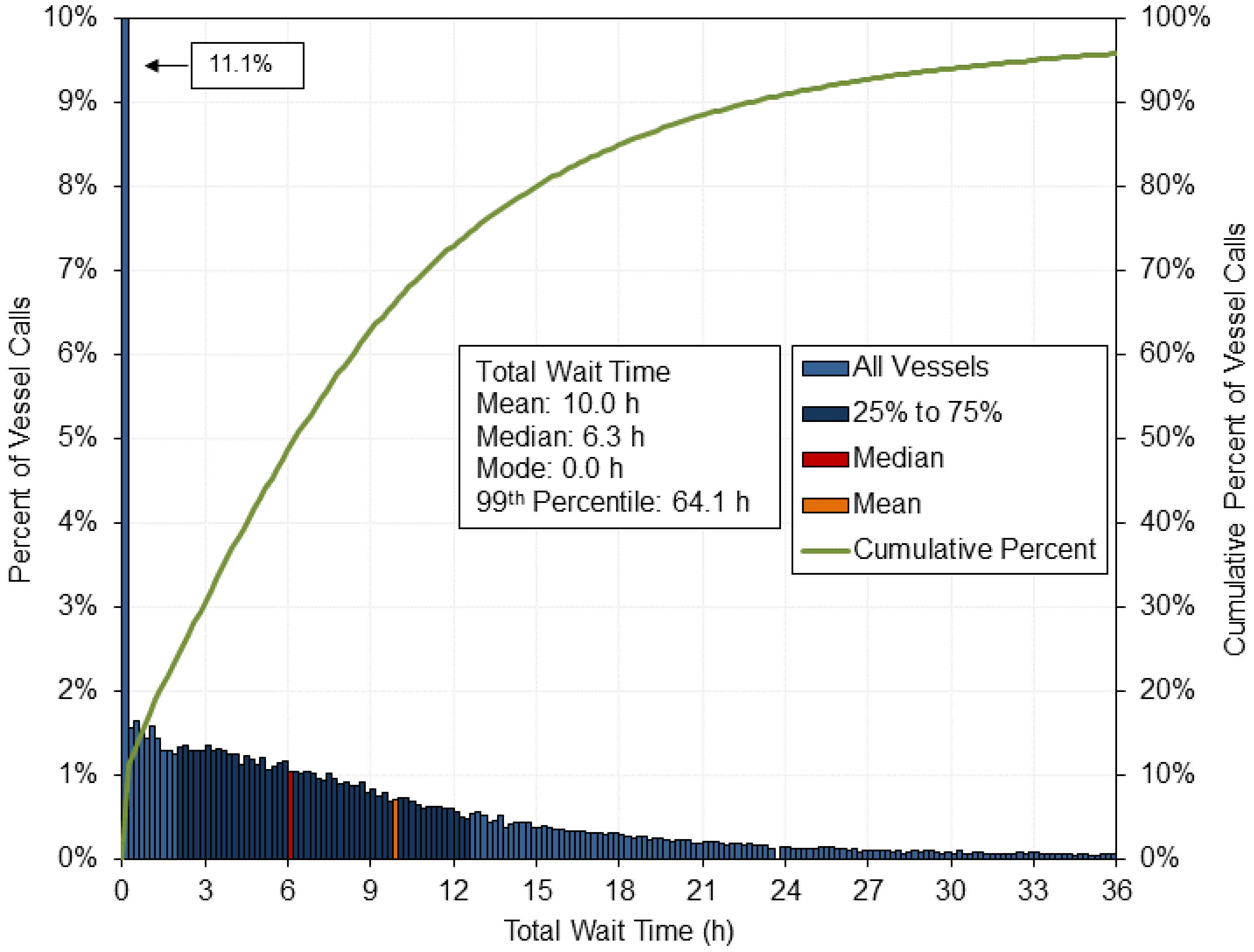


Figure 13 Histogram of Total Wait Times for Narrow Vessels in 2023

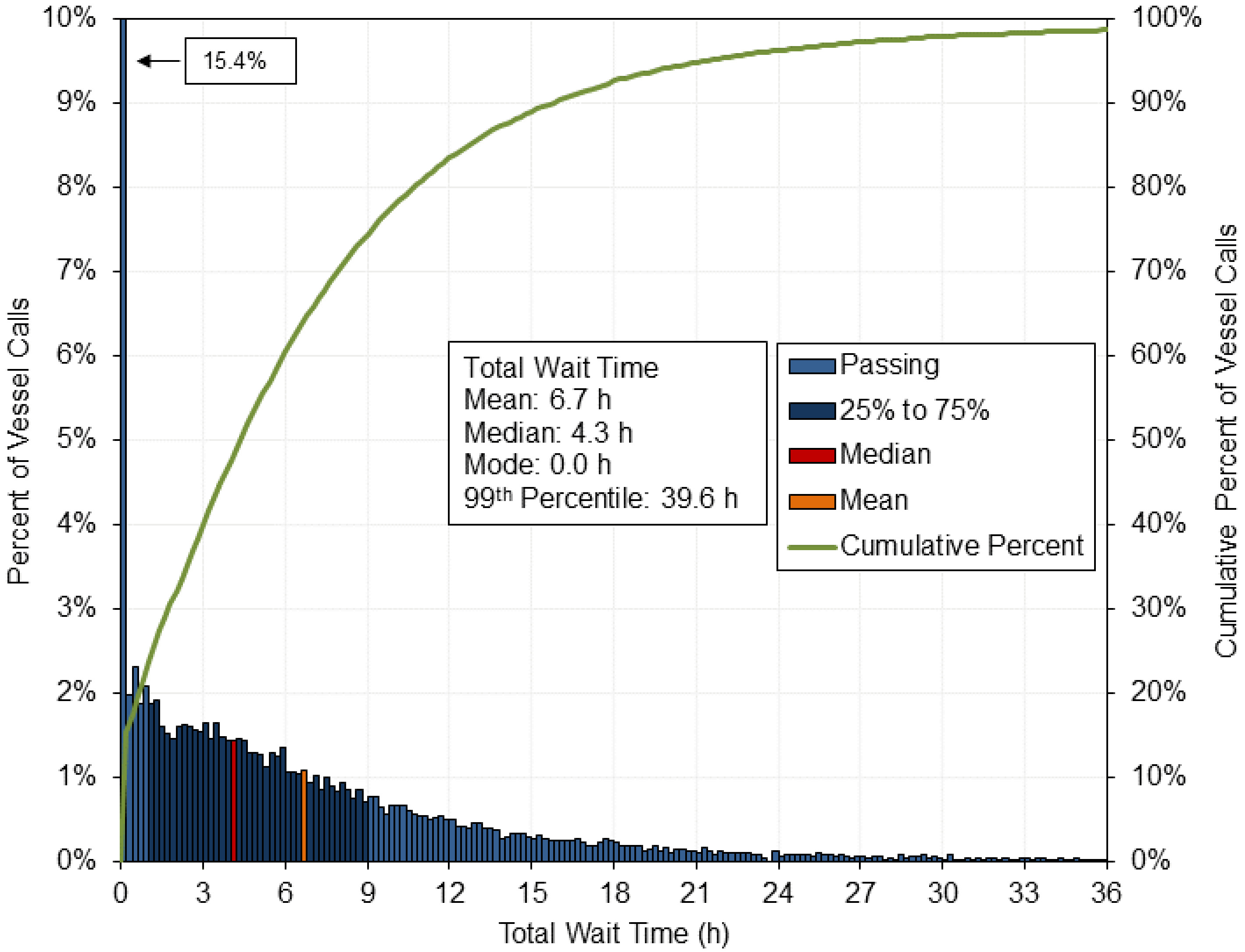


Figure 14 Histogram of Total Wait Times for Wide Vessels in 2023

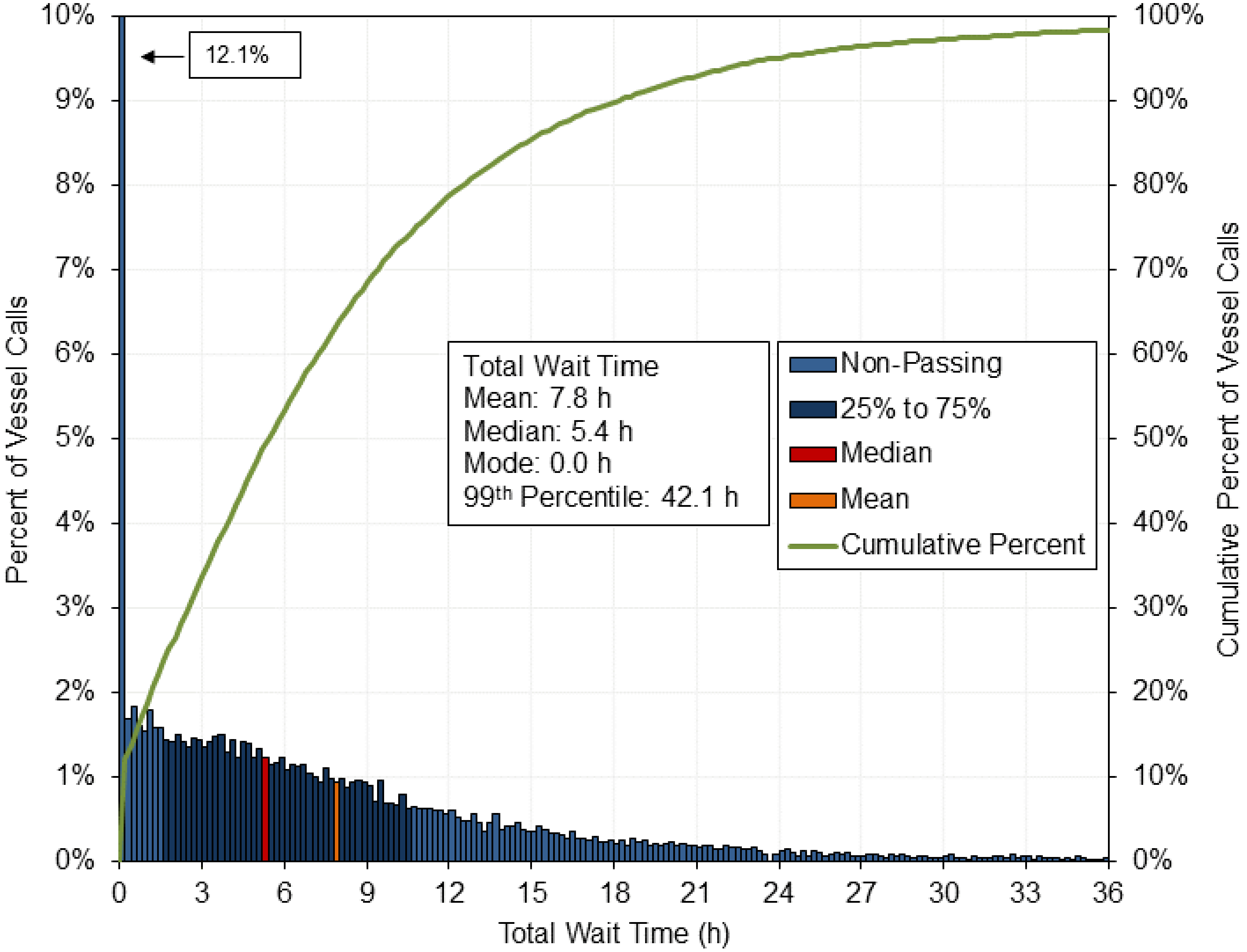


Figure 15 Histogram of Total Wait Times for Deep Draft (Loaded Inbound) Vessels in 2023

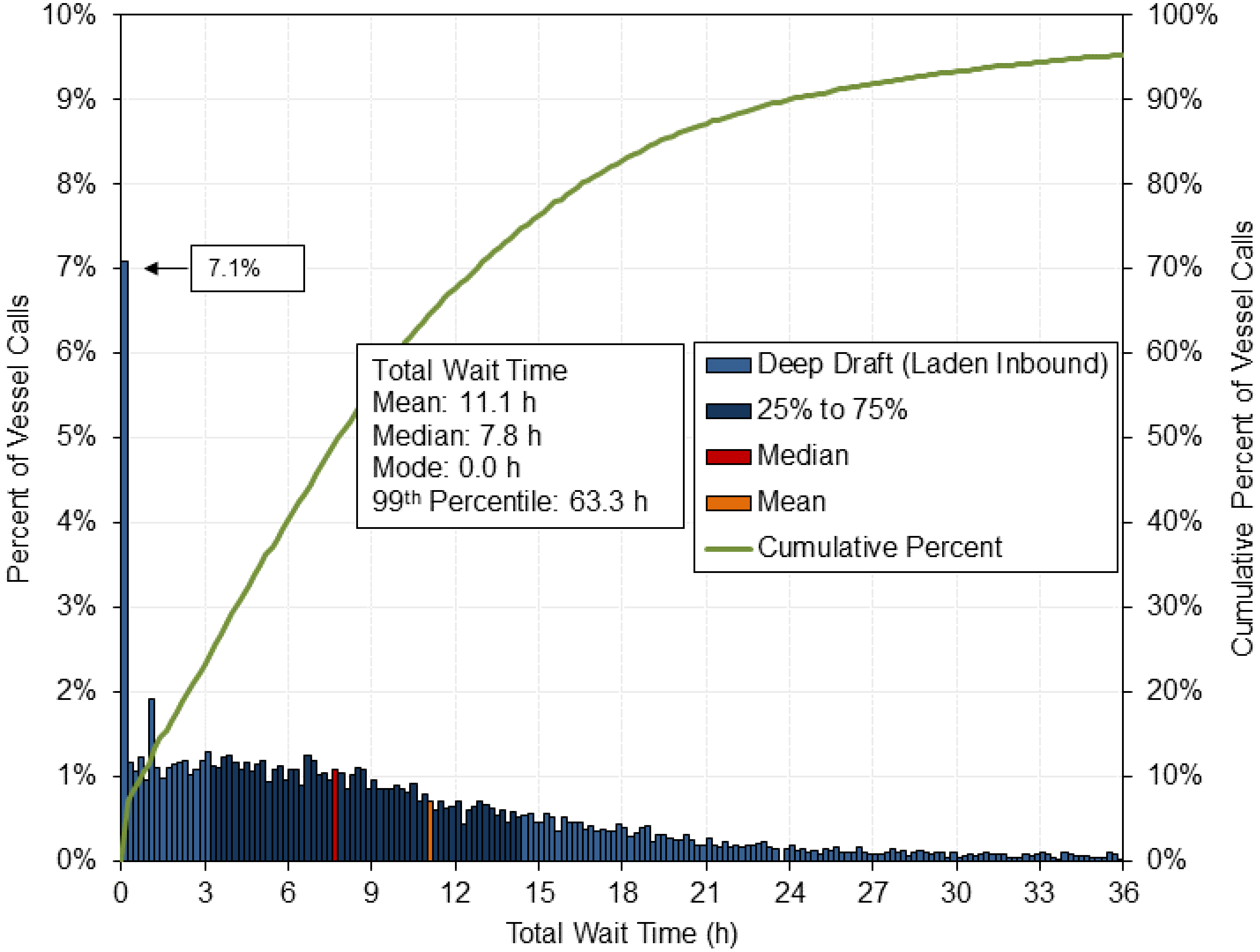


Figure 16 Histogram of Total Wait Times for Deep Draft (Loaded Outbound) Vessels in 2023

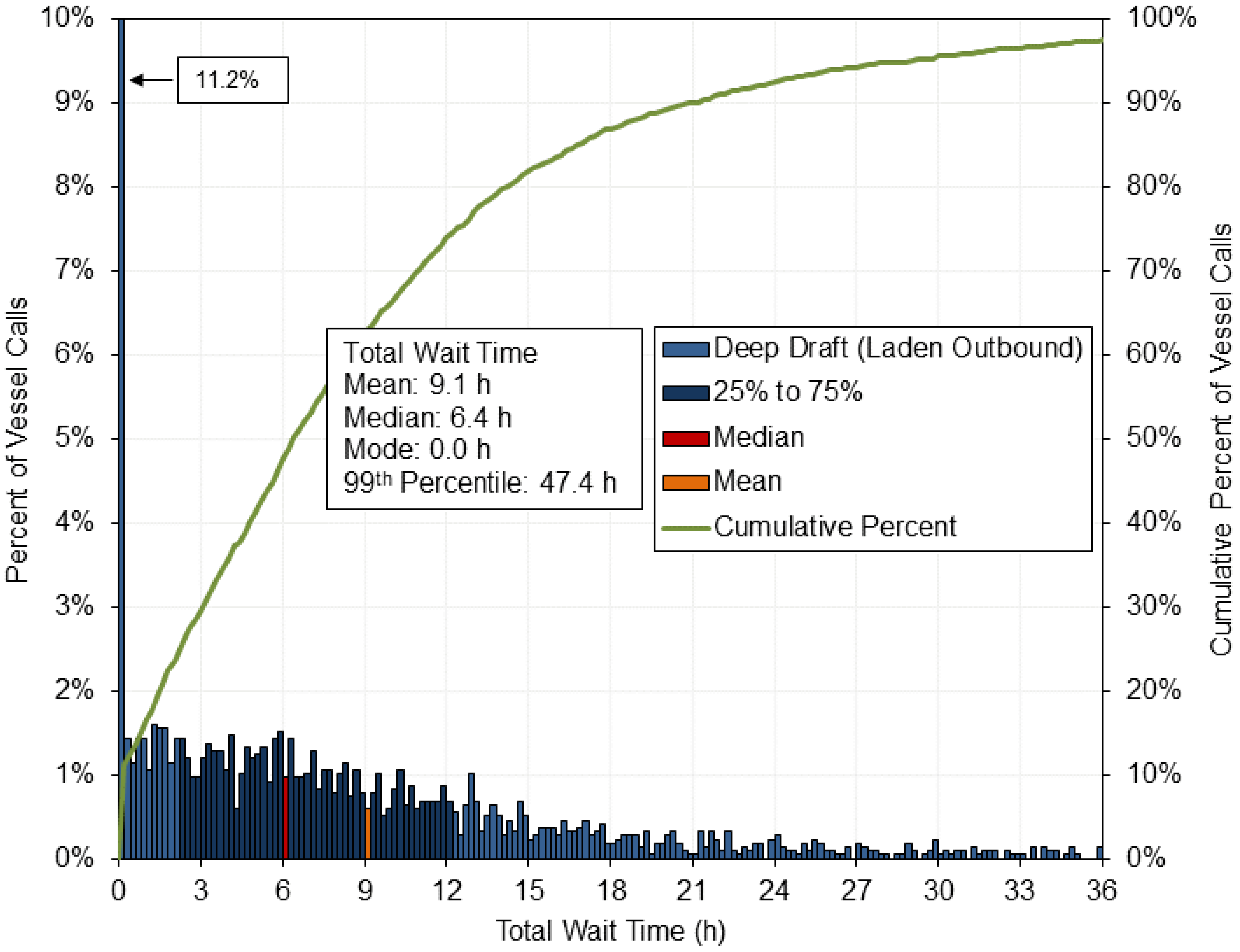


Figure 17 Histogram of Total Wait Times for Small LNG Carriers in 2023

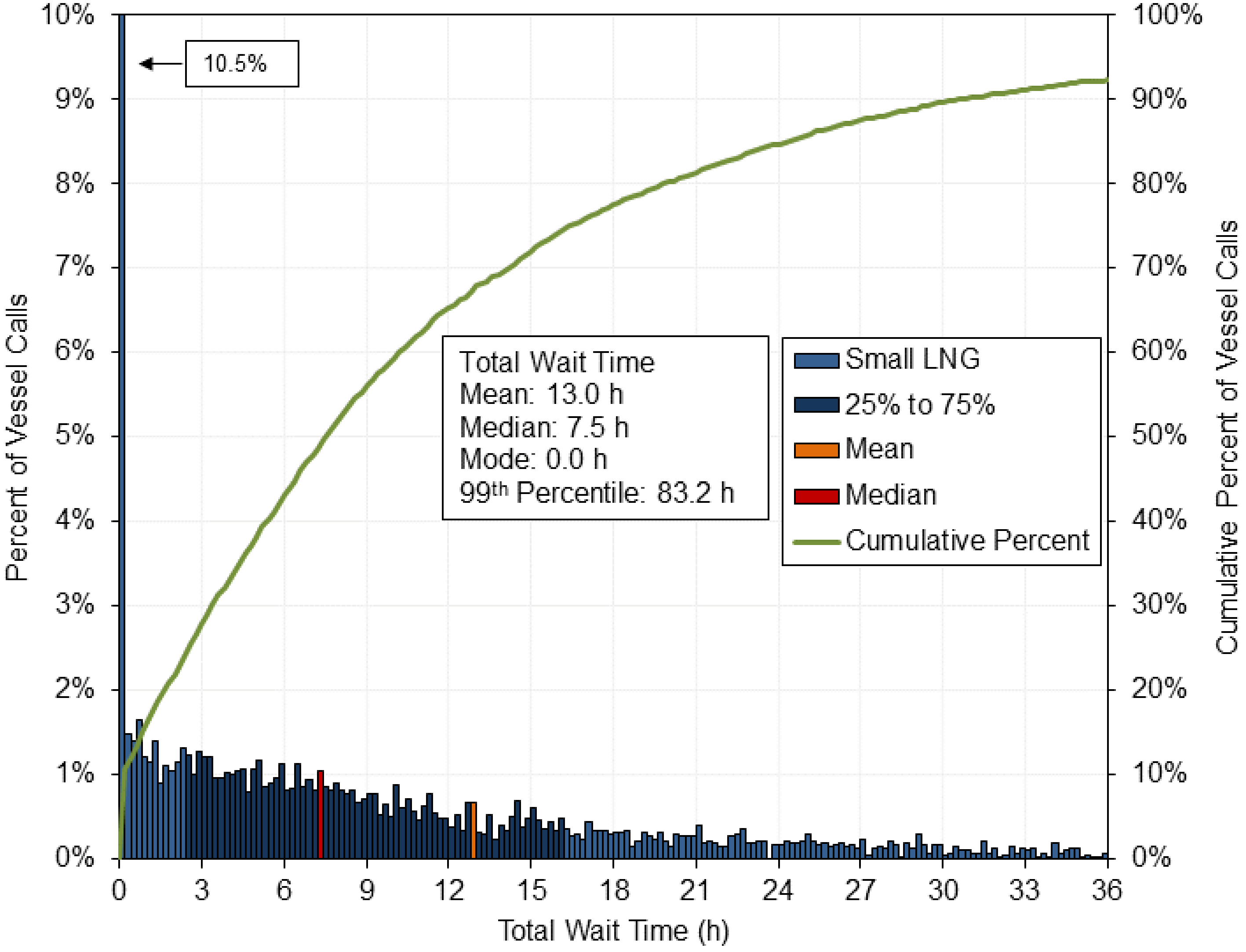


Figure 18 Histogram of Total Wait Times for Midsize LNG Carriers in 2023

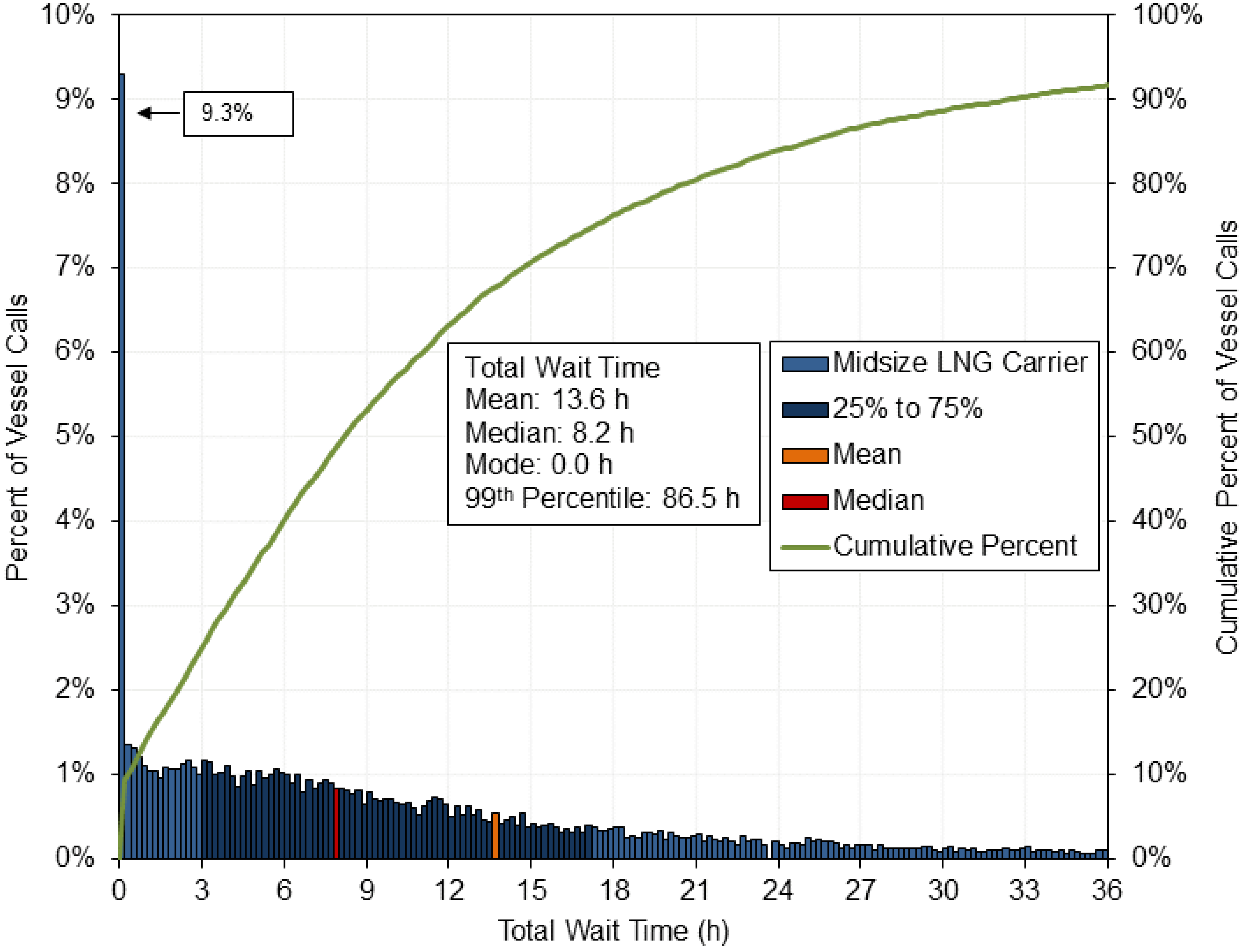
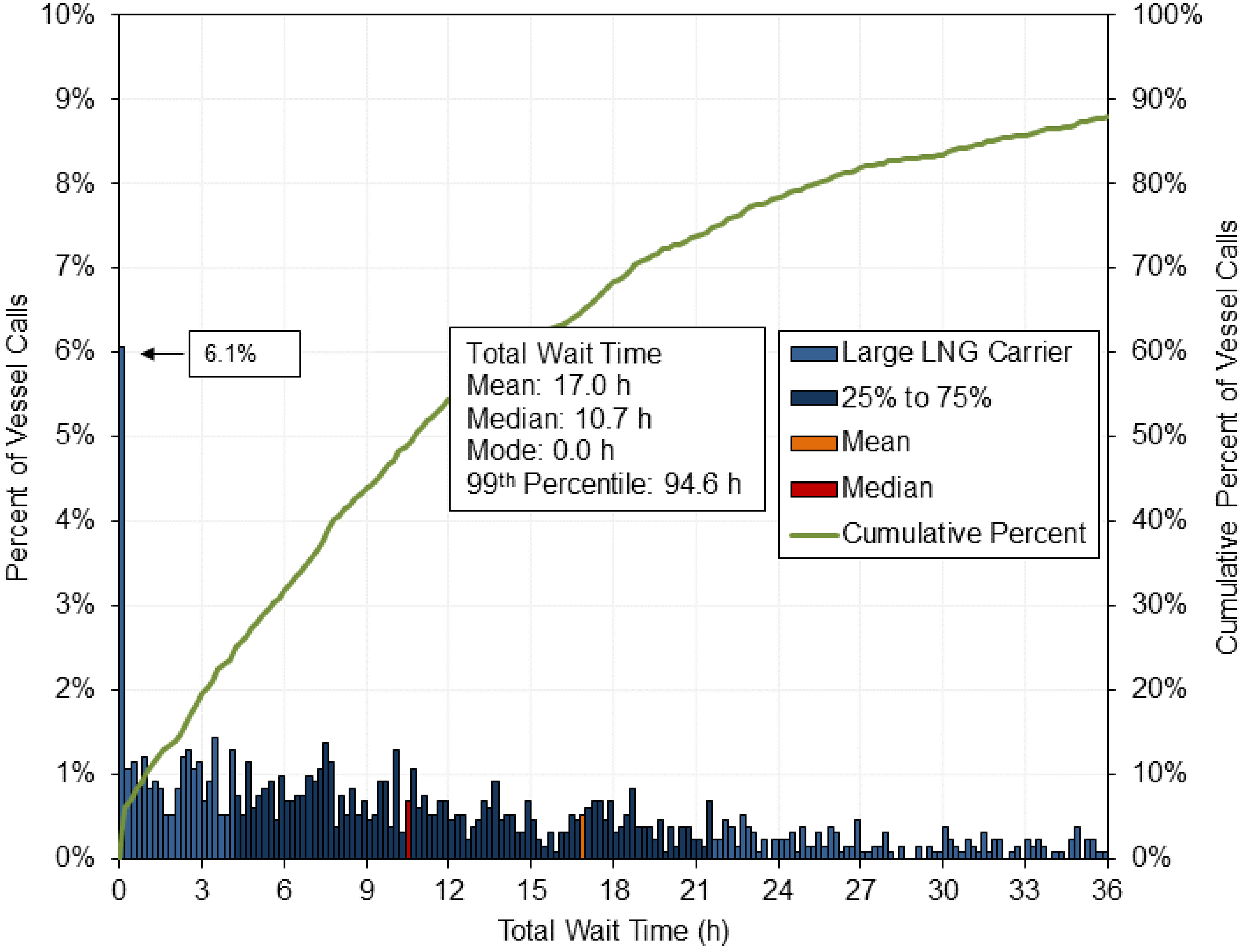


Figure 19 Histogram of Total Wait Times for Large LNG Carriers in 2023



Traffic Year 2028

Figure 20 Histogram of Total Wait Times for All Vessels in 2028

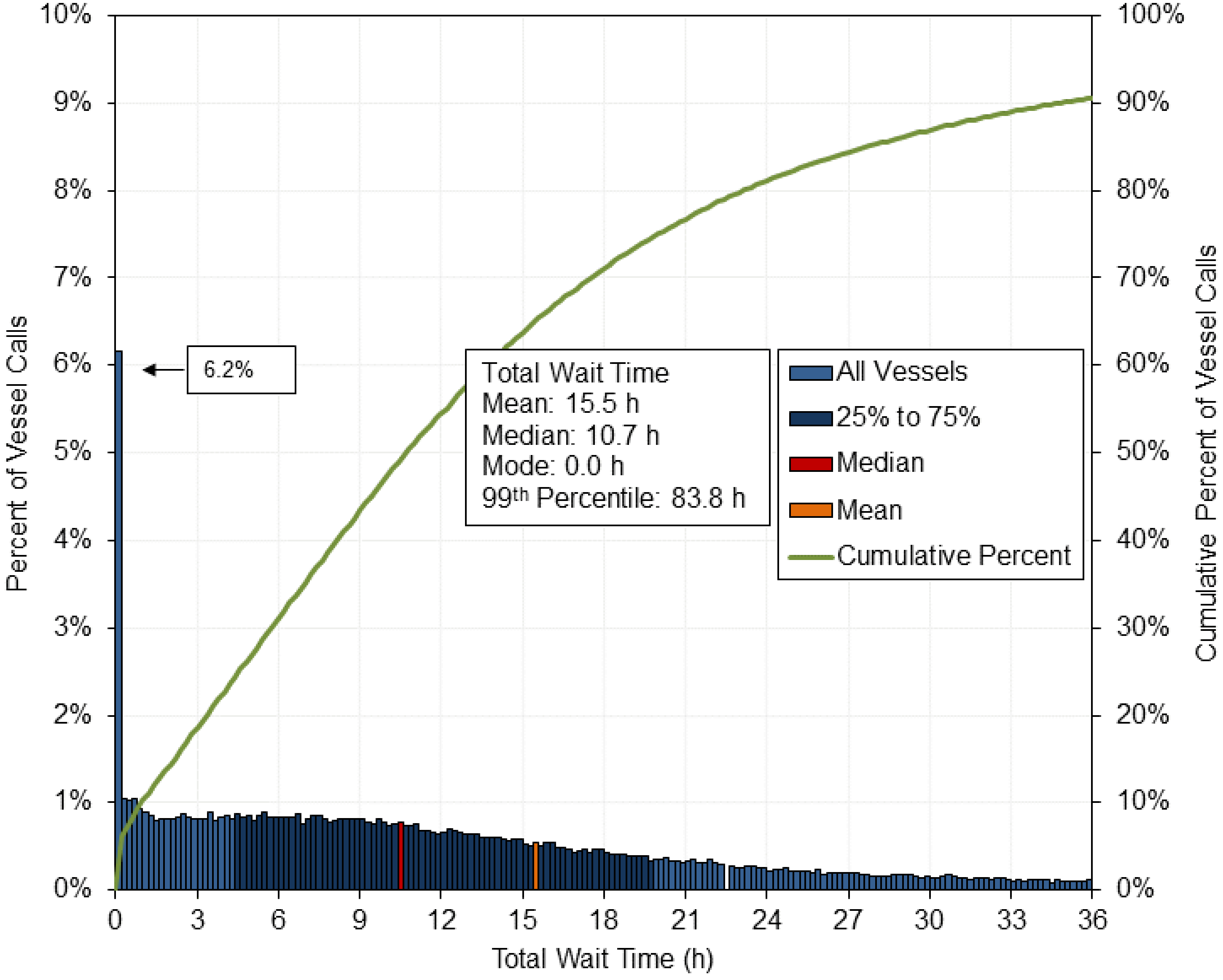


Figure 21 Histogram of Total Wait Times for Narrow Vessels in 2028

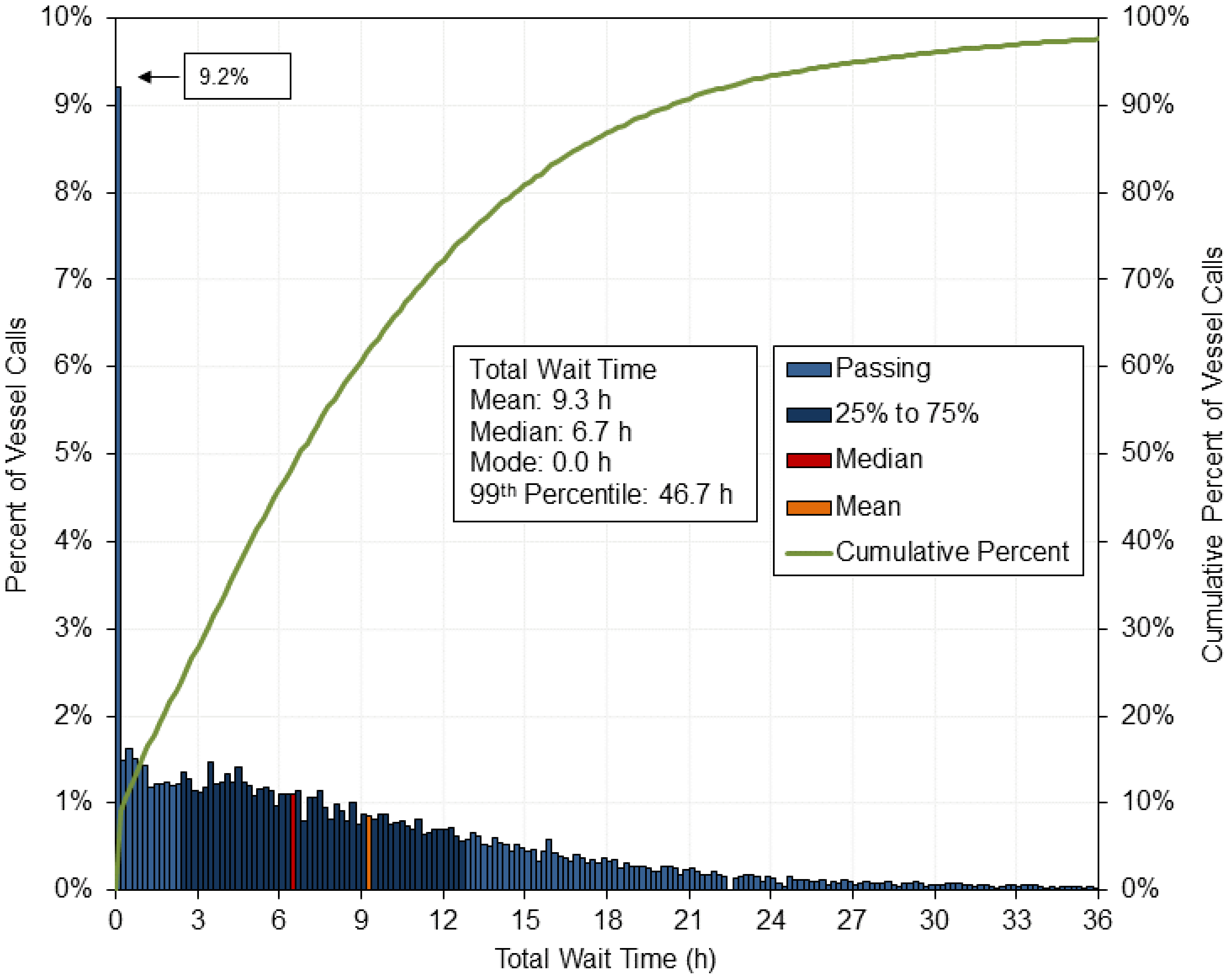


Figure 22 Histogram of Total Wait Times for Wide Vessels in 2028

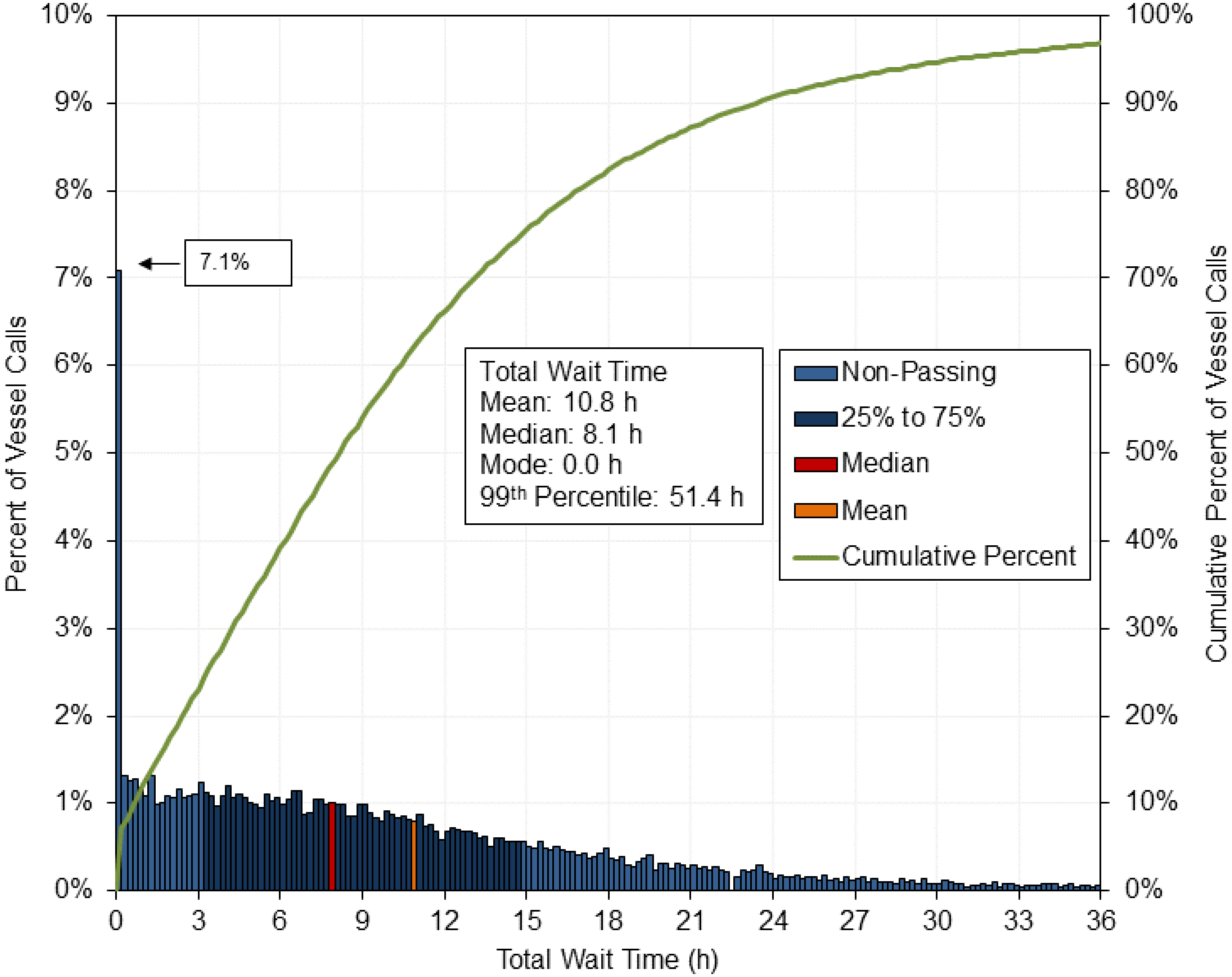


Figure 23 Histogram of Total Wait Times for Deep Draft (Loaded Inbound) Vessels in 2028

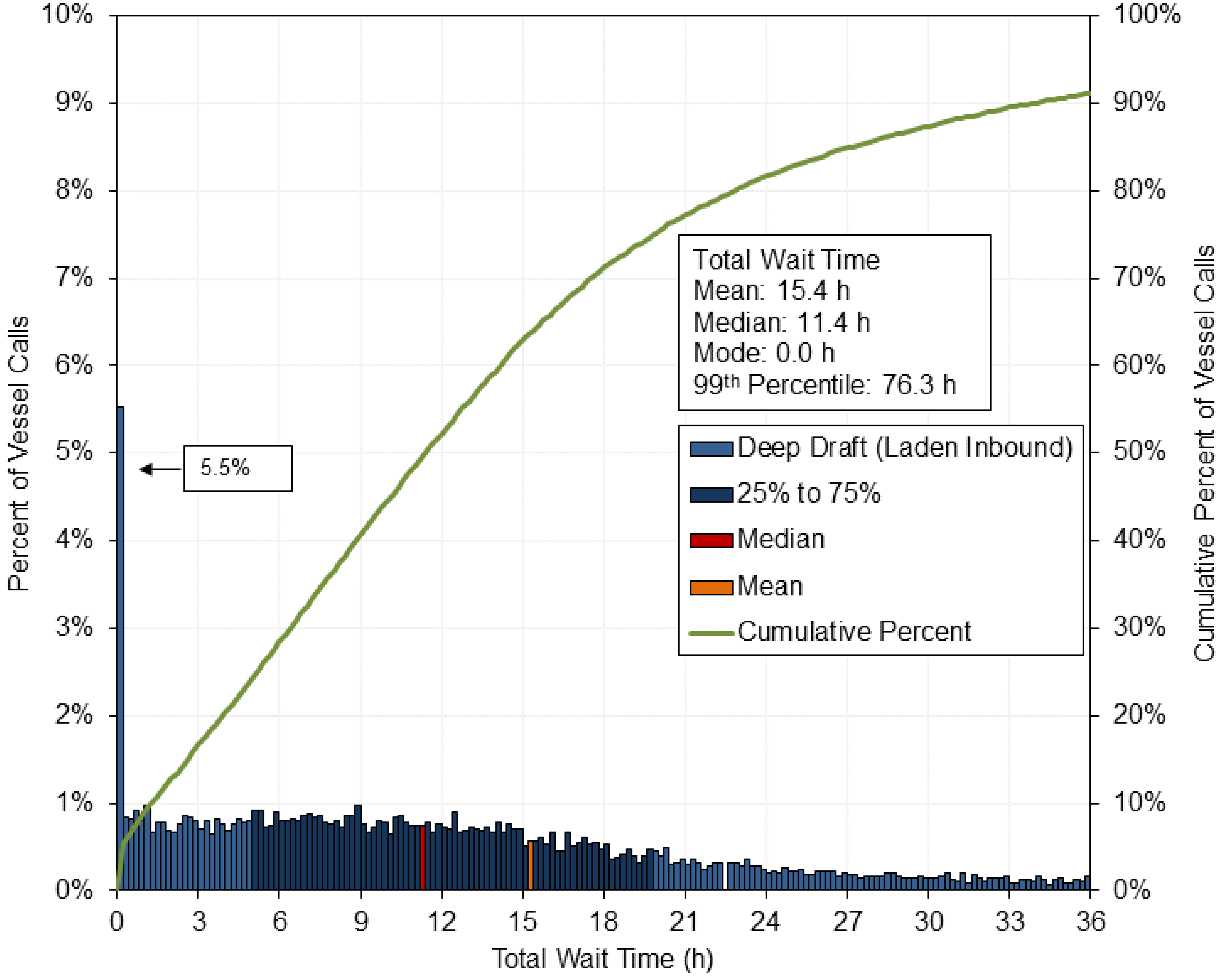


Figure 24 Histogram of Total Wait Times for Deep Draft (Loaded Outbound) Vessels in 2028

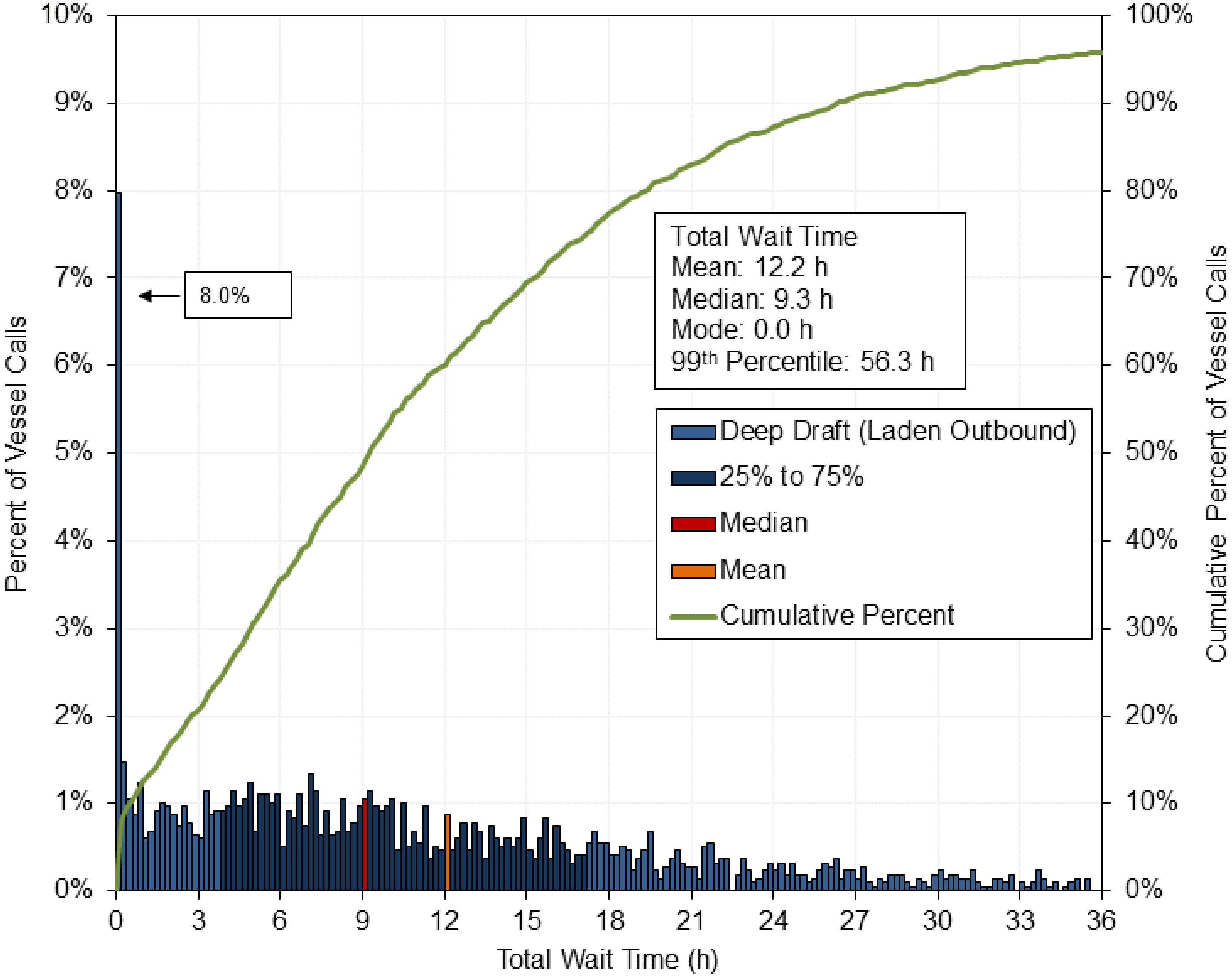


Figure 25 Histogram of Total Wait Times for Small LNG Carriers in 2028

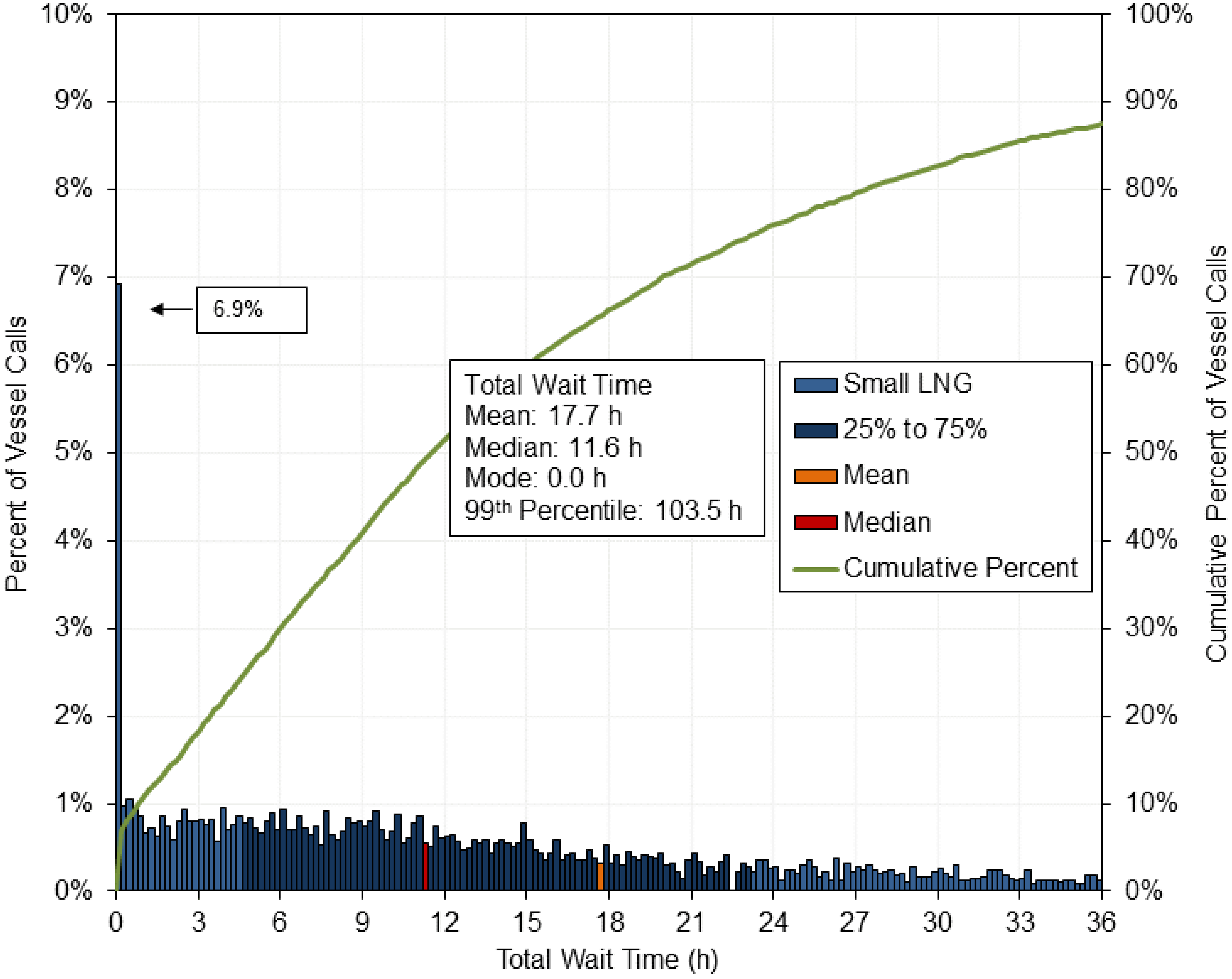


Figure 26 Histogram of Total Wait Times for Midsize LNG Carriers in 2028

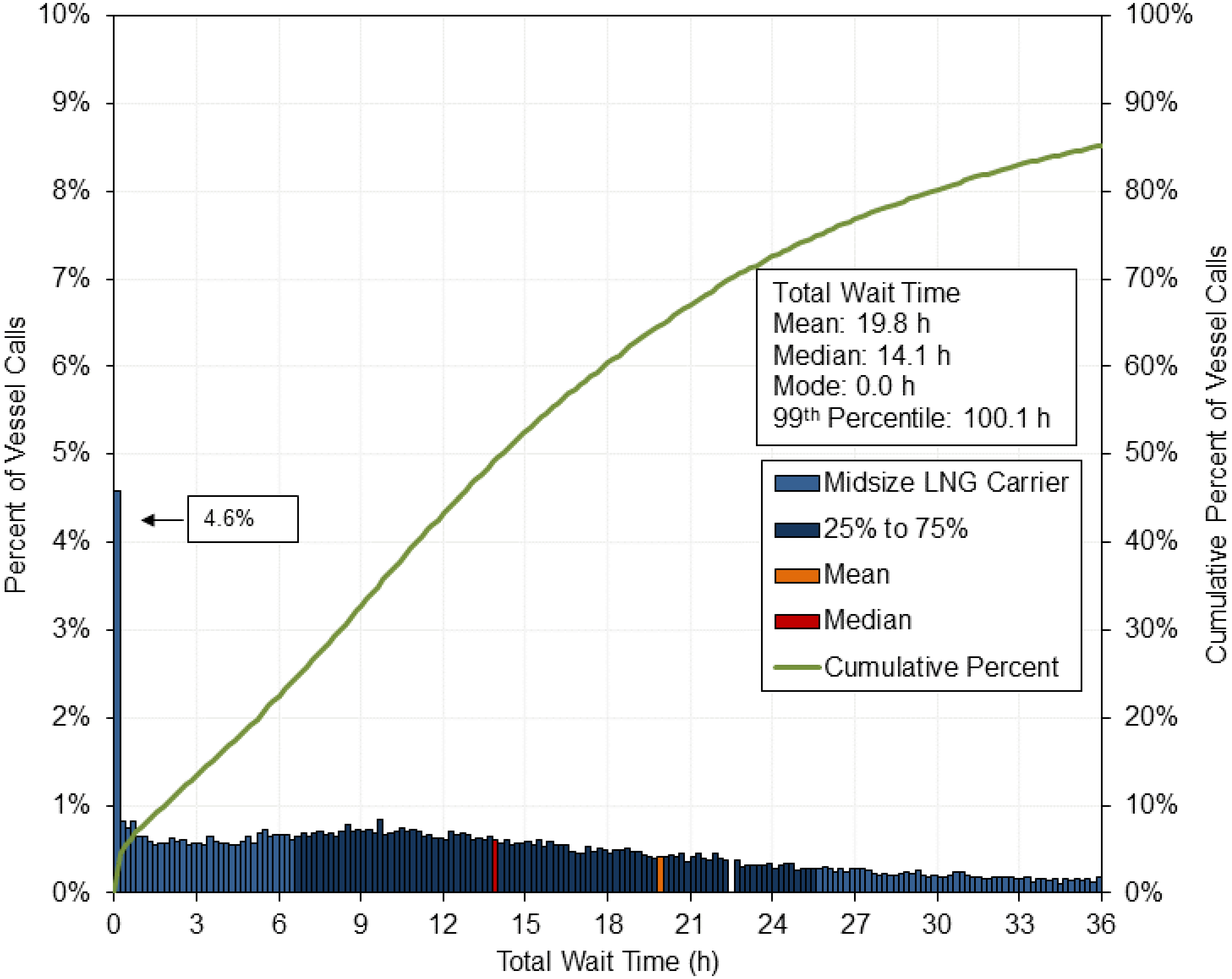


Figure 27 Histogram of Total Wait Times for Large LNG Carriers in 2028