Offshore Wind Ports: Vessel Traffic Risk Assessment Supplement

Final Report | Report Number 22-31 | August 2022

NEW YORK STATE | NYSERDA

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Offshore Wind Ports:
Vessel Traffic Risk Assessment Supplement

Final Report

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Notice

Abstract

This study supplements a collection of studies prepared on behalf of NYSERDA to provide information related to a variety of environmental, social, economic, regulatory, and infrastructure-related issues implicated in planning for future offshore wind energy development off the coast of New York State. This study provides an assessment of the changes in risk on vessel traffic that may be seen as a result of future offshore wind activity within the State. NYSERDA's intent is to facilitate the principled planning of future offshore development to provide a resource for the various stakeholders and to support the achievement of the State's offshore wind energy goals.

Keywords

Offshore wind, vessel, port, traffic, model, AIS, navigation, risk

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Acronyms and Abbreviations

The following acronyms and abbreviations are used throughout this document.

AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
AWOIS	Automated Wreck and Obstruction Information System
ATON	Aids to Navigation
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
COD	Commercial Operation Date
CTV	Crew Transfer Vessel
ECDIS	Electronic Chart Display and Information System
ENC	Electronic Navigation Charts
ft.	feet
GIS	Geographic Information System
GW	Gigawatt
IMO	International Maritime Organization
LOA	Length Overall
M	Meter
MISLE	Marine Information for Safety and Law Enforcement
MLLW	Mean Lower Low Water
MMSI	Maritime Mobile Service Identity

MW	Megawatt
nm	Nautical Mile
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NSRA	Navigation Safety Risk Assessment
NVIC	Navigation and Vessel Inspection Circular
NYC	New York City
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
O&M	Operations and Maintenance
OREI	Offshore Renewable Energy Installation
OSW	Offshore Wind
OWF	Offshore Wind Farm
PANYNJ	Port Authority of New York and New Jersey
PARS	Port Access Route Studies
PDE	Project Design Envelope
SOV	Service Offshore Vessel
TSS	Traffic Separation Scheme
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
VHF	Very High Frequency
VTM	Vessel Traffic Model
VTS	Vessel Traffic Services

Executive Summary

This vessel traffic risk assessment identifies navigation risks associated with the introduction of new vessel traffic from a series of known and hypothetical offshore wind (OSW) projects and associated ports. The area of interest is physically limited to be New York State waters and therefore considers only the vessel transit activity to/from ports within the State and the portions of the vessel trips to the offshore wind farms (OWF) within State waters. This study does not serve as the formal navigation safety risk assessment (NSRA) that must be carried out as part of the permitting process for any specific OWF project. This study provides insight and decision support to evaluate the cumulative change in risk expected within State waters resulting from increases in vessel traffic.

This assessment builds upon the NYSERDA Offshore Wind Ports: Cumulative Vessel Traffic Assessment (COWI 2022) in which future known and hypothetical port uses related to OSW vessel traffic are assessed and a vessel traffic model (VTM) is developed to analyze current and future vessel traffic patterns. Eight locations, referred to as passage lines are selected and used to evaluate changes in vessel traffic resulting from potential future OSW vessel traffic.

This vessel traffic risk assessment includes a description of the considered waterways including obstructions and historical incidents. The existing vessel traffic and traffic patterns from 2017 Automatic Identification System (AIS) data, including vessel characteristics and detailed information about vessel size and types, is also presented. Information regarding expected future vessel traffic resulting from both non-OSW and OSW developed in the Cumulative Vessel Traffic Assessment is reiterated herein due to its importance when evaluating risks.

While there can be many risks associated with the introduction of an OWF, this study is limited to the impact from changes in vessel traffic within New York State waters. The main risks identified and evaluated are therefore:

1. Vessel allision with fixed object(s).
2. Ship-ship collision.

This report presents the methodology for evaluating the above risks and presents a semi-quantitative evaluation based on available vessel traffic information. The probability of either type of risk is generally found as the product of causation probability (the probability of aberrancy that potentially can lead to collision/allision), geometrical probability for a vessel to be on collision course, and number of vessels and risk reducing measures. Within this equation, most of the variables are not expected to change significantly when introducing the estimated OSW vessel traffic. The overall number of vessels will increase and, as a result, cause an increase in collision/allision frequency.

The expected increase in vessel allisions with fixed objects is roughly proportional to the increase in vessel traffic which typically is 1–5% above baseline at the considered locations (passage lines). The individual risk per vessel passage is assumed to be unchanged by a vessel increase of this magnitude.

In the case of ship-to-ship collisions the number of meeting situations increase with the square of the vessel traffic increase and hence the increase in ship-to-ship collision probability is found to be slightly higher for this scenario and generally between 1–10% above baseline. It is observed that the expected increase in risk resulting from assumed development in non-OSW vessel traffic vastly exceeds that associated with OSW vessel traffic.

This evaluation is contingent upon a series of assumptions related to the determination of future OSW and non-OSW vessel traffic, all presented in NYSERDA Offshore Wind Ports: Cumulative Vessel Traffic Assessment. It would be beneficial to re-evaluate the input and assumptions for this study when more information on expected OSW ports and traffic is available. It should also be emphasized that a project specific NSRA is expected to be developed for each OWF to provide detailed evaluation of the risks associated with the individual project and the Offshore Renewable Energy Installations (OREIs).

1 Introduction

1.1 Purpose

This vessel traffic risk assessment identifies navigation risks associated with the introduction of new vessel traffic from known and hypothetical offshore wind (OSW) projects and associated ports. The area of interest, referred to as the study area, is physically limited to New York State waters and therefore only considers the vessel transit activity to/from ports within the State and the portions of the vessel trips to the offshore wind farms (OWF) within State waters. Thus, this study does not serve as the formal navigation safety risk assessment (NSRA) that is required for any wind farm project but instead provides insight and decision support to evaluate the cumulative change expected within the State waters resulting from increases in vessel traffic.

The vessel traffic risk assessment builds upon the NYSERDA Offshore Wind Ports: Cumulative Vessel Traffic Assessment which has already been carried out and documented in that report (COWI 2022). It includes a description of the considered waterways, the existing vessel traffic, including vessel characteristics and movements data from 2017 AIS data, as well as vessel traffic patterns and detailed information about vessel size and types. Information on expected future vessel traffic resulting from OSW is also developed as part of this study and only key information is reiterated.

Additional information specifically for the purpose of the risk assessment is analyzed and presented in this report along with the identification and evaluation of risks associated with the increase in vessel traffic from OSW in the study area.

1.2 Approach to the Work

Per United States Coast Guard (USCG) 2019 Circular, an NSRA is to be performed to assess impacts of a specific Offshore Renewable Energy Installation (OREI) on marine navigation safety (United States Coast Guard 2019, 3). This study does not assess a specific OREI and instead aims to perform an assessment of potential cumulative impacts on existing navigational channels generated by a series of potential OREI's located at offshore sites outside of the study area. These OREIs are collectively referred to as "OSW projects" in the document. With the scope and general nature of this study in mind, Cumulative Vessel Traffic Assessment’s goal was to identify and analyze areas experiencing the largest increase in vessel traffic as a result of the potential future OSW development in the region.

1.3 Contents

This study seeks to answer specific questions that are directly relevant to vessel navigation and safety concerns. The report outline is as follows:

- Waterway Characteristics: Section 3 provides an overall description of the existing waterway characteristics including climate considerations, sea states, channels, overall traffic patterns, and existing aids to navigation within the study area.
- Vessel Characteristics and Traffic: Section 4 provides an overview of vessel traffic characteristics now and projected into the future. This includes frequency of passages at key locations, vessel types, typical uses, etc. In this section, select locations referred to as "passage lines" are analyzed in greater detail.
- Potential Effects on Safe Navigation: Section 5 provides an overview of the baseline (existing) and projected impacts of the increase in vessel traffic. The main risks associated with the introduction of OSW vessel traffic are identified and evaluated.
- Potential Mitigation Strategies: Section 6 presents navigational risks associated with the increase in traffic and provides potential changes in navigational waterways to manage those risks.

1.4 Assumptions

The results of this analysis are predicated on assumptions made on future OSW projects and locations. These are described in detail in the Cumulative Vessel Traffic Assessment (COWI 2022).

1.5 Consistency with the 01-19 Navigation and Vessel Inspection Circular Recommendations

Changes in vessel traffic patterns within a navigation route have the potential to increase the existing risks associated with vessel traffic in that route. Understanding the hazards posed by increased vessel traffic quantity due to offshore wind farms and, furthermore, mitigating the risks associated with the hazards, is necessary to ensure the continued safe practice of vessel navigation within the study area.

1.5.1 Risk Assessment Approach

Per the Navigation and Vessel Inspection Circular (NVIC) 02-07 (United States Coast Guard 2019), the risk assessment approach adopted for this study employs a "change analysis" technique, where the potential impacts of offshore wind vessel traffic are compared to the baseline situation, which is defined as the vessel traffic forecast for the study area that will occur without offshore wind vessel traffic. The study area for this analysis is confined to New York State waterways as defined in Cumulative Vessel Traffic Assessment (2022) and has been performed with the intent to understand the impact of offshore wind vessel traffic specifically in this area. As such, the areas impacted by OSW vessel traffic are within existing New York State navigation channels.

Employing this technique and adapting the risk assessment guidelines as outlined in the NVIC to account for the specificity of the study area, the focus, which is traditionally specific to offshore wind project sites, is pivoted to selected locations within the study area, analyzed through defined passage lines. This allows the study team to assess the effects of increased traffic density within the study area.

1.5.2 Navigational Impacts

To determine impacts to navigational safety and employ appropriate mitigative measures, the USCG must be made aware of, "the characteristics and number of waterway users, the routes used, the channel dimensions, bottom conditions, etc.," (United States Coast Guard 2019). By implementing the data and models as discussed in the NYSERDA Offshore Wind Ports: Cumulative Vessel Traffic Assessment, the risk assessment uses the passage lines outlined in section 4.3 to analyze the impacts on navigational risk within the context of section 1.5.1.

2 Projects Description

Future offshore wind project characteristics including location, size (megawatt [MW] capacity and turbine quantity), and Commercial Operation Date (COD) was developed in the Offshore Wind Ports: Cumulative Vessel Traffic Assessment and is the basis for evaluating the impact from offshore wind vessel traffic. This section will present the key assumptions regarding location of OSW port facilities and OWF locations as well as the resulting OSW induced vessel traffic.

2.1 Assumed Port and Offshore Wind Farm Locations

Vessel traffic incurred by offshore wind activity will take place along specific routes between ports or between port and project. Routes were developed between the locations that are part of the proposed Project Design Envelope (PDE) per the Cumulative Vessel Traffic Assessment. Locations for future projects (projects 2029–2035) and ports were assigned to best of the assessment's information at the time of preparing this report and represent one hypothetical scenario.

The following projects used in determining the offshore wind vessel traffic routes are as follows:

Table 1. Table Projects for Vessel Traffic

Project	Capacity (MW)	COD
South Fork	132	2023
Empire Wind	816	2024
Sunrise Wind	932	2024
Empire Wind 2	1260	2027
Beacon Wind	1230	2028
Project 2029[a]	1250	2029
Project 2031[a]	1250	2031
Project 2033[a]	1250	2033
Project 2035[a]	1250	2035

[a] Projects 2029 and beyond are indicative for the purposes of analysis only. The project years, capacity, COD, anticipated WTG Capacity, and location should not be used as an inference of New York State policy or procurement intentions.

Port locations used to develop the vessel traffic routes are those included in the PDE as defined in the Cumulative Vessel Traffic Assessment. The port locations are summarized in Table 2. below. Additional background on the selection of these ports can be found in the 2022 assessment.

Table 2. Port Locations per Cumulative Vessel Traffic Assessment

	Port Location	NYS Region
KNWON	South Brooklyn Marine Terminal	NYC Harbor
	Port of Albany	Capital Region
	Port of Coeymans	Capital Region
	Port Jefferson	North Shore LI
	Port of Montauk	North Shore LI
REPRESENTATIVE PROPOSED FOR PDE	Arthur Kill Terminal	NYC Harbor (Staten Island)
	Port Ivory	NYC Harbor (Staten Island)
	Homeport Pier	NYC Harbor (Staten Island)
	Brooklyn Navy Yard	NYC Harbor (Brooklyn)
	Brooklyn Port Authority Marine Terminal (PAMT)	NYC Harbor (Brooklyn)
	NYS Wind Port (East Greenbush)	Capital Region
	Cortland	Upper Hudson Valley
	Tomkins Cove	Upper Hudson Valley

2.2 Anticipated Vessel Traffic for Construction and Operation

The effects of an OREI on vessel traffic density differ based on whether the construction phase or operational phase of the OREI is under consideration. The hypothetical port locations comprise the PDE and provide a scenario of a fully developed offshore wind supply chain within New York State. The project locations provide a hypothetical scenario of number and locations of projects needed for the State to achieve 9 gigawatt (GW) of offshore wind energy by 2035. Using the port and project details outlined above, the Cumulative Vessel Traffic Assessment developed an OSW vessel traffic forecast model and estimated the anticipated offshore wind vessel traffic in State waterways. A summary of the resulting total number of vessel trips for the capital construction and O&M activities is provided in Figure 1 and Figure 2.

Figure 1. Snapshot of Number of Trips per Year Incurred by Offshore Wind Capital Construction Activities

Source: COWI (December 2021)

Sum of # Trips	Year																
Projects then Routes	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Grand Total
South Fork	10	22	16	4													52
Sunrise Wind		47	106	76	17												246
Empire Wind		29	66	48	11												154
Empire Wind 2					44	100	72	16									232
Beacon Wind						35	81	59	13								188
Project 2029							35	84	63	14							196
Project 2031									35	84	63	14					196
Project 2033											35	84	63	14			196
Project 2035													33	78	58	13	182
Grand Total	10	98	188	128	72	135	188	159	111	98	98	98	96	92	58	13	1642

Figure 2. Results: Snapshot of Number of Operations and Maintenance Round Trips per Year Incurred by Offshore Wind Projects

Source: COWI (December 2021)

Sum of Round Trips			Year															
Project	**Route (Assumed)**	**Vessel**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
South Fork	Port Montauk - South Fork	CTV	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Empire Wind	SBMT - Empire Wind	SOV	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20
Sunrise Wind	Port Jefferson - Sunrise Wind	SOV	0	0	0	0	33	33	33	33	33	33	33	33	33	33	33	33
Empire Wind 2	SBMT - Empire Wind 2	SOV	0	0	0	0	0	0	0	31	31	31	31	31	31	31	31	31
Beacon Wind	SBMT - Beacon Wind	SOV	0	0	0	0	0	0	0	0	24	24	24	24	24	24	24	24
Project 2029	Brooklyn PAMT - Project 2029	SOV	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25	25
Project 2031	Brooklyn PAMT - Project 2031	SOV	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
Project 2033	Homeport Pier - Project 2033	SOV	0	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25
Project 2035	Brooklyn Navy Yard - Project 2035	SOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25

2.3 Passage Lines

For the purpose of the Offshore Wind Ports: Cumulative Vessel Traffic Assessment and this study so-called passage lines were defined. These passage lines were selected specifically for their value in identifying potential bottlenecks or navigational hazards that could challenge traffic safety over time. The passage lines extend perpendicularly across a navigation channel (such as Ambrose channel) or junction (such as the Narrows), allowing for a numerical representation of the vessel traffic passing through a given location. Comparative assessment was conducted for these passage lines in the Cumulative Vessel Traffic Assessment and are also the basis for the risk evaluation in this supplemental study.

Table 3 lists the considered passage lines along with the relevant navigation channel and its width. Figure 3, Figure 4, and Figure 5 display the location of all passage lines together with the hypothetical OSW port and expected OSW vessel routes.

Table 3. Passage Line Navigation Channel Widths

Passage Line–Name	Navigation Channel	Channel Width (at Passage Line) [ft]
The Narrows	Ambrose Channel	2,000
Hudson River	Hudson River Channel	2,000
East River	East River Channel	1,000
Ambrose Channel	Ambrose Channel	2,000
Ward Point	Ward Point Bend West Reach	600
Sandy Hook	Sandy Hook Channel – Bayside Reach	800
Tomkins Cove	Hudson River Channel	2300
Port of Coeymans	Hudson River Channel	400

Figure 3. Overview of Vessel Traffic, Passage Lines, and Offshore Wind Ports and Vessel Traffic

OSW traffic is shown on the figure as thick black lines. Passage lines represented by cyan circles with PL in brackets. Potential and existing facilities are shown as red and green circles accordingly. Background colors represent transit counts with yellow representing higher transit count and dark blue/magenta representing lower transit count.

Source: COWI (December 2021); ESRI Ocean; Google Earth; NOAA

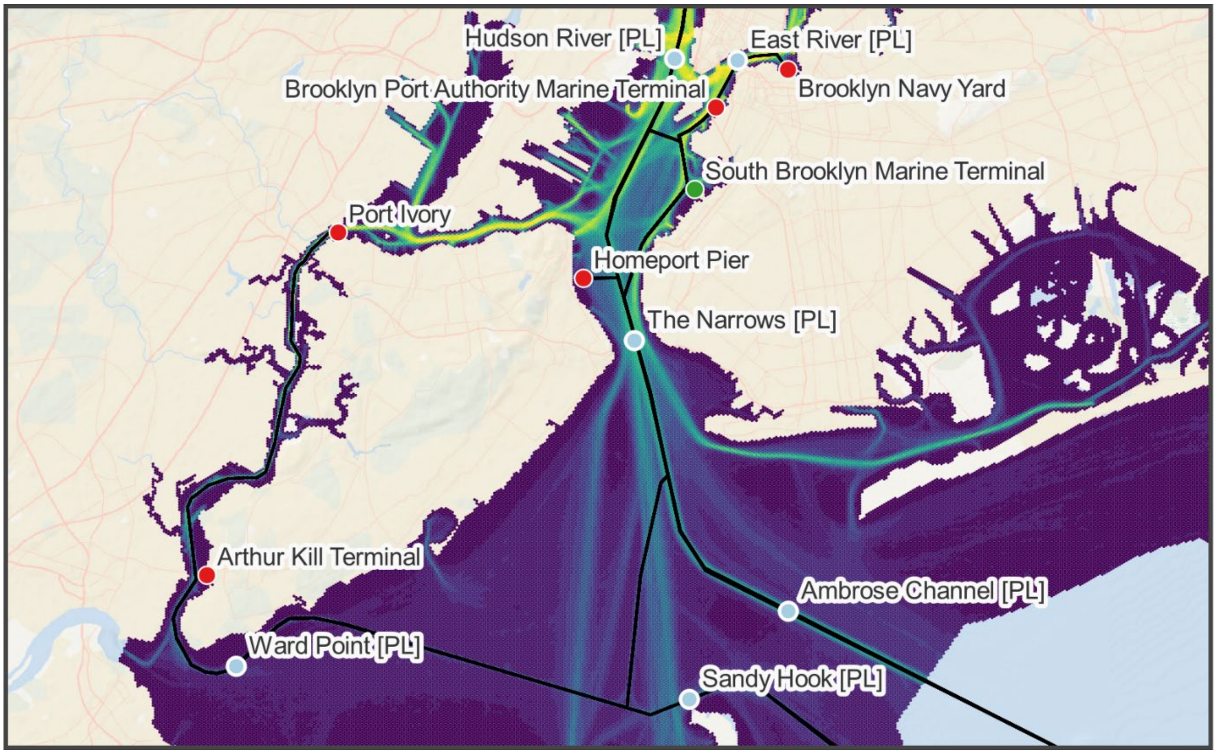


Figure 4. Overview of Vessel Traffic, Passage Lines, and Offshore Ports and Vessel Traffic (Continued)

OSW traffic is shown on the figure as thick black lines. Passage lines represented by cyan circles with PL in brackets. Potential and existing facilities are shown as red and green circles accordingly. Background colors represent transit counts with yellow representing higher transit count and dark blue/magenta representing lower transit count.

Source: COWI (December 2021); ESRI Ocean; Google Earth; NOAA

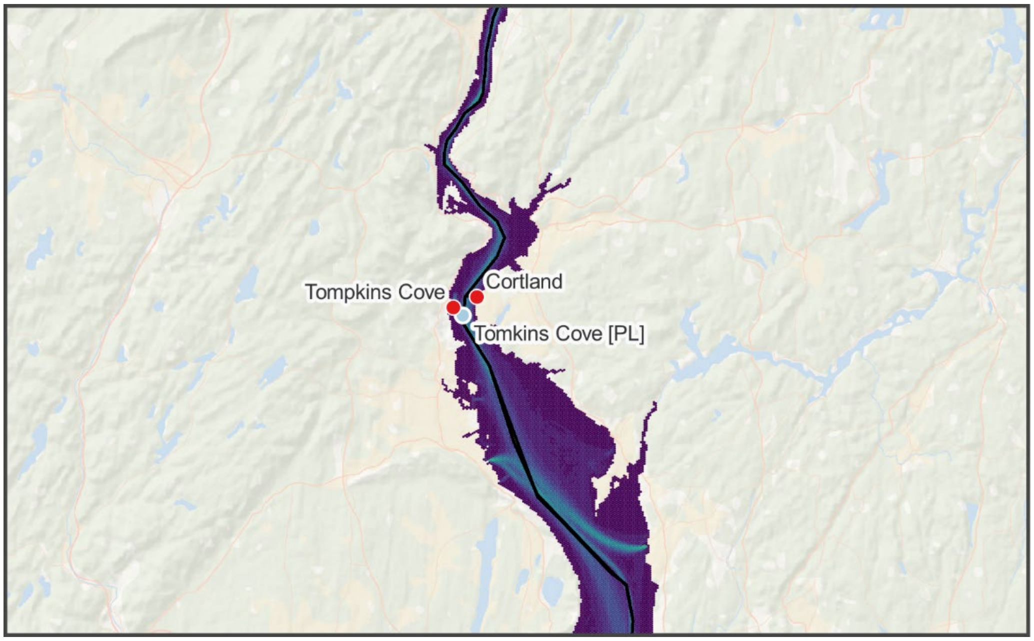
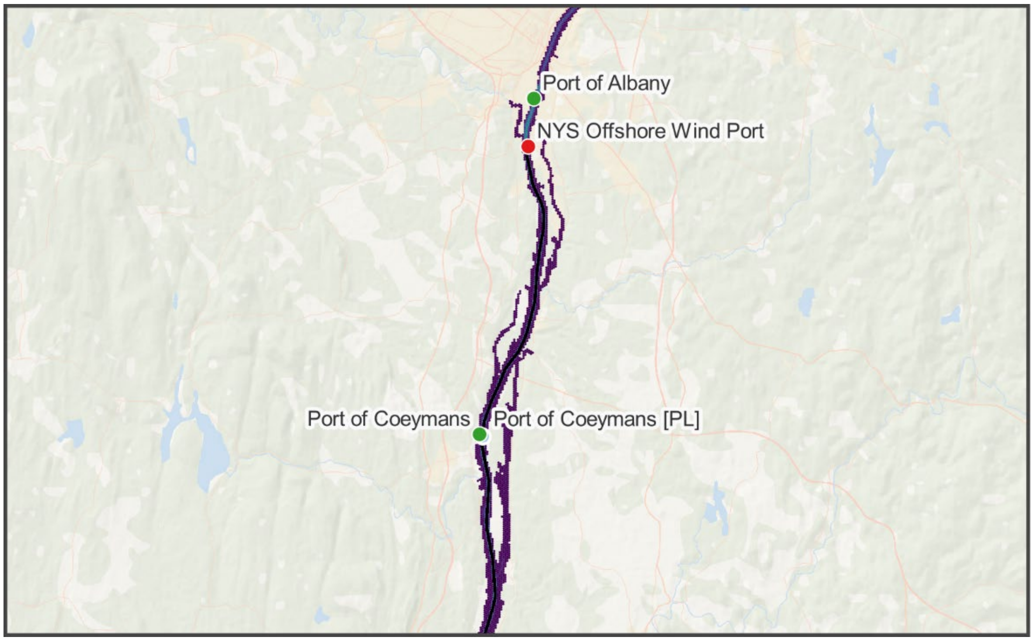


Figure 5. Overview of Vessel Traffic, Passage Lines, and OSW Ports and Vessel Traffic (Continued)

OSW traffic is shown on the figure as thick black lines. Passage lines shown by cyan circles with PL in brackets. Potential and existing facilities are shown as red and green circles accordingly. Background colors represent transit counts with yellow representing higher transit count and dark blue/magenta representing lower transit count.

Source: COWI (December 2021); ESRI Ocean; Google Earth; NOAA



3 Waterway Characteristics

Navigational operations in New York Bight near the study area are affected by metocean conditions, channel size and configuration, obstructions, and aids to navigation. Each of these factors is addressed in the following subsections together with a review of historical incidents in the area.

3.1 Metocean Conditions

Metocean and environmental conditions such as wind, wave, current, and tidal information are relevant when evaluating navigational safety and risks associated with the introduction of OREIs. Dominating wind and current directions may directly influence the risk of vessel aberrancy potentially leading to collisions or allisions. For any specific OREI it is expected that a review of relevant metocean and environmental conditions be presented and assessed as part of the project specific NSRA.

For this study, the focus is on impacts from increases in vessel traffic and wind, current, and wave conditions are not directly relevant when evaluating the change in risk. It is assumed that the existing metocean condition allow for safe navigation in the study area. A simple overview of metocean and environmental conditions for the study area is included in appendix A.

3.2 Navigation Channel Size and Configuration

Per the assumptions stated in the introduction, the anticipated OREI project locations will be seaward of the entrance to the Ambrose Channel, the main shipping channel in and out of the Port of New York and New Jersey. The Ambrose Channel is part of the Lower New York Bay located several miles off the coasts of Sandy Hook, New Jersey, and Breezy Point, Queens, NY. It starts at Ambrose Anchorage and connects to the Anchorage Channel at the north, which extends further north to connect with the Hudson River Channel and East River Channel. Figure 6 shows the layout of the navigation channels into the Port of New York and New Jersey.

In relation to the defined passage lines, the associated relevant navigation channels are as follows:

- Ambrose Channel
- Hudson River Channel
- East River Channel
- Ward Point Bend West Reach
- Sandy Hook Channel—Bayside Reach

The layout and characteristics of each of these channels will be presented in the following.

3.2.1 Ambrose Channel

The length of Ambrose channel is approximately 16.9 miles, and its approximate width is 2000 feet (USACE 2020). It ends about 2000 feet north of the Verrazano Narrows Bridge. Traffic in the Ambrose Channel is two-way for deep-draft vessels, with an occasional overtaking of one vessel by another in the same direction. The depth of Ambrose Channel at its mouth is greater than 90 feet below Mean Lower Low Water (MLLW), while its authorized depth is 53 feet below MLLW. The channel is commercially mined for sand. Inbound vessels reduce their speed to about 12 to 14 knots when entering Ambrose Channel from sea.

3.2.2 Hudson River Channel

The Hudson River Channel, which connects to the Anchorage Channel at the south, maintains a 45-foot depth MLW from Upper New York Bay to West 40th Street, Manhattan, and thence a 48 feet depth MLW to 59th Street. It is approximately 2000 feet wide (USACE, 2020). The width of Hudson River Channel at Port Coeymns is approximately 400 feet (NOAA 2010). The federally authorized navigable depth at Port Coeymans for Hudson River Channel is 32 feet MLLW (COWI 2019).

The width of Hudson River Channel near Tomkins Cove is approximately 2500 feet with a water depth of approximately 65 feet MLLW (NOAA 2020).

3.2.3 East River Channel

The East River Channel, which connects the Hudson River with Long Island Sound, is 40 feet deep, 1000 feet wide from Upper New York Bay to the former Brooklyn Navy Yard, and thence 35 feet deep, 550 to 1000 feet wide to Throgs Neck, NY. It has a total length of 16 miles approximately (USACE, USACE Fact Sheet - East River South Brother Island Channel, New York 2021).

3.2.4 Ward Point Bend West Reach

The Ward Point Bend Reach of the New York and New Jersey channels has an authorized depth of 35 feet and is generally 600 to 800 feet wide with widening at the bend (USACE 2018). The Ward Point Bend West Reach spans from about 4,200 feet seaward of bouy #2 (RED #2 W/LIGHT EBB) to the approximate location of bouy #56 (RED #56 W/LIGHT EBB) with a length of 1.29 miles (USACE 2021). There is unrestricted anchorage area west of Ward Point Bend West Reach (Office for Coastal Management 2022).

3.2.5 Sandy Hook Channel—Bayside Reach

Sandy Hook Federal Navigation Channel provides a secondary route from the ocean to Lower New York Bay. It connects with Raritan Bay Channel to the westward, Chapel Hill Channel to the north, and Terminal Channel to the south. Entrance to Sandy Hook Channel is marked by Scotland Lighted Horn Buoy equipped with a radar beacon (NOAA n.d.). The channel extends 7.1 miles long and has an authorized depth of 35 feet MLLW. It is 800 feet wide and widens at the junction with the Main Ship Channel and at the bend between the East Section and the Bayside Section. (USACE 2022) There is unrestricted anchorage area north of Sandy Hook Channel—Bayside Reach (Office for Coastal Management 2022).

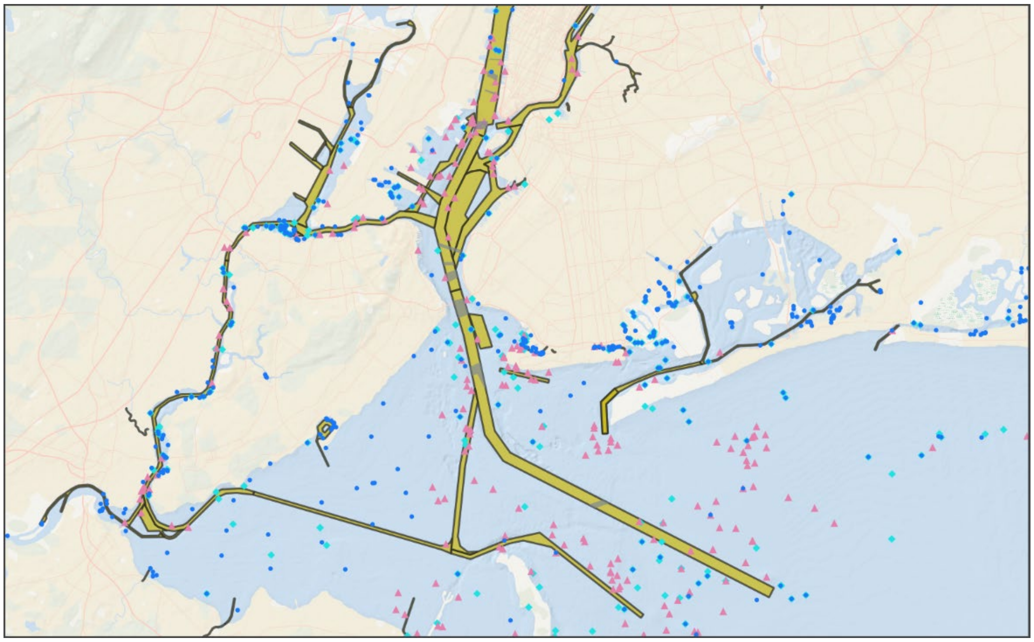
3.3 Obstructions

NOAA's Automated Wreck and Obstruction Information System (AWOIS) and Electronic Navigation Charts (ENC) were consulted to identify submerged wrecks and obstructions in the navigation channels (Figures 3–7). The NOAA Navigational Chart (#12327) was also used to determine the pipeline areas, tunnels, and the cable areas. Information pertaining to obstructions may be relevant when evaluating the navigation risks from OREIs and OSW vessels, in particular if new vessel traffic and routes are introduced. Within the study area for this assessment new waterways are not introduced. OSW vessels are expected to follow existing waterways and the size of the expected vessel traffic is not expected to be different from current users.

Figure 6. National Oceanic and Atmospheric Administration Obstructions

Cyan diamond: AWOIS Wrecks; Pink triangle: AWOIS Obstructions; Blue dots: ENC Wrecks; Grey polygon: NOAA Nautical Chart pipeline and cable areas and tunnels.

Source: COWI (December 2021); ESRI Ocean; Google Earth



3.4 Incident Reports

This section summarizes the screening of an incident report that has been gathered for the relevant channels within the study area. This data can be used to identify areas of high risk and to evaluate the historical probability of vessel aberrancy, collisions, and allisions.

Code of Federal Regulations (CFR) under 46 CFR 4.03 and 33 CFR 153.203 mandate any maritime craft report incidents to the UCSG through an automated system. The instances are reported under the Marine Information for Safety and Law Enforcement (MISLE) database which is managed by the USCG. Information input into this system includes law enforcement, pollution, and, more relevant to this study, marine accidents across the United States major waterways and intercoastal regions. In relation to this report, a high-level investigation of the currently reported instances is portrayed in the table below regarding the channels of interest in the New York State region. Each individual passage line or channel location for potential incidents was investigated and the total reported instances from 20012015 to establish a baseline of total incidents per year. Overall results are listed in Table 4 and filtered to include only larger vessels (vessels larger than 60-meter (m) length overall (LOA) and all tugs).

Table 4. Marine Information for Safety Law Enforcement Data 2001–2015

MISLE Data 2001—2015			
Navigation Channel	**Passage Line Locations**	**Total Potential Incidents***	**Total Incidents Per Year**
Ambrose	The Narrows	27	1.93
Hudson***	Hudson River	80	5.71
East River	East River	32	2.29
Ambrose	Ambrose Channel	27	1.93
Ward**	Ward Point	0	0.00
Sandy Hook**	Sandy Hook	10	0.71

* Total Potential Incidents include reported: allision, manueveability, grunding, environmental damage, capsizes, sinking, collisions, evasive manuevers, and loss of electrial power.

** No offical incidents reported in the Database.

*** The Hudson River Channel is taken from Upper New York Harbor to Albany.

Total reported incidents per year from 2001 through 2015 are presented in Table 5. No yearly trends were observed in this data.

Table 5. Reported Incidents in Area of Interest per Year

Year	Number of Reported Incidents
2014	4
2013	7
2012	7
2011	4
2010	5
2009	5
2008	7
2007	12
2006	11
2005	7
2004	12
2003	12
2002	10
2001	4
2000	4

4 Vessel Characteristics and Traffic

4.1 Approach

The New York Metropolitan Area is one of the busiest maritime hubs in the world, with heavy traffic in all major vessel categories such as cargo and container, tanker, passenger, fishing, military, and recreational. A comprehensive assessment of existing and future vessel traffic for each of the major USCG vessel categories was performed by Cumulative Vessel Traffic Assessment for non-OSW (baseline) and OSW vessels. Results of this assessment formed the vessel quantity inputs into the risk analysis summarized in this report.

Baseline traffic conditions represent existing vessel traffic in the study area. For the purpose of this analysis, 2017 was selected as the baseline year for this study. AIS data for the year was collected, processed, and analyzed as discussed in this section and served as an input for the future vessel traffic conditions projection and evaluation.

Future traffic conditions were developed for years 2017 to 2040 (inclusive) for both non-OSW (baseline) and OSW vessel traffic. The two projections were then compared to assess significance of the future OSW-induced traffic increase in each of the key areas (passage lines).

4.1.1 AIS Disclaimer

As mentioned in the 2022 Port Access Route Study (PARS) for New Jersey, there are inherent limitations associated with using AIS data to estimate and provide insights into vessel traffic:

"AIS traffic data does not capture all vessels that operate in the study area. Federal and international carriage regulations stipulate only certain vessels are required to send and/or receive AIS signals. This includes but is not limited to: vessels of 65 feet or greater, towing vessels of 26 feet or greater, vessels certificated for 150 or more passengers, dredging vessels near a channel, fishing vessels, and vessels over 300 gross tons on an international voyage. A full description of applicability and general United States requirements can be found in 33 CFR 164.46. Despite these limitations, AIS traffic data provides a satisfactory representation of the traffic in the study area. Deep draft and large vessels are required to broadcast an AIS signal; the counts of these vessels as well as their geographic locations area assumed to be accurate. The transit patterns for vessels that are not required to broadcast on AIS, such as small recreational vessels, are apparent even if these vessels are undercounted in the data set. This is based on the assumption that since a portion of the population of vessels not required by law to carry AIS voluntarily comply, these vessels provide a representative sample of the whole population."

4.2 Future Non-OSW Traffic

Future non-OSW (baseline) traffic was projected on an annual basis from 2017 up to 2040. The methodology is described in detail in the Cumulative Vessel Traffic Assessment together with a detailed presentation of the results. Overall results are listed in Table 6 and filtered to include only larger vessels (vessels larger than 60 m in length over all [LOA] and all tugs) in Table 7**.** To provide an overview of the scale of the vessel traffic at the eight passage lines, Figure 7 shows the average number of vessels passing the passage lines per hour. Seasonal trends are not considered and would likely most affect smaller pleasure crafts. It is observed that the Hudson River, East River, and The Narrows passage lines experience the highest volume of hourly vessel traffic in the range of five to 20 vessels per hour. When only vessels larger than 60 m LOA and tugs are considered, the average hourly passages is between 0.2 and 2.2 at all the considered passage lines.

Table 6. Future Non-Offshore Wind Vessel Traffic, Shown as Counts for Each Passage Line

For Years 2017–2040

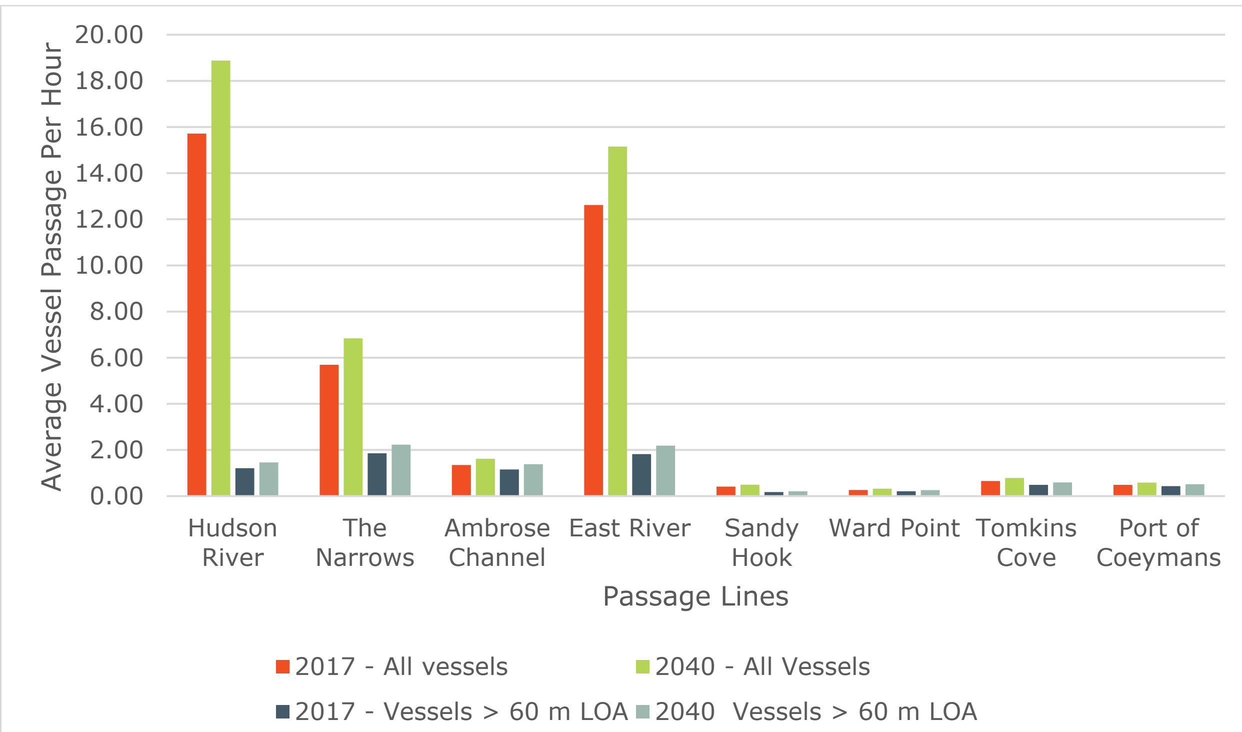
Year	Hudson River	The Narrows	Ambrose Channel	East River	Sandy Hook	Ward Point	Tomkins Cove	Port of Coeymans
2017	137,697	49,859	11,821	110,536	3,648	2,357	5,750	4,303
2020	141,028	51,065	12,105	113,211	3,735	2,414	5,889	4,407
2025	146,760	53,140	12,599	117,812	3,888	2,513	6,130	4,587
2030	152,727	55,300	13,111	122,599	4,046	2,614	6,378	4,774
2035	158,933	57,548	13,644	127,582	4,211	2,721	6,637	4,967
2040	165,393	59,887	14,198	132,769	4,382	2,831	6,907	5,168

Table 7. Future Non-Offshore Wind Vessel Traffic Greater than 60 Meters LOA, Shown as Counts for Each Passage Line

For Years 2017–2040

Year	Hudson River	The Narrows	Ambrose Channel	East River	Sandy Hook	Ward Point	Tomkins Cove	Port of Coeymans
2017	10,635	16,252	10,111	15,980	1,565	1,882	4,321	3,785
2020	10,892	16,645	10,356	16,367	1,603	1,928	4,426	3,877
2025	11,335	17,322	10,777	17,032	1,668	2,006	4,605	4,034
2030	11,796	18,026	11,215	17,724	1,736	2,087	4,793	4,198
2035	12,275	18,758	11,670	18,444	1,806	2,172	4,987	4,369
2040	12,774	19,521	12,145	19,194	1,880	2,261	5,190	4,546

Figure 7. Hourly Baseline (2017) and Future (2040) Non-Offshore Wind Vessel Traffic for Each Passage Line



4.3 Comparing Future Non-Offshore Wind and Future Offshore Wind Vessel Traffic

Future non-OSW (baseline) traffic was projected on an annual basis from 2017 up to 2040 inclusively using publicly available data and reports and using an estimate of the compound average growth rate of 0.8% provided by SUNY Maritime in the Offshore Wind Ports: Cumulative Vessel Traffic Assessment (COWI 2022).

The Cumulative Vessel Traffic Assessment created an analytical OSW VTM which was used to estimate future OSW vessel traffic in the study area. The results were summarized in the form of yearly vessel trip quantities between hypothetical ports and project locations for both capital construction and O&M activities. See section 2.2.

Leveraging the results of the OSW and non-OSW vessel traffic forecast, a comparative assessment was conducted along eight specific lines located in areas referred to as passage lines, which were identified in Cumulative Vessel Traffic Assessment and reiterated in section 2.3. The projected vessel traffic for both OSW and non-OSW at each passage line by year is presented in Table 8.

A summary of transit count increase for each of the passage lines for all vessels is shown in Table 9. It is evident that the largest relative traffic increase is observed at Tomkins Cove, Port of Coeymans and in the Ambrose Channel Passage Line—this is because the other passage lines contain a large amount of passenger traffic, which mainly consist of ferries moving passengers between New Jersey and boroughs of New York State, while the area at Tomkins Cove, Port of Coeymans and the Ambrose Channel primarily handles commercial traffic from locations outside of the New York Harbor.

Table 8. Projected Vessel Traffic for OSW and non-OSW by year and Passage Line

Year	Hudson River		The Narrows		Ambrose Channel		East River		Sandy Hook		Ward Point		Tomkins Cove		Port of Coeymans	
	Non-OSW	OSW	Non-OSW	OSW	Non-OSW	OSW	Non-OSW	OSW	Non-OSW	OSW	Non-OSW	OSW	Non-OSW	OSW	Non-OSW	OSW
2017	137,697	0	49,859	0	11,821	0	110,536	0	3,648	0	2,357	0	5,750	0	4,303	0
2020	141,028	0	51,065	0	12,105	0	113,211	0	3,735	0	2,414	0	5,889	0	4,407	0
2025	146,760	188	53,140	130	12,599	130	117,812	0	3,888	0	2,513	0	6,130	188	4,587	180
2030	152,727	142	55,300	278	13,111	246	122,599	0	4,046	16	2,614	48	6,378	142	4,774	114
2035	158,933	0	57,548	358	13,644	358	127,582	48	4,211	16	2,721	16	6,637	0	4,967	0
2040	165,393	0	59,887	348	14,198	348	132,769	48	4,382	0	2,831	0	6,907	0	5,168	0

Table 9. Fraction of Vessel Traffic Increase Incurred by the OSW Projects, by Year and Passage Line, Relative to the Total Combined Estimated Traffic (non-OSW + OSW)

Year	Hudson River	The Narrows	Ambrose Channel	East River	Sandy Hook	Ward Point	Tomkins Cove	Port of Coeymans
2017	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2020	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2025	0.1%	0.2%	1.0%	0.0%	0.0%	0.0%	3.1%	3.9%
2030	0.1%	0.5%	1.9%	0.0%	0.4%	1.8%	2.2%	2.4%
2035	0.0%	0.6%	2.6%	0.0%	0.4%	0.6%	0.0%	0.0%
2040	0.0%	0.6%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%

With the abundance of smaller recreational crafts and passenger vessels at many of the passage lines, it is considered relevant to provide a comparison that excludes these relatively small vessels. Therefore, large vessels are defined consistently in the Cumulative Vessel Traffic Assessment to be vessels with a LOA larger than 60 m and all tugs irrespective of size as they may be towing a barge. It is observed that the relative impact from OSW vessels increases particularly at the Hudson River and The Narrows passage lines when comparing values in Table 9 and Table 10. However, the overall increase is still between 0–5% across all passage lines.

Table 10. Future Offshore Wind Vessel Traffic at Passage Lines

Large vessels (> 60 m) and tugs only relative increase in traffic counts.

Year	Hudson River	The Narrows	Ambrose Channel	East River	Sandy Hook	Ward Point	Tomkins Cove	Port of Coeymans
2017	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2020	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2025	1.7%	0.8%	1.2%	0.0%	0.0%	0.0%	4.1%	4.5%
2030	1.2%	1.5%	2.2%	0.0%	0.9%	2.3%	3.0%	2.7%
2035	0.0%	1.9%	3.1%	0.3%	0.9%	0.7%	0.0%	0.0%
2040	0.0%	1.8%	2.9%	0.3%	0.0%	0.0%	0.0%	0.0%

5 Potential Effects on Safe Navigation

5.1 Risk Identification

Changes in vessel traffic patterns within a navigation route have the potential to increase the existing risks associated with vessel traffic in that route. Understanding the hazards posed by increased vessel traffic quantity due to offshore wind farms and, furthermore, mitigating the risks associated with the hazards, is necessary to ensure the continued safe practice of vessel navigation within the study area.

Within the confines of the pre-determined study area (i.e., within New York State waterways), the vessel navigation characteristic most affected by construction and operation of an offshore wind farm is vessel traffic density. In alignment with the nature of this study, the cumulative effects of the offshore wind projects on vessel traffic quantity were analyzed in this section to assess the impact on vessel navigation over time.

Risks associated with changes in vessel traffic density in existing waterways is grouped into two main hazards, namely:

1. Allision with fixed object (drifting or motorized).
2. Ship-to-ship collision.

The following sections will address how the two groups may be impacted by the introduction of new OSW vessel traffic. This involves an evaluation of the baseline risk in a situation where OSW vessels are not introduced as well as the future situation where OSW vessel are present. A combination of qualitative and quantitative evaluations will be adopted to provide a nuanced and relevant overview of the impact from offshore wind vessels. Furthermore, the principles for calculating collision and allision frequencies are outlined and discussed. Similar methodology could potentially be applied when carrying out a NSRA for a specific OWF project.

5.2 Allision with Fixed Object

Allision with objects will, in the context of this study and associated study area generally be bridges, reefs, the shoreline, or other fixed structures. When carrying out the NSRA for a specific OREI the most predominant allision scenario will likely be with the OSW turbines. Irrespective of the object of impact, the methodology for calculating allision frequency P can be described by the following expression:

$P = N \cdot Pc \cdot G \cdot R$

where:

- N is the frequency of ships within the considered timeframe.
- Pc is the causation probability (the probability of aberrancy that potentially can lead to allision or collision. For drifting vessels this may be the blackout frequency).
- G is the geometrical probability of a vessel heading towards an object.
- R is the combined effect of accident risk reduction factors arising from e.g., Vessel Traffic Services (VTS), Traffic Separation Scheme (TSS), Electronic Chart Display and Information System (ECDIS)—and/or pilotage.

The principles behind the estimation of the above parameters and the impact OSW vessels may have on them will be outlined in the following.

The main factor considered to be influenced by the introduction of OSW vessels is the frequency of ships N. The frequency of vessel allisions with fixed objects is expected to increase proportional to the increase in vessel traffic (see Table 9 and Table 10) i.e., approximately 1–5% depending on the considered passage line and whether or not only large vessels are considered.

The causation probability, P_C, is the probability of a ship being aberrant or failing to correct to intended course on the navigation route. Factors that may influence the causation probability are the visibility, wind, current, traffic density and waterway characteristics. The literature suggests a number of different values and methods to be used for the causation probability. The American Association of State Highway and Transportation Officials (AASHTO) guideline used to calculate probability of impact with bridges suggests that the causation probability be based on accident statistics or alternatively it be taken as 0.6×10^{-4} per passage for ships and 1.2×10^{-4} per vessel passage for barges.

Considering the incident statistics extracted and presented in section 4.4 the causation probability can be estimated to be in the range of 1×10^{-4} to 5×10^{-4} per vessel passage. Vessel passage information from 2017 is used to convert incidents per year to incidents per passage. Optimally, vessel passages for each of the years from 2001 to 2015, corresponding to the years of the accident data, should have been used. However, in the absence of this information the estimates provide a rough order of magnitude and suggest that the proposed value in AASHTO and other sources (Larsen 1992) seems applicable also within our study area. Overall, the causation probability is not expected to change significantly as a result of the estimated OSW vessel traffic.

The geometric probability of a vessel heading toward an object is not expected to change within the study area. OSW vessel are expected to follow the existing routes and channels and lateral distribution across channels. Drifting allisions will for all vessels be impacted by wind and current direction with no specific impact from OSW vessels.

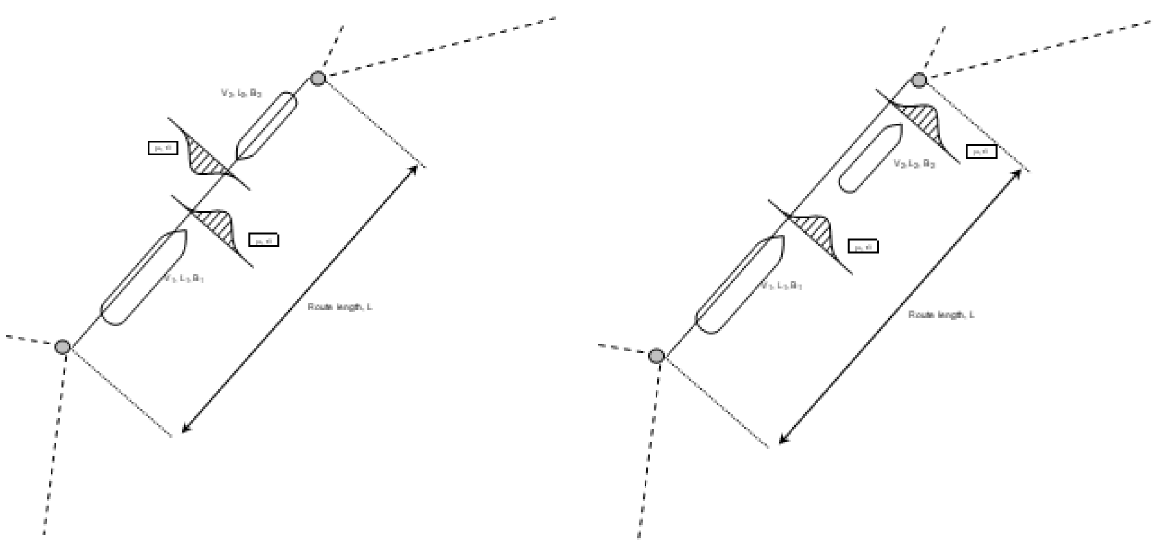
Risk reducing measures may be introduced generally or project specifically by the authorities and/or developers. A cursory review of some potential mitigation measures is found in section 6.

The majority of the input parameters to calculate allision frequency remain more or less unaffected in the future scenario with OSW vessel traffic. The frequency of vessel allisions with fixed objects is expected to increase proportional to the increase in vessel traffic i.e., approximately 1–5% depending on the considered passage line and whether or not only large vessels are considered.

5.3 Ship-to-Ship Collision

Collisions between two ships are generally divided into two types, namely route collision and node collisions. Route collisions arise from vessels navigating in parallel, either in the same direction (overtaking) or opposite direction (head-on) as displayed in Figure 8. Node collisions, arising from bends/crossings in the navigation channel are generally also relevant, but there are no nodes in the vicinity of the passage lines and this scenario is not considered to change appreciably within the study area. It may, however, be relevant when varying out the project specific NSRA where new routes may be introduced.

Figure 8. Principles for Calculation of Ship-to-Ship Collisions



The calculation of collision frequencies of route collisions is based on the same principles as collisions with fixed objects. The key inputs are the length of the route segment, the traffic intensity in each of the two directions, the width and speed of the ships, the deviation of the ships from the route axis and the causation probability of a ship being aberrant or failing to correct to intended course on the navigation route. A detailed description of the model is provided in appendix B.

The meeting frequency of two vessels is one of the key inputs, and this information is obtained by combining every ship with every possible collision partner and hence, the number of meeting situations is proportional to the square of the vessel traffic.

The geometrical collision probability is obtained based on the lateral distribution of vessels across the waterway or channel taking into account the breadth of the ship as well. A normal distribution is assumed for the vessel traffic in each direction. The distribution and geometrical collision probability is not considered to be impacted from the OSW induced vessel traffic.

The causation probability represents the probability that two ships sailing on collision course do not undertake any evasive measures. The impacting factors are similar to those described in the previous section and are not expected to be significantly impacted by the projected OSW vessel traffic.

To provide an idea of the change in collision frequency for this scenario, a number of rough calculations were carried out based on the calculation principles described above and detailed in appendix B. Vessel traffic distributions were established based on available information from Automatic Identification System (AIS) data and the width of the channel. While these calculations cannot be seen as exact results, they provide a reasonable indication of the expected impact. Only the year with maximum added OSW vessel traffic is considered as well as the 2017 baseline year. Overall, the return period for ship-to-ship collisions within the considered area was estimated to be nine years based on 2017 vessel traffic. The increase in collision frequency from future non-OSW vessel traffic increase was generally leading to an increase in ship-to-ship collision of 10–40% depending on the year considered.

The estimated collision frequencies resulting from OSW vessel traffic were found to increase by 1–10% in the year with the largest OSW vessel traffic increase when comparing to the results for that same year without OSW vessel traffic.

5.4 Summary of Findings

In this chapter the identified risks were presented and evaluated. The two considered risks are:

1. Vessel collision with fixed object.
2. Ship-to-ship allision.

The principles for evaluating the above risks have been presented along with a semi-quantitative evaluation based on available vessel traffic information.

The expected increase in vessel allisions with fixed objects is roughly proportional to the increase in vessel traffic which was previously estimated to be 1–5% at the considered passage lines.

In the case of ship-to-ship collisions the number of meeting situations increase with the square of the vessel traffic increase and hence the increase in ship-to-ship collision probability is found to be slightly higher for this scenario and generally between 1–10%. It is observed that the expected increase in risk resulting from assumed development in non-OSW vessel traffic vastly exceeds that associated with OSW vessel traffic.

6 Mitigation Measures

This section covers a cursory review of navigational rules and mitigation measures that may be relevant on a local and regional level to address risks associated with an increase in vessel traffic identified in the previous sections. However, it will always be the developer and regulatory authorities who determine the extent of mitigation measures required to obtain an acceptable risk level for a specific project.

6.1 Navigational Rules

To mitigate potential risks to navigational safety, navigational rules as outlined by governing authorities must be followed. According to USCG Navigation and Vessel Inspection Circular No. 01-19 (United States Coast Guard 2019), navigation safety requires that mariners are able to:

- Determine their position at all times.
- Determine a safe course to steer well in advance of detecting a potential obstacle.
- Be aware of unseen dangers via charts, maps, or signs.
- Determine if risk of collision or allision exists either visually or when using radar systems.
- Take action to avoid collision and allision.

Additionally, vessels, including those with OREI-associated navigational purpose, must adhere to the USCG Navigation Rule and Regulations Handbook (United States Coast Guard 2014). The Handbook consists of the following rules and regulations for operating vessels:

- 77 COLREGS: International Regulations for Preventing Collisions at Sea, 1972.
- 33 CFR 83: Inland Navigation Rules.
- 33 CFR 84-90: Respective technical annexes to the above.
- 33 CFR 80: COLREGS Demarcation Lines.
- 33 CFR 26: Vessel Bridge-to-Bridge Radiotelephone Regulations.
- 33 CFR 161: Vessel Traffic Management Regulations.

Additional pertinent provisions of the U.S. Code and Code of Federal Regulations regarding compliance and penalties associated with the Navigation rules.

Additional local navigational restrictions and regulations may be present and must be adhered to by all vessel traffic.

6.2 Mitigative Measures

Referring to USCG Navigation and Vessel Inspection Circular No. 01-19 (United States Coast Guard 2019), potential mitigations to the possible increase in navigation risk caused by intensified vessel traffic density and/or changes to navigation patterns because of the installation of OREI projects and introduction of new offshore wind vessel types within existing navigation channels are listed below. These measures are generally already adopted and could potentially be expanded or extended to address new risks:

- Aids to navigation (ATON).
- Pilotage in high congestion areas.
- VTS and AIS-based services.
- Precautionary areas and areas to be avoided.
- Anchorage restrictions.
- Limited access areas.
- Advanced notification systems.
- Other routing measures.

Specific examples of risk mitigation strategies provided in NVIC 01-19 (United States Coast Guard 2019) that are applicable to risks studied include:

- Monitor vessel traffic on a regular basis (i.e., monthly) and continuously assess trends. Continuous monitoring may help identify new passage lines or areas of interests that may not have been captured during the permitting stage of OREI projects. If problematic areas are detected, competent jurisdictions may be able to enable information broadcast (live information) to vessels; or work with the USCG and/or NOAA to inform mariners via navigation charts.
- Marine structure upgrades (such as pier extensions, mooring facilities upgrades, or terminal reconfiguration) may cause obstructions to navigation and in turn, increase the risk of collision and allusion. Awareness shall be maintained as port upgrades are performed. Changes to the topography or configuration of constricted channels (particularly further inland) should be communicated to NOAA, USCG, in a timely manner.
- Provision of forecast vessel traffic estimates and coordination with local authorities on management of increased vessel traffic, specifically in the passage lines identified in this study.
- Advertisement of information and warnings of increased vessel traffic as well as vessel types through Local Notices to Mariners and Broadcast Notice to Mariners, as well as other media channels (including mobile and satellite phones, multi-channel very high frequency [VHF]).
- Provision of cautionary notation on nautical charts during execution of the construction and operation phases. The rise of digital NOAA electronic navigation chart products facilitate rapid update cycles.
- Continuous communications watch using multi-channel VHF, including digital selective calling.

Mitigating factors and examples as described above are typically implemented with the intent of lowering risk, including raising situational awareness, increasing local knowledge and expertise, or improving navigation (United States Coast Guard 2019).

The proposed OREI projects are in an early stage, with only a few key parameters known at this time. This limits our ability to describe their impacts on navigation safety in more detail. When the projects have sufficiently advanced to later design stages, we recommend coordination with governing authorities to manage additional potential risks induced by increased traffic density and introduction of new vessel types to the navigation routes as well as increasing awareness of these effects among mariners. We anticipate that a project specific NSRA be produced together with an update of this study to consider the combined effects of increased vessel traffic. Integrating these projects and managing risks will be of utmost importance to ensure safe, continued use of the navigation routes in the study area.

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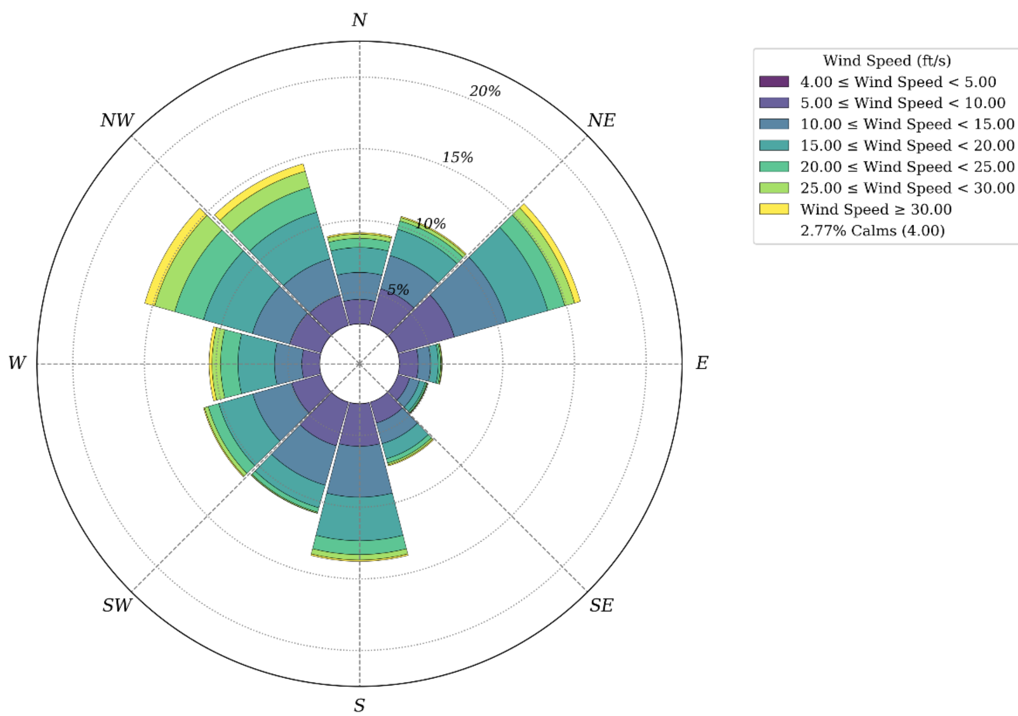
Appendix A. Metocean Conditions

A.1 Wind Data

A wind rose extracted from data from La Guardia Airport (NOAA 2018) is displayed in the figure below.

Figure A-1. La Guardia Airport 1-Hour Wind Speed Rose



A.2 Water Levels

The tides in New York Bight are semi-diurnal with a period of about 12.4 hours. Tidal datum at NOAA Station Sandy Hook, NJ (Station ID 8531680) is provided in Table 11. The mean tidal range at Sandy Hook is 4.7 ft. The highest observed tide at Sandy Hook was 7.27 ft, NAVD88 at 09/12/1960 13:00, while the lowest observed tide there was -7.53 ft, NAVD88 at 02/02/1976 16:00.

Table A-1. Table Tidal Datums at NOAA Station Sandy Hook, NJ, 1983–2001 Epoch

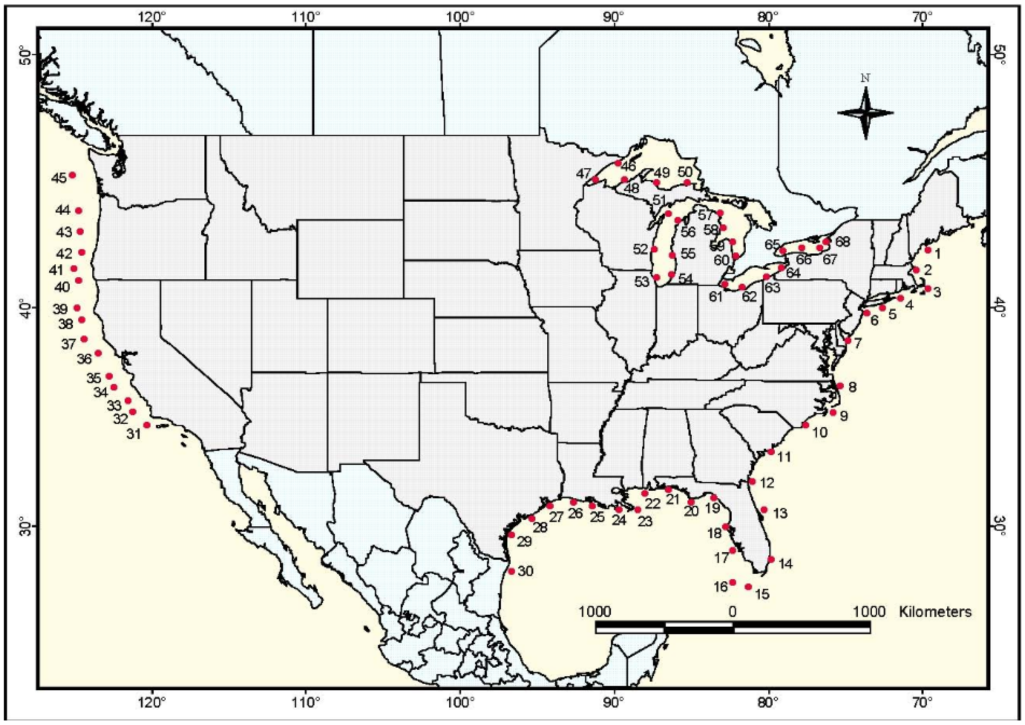
Tidal datum	Value [ft]	Definition
MHHW	5.23	Mean Higher High Water
MHW	4.89	Mean High Water
DTL	2.61	Diurnal Tide Level
MTL	2.54	Mean Tide Level
MSL	2.58	Mean Sea Level
MLW	0.19	Mean Low Water
MLLW	0.000	Mean Lower Low Water
GT	2.71	Great Diurnal Range
MN	2.19	Mean Range of Tide
DHQ	-2.18	Mean Diurnal High Water Inequality
DLQ	-2.32	Mean Diurnal Low Water Inequality
NAVD	2.82	North American Vertical Datum of 1988 (NAVD88)
LWI	19.28	Greenwich Low Water Interval
HWI	-1.57	Greenwich High Water Interval

A.3 Wave Climate

The wave climate at New York Bight comprises of a mixture of swells that propagate from offshore and locally generated wind-waves. The USACE provides representative mean wave statistics at two locations in the vicinity of New York Bight (see Point 5 and Point 6 in Figure 10).

Figure A-3. Map of Locations with Representative Wave Statistics in Atlantic Ocean

Source: USACE Coastal Engineering Manual



A.4 Currents

Tidal currents in New York Harbor and New York Bight are moderate, with ebb currents ranging from -1.1 to -2.1 knots and flood currents ranging from 0.6 to 2.2 knots (USACE 2020). Table 12 shows the ebb and flood currents condition at stations throughout New York Harbor and New York Bight, with the locations of the stations presented in Figure 11.

Table A-4. Ebb and Flood Currents Throughout New York Harbor and New York Bight

Source: (USACE 2020).

Location	Average Ebb (knots)	Average Flood (knots)
Ambrose Channel	-1.68	1.54
Robbins Reef	-1.58	1.28
The Narrows	-2.00	1.31
Bergen Point West	-1.49	1.84

Figure A-4. Locations of the Currents Stations

Source: (USACE 2020).

Appendix B. Probability of Two Ships Being on Collision Course

The geometric probability of two ships being on collision course $P_g(SS)$ is an input parameter to the model describing ship-bridge collision due to ship-ship collision evasion manoeuvres.

There are two types of ship-ship collisions, only route collisions are considered in this analysis:

- Route collisions
- Node collisions

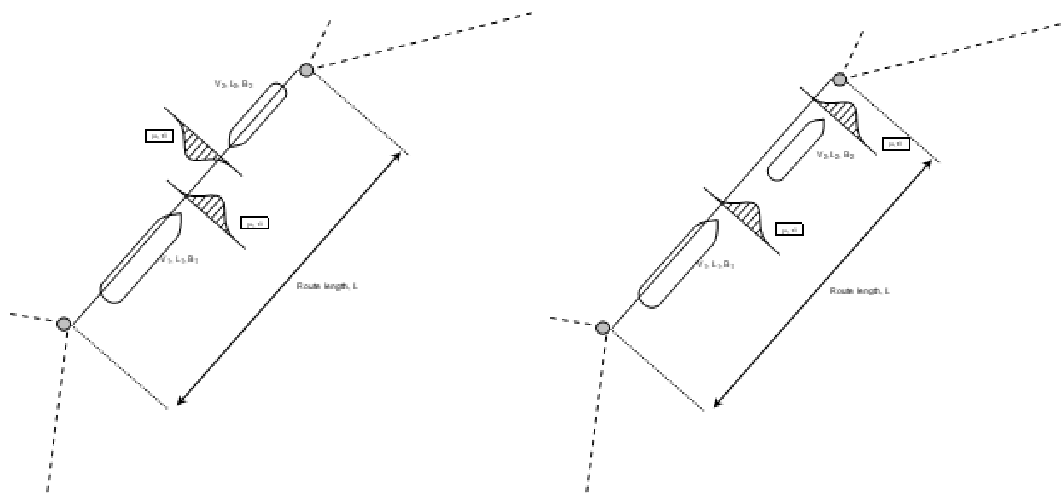
B.1 Route Collisions

When two ships collide while sailing on the same route, this is referred to as route collision. There are two basic cases:

- Head-on collisions between two ships heading in opposed directions.
- Overtaking collisions between two ships heading in the same direction.

These two cases are illustrated in Figure 12.

Figure B-1. Head-On and Overtaking Collisions



For route collisions, $P_g(SS)$ depends on:

- the length of the route segment.
- the traffic intensity in each of the two directions.
- width and speed of the ships.
- the deviation of the ships from the route axis.

In the course of calculation, every ship (ship_1) is combined with every possible collision partner (ship_2). Then, their collision probability is calculated. Both ship_1 and ship_2 have an array of properties such as ship type, speed, size, breadth which are all taken into account.

Two ships sailing along the same route get on collision course with a yearly frequency of:

$$\mathbf{r_x = r_t \cdot P_{g0}}$$

where:

r_t = yearly frequency of meeting within one route segment (a matter of time and route length)

P_{g0} = basic geometrical collision probability (a matter of width)

For ship_1, the probability of getting on collision course with another ship during a given passage is:

$$\mathbf{P_g(SS)=r_x \cdot N_1 \cdot P_g(SS)=r_x \cdot N_1}$$

where: N_1 is the yearly number of ship passages of ship_1.

The partial probabilities are obtained as:

$$r_t = LN_1N_2\left|\frac{V_1 - V_2}{V_1V_2}\right|$$

where:

L = length of route segment

N_1, N_2 = yearly number of passings (ship_1, ship_2)

V_1, V_2 = vessel speed (ship_1, ship_2)

Basic geometrical collision probability:

$$P_{g0} = \Phi\left(\frac{|\mu_1 - \mu_2| + \overline{B}}{\overline{\sigma}}\right) - \Phi\left(\frac{|\mu_1 - \mu_2| - \overline{B}}{\overline{\sigma}}\right)$$

with $\overline{B} = \dfrac{B_1 + B_2}{2}$ and $\overline{\sigma} = \sqrt{\sigma_1^2 + \sigma_2^2}$

where:

m_1, m_2 = mean value of the transversal position of $ship_1$ and $ship_2$, respectively, relative to the route axis

s_1, s_2 = standard deviation of the transversal position of $ship_1$ and $ship_2$, respectively, relative to the route axis

B_1, B_2 = beam ($ship_1$, $ship_2$)

F(…) = Cumulative density function of the standard normal distribution

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