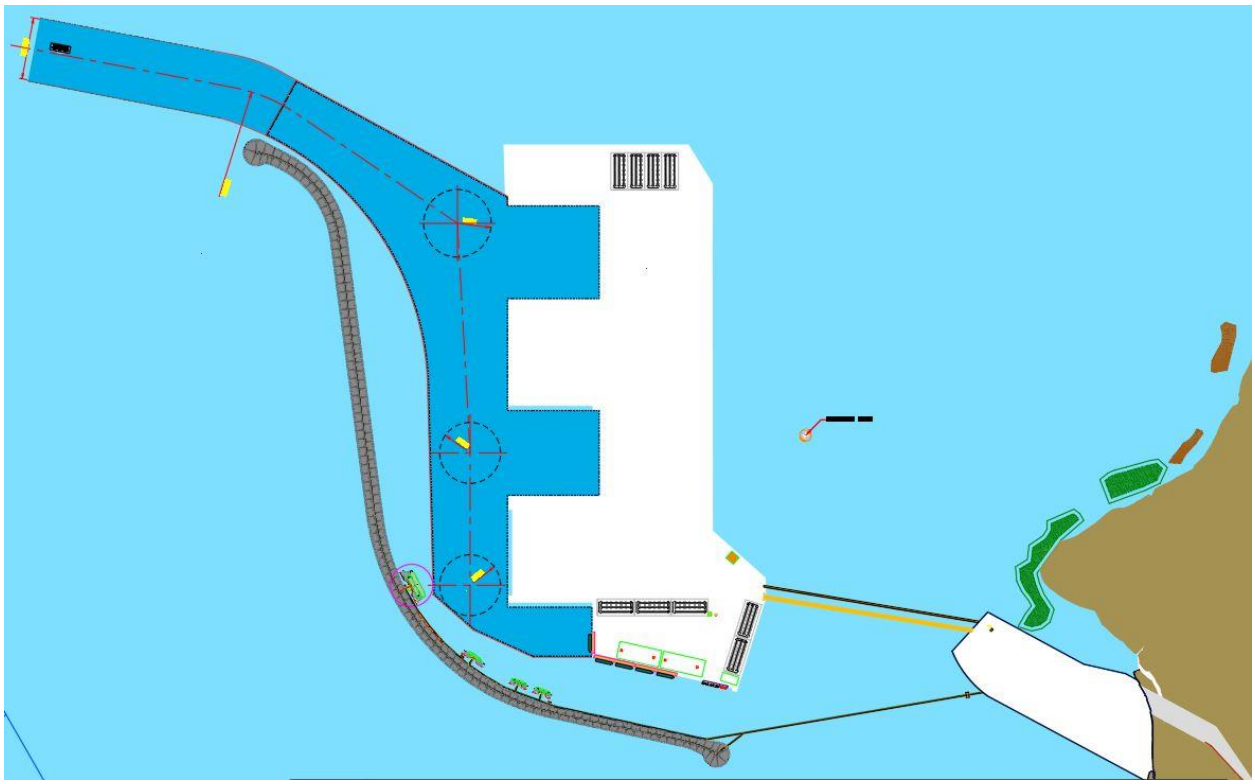
Vadhavan Port
Proposed New Layout

2D Desktop Navigation Simulation Study

FORCE Singapore **Date: 18 March 2022**



FORCE Singapore

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2D Desktop Navigation Simulation Study

FINAL Report

Client: DHI India	***Client's Ref.:*** WO No. 63802607-DHI/WO/February 2022 (Vadhavan Port)
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Abbreviation list

FT	FORCE Technology Maritime Simulation Services Pte Ltd
DHI	DHI (India) Water & Environment Private Limited
RHDHV	Royal HaskoningDHV Engineering (India)
ASD	Azimuth Stern Drive
CD	Chart Datum
kts	knots
LOA	Length Overall
m	metres
mins	minutes
NE	North-east
nm	nautical miles
NW	North-west
SE	South-east
stbd	starboard
SW	South-west

1 Introduction

Vadhavan port is proposing a new layout for the port compared to the layout that was used during a navigation simulation study that was made in August 2018.

The aim of this paper is to report on the 2D desktop simulation study work for the proposed new layout for Vadhavan port carried out by FORCE Technology Maritime Simulation Services Pte Ltd Singapore in accordance to the Term of Reference and consultancy agreement with DHI.

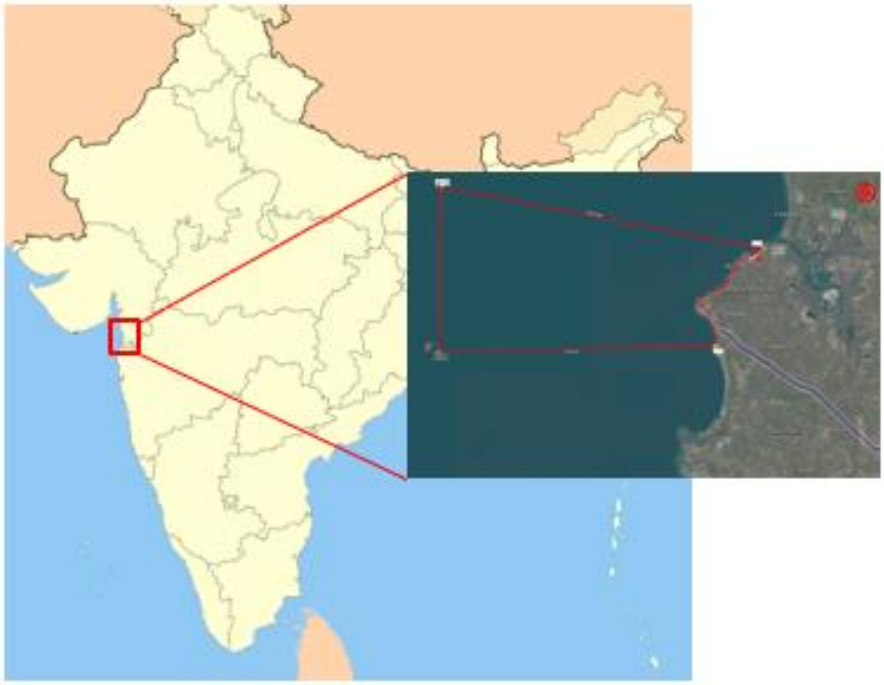


Figure 1 - Location of Proposed Vadhavan Port (Source: Force)

The conclusions and recommendations provided in this report are based on the results of the simulation exercise and the findings made by FT Master Mariner/Pilot.

All ship simulation assessments were conducted by experienced Master Mariners with pilotage experience.

1.1 Objectives

The scope of work and objective of the 2D desktop navigation simulation study is to identify potential concerns, if any, and verify safe clearing distance in the approaches to berth and un-berth the largest design container vessel at proposed new layout of Vadhavan Port container terminal 1 and 2.

2 Model Setup

Virtual based engineering and testing in environments replicating reality, i.e. using simulators to mimic reality is a highly efficient way to verify the efficiency of a proposed port layout and identify associated manoeuvering risk of berthing and un-berthing the designed ship size to the berth with adjacent infrastructure.

This section documents the data used in setting up the SIMFLEX navigation simulator.

A 2D database environment model of the proposed new layout at Vadhavan Port and study area with sufficient accuracy and detail level was created by FT and programmed into FT simulator.

2.1 Study Area Description

The study area covers the port basin and the approach to the two berths at container terminal 1 and 2. The study does not cover the approach channel/fairway as the previous 2018 study had already covered the area.

Vadhavan Port proposed new layout consist of a port basin with three turning circles. Turning circle no.1 has a diameter of 800m. Turning circle no.2 and no.3 each has a diameter of 720m.

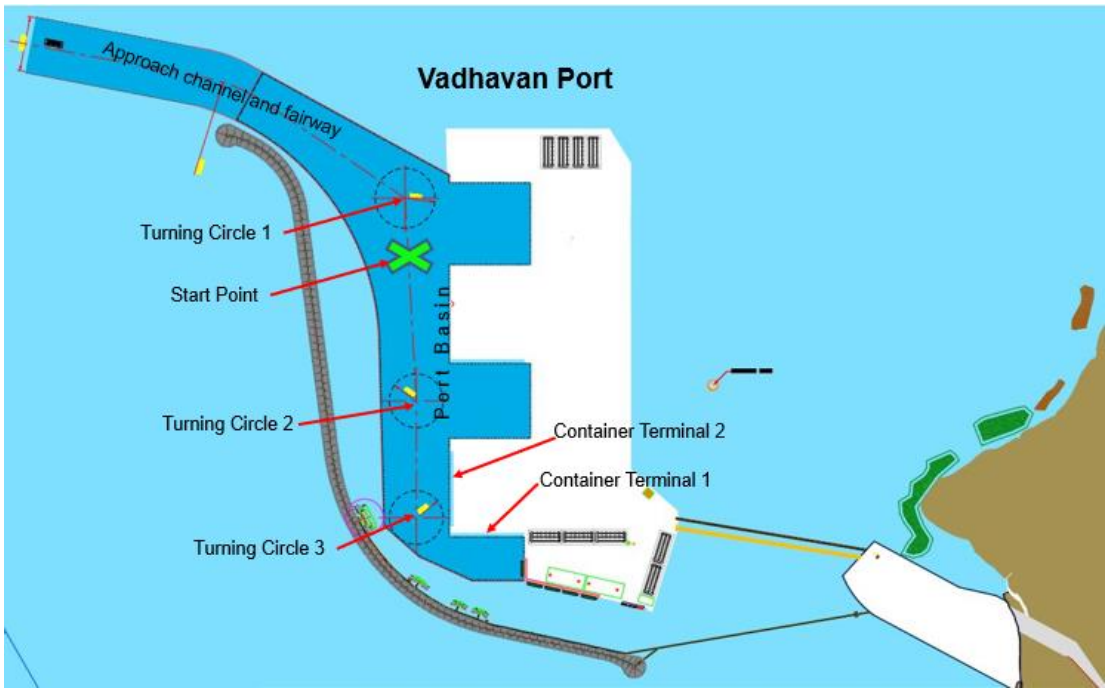


Figure 2 – Vadhavan Port basin and approach to study berths (Source: Force)

The study simulation run starts from south of turning circle no. 1 with all four tugs being made fast as shown in above Figure 2.

The two berths for study are located at the corner between container terminal 1 and 2 as shown in below Figure 3.

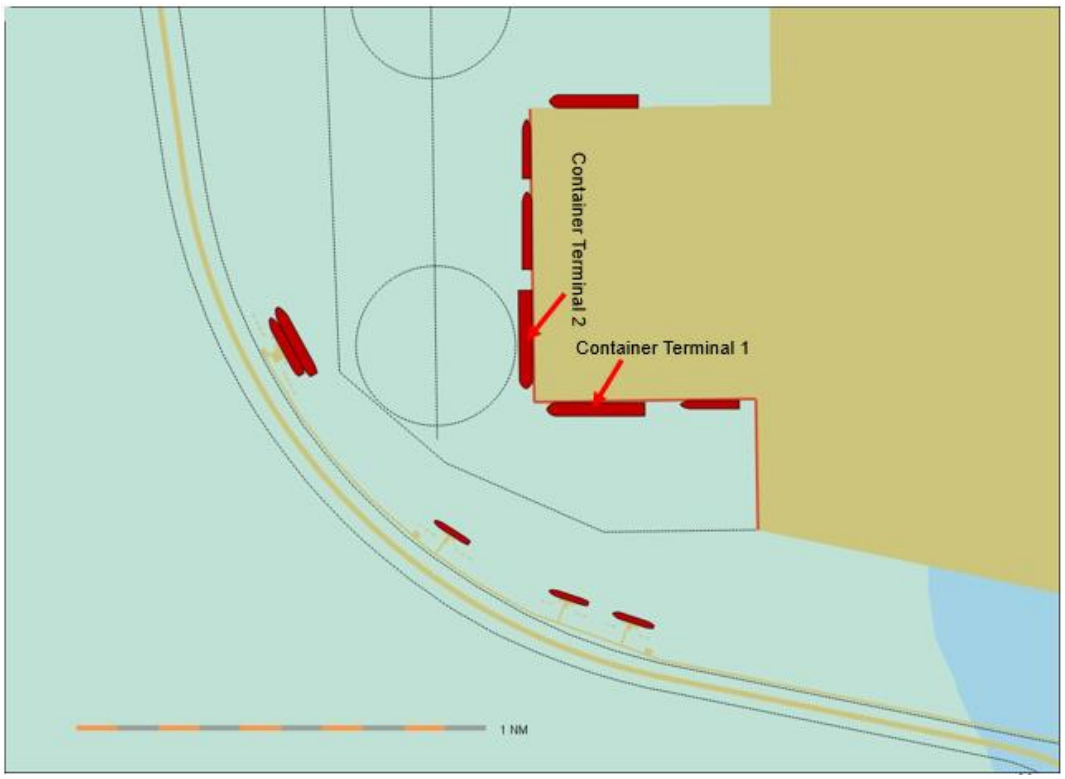


Figure 3 - Location of 2 berths for study (Source: Force)

2.2 Ships at Berth

In order that a worst-case scenario on the availability of manoeuvering space be tested in the port basin, it was proposed that all berths along the approach be occupied and have a moored ship at the berth.

Figure 4 - Ship at berth (Source: Force)

2.3 Bathymetry

Bathymetric grid mapping data of area was provided by DHI for the study area as shown below.

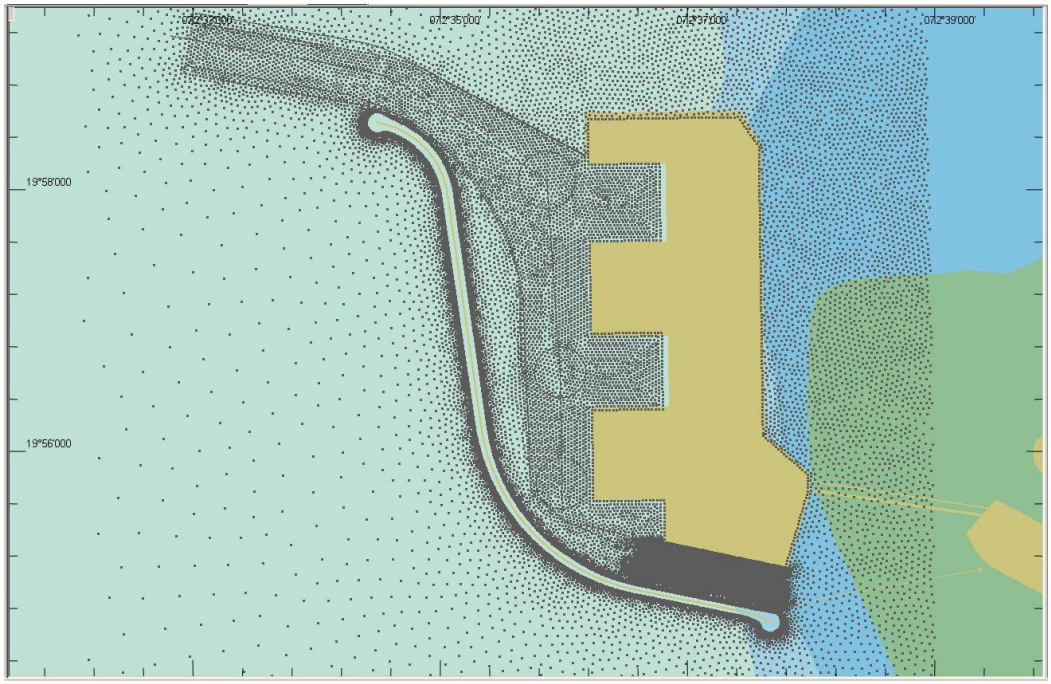


Figure 5 - Bathymetry grid map for study area (Source: DHI)

Port basin area was dredged to a depth of 19.5m below CD

2.4 Tidal Height

For the navigation simulation study, all scenarios were taken with zero tide.

2.5 Tidal Current

A total of two tidal time-stamps for the maximum flood and maximum ebb currents were imported into FT SIMFLEX simulator. The current profiles in the study area are shown in the figures below:

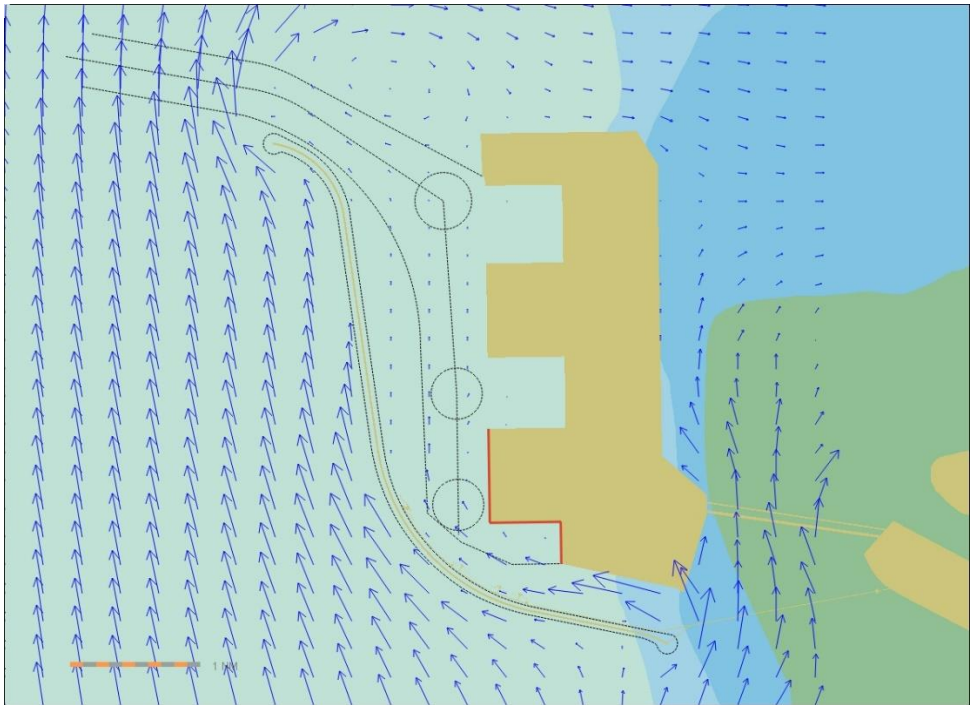


Figure 6 - North Flowing Maximum Flood Current (Source: DHI)

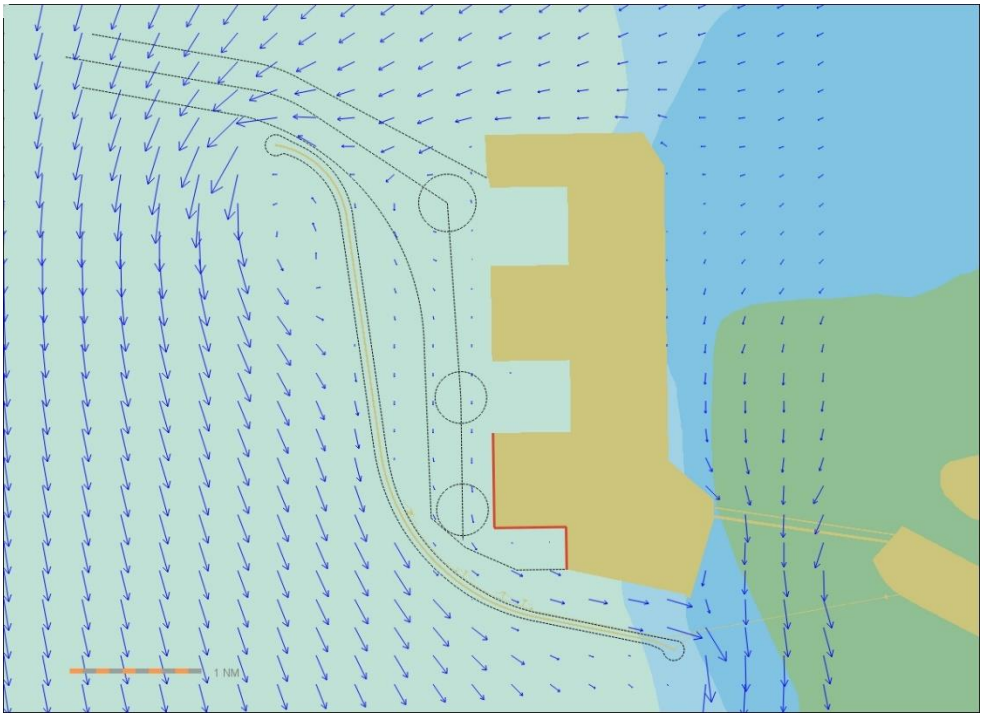


Figure 7 - South Flowing Maximum Ebb Current (Source: DHI)

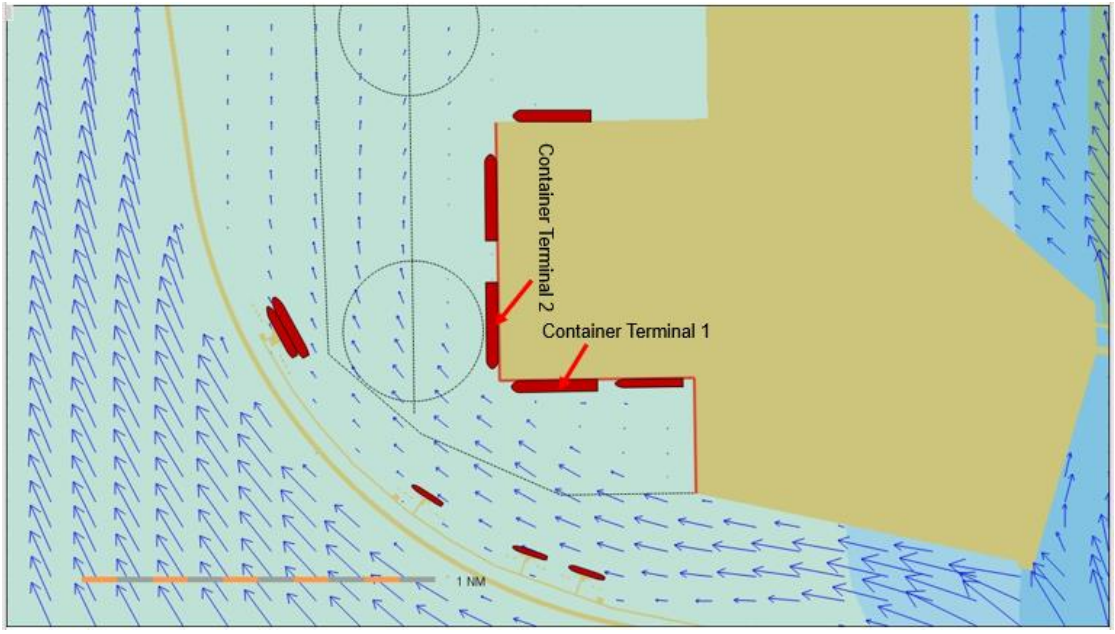


Figure 8 - North Flowing Maximum Flood Current at two study berths (Source: DHI)

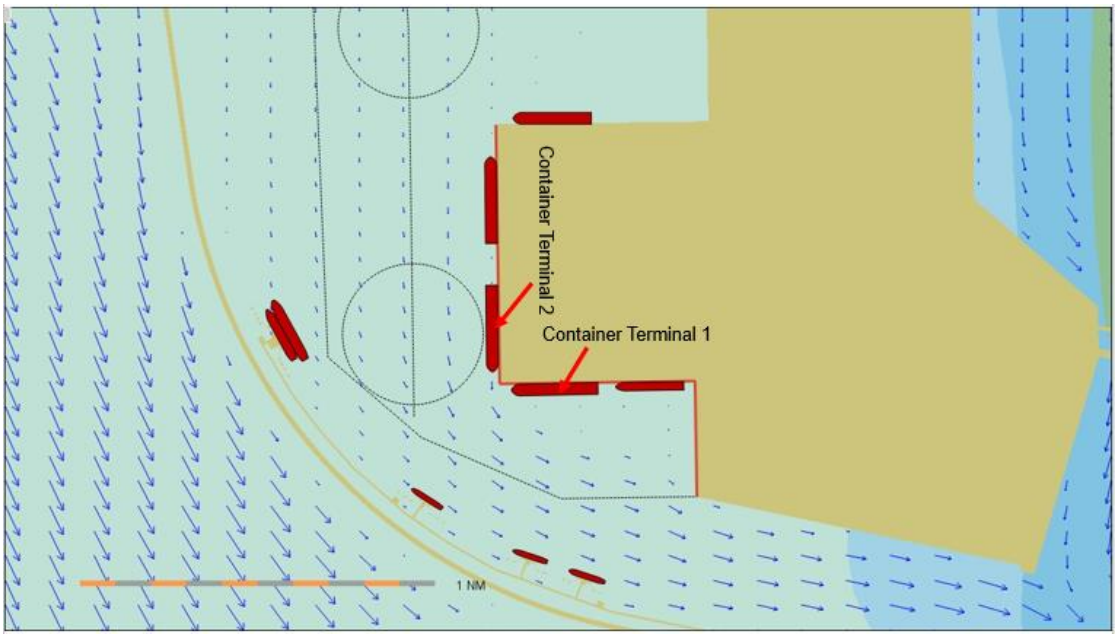


Figure 9 - South Flowing Maximum Ebb Current at two study berths (Source: DHI)

The tidal current during flood flows in the northerly direction with speed ranging from 0.9 knots to 1.9 knots at the vicinity of the two berths and near the berth corner.

The tidal current during ebb flows in the southerly direction with speed ranging from 0.4 knots to 1.1 knots at the vicinity of the two berths and near the berth corner.

2.6 Prevailing Wind

Following wind rose (Figure 10) provided by DHI metocean report describes the wind intensity and direction in the study area.

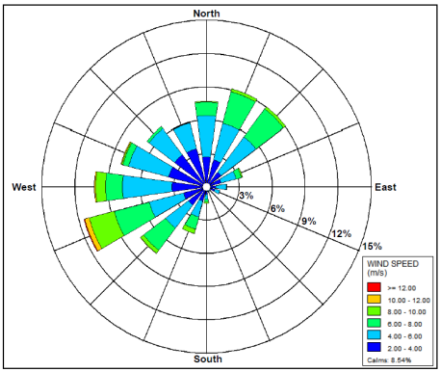


Figure 10 - Wind Rose of study area (Source: DHI)

Wind Speed (m/s)	2.00 - 4.00	4.00 - 6.00	6.00 - 8.00	8.00 - 10.00	10.00 - 12.00	>= 12.00	Total (%)
Wind Direction (Deg N)						Calm %	10.76
22.50	2.53	3.35	2.94	0.27	0.00	0.00	9.09
45.00	1.71	3.96	3.11	0.24	0.00	0.00	9.02
67.50	1.40	1.40	0.51	0.10	0.00	0.00	3.42
90.00	0.85	0.96	0.03	0.00	0.00	0.00	1.84
112.50	0.79	0.51	0.00	0.00	0.00	0.00	1.30
135.00	0.27	0.17	0.03	0.00	0.00	0.00	0.48
157.50	0.38	0.07	0.03	0.00	0.00	0.00	0.48
180.00	0.68	0.41	0.27	0.10	0.00	0.00	1.47
202.50	1.33	1.47	1.13	0.44	0.00	0.00	4.37
225.00	2.08	2.60	2.49	0.34	0.03	0.00	7.55
247.50	2.15	3.25	3.28	2.32	0.44	0.07	11.51
270.00	3.14	4.48	1.54	0.89	0.14	0.00	10.18
292.50	3.59	3.72	0.55	0.10	0.10	0.00	8.06
315.00	3.66	2.90	0.24	0.00	0.00	0.00	6.80
337.50	3.55	2.36	0.07	0.03	0.00	0.00	6.01
360.00	2.70	3.69	1.20	0.07	0.00	0.00	7.65
	30.82	35.29	17.42	4.92	0.72	0.07	100.00

Table 1 - Wind Occurrence Percentage Table (Source: DHI)

Table 1 is the wind occurrence percentage table showing direction and percentage of occurrence at various wind speed.

Although, the wind direction is variable, there are two dominant directions in the NE and WSW quadrant with wind speed about 4 m/s and 6 m/s respectively, which corresponds to the Northeast and Southwest Monsoon seasons. For a conservative estimate, the navigation study uses a prominent wind direction and speed as shown in Table 2 below.

During Monsoon	Wind Direction From	Wind Speed
North East Monsoon	045degrees	10 knots
South West Monsoon	250 degrees	15 knots

Table 2 - Prominent maximum wind direction and speed used in study (Source: Force)

In the simulator, the wind speed is given in "meteorological wind speed" which corresponds to a 10- minute mean wind at 10-metre height.

2.7 SIMFLEX - Simulation Ship Model Specification

The following SIMFLEX ship model was used for the navigation simulation study. The main particulars of the ship model can be seen in Table 3 below. For the full documentation on the ship model please refer to Appendix 5 of this report.

Model	Vessel	LOA (m)	Beam (m)	Draft (m)	Displacement (m3)	Propeller	Rudder	Thruster
3749	20,000 TEU Container	440.0	60.0	16.0	300,040	1F	1	2xFwd 2 x Aft

Table 3 - Simulation Ship Model Particulars (Source: Force)

The above ship model was selected from the available ships in the SIMFLEX library that most closely match the expected largest berth design vessel of the proposed container terminal berths.

Figure 11 - Ship Model 3749 – Post Panamax Container Ship (Source: Force).

The ship model 3749 is a Post-Panmax Container ship with a capacity of 20,000 TEU, a LOA of 440 m and a beam of 60 m. The vessel is modelled in a loaded condition with a full load of containers on deck. It is driven by a diesel engine of 82 MW and has a fixed pitch propeller. The vessel is equipped with one semi-spade rudder mounted in the centreline and has two bow thrusters and two stern thrusters. The bow and stern thruster were NOT USED during the simulation study.

2.8 Basis for Mathematical Ship Model

The mathematical model of the ship is based on the mathematical model of an existing similar ship. The manoeuvring and sea keeping properties have been scaled to fit the conditions of the present ship. Wind load data has been obtained from wind tunnel test measurements of a similar ship.

2.9 Tugs in the Simulator

During simulation runs Vector Tugs were used to simulate 65-ton and 100-ton bollard pull ASD tugs of about 30m LOA. The vector tugs were controlled by the simulator operator and can push or pull in a given direction and/or with a given force as

requested by the pilot/captain. Length of tug line used was between 35m to 70m and changes depending on surrounding space available when pulling on ship.

Figure 12 – 65-ton Bollard Pull ASD Tug (Source: Force)

Figure 13 – 100-ton Bollard Pull ASD Tug (Source: Force)

Just like real tugs, vector tugs are influenced by current, the assisted ship's speed, the wind force and requires a realistic time span to move/change position. The agility of the vector tugs was set to "intermediate" in the SIMFLEX simulator.

Documentation on the tug model used can be found in Appendix 5 of this report.

3 Methodology

3.1 Simulator Procedure

The 2D desktop navigation simulation runs were conducted using Force Technology SIMFLEX desktop simulator in real time. The below picture shows the SIMFLEX desktop simulator.

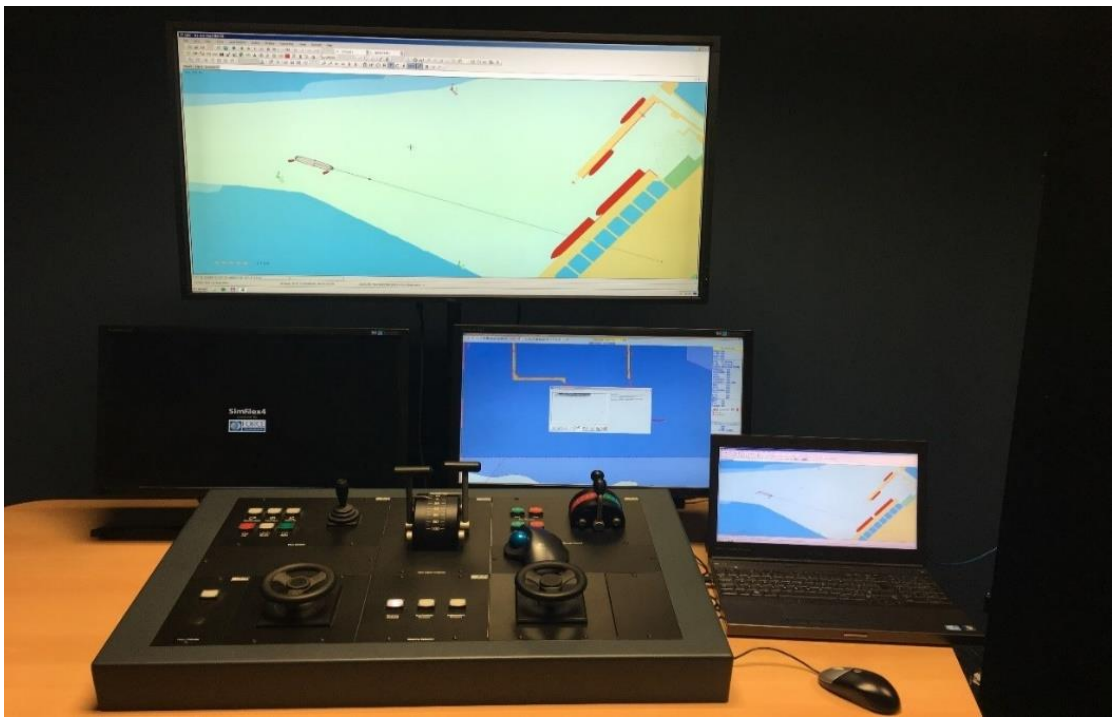


Figure 14 – Force Technology SIMFLEX desktop 2D simulator (Source: Force)

The simulator was controlled by a navigator, the 'Captain', with a mock-up of a standard navigation bridge engine telegraph and rudder controls in front of a screen with a "Bird's eye" view of the study area.

Information about wind, current, waves and other environment condition are fed into the simulator as per determined simulation run matrix. Based on the displayed information the captain/pilot can activate his engines, rudders and thrusters by means of the analogue control handles.

For the navigation study, all the arrival simulation runs start from south of turning circle no. 1 to the proposed 2 berths at container terminal 1 and 2. All departure simulation runs start from the 2 berths at container terminal 1 and 2berth to just after turning circle no.2. All simulation runs terminate when the objective of the run has been met.

Two 100-ton bollard pull tugs were connected with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft when the ship simulation run starts.

The study identifies potential concerns, if any, on the ship berthing and unberthing at the proposed berth and during the approach in a combination of winds and tidal current conditions.

All simulation scenario runs were undertaken as far as practicable according to existing pilotage practices.

Particular attention was given to analyze the challenges in each simulation scenario taking into consideration the available resources, ship's maneuverability with respect to speed, course, turning circle, drift angle and the influence with wind and tidal current.

Critical elements such as the swinging circle diameter, the approach passage and available space were assessed.

All simulation runs were logged electronically to enable real time re-play of what happened during the runs. This includes time series of a large number of parameters, e.g. rate of turn, under keel clearance, angle of heel, speed over ground and through the water, rudder angle, propeller revolutions etc. This allows for investigation of all runs in detail at a later stage.

The summary of simulation run result can be found in Appendix 2 to this report. The conclusions are drawn based on the result of these simulation runs.

3.2 Assumptions

Following assumption were made for the simulation study.

1. There was no traffic situation impeding the vessel during her berthing and un-berthing manoeuvers.
2. There was no other traffic movement during the vessel approach to or leaving from the berths.
3. Tugs were made fast as soon as vessel is inside the breakwater.
4. Visibility was clear.

3.3 Run Matrices - Simulation Runs Undertaken

A total of eight (8) simulation runs were undertaken by Force Technology Master Mariner/Pilot on the SIMFLEX desktop simulator at Force Technology Simulator Center.

The number of runs was derived from calculated combination based on the use of 2 predominant current setting, 2 prevailing wind setting, arrival, departure, 2 berths, 1 ship models and from the perspective of manoeuvering difficulty and challenges.

The final port layout and formulation of the simulation run matrix was confirmed with RHDHV and DHI on a meeting on 25th February 2022.

Details on the simulation run matrix can be found in Appendix 1 of this report.

4 Results

4.1 Findings and Observation

For the purpose of categorizing the safety of the ship berthing and unberthing at the proposed berth and during channel transit, each simulation runs were graded as follows:

Successful: To obtain the grading "successful" the simulation must be completed with a satisfactory safety margin. A satisfactory safety margin is defined as the situation where the tested port layout and the environmental conditions provide sufficient under keel clearance to avoid grounding, sufficient distance to shallow water areas and constructions or moored ships and a possibility to correct minor manoeuvering mistakes without compromising the safety.

Marginal: The grading "marginal" is given for the simulations which were completed successfully but needed full utilization of all available resources such as use of full engine or tug power, hence no or little possibility of correction error or misjudgment. The "marginal" grade is also given when timeliness on availability of resources are critical or when manoeuvering risk is higher than available alternative.

Fail: The grading "fail" is given for simulations that could not be completed with the available resources.

4.2 Conclusion

The conclusions were drawn based on the results of the simulation exercises and the findings made by Force Technology Master Mariner/Pilot with due consideration to International Standards, PIANC recommendations.

All conclusions were based on the assumption that the future operations will be assisted or commanded by qualified pilots with a vast experience of handling and manoeuvering the designed ship.

Equally it is assumed that the tugs are commanded by qualified and experienced tug masters mastering all positions, transitions, direct and in-direct modes and techniques.

The navigation simulation study runs were deliberately performed in "worst case" credible combinations of wind and current conditions.

This should be considered when reviewing these conclusions, as any reduction in environmental conditions would make manoeuvering less intensive and reduce for any potential risks.

In summary, the simulation results and key conclusions of the desktop navigation simulation study are as follows.

Container Terminal 1 and 2

- The results of the desktop navigation simulation study concluded that the proposed container terminal 1 and 2 berths were able to berth and un-berth the largest designed container ship of 440 m LOA.
- There was no significant concern with the berthing and unberthing of the largest designed container ship at the proposed two berths.
- All berthing and unberthing runs were undertaken successfully in a controllable manner within acceptable level of safety.
- The port basin space at berth corner shown in Figure 15 below is wide enough for the largest designed container ship to transit its berth safely and passing all other moored ship by more than 2 beam widths.

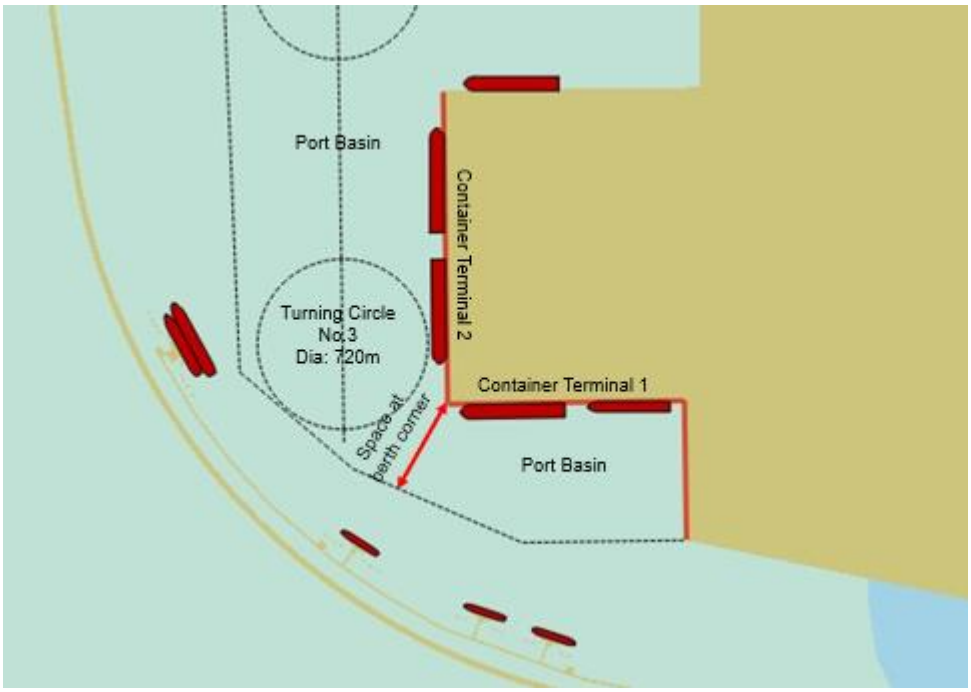


Figure 15 - Space at berth corner (Source: Force)

- The berthing simulation run showed that, during the manoeuvering of a ship backing in stern first (Run no.002 and 006), it is a difficult task to have exact awareness and positioning of the vessel's stern; although such can be overcome with good seamanship.

Turning Circle

- The turning circles of 720m diameter, for the largest designed container ship to execute a swing during the berthing / un-berthing manoeuver was found to be adequate and provides enough clearance and distance for possibility to correct minor manoeuvering mistakes without compromising safety.

- The optimum speed for the ship before a swing manoeuver was found to be below 0.5 knots. A higher speed may compromise safety in case of loss of tug power and control.

Stopping Distance

- Basis the august 2018 navigation study report of simulation runs at the entrance of the channel, considering that all tugs will be made fast soonest possible after vessel enters and in the shelter of the breakwater, there is adequate distance from the entrance of the breakwater to turning circle no.1 to reduce the vessel's speed and stop.

Tugs

- Vessel was assisted by four ASD tugs during the simulation study. Two 100-ton bollard pull tugs were connected with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft.
- The four ASD tugs proved sufficient to provide the needed assistance with comfortable un-used power reserves to cope with human error and unforeseen circumstances. Maximum tug power used was between 50% and 75% for most of the normal scenario simulation runs.

4.3 Recommendations

The following recommendations are based on the desktop simulation results as well as relevant recommendations from the august 2018 navigation study report and international best practices.

- The vessel approach speed to the berth should be consistent with existing pilotage practice.
- During vessel's arrival, it is recommended that all tugs to be made fast soonest possible after vessel enters and in the shelter of the breakwater.
- Consider using at least two 65ton bollard pull ASD tugs and two 100ton bollard pull ASD tugs capacity during the berthing and un-berthing of large vessel.
- Recommend that constant vigilance be exercised in controlling the vessel's bow during manoeuvering near the entrance of approach channel due to strong cross tidal current of between 2.5 to 3.2 knots during maximum flood and ebb. Vessel set and drift must be closely monitored. A channel transit speed of between 9 to 10 knots at the entrance of the approach channel during study proofs to be sufficient to keep vessel's heading with manageable angle of drift.
- Although there were sufficient resources in terms of vessel's ability to apply early counter helm and use of engine power, it is recommended that non-piloted vessel be made aware to exercise vigilance during vessel approach in maximum flood, as the vessel will experience a starboard sheer/swing caused by flood current at stern of vessel as the vessel's bow enter sheltered waters at breakwater.

- Although the 750m wide approach channel is sufficiently wide for a two-way vessel traffic, consider such be allowed during lesser current speed or during slack tide for large vessels or with piloted vessels.

- Considering the august 2018 navigation study report uses a maximum wind speed of 20 knots, consider suspending berthing and un-berthing operations when wind speed exceeds 20 knots or when the risk is deemed to be high.

- It is recommended to limit the operable wind speed and tidal current to low initially during the handling of large vessel with deep draft and large windage area. This restriction can possibly be relaxed when routine and experience has been acquired.

- It is recommended that other traffic movement be restricted or controlled in the port basin area while a vessel is conducting a berthing or un-berthing manoeuver in the area.

- As good seamanship practice, it is recommended that pilot check with Master that the vessel's anchor to be ready for emergency use at all time during manoeuvering.

- That further simulation runs be conducted by the pilots of the port on a Full Mission Ship Simulator to further evaluate the conditions of safe operation and to establish the preliminary pilotage guidelines.

4.4 Training

It is recommended that both pilots and tug masters attend full mission simulation training once the final layout of Vadhavan port and its various jetties and berths has been decided.

The objective is to train and become familiarized with the new port, manoeuvring guidelines, tug positions and emergency scenarios.

Together pilots and tug masters can learn and develop strategies and best practice for all phases in the operation. In general, it is our experience that simulation training has a positive effect on the pilot/tug corporation as they develop a larger insight into each other's field of expertise.

Such training can also be a part of evaluating the conditions of safe operation and to establish the preliminary pilotage guidelines and SOP (standard operating procedures) for the proposed Vadhavan port.

APPENDIX 1

Simulation Run Matrix

Desktop Navigation Simulations Study for Proposed New Layout of Vadhavan Port

Appendix 1

Navigation Simulation Run Matrix

20,000 TEU Container Ship (Model 3749)

Run No.	Berth	Route		Side Alongside	Current		Wind		Scenario
		Arrival	Depart		Max South'ly Ebb	Max North'ly Flood	NE Wind 045° x 10kts	SW Wind 250° x 15kts	
001	Cont.Terminal 2	X		Port		X		X	Arrival Port Side Direct - In
002	Cont.Terminal 2	X		Starboard	X			X	Arrival Swing and back in
003	Cont.Terminal 2		X	Port	X		X		Departure Swing and head out
004	Cont.Terminal 2		X	Starboard		X	X		Departure Direct Out
005	Cont.Terminal 1	X		Port		X		X	Arrival Port Side Direct - In
006	Cont.Terminal 1	X		Starboard	X			X	Arrival Swing and back in
007	Cont.Terminal 1		X	Port	X		X		Departure Swing and head out
008	Cont.Terminal 1		X	Starboard		X	X		Departure Direct Out

APPENDIX 2

Summary of Simulation Run Results

Desktop Navigation Simulations Study for Proposed New Layout of Vadhavan Port

Appendix 2

Summary of Simulation Run Result Matrix

20,000 TEU Container Ship (Model 3749)

						65-ton Bollard Pull Tug		100-ton Bollard Pull Tug				
Run No.	Berth	Route	Side Alongside	Current (Going to)	Wind (From)	Fwd Tug No.1 Max Power Used	Aft Tug No.2 Max Power Used	Fwd Tug No.1 Max Power Used	Aft Tug No.2 Max Power Used	Max Tug Power used (%)	Manoeuver Grade	Duration
001	Cont.Terminal 2	Arrival	Port	Flood (flowing North)	250° x 15 knot	75%	75%	50%	75%	50% to 75%	Successful	47 mins
002	Cont.Terminal 2	Arrival	Stbd	Ebb (flowing South)	250° x 15 knot	75%	75%	75%	75%	75%	Successful	1hr 13mins
003	Cont.Terminal 2	Depart	Port	Ebb (flowing South)	045° x 10 knot	75%	50%	50%	50%	50% occasional 75%	Successful	57 mins
004	Cont.Terminal 2	Depart	Stbd	Flood (flowing North)	045° x 10 knot	50%	50%	nil	nil	50%	Successful	35 mins
005	Cont.Terminal 1	Arrival	Port	Flood (flowing North)	250° x 15 knot	75%	75%	50%	50%	50% to 75%	Successful	1hr 7mins
006	Cont.Terminal 1	Arrival	Stbd	Ebb (flowing South)	250° x 15 knot	75%	50%	50%	50%	50% occasional 75%	Successful	1hr 31mins
007	Cont.Terminal 1	Depart	Port	Ebb (flowing South)	045° x 10 knot	50%	50%	50%	50%	50%	Successful	1hr 8mins
008	Cont.Terminal 1	Depart	Stbd	Flood (flowing North)	045° x 10 knot	50%	50%	50%	50%	50%	Successful	51 mins

APPENDIX 3

Simulation Plot and Run Comments

Run No.001

Berth	Container Terminal 2	Route	Arrival Port side
Wind	250° x 15 knot	Current	Flood (flowing North)
Duration	47 mins	Grade	Successful

Comments

Vessel passes the first turning circle with speed of 5 knots.

Two 100-ton bollard pull tugs were connected on starboard side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft.

Vessel speed was reduced to below 3 knots on passing second turning circle. Vessel approached the berth at a small angle. When vessel was abeam of berth, tugs assistance was used to bring the vessel alongside the berth.

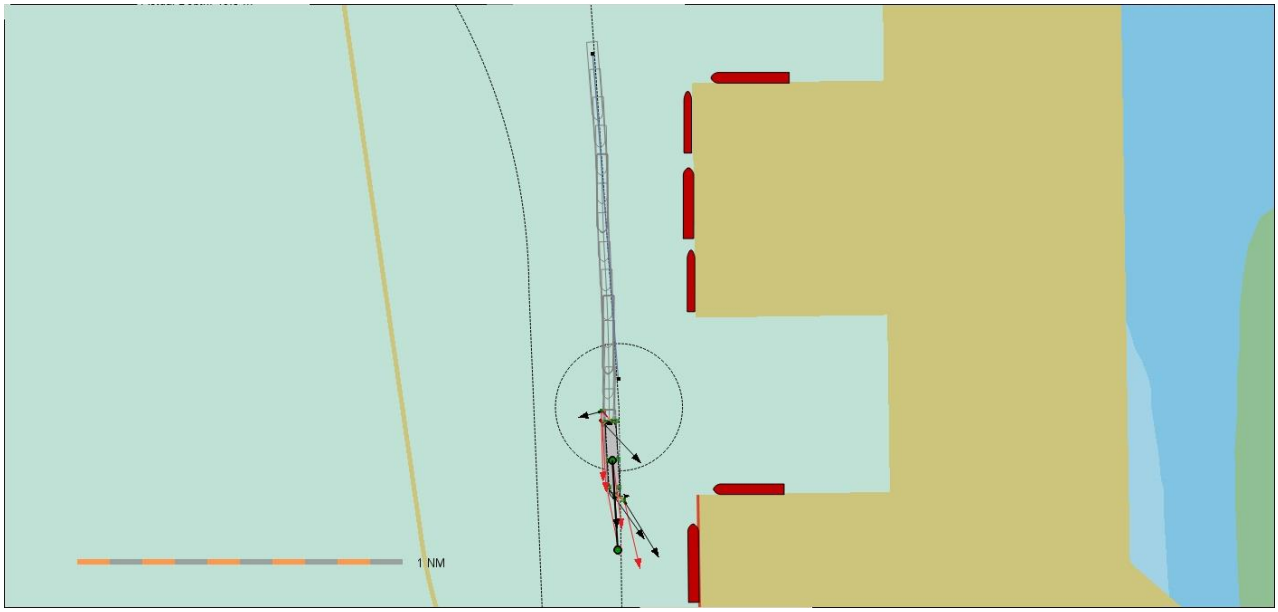
Vessel was berthed port side alongside without any incident. Vessel had enough resources to berth successfully alongside in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

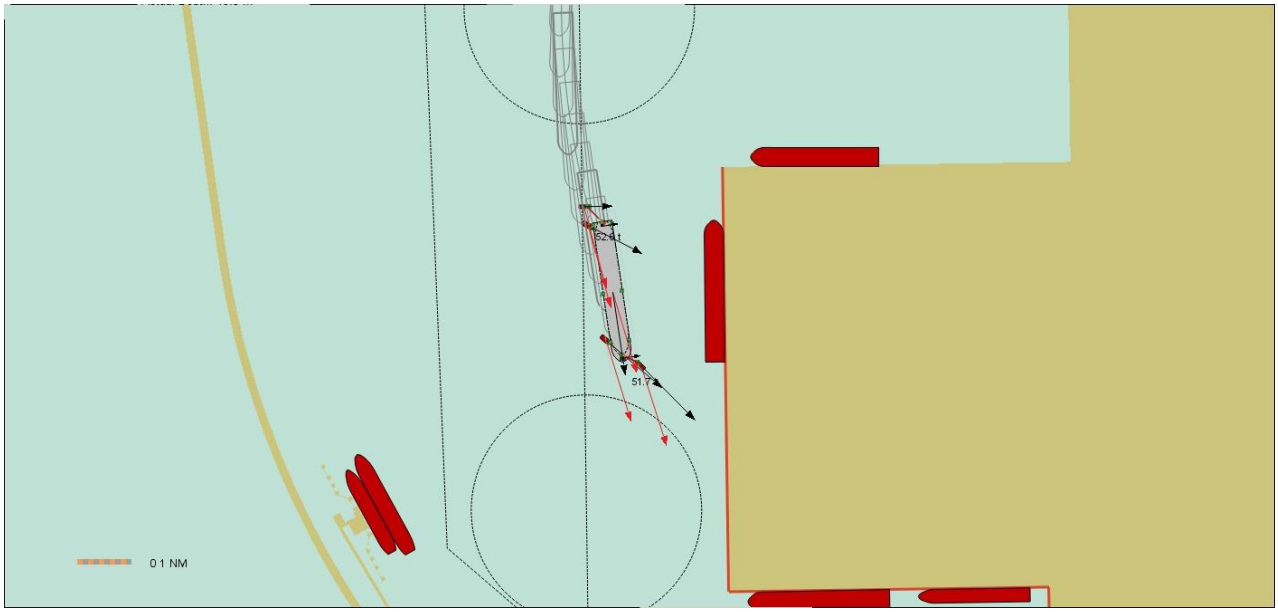
The entire run takes 47 minutes till the vessel was in a safe position to send out the mooring lines.

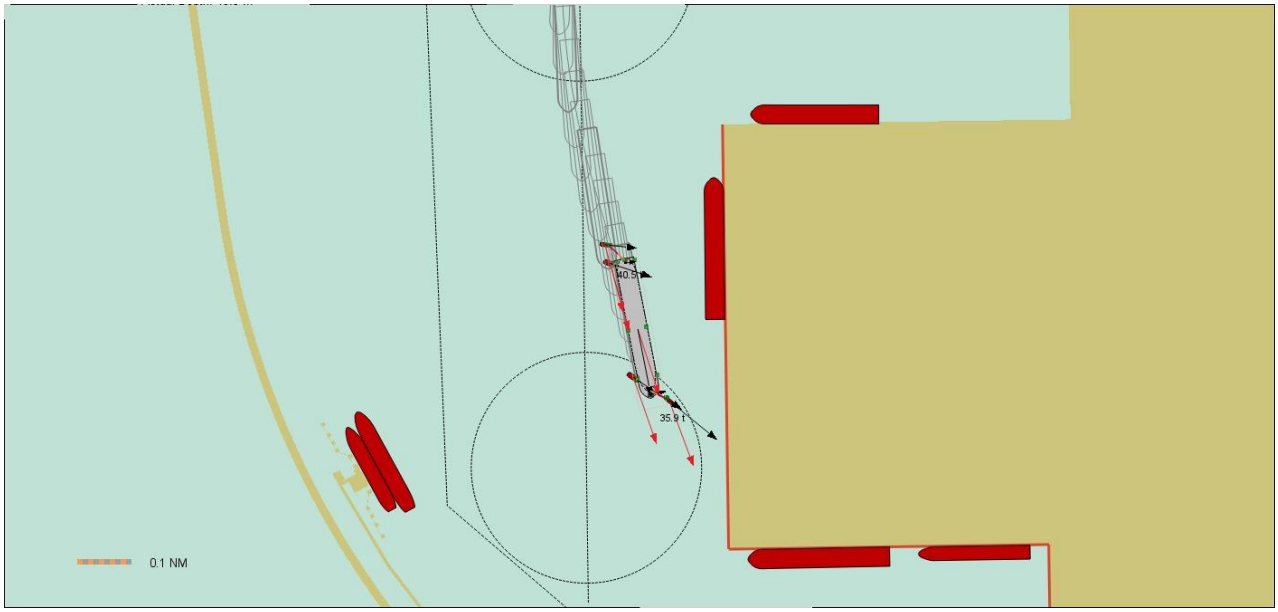
Maximum tug power used was between 50% to 75%.

Manoeuver was graded as SUCCESSFUL.

Run No.001







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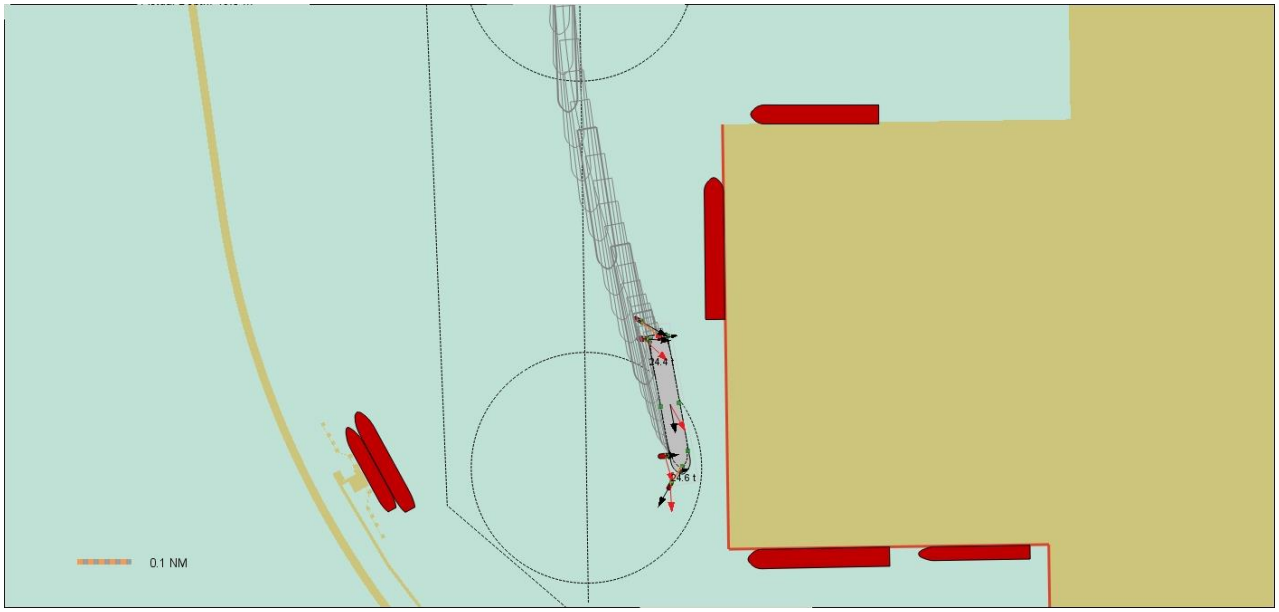
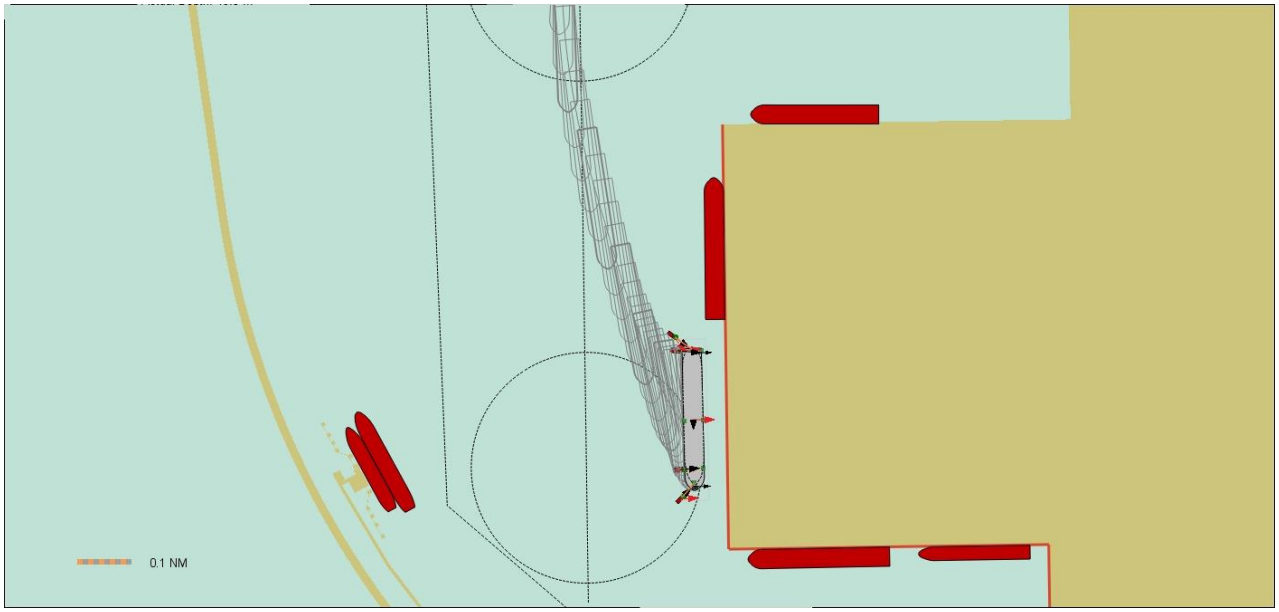
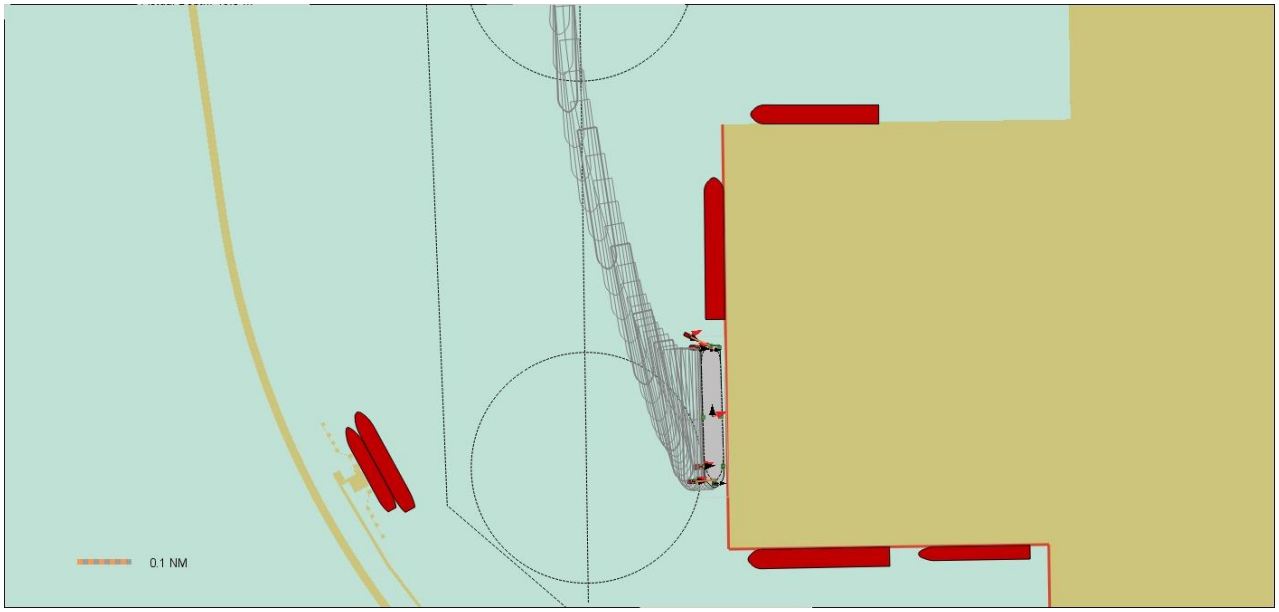






Run No.002

Berth	Container Terminal 2	Route	Arrival Stbd side
Wind	250° x 15 knot	Current	Ebb (flowing South)
Duration	1hr 13mins	Grade	Successful

Comments

Vessel passes the first turning circle with speed of 5 knots.

Two 100-ton bollard pull tugs were connected on port side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft.

Vessel speed was reduced to near zero knots at southern tip of second turning circle. Tug assistance were used to swing the vessel to starboard into the wind. When the vessel bow was heading north stemming the current, the vessel's engine was used to back the vessel at a controlled speed of about 2 knots. When vessel was abeam of berth, tugs assistance was used to bring the vessel alongside the berth.

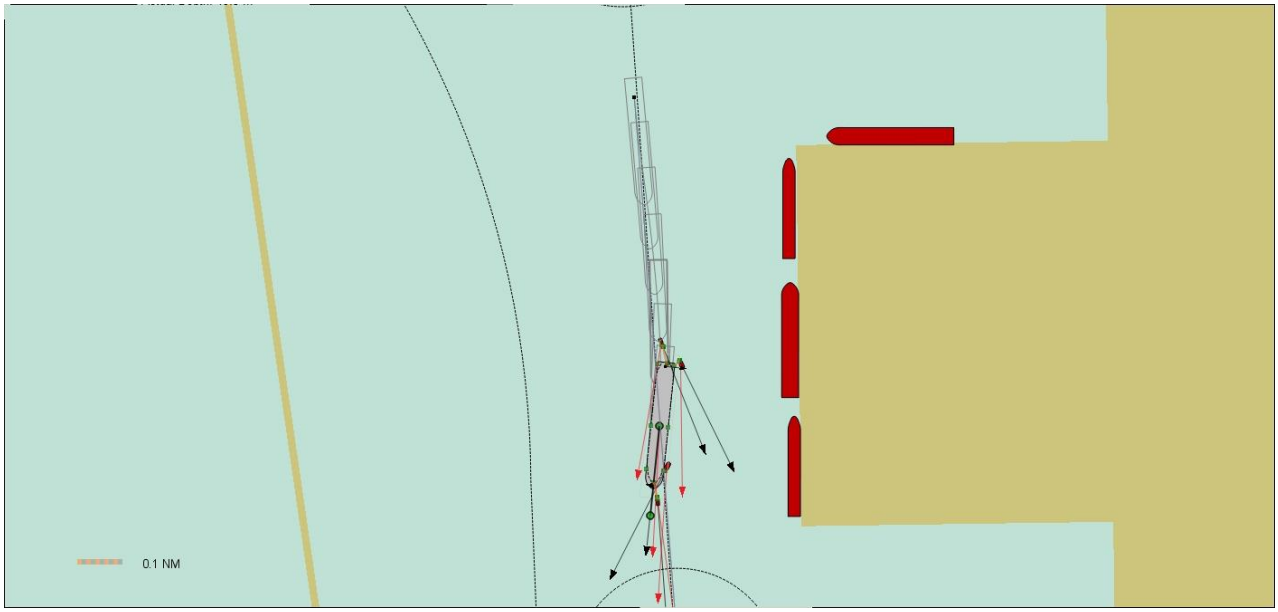
Vessel was berthed starboard side alongside without any incident. Vessel had enough resources to berth successfully alongside in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

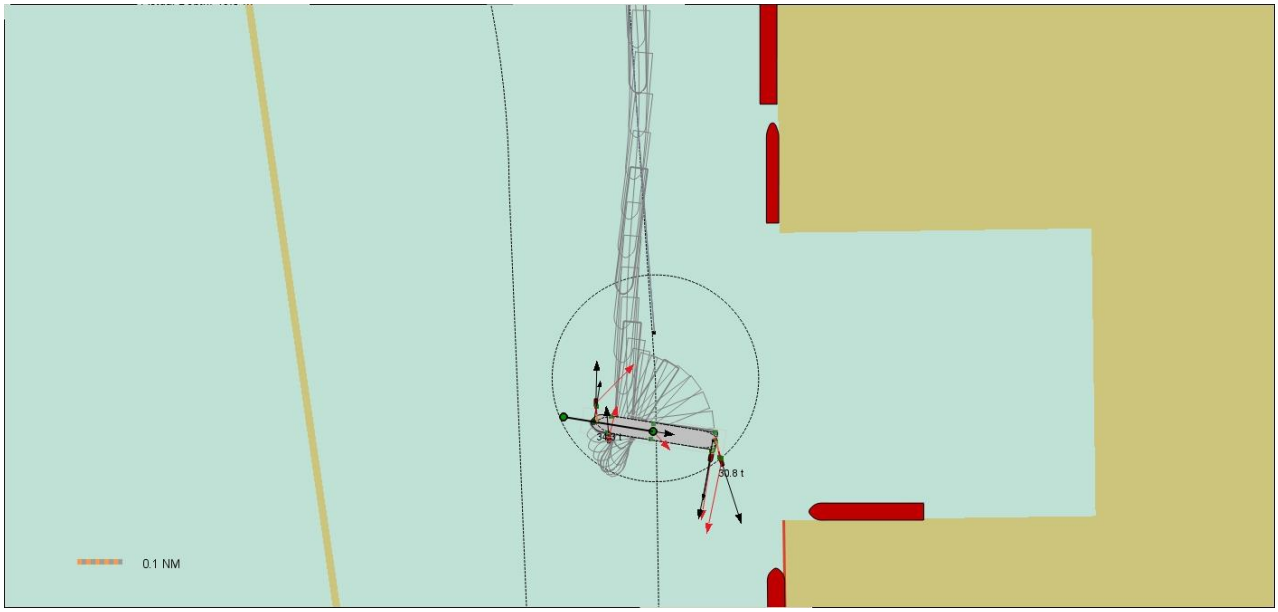
The entire run takes 1hr 13mins till the vessel was in a safe position to send out the mooring lines.

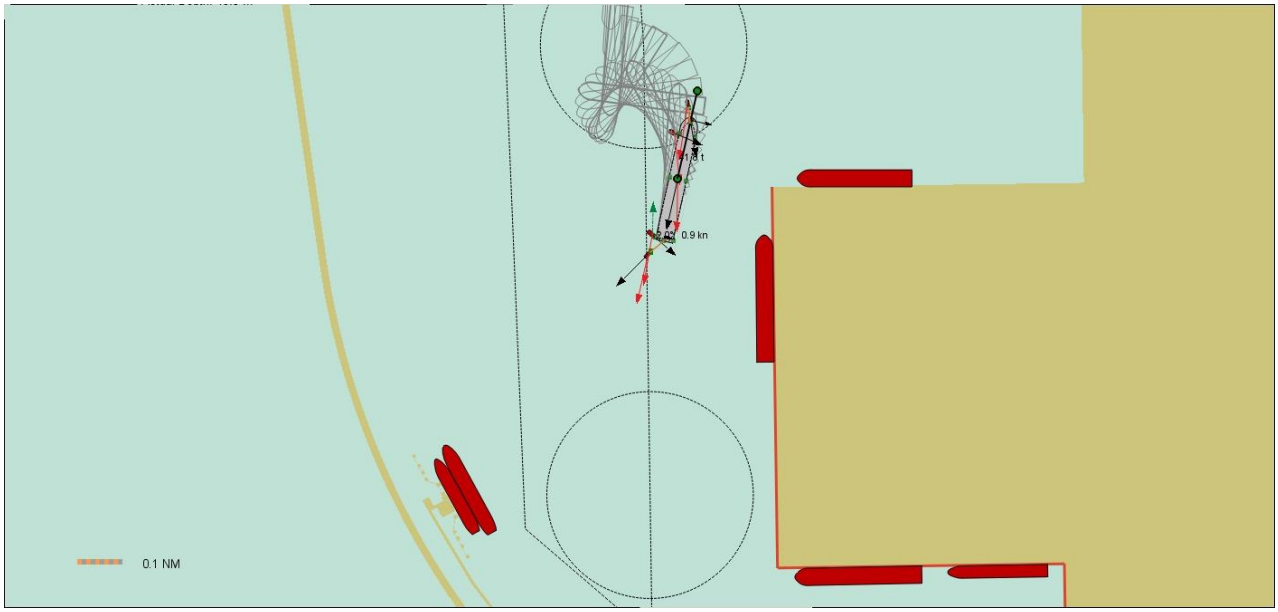
Maximum tug power used was 75%.

Manoeuver was graded as SUCCESSFUL.

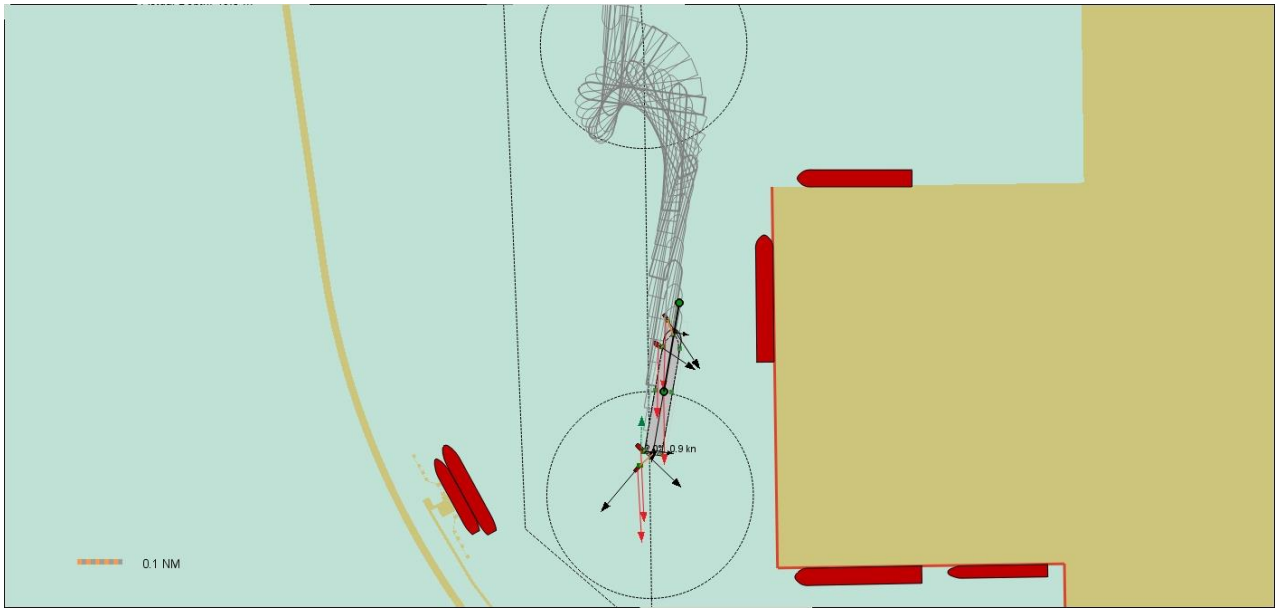
Run No.002

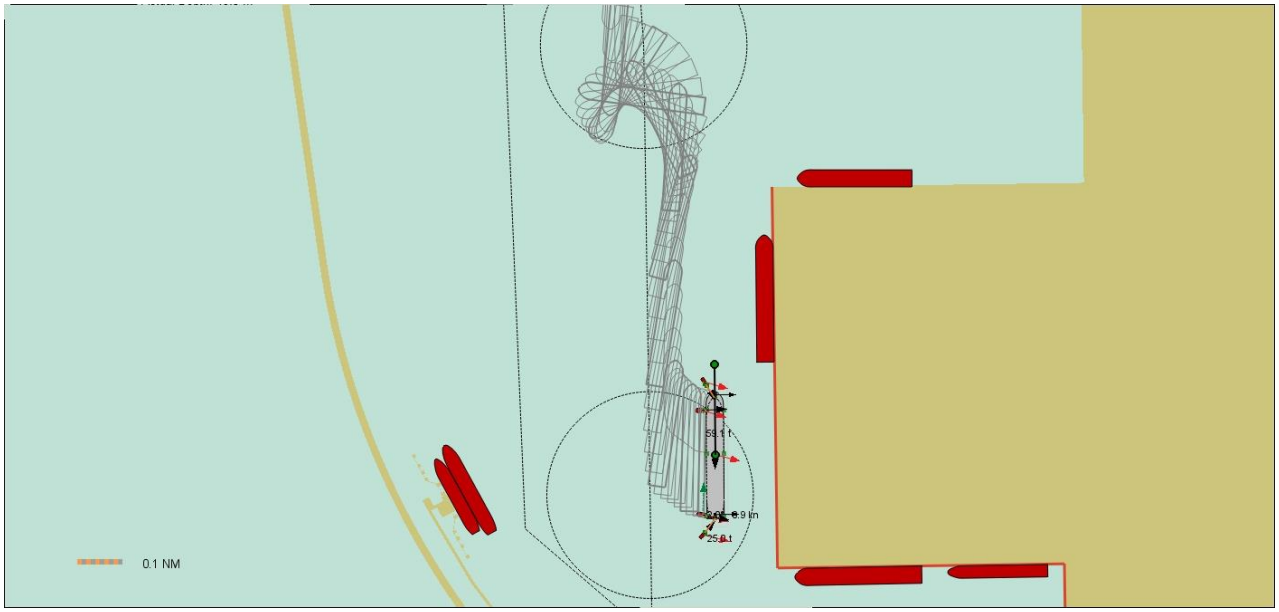


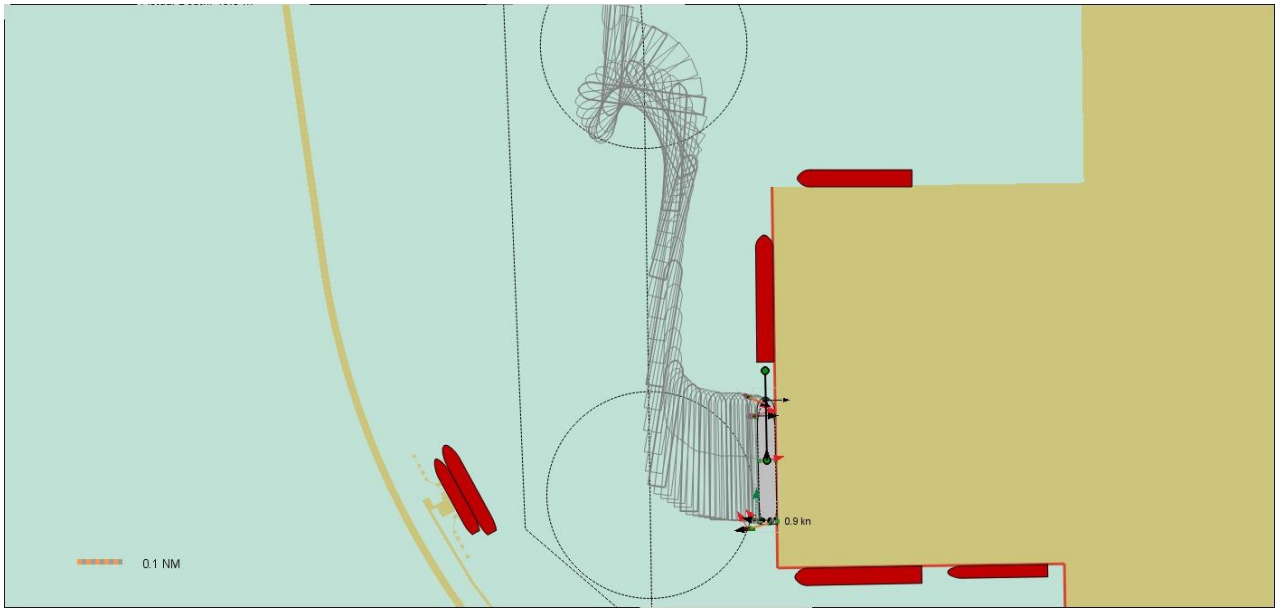




Run No.002







Run No.003

Berth	Container Terminal 2	Route	Depart Port side
Wind	045° x 10 knot	Current	Ebb (flowing South)
Duration	57 mins	Grade	Successful

Comments

Two 100-ton bollard pull tugs were connected on port side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft. The tugs were used to pull vessel parallel off berth.

When vessel clears the berth by about 3 beam widths, the vessel stern was swung to starboard and the vessel engine was used sparingly to control speed to not more than 1 knot astern.

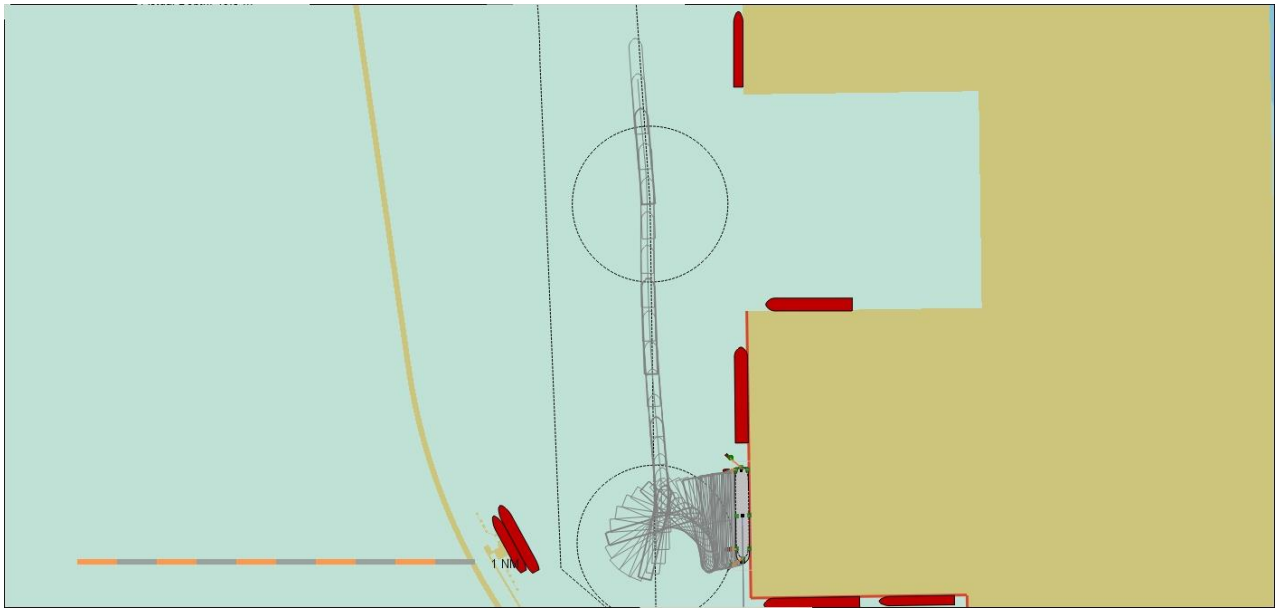
Vigilance was maintained to ensure vessel stays in middle of turning circle as the tugs swings the vessel and points the vessel bow northward. Vessel engine was put to slow ahead followed by half ahead to steer the vessel out. All tugs were casted off near the second turning circle.

Vessel had enough resources to un-berth and manoeuver towards the port exit in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

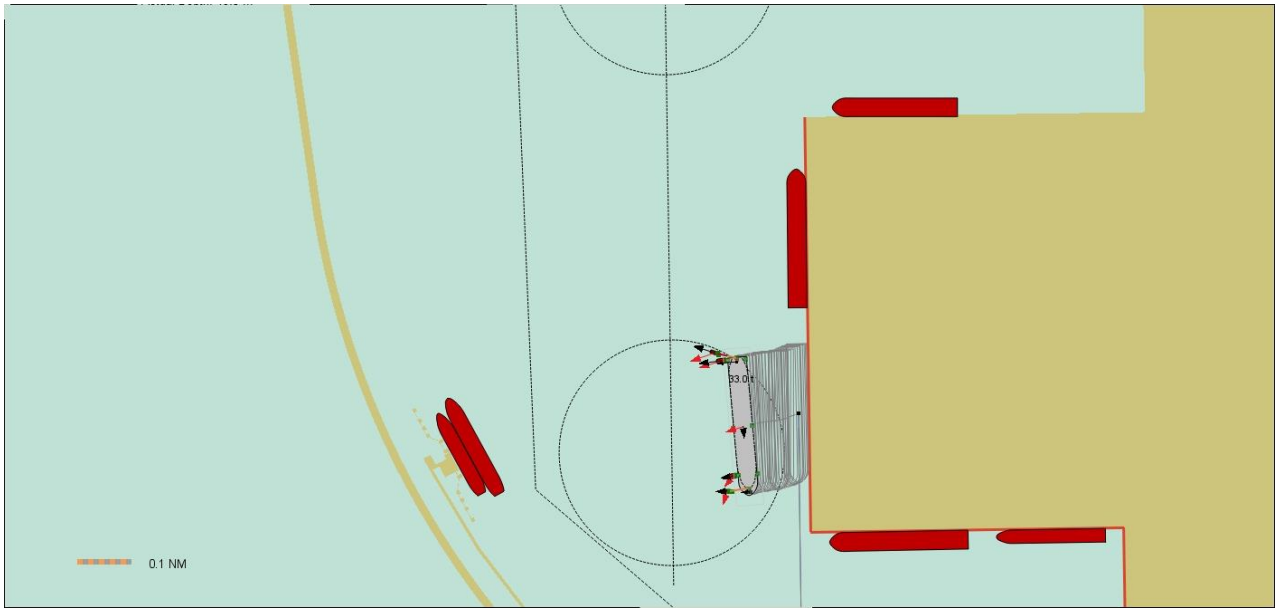
The entire run takes 57 mins till the vessel was in a safe outbound position.

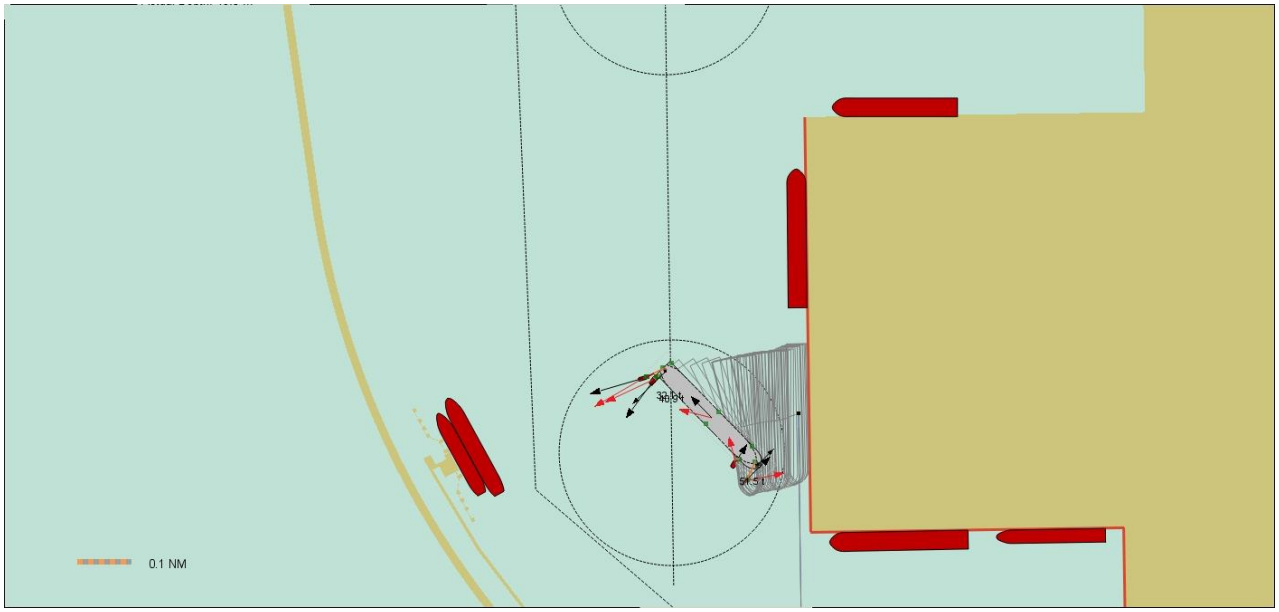
Maximum tug power used was 50% with occasional 75%.

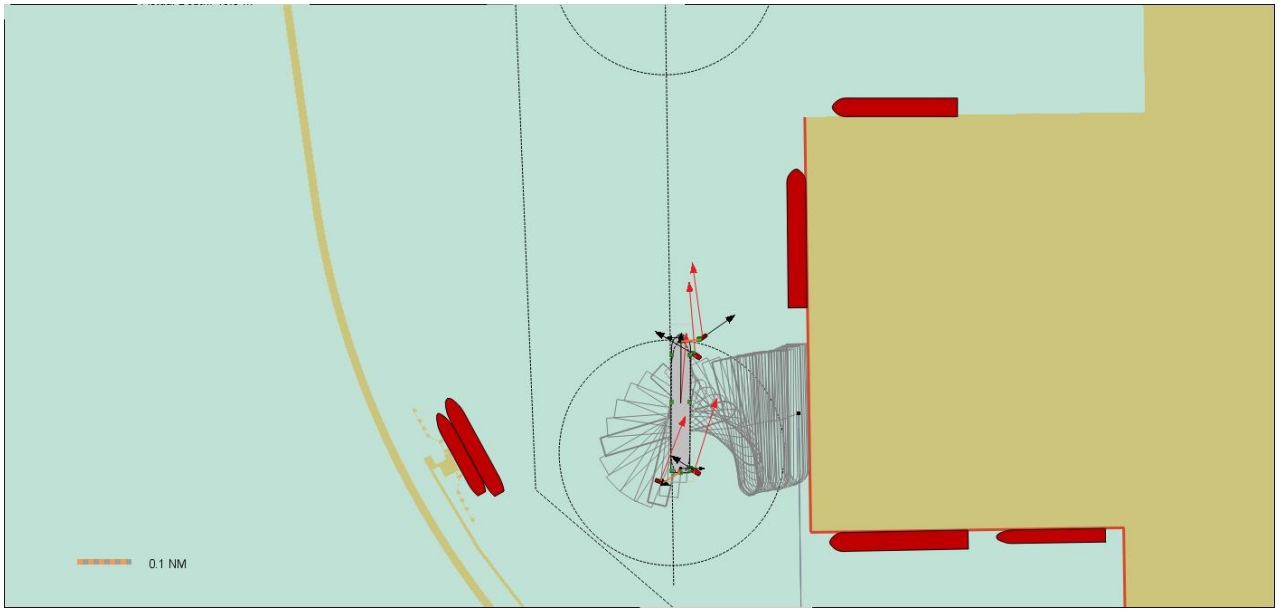
Manoeuver was graded as SUCCESSFUL.



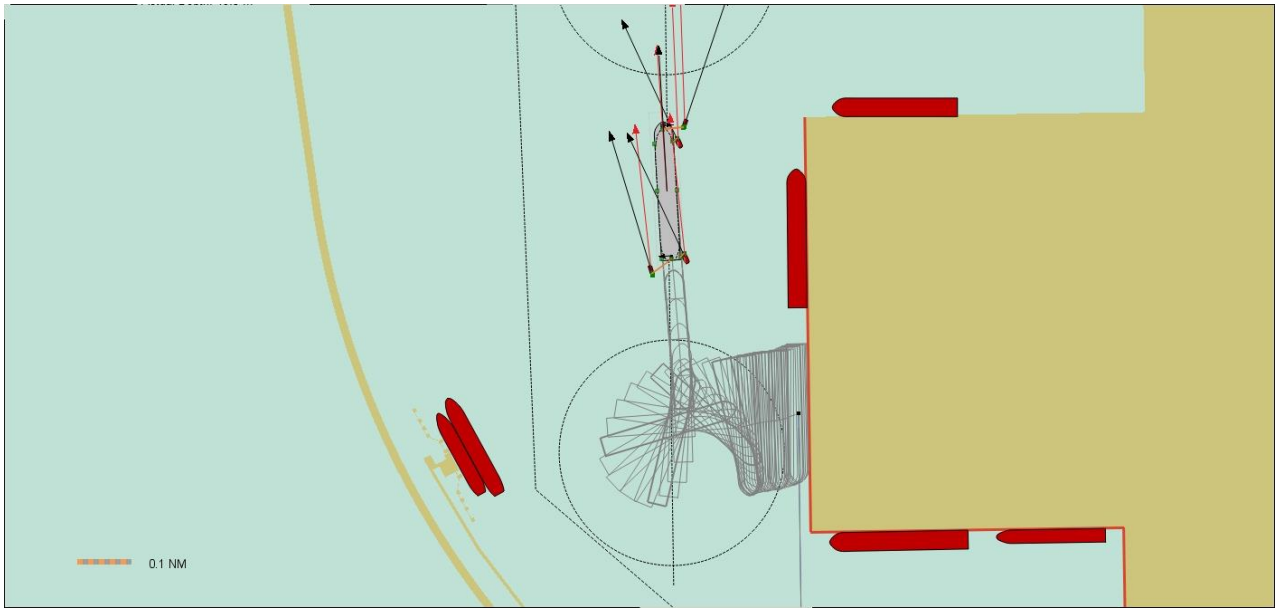
Run No.003

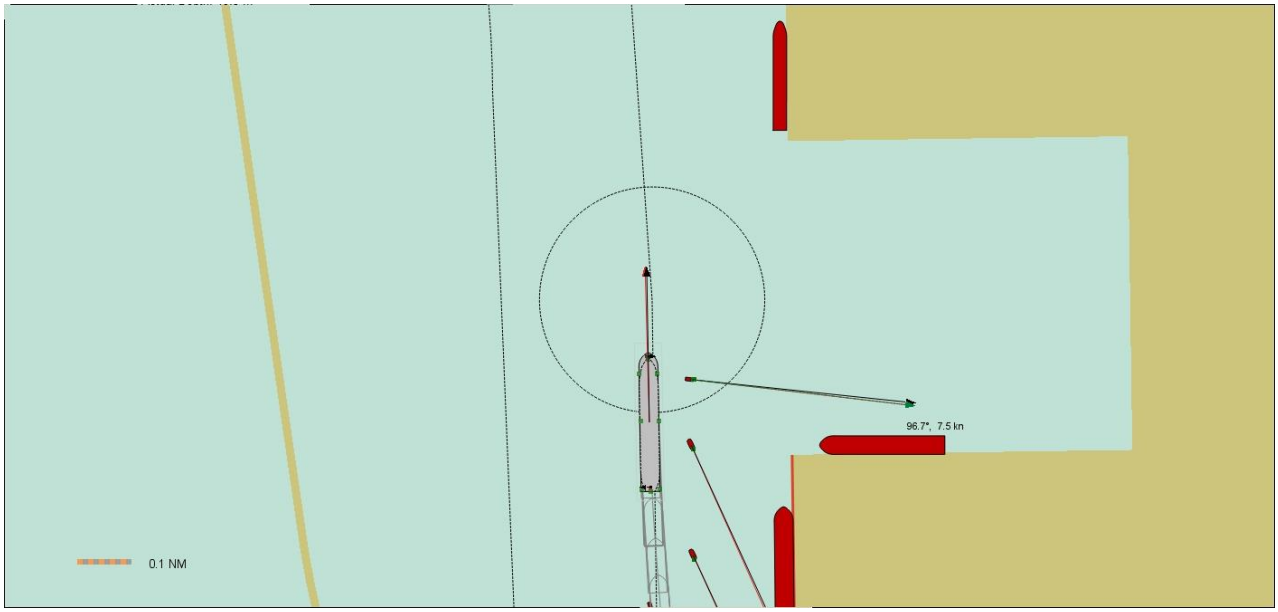


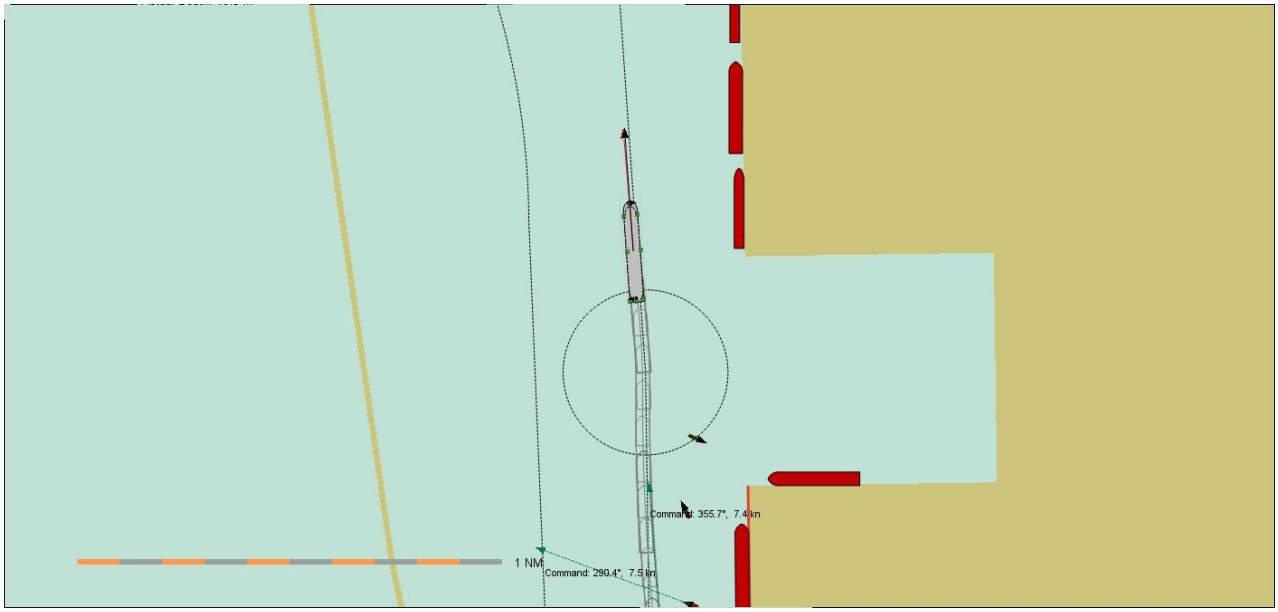




Run No.003







Run No.004

Berth	Container Terminal 2	Route	Depart Stbd side
Wind	045° x 10 knot	Current	Flood (flowing North)
Duration	35 mins	Grade	Successful

Comments

Two 100-ton bollard pull tugs were connected on starboard side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft. The tugs were used to pull vessel parallel off berth.

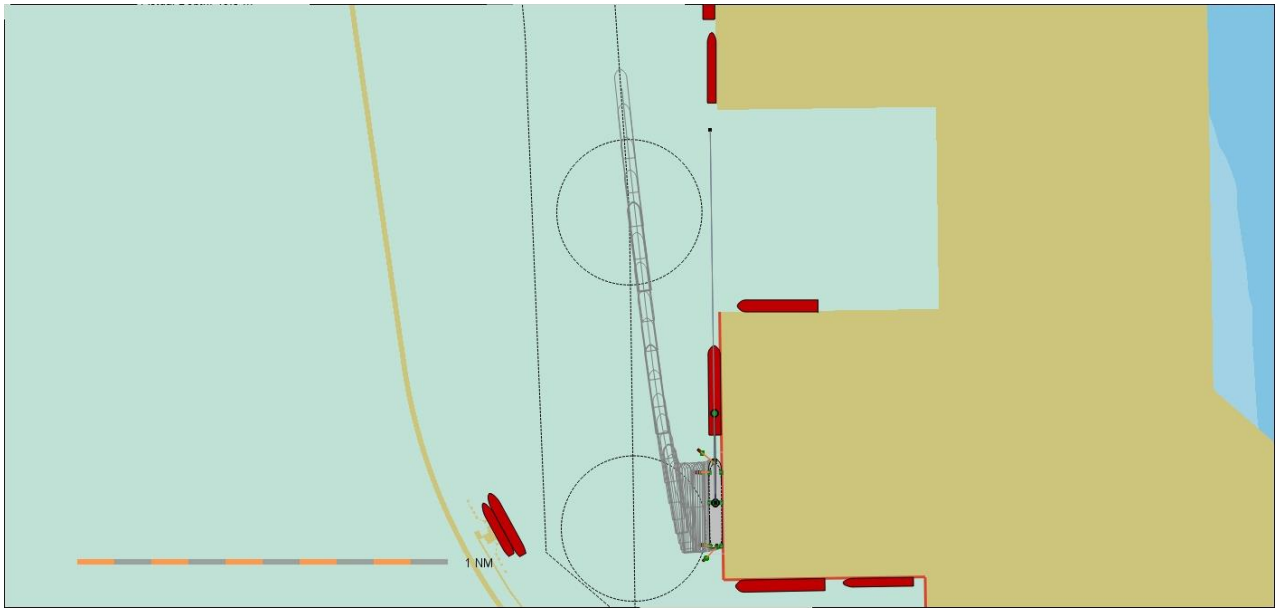
When vessel clears the berth by about 3 beam widths, vessel engine was put to slow ahead followed by half ahead to steer the vessel out. All tugs were casted off near the second turning circle.

Vessel had enough resources to un-berth and manoeuver towards the port exit in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

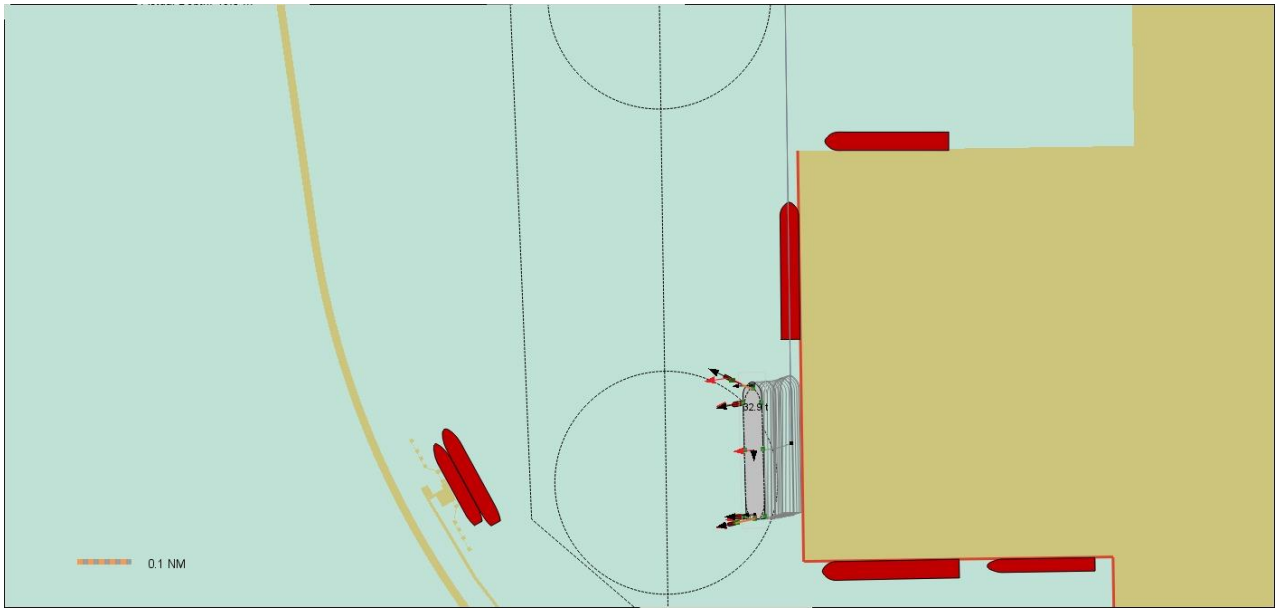
The entire run takes 35 mins till the vessel was in a safe outbound position.

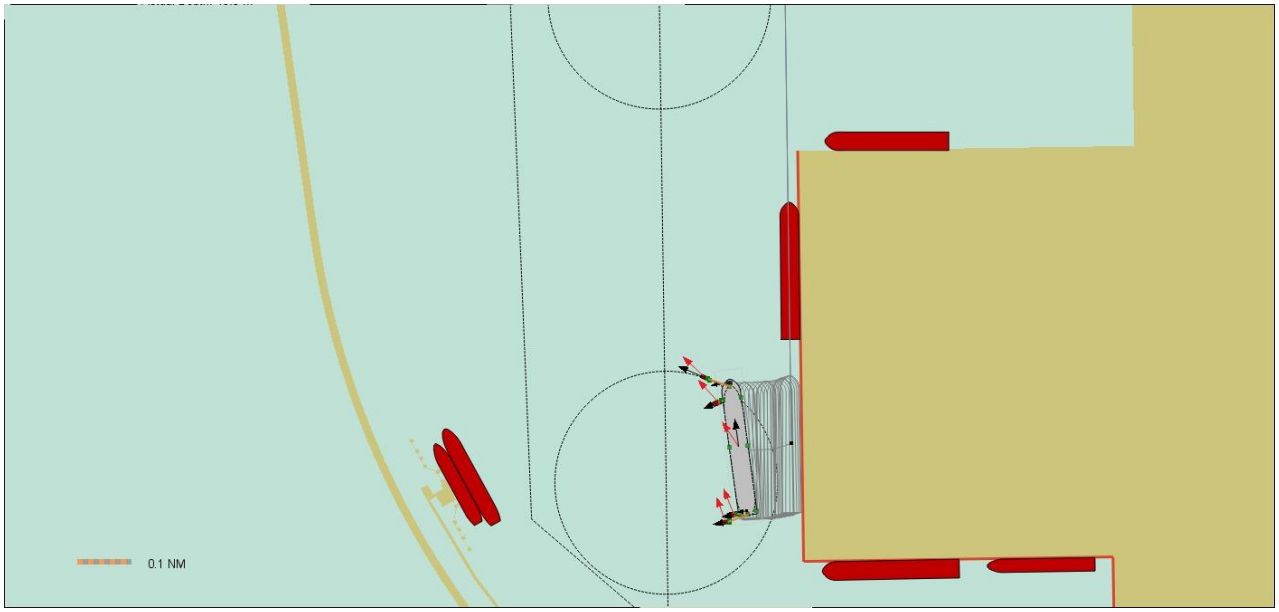
Maximum tug power used was 50%.

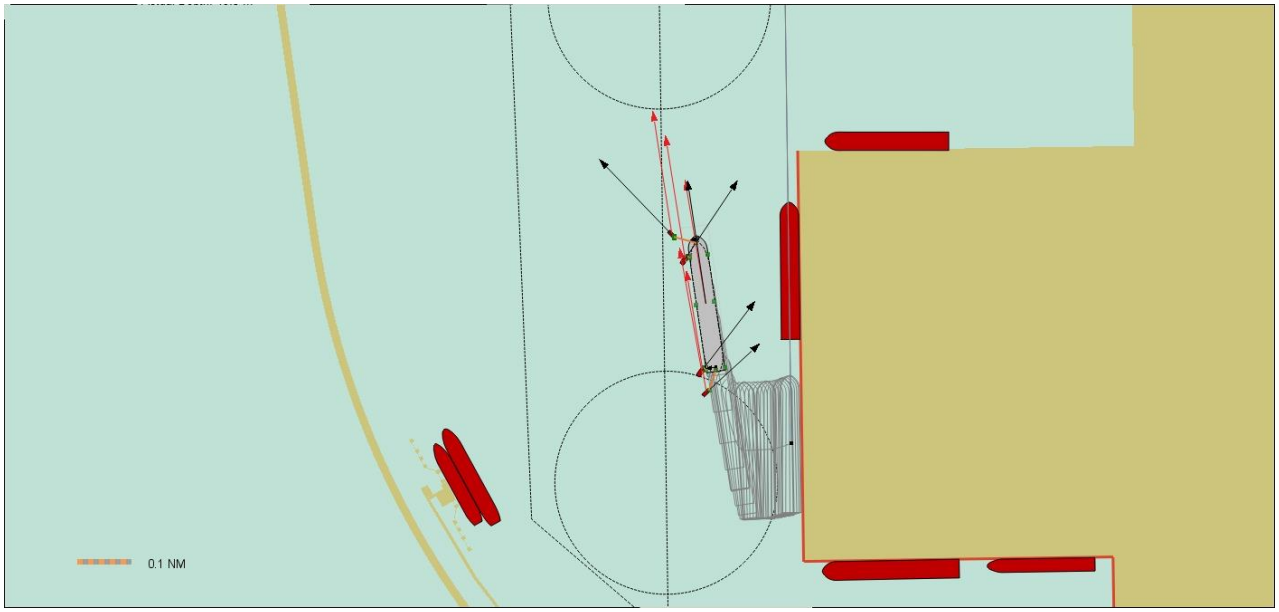
Manoeuver was graded as SUCCESSFUL.



Run No.004







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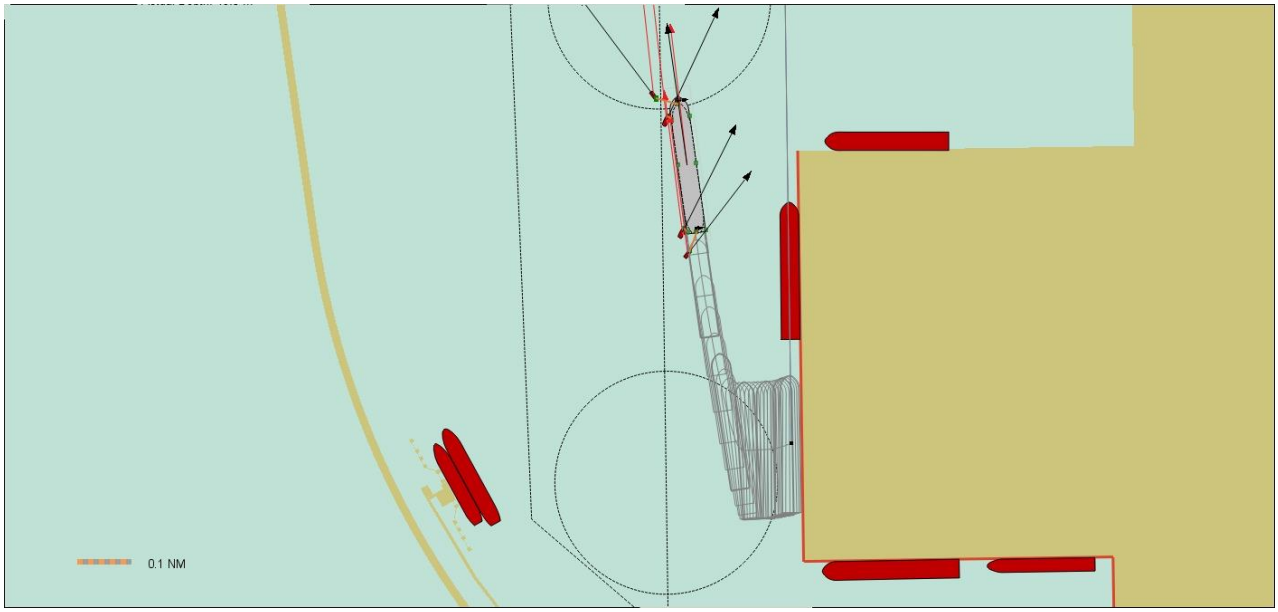
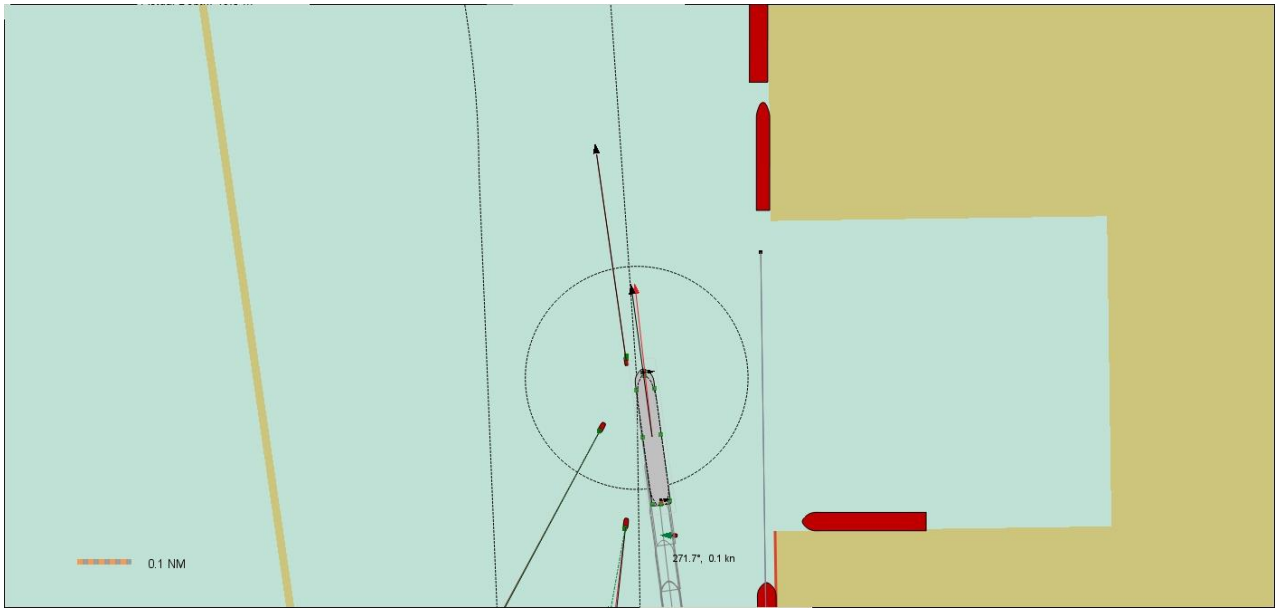
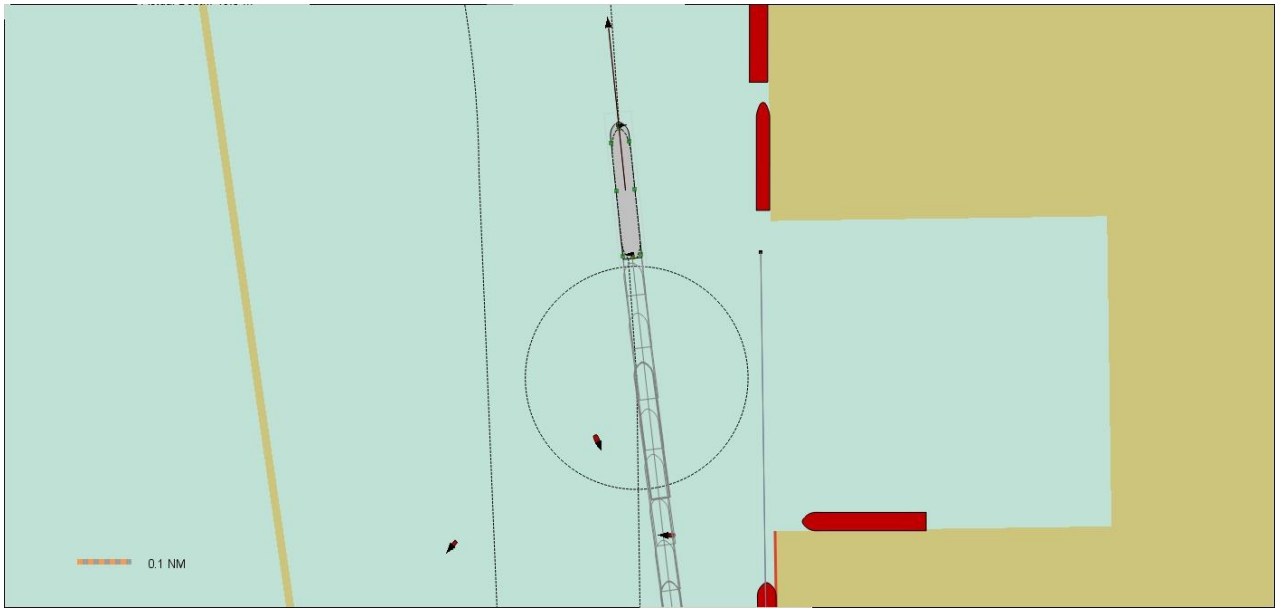






Run No.005

Berth	Container Terminal 1	Route	Arrival Port side
Wind	250° x 15 knot	Current	Flood (flowing North)
Duration	1hr 7mins	Grade	Successful

Comments

Vessel passes the first turning circle with speed of 5 knots.

Two 100-ton bollard pull tugs were connected on starboard side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft.

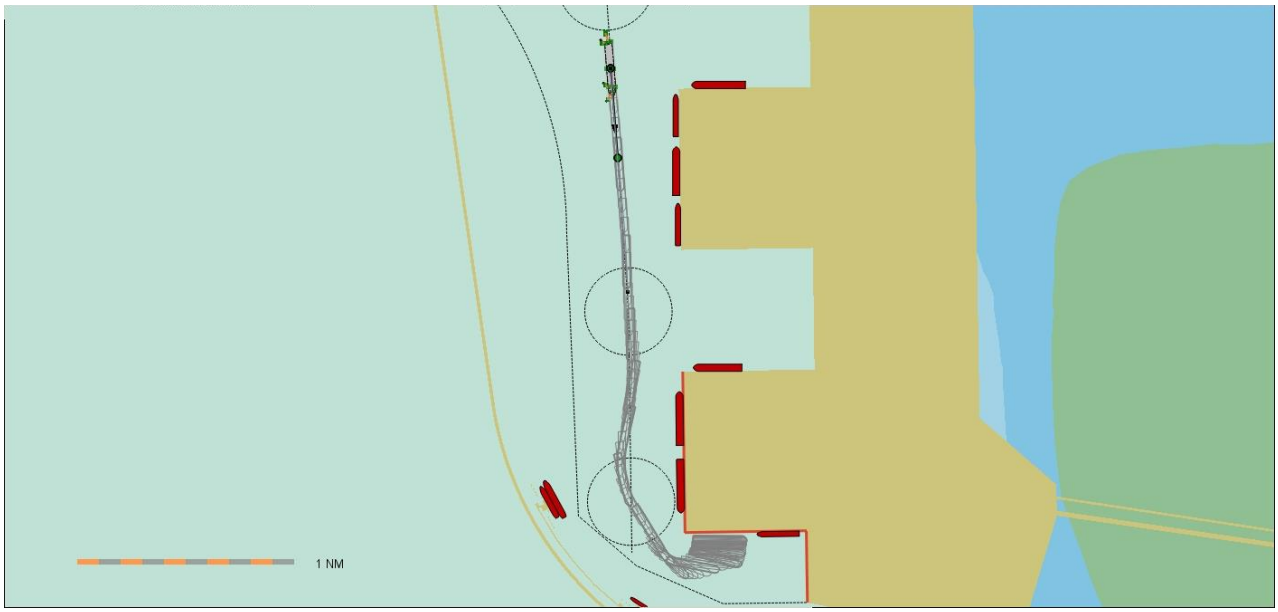
Vessel speed was reduced to below 3 knots at the third turning circle. Vessel bow was aligned to steer and swing pass the berth corner at a distance of about 0.5 LOA. Vessel speed was brought down to below 0.5 knot as the vessel points east. When vessel was abeam of berth, tugs assistance was used to bring the vessel alongside the berth.

Vessel was berthed port side alongside without any incident. Vessel had enough resources to berth successfully alongside in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

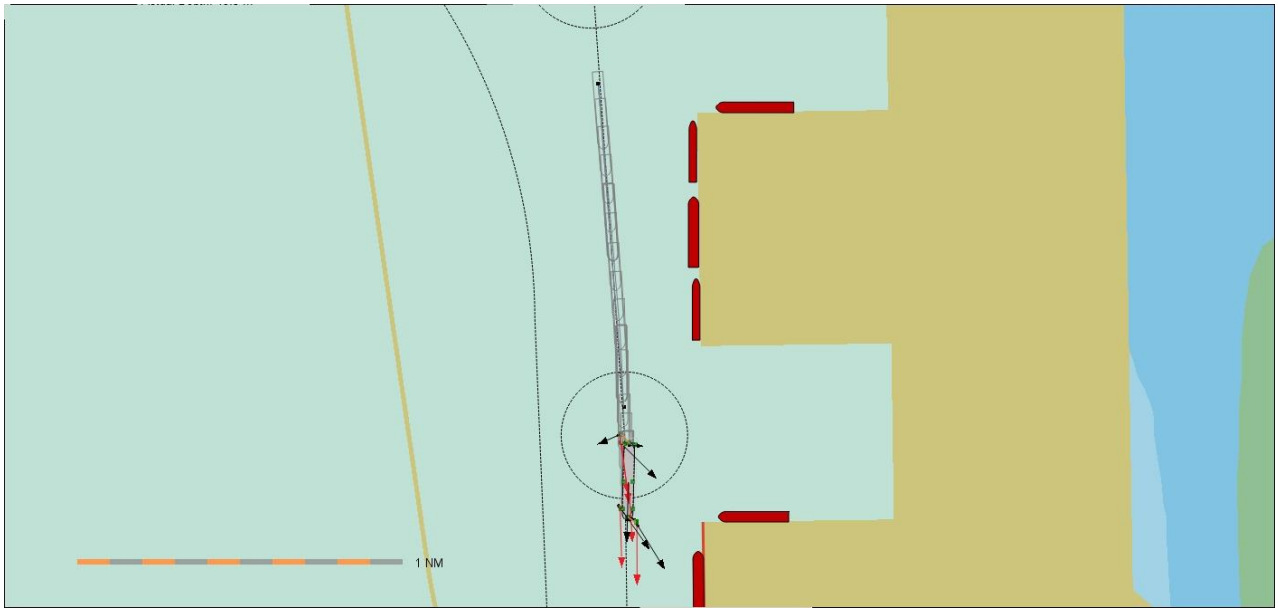
The entire run takes 1hr 7mins till the vessel was in a safe position to send out the mooring lines.

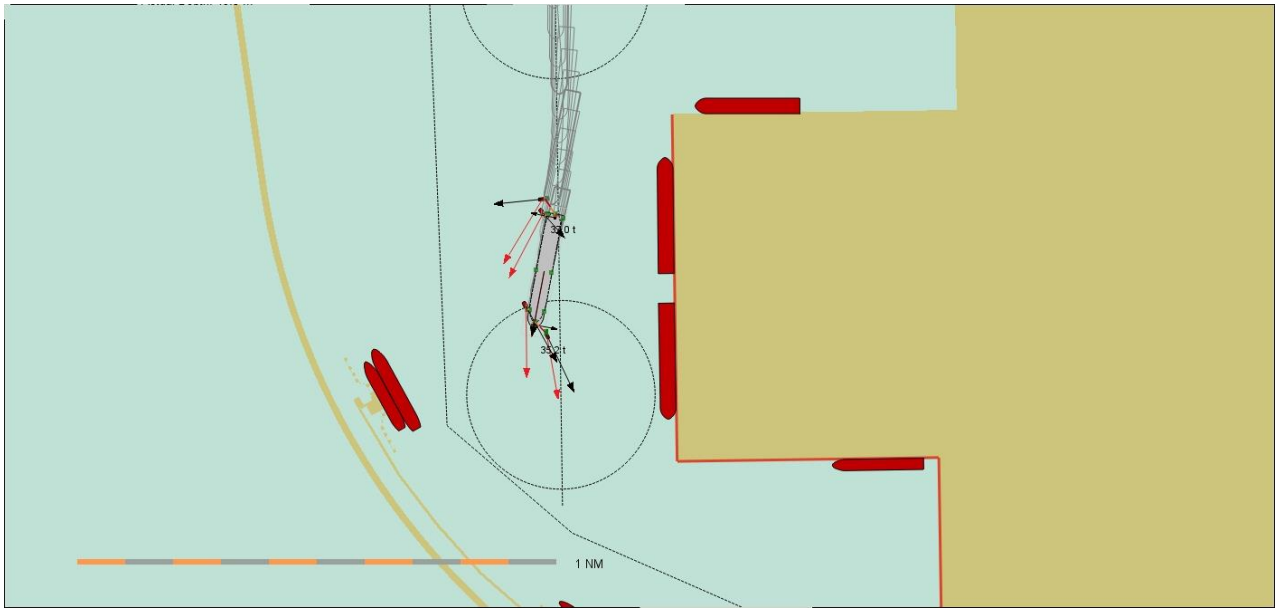
Maximum tug power used was between 50% to 75%.

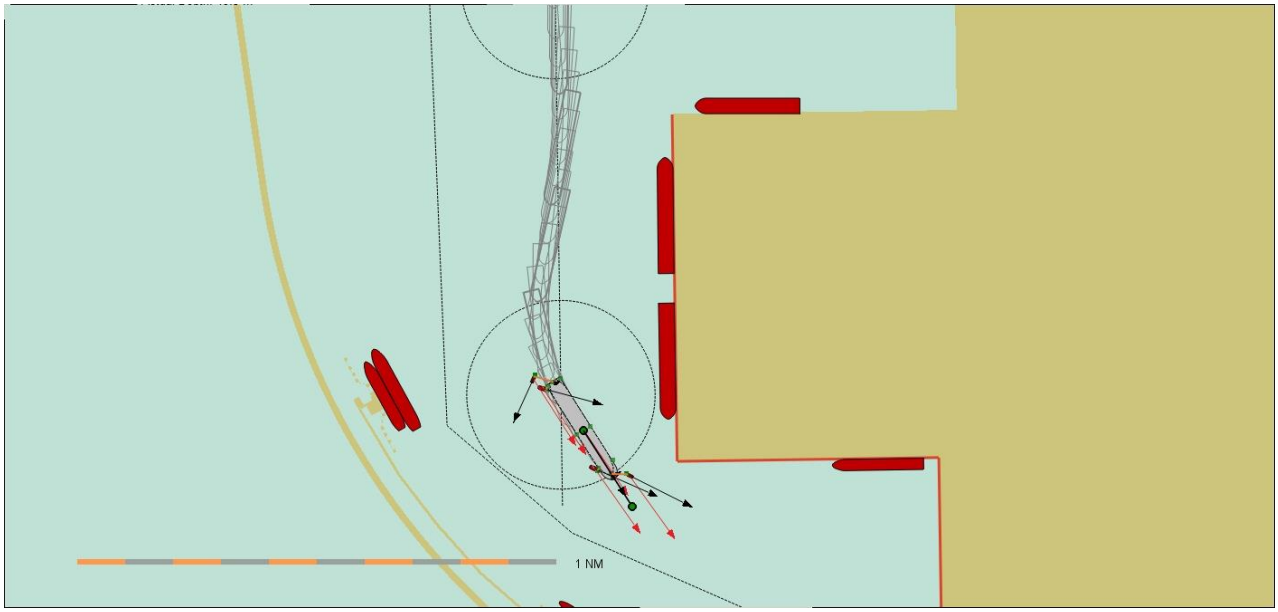
Manoeuver was graded as SUCCESSFUL.



Run No.005







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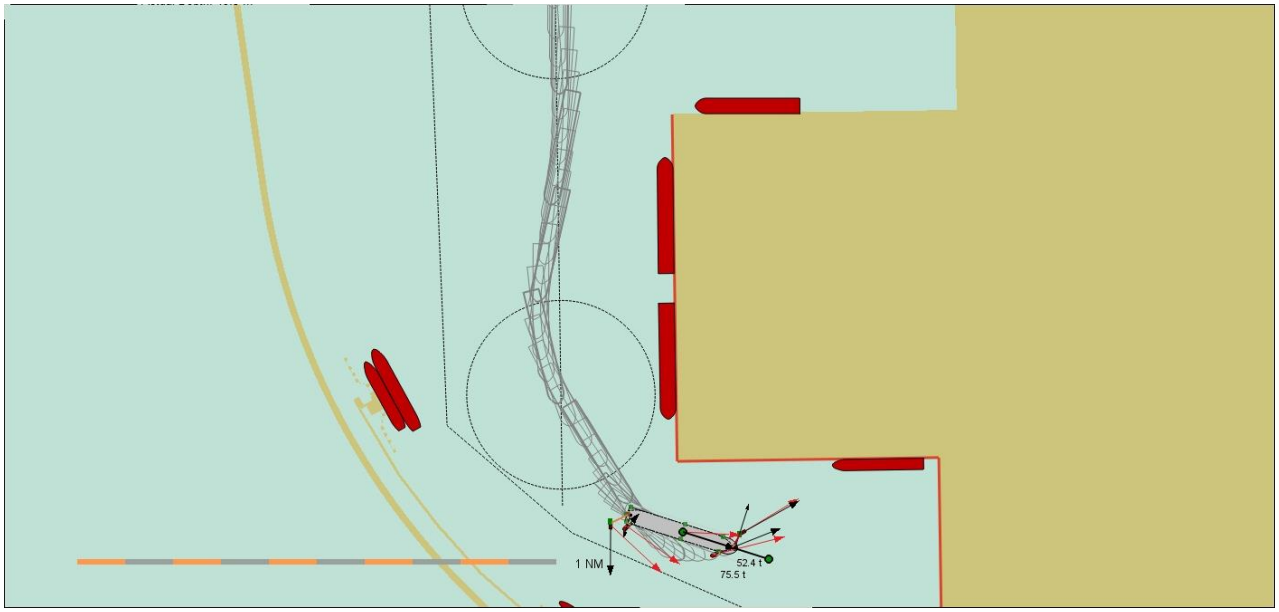
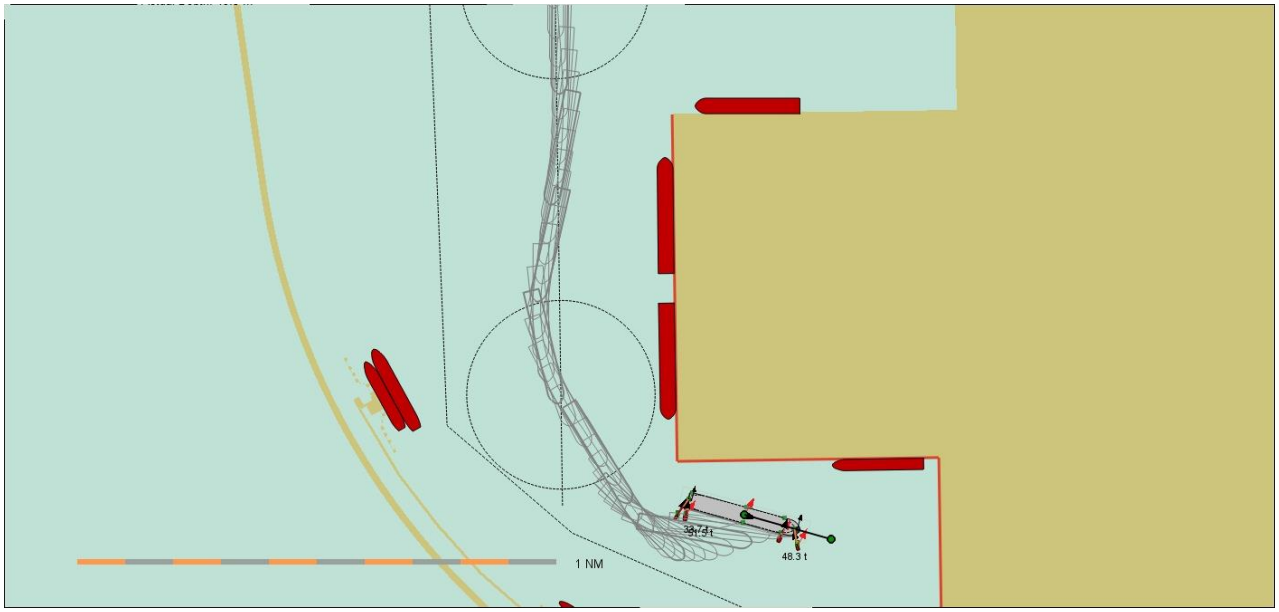
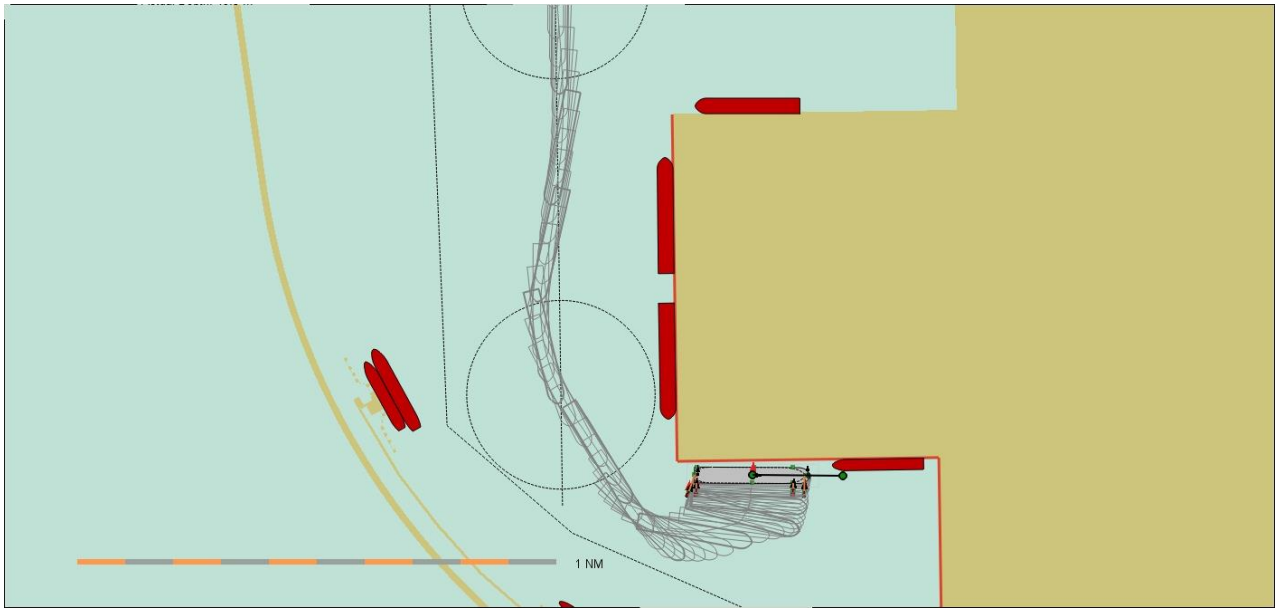






Run No.006

Berth	Container Terminal 1	Route	Arrival Stbd side
Wind	250° x 15 knot	Current	Ebb (flowing South)
Duration	1hr 31mins	Grade	Successful

Comments
Vessel passes the first turning circle with speed of 5 knots.

Two 100-ton bollard pull tugs were connected on port side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft.

Vessel speed was reduced to near zero knots at the third turning circle. Tug assistance were used to swing the vessel to starboard into the wind.

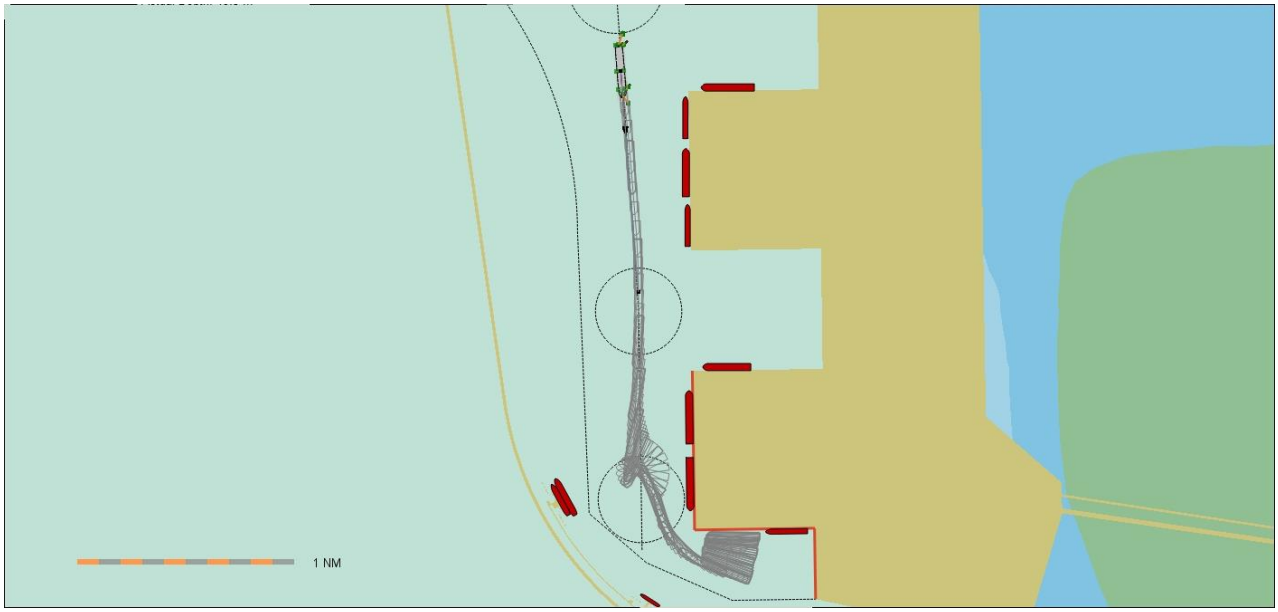
When the vessel stern was aligned to clear pass the berth corner at a distance of about 0.5 LOA, the vessel's engine was used to back the vessel at a controlled speed of about 2 knots. Vessel speed was brought down to below 0.5 knot as the vessel stern points east. When vessel was abeam of berth, tugs assistance was used to bring the vessel alongside the berth.

Vessel was berthed starboard side alongside without any incident. Vessel had enough resources to berth successfully alongside in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

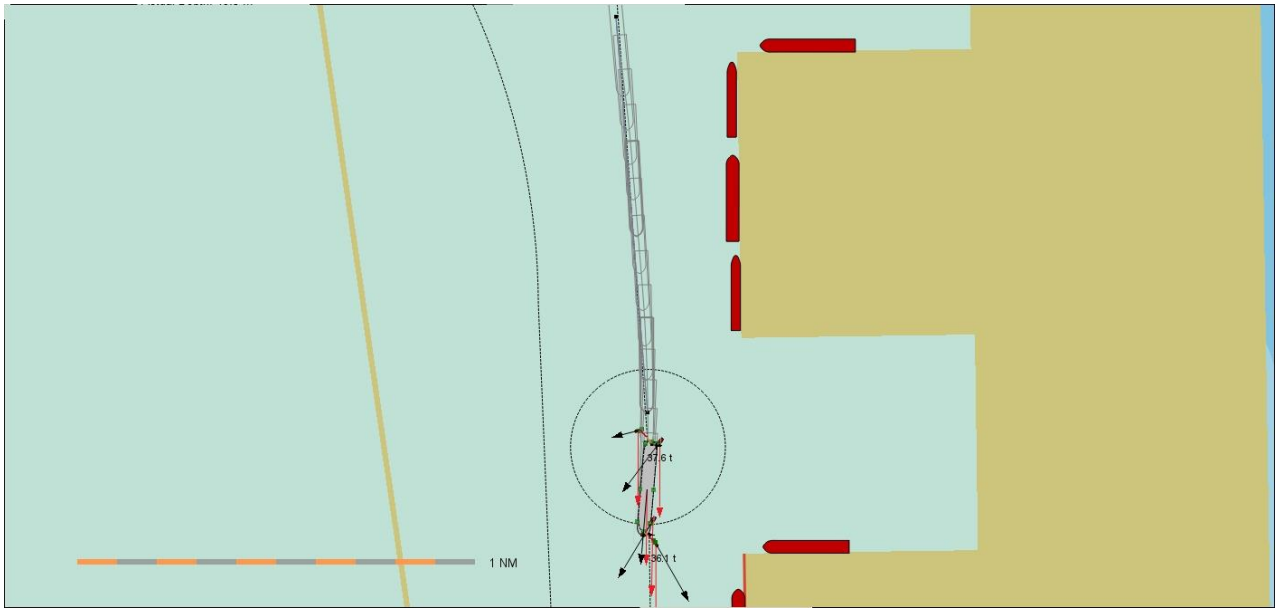
The entire run takes 1hr 31mins till the vessel was in a safe position to send out the mooring lines.

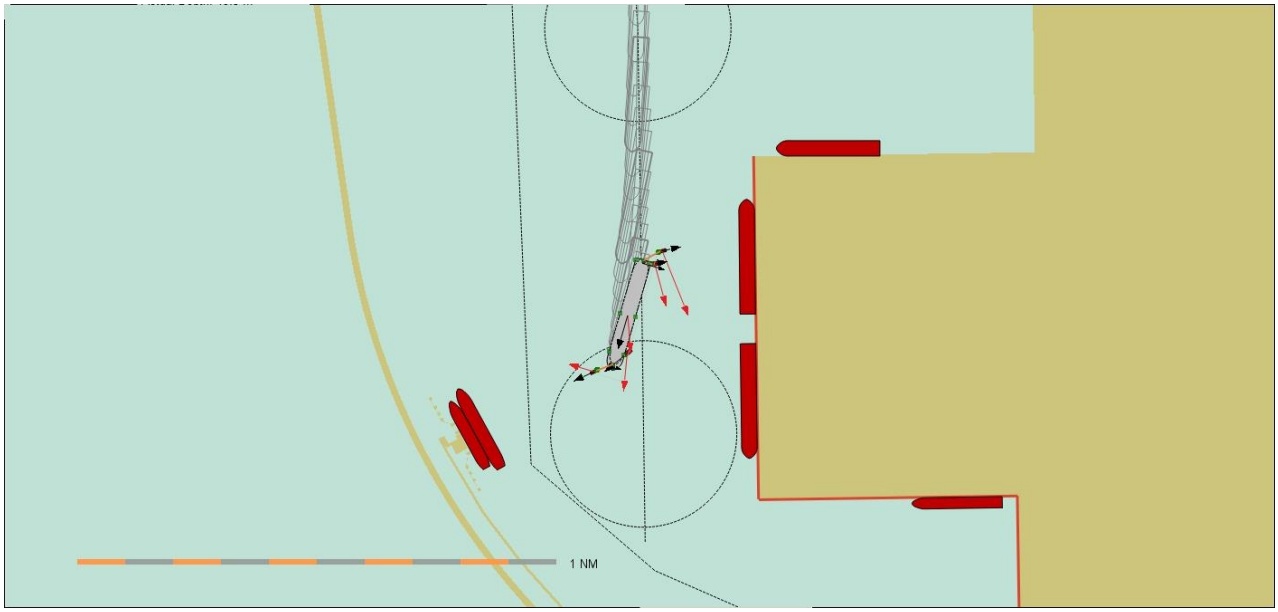
Maximum tug power used was 50% with occasional 75%.

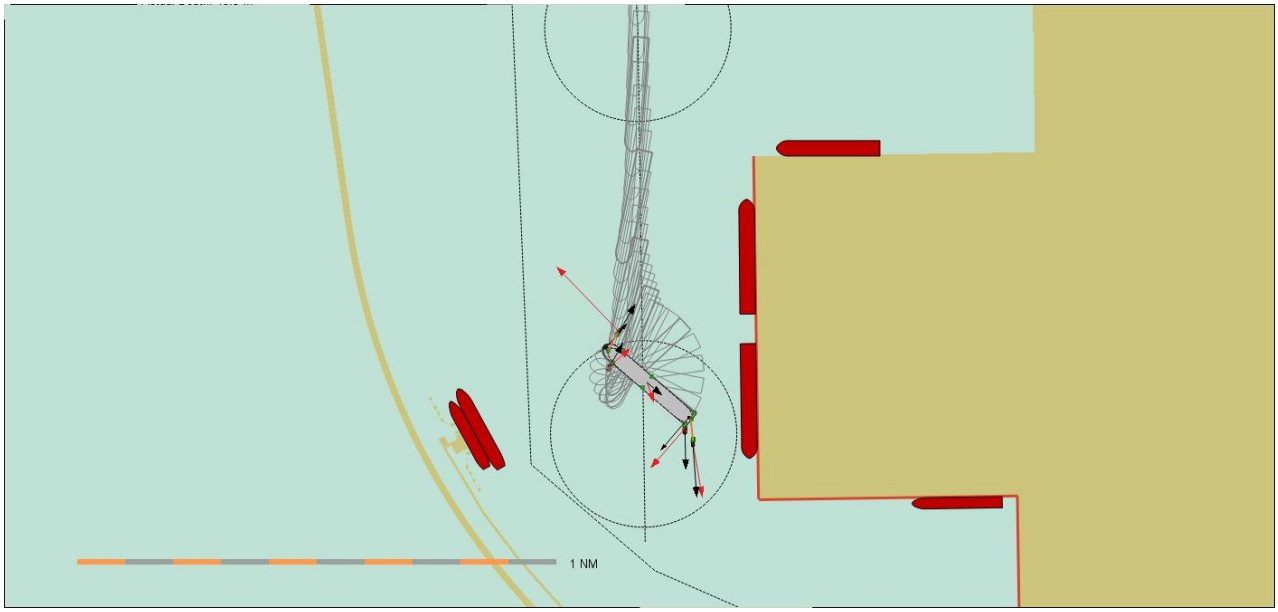
Manoeuver was graded as SUCCESSFUL.



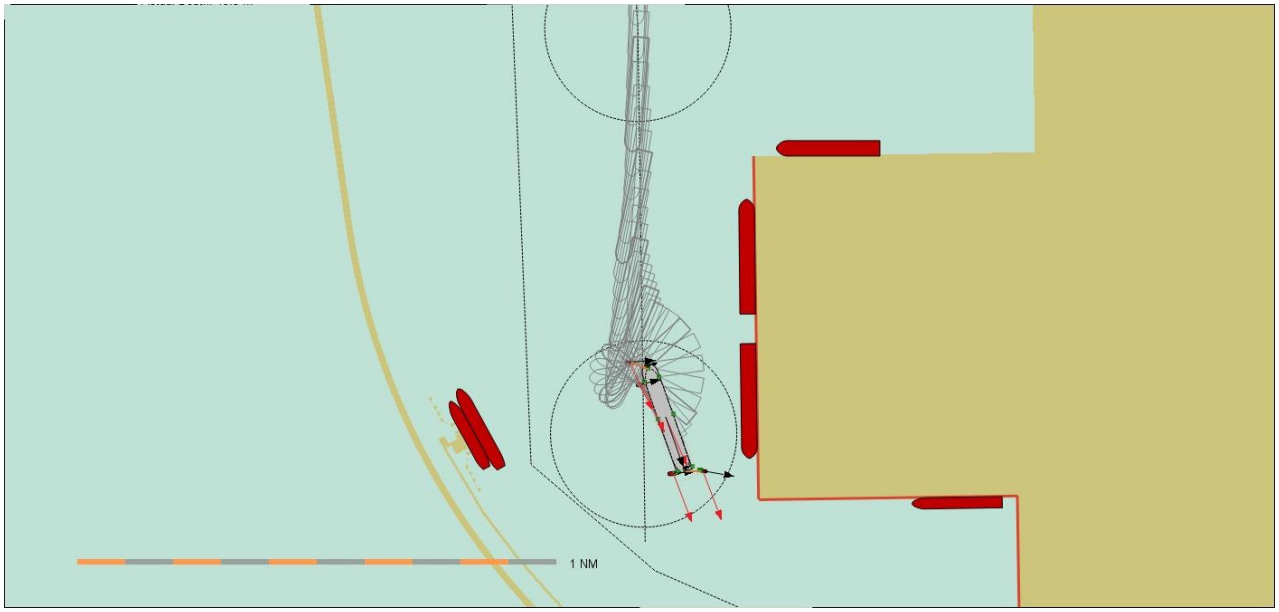
Run No.006

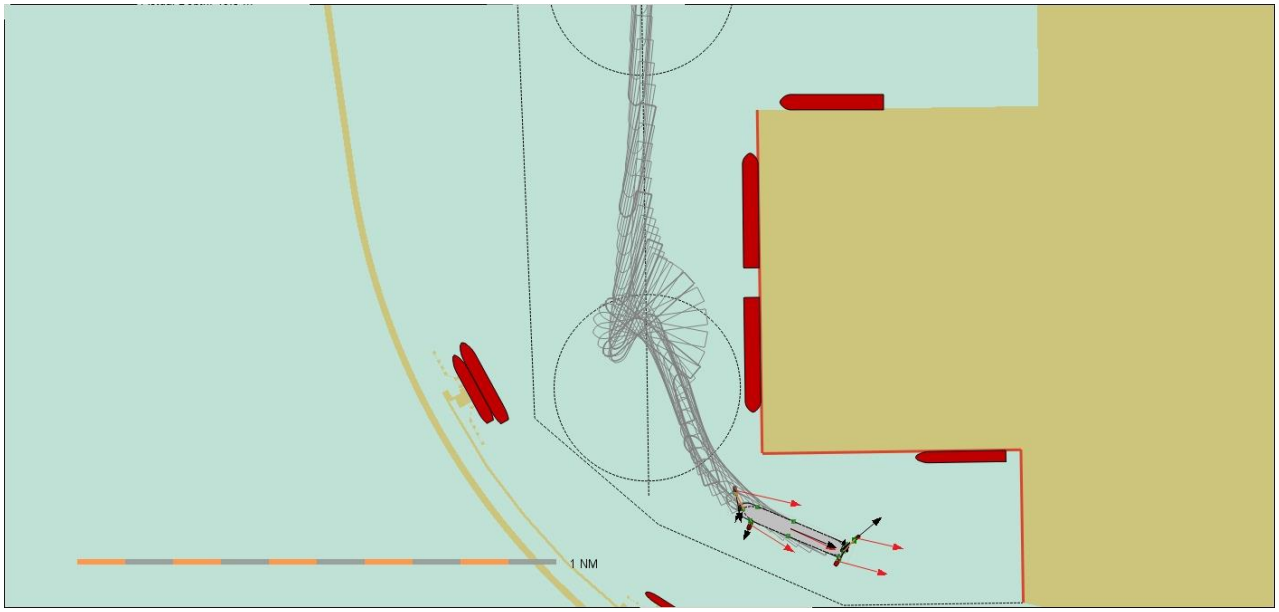


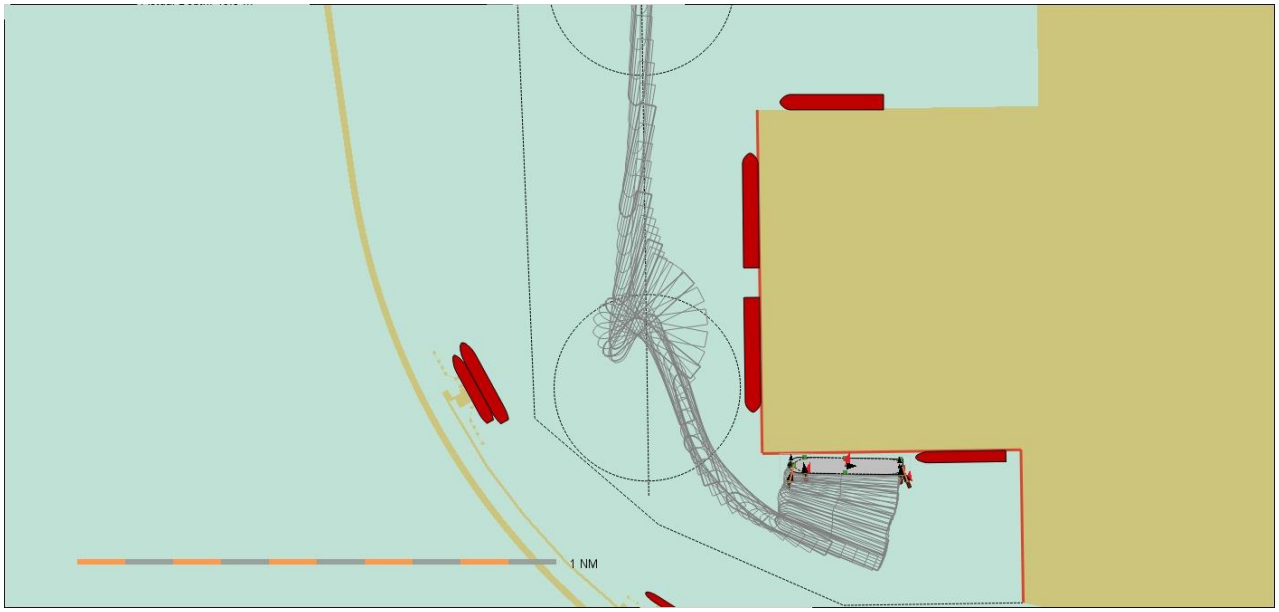




Run No.006







Run No.007

Berth	Container Terminal 1	Route	Depart Port side
Wind	045° x 10 knot	Current	Ebb (flowing South)
Duration	1hr 8mins	Grade	Successful

Comments

Two 100-ton bollard pull tugs were connected on starboard side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft. The tugs were used to pull vessel parallel off berth.

When vessel clears the berth by about 3 beam widths, the vessel's engine was used to back-out the vessel at a controlled speed of about 2 knots.

Forward and aft tugs were used to steer the vessel to clear pass the berth corner at a distance of about 0.5 LOA, and swing the vessel stern northward to the middle of fairway.

As vessel reaches the center of the third turning circle, the vessel speed was reduced to near zero knots and the tugs were used to swing the vessel stern to starboard. Vigilance was maintained to ensure vessel stays in middle of turning circle as the tugs swings the vessel and points the vessel bow northward.

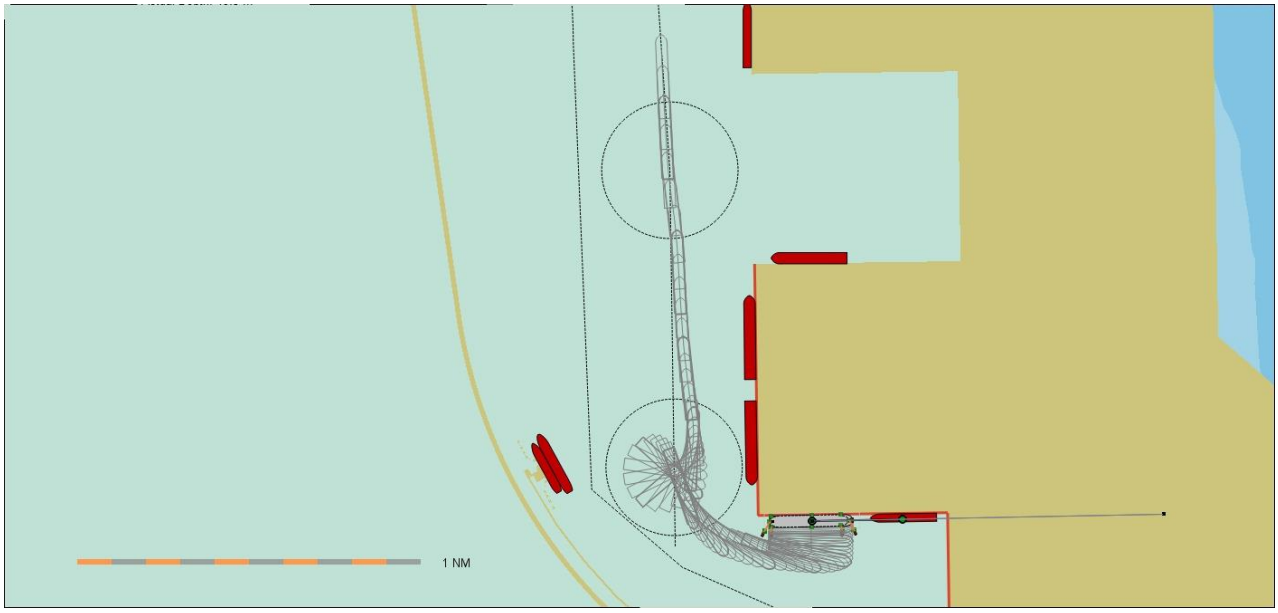
When the vessel bow was heading north stemming the current, the vessel's engine was put to slow ahead followed by half ahead to steer the vessel out. All tugs were casted off near the second turning circle.

Vessel had enough resources to un-berth and manoeuver towards the port exit in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

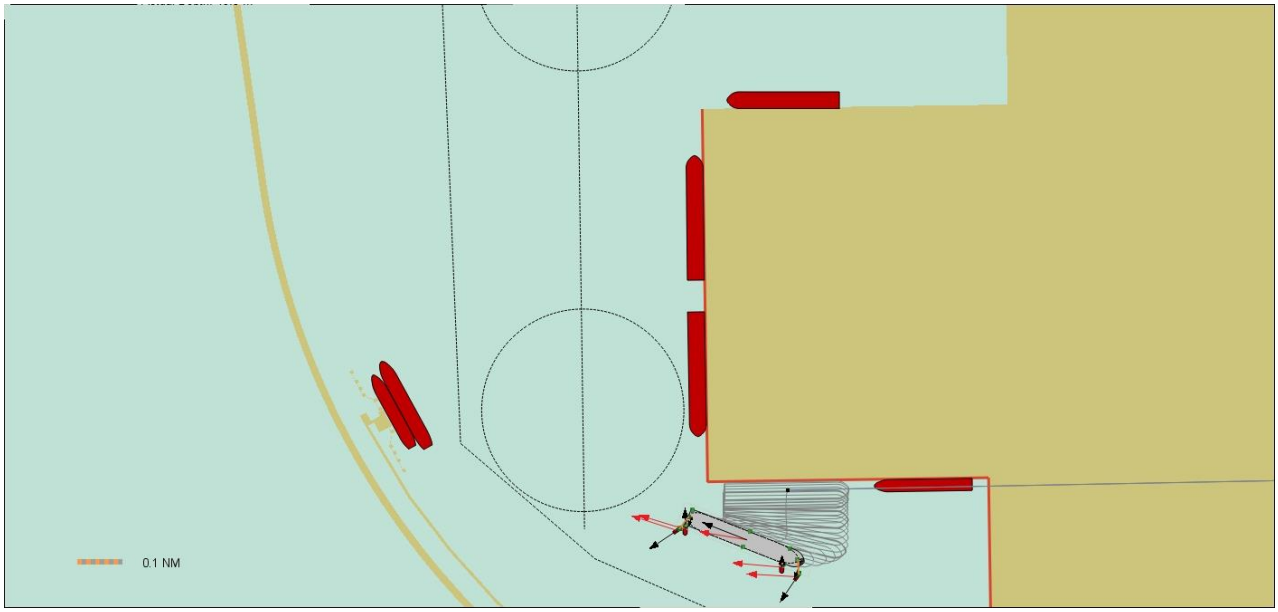
The entire run takes 1hr 8mins till the vessel was in a safe outbound position.

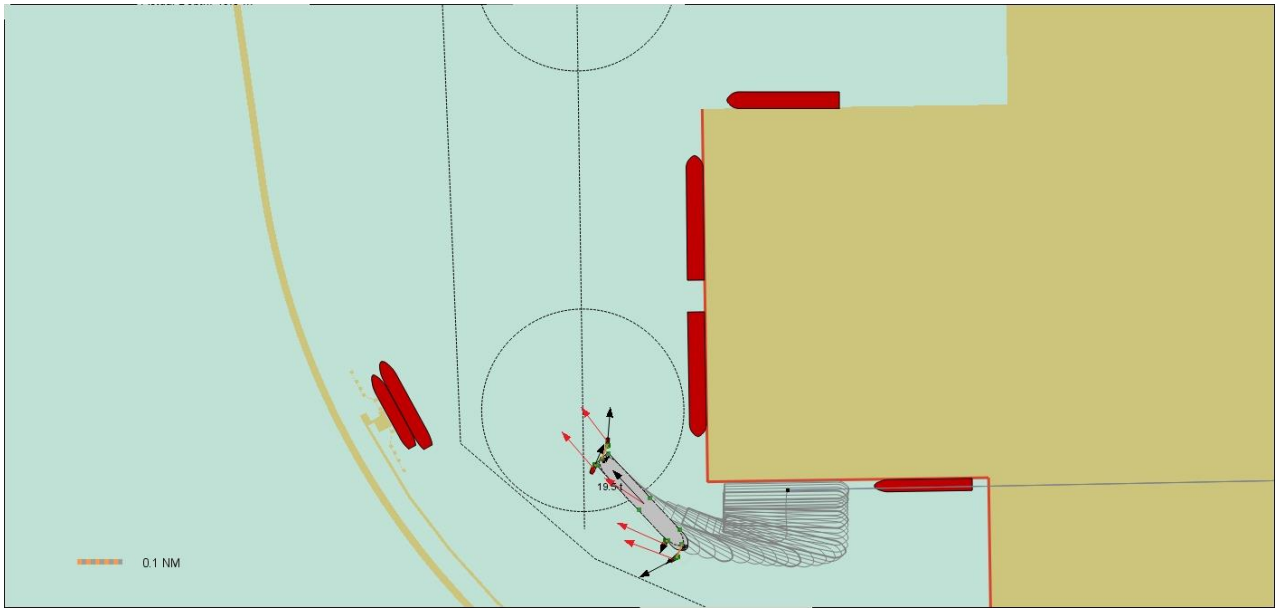
Maximum tug power used was 50%.

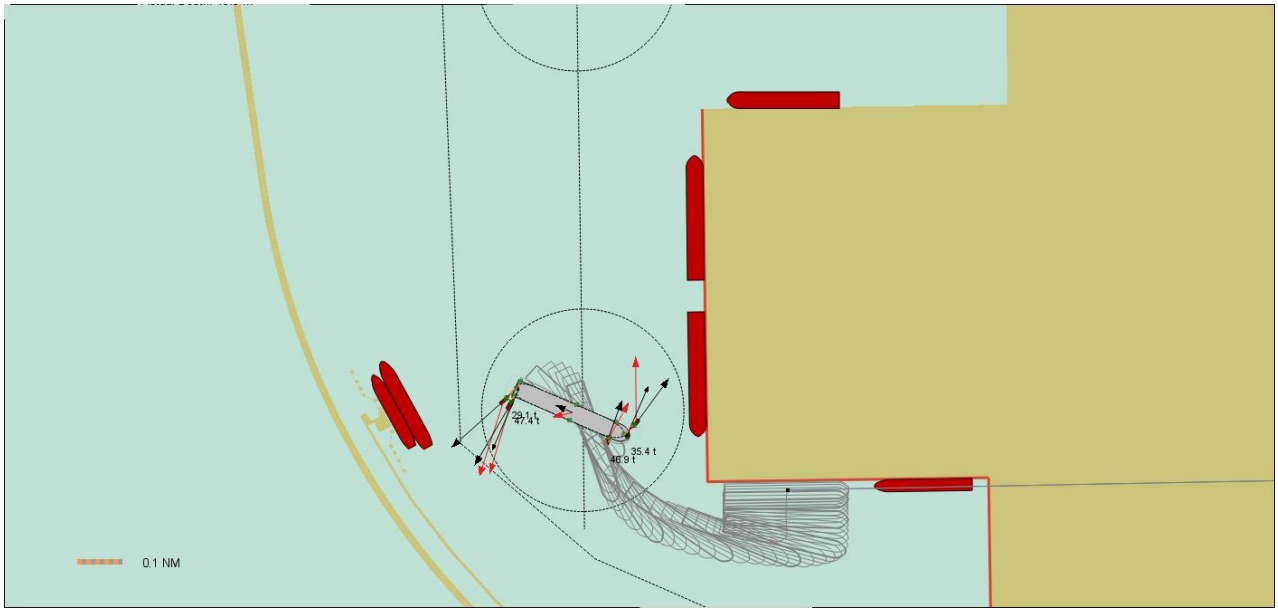
Manoeuver was graded as SUCCESSFUL.



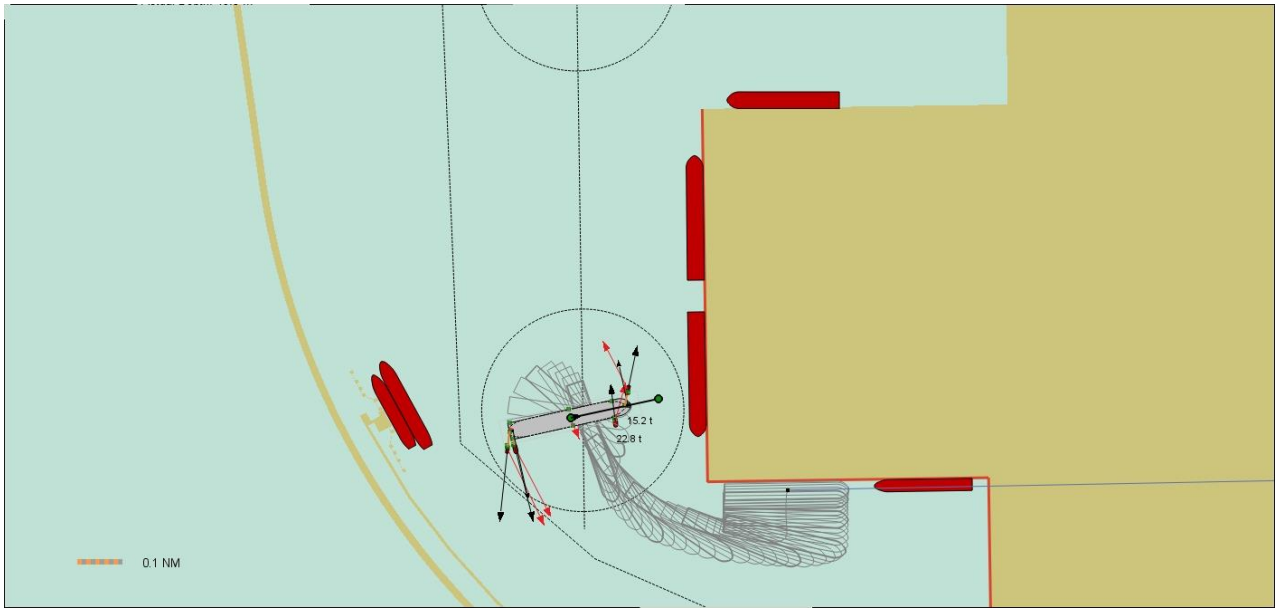
Run No.007

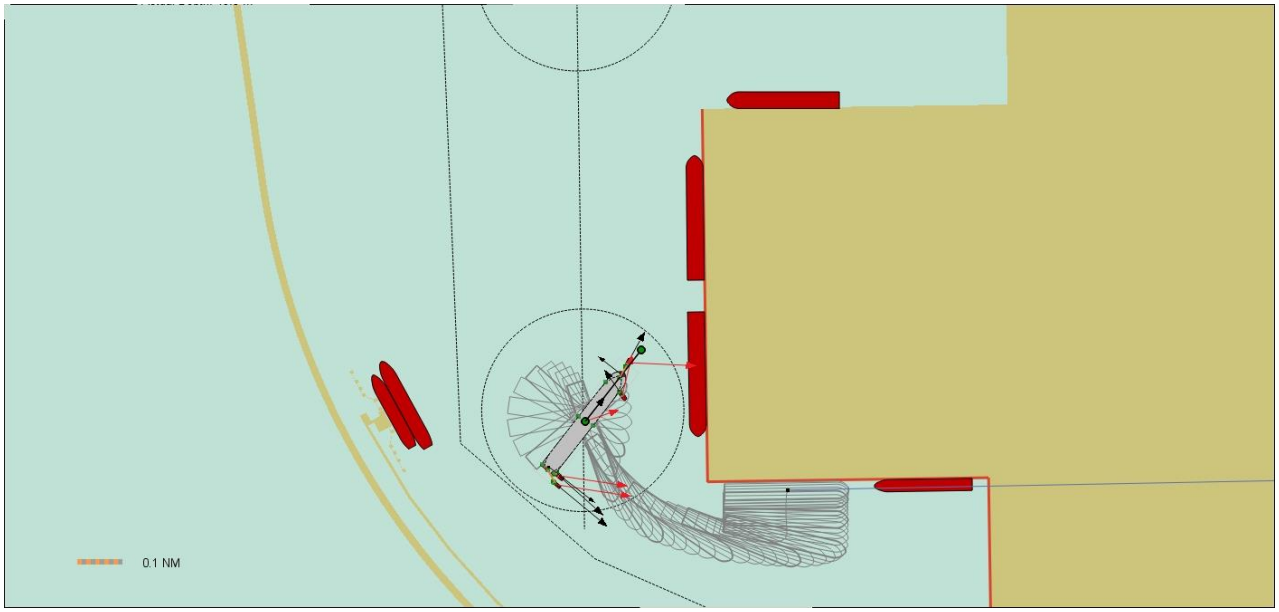


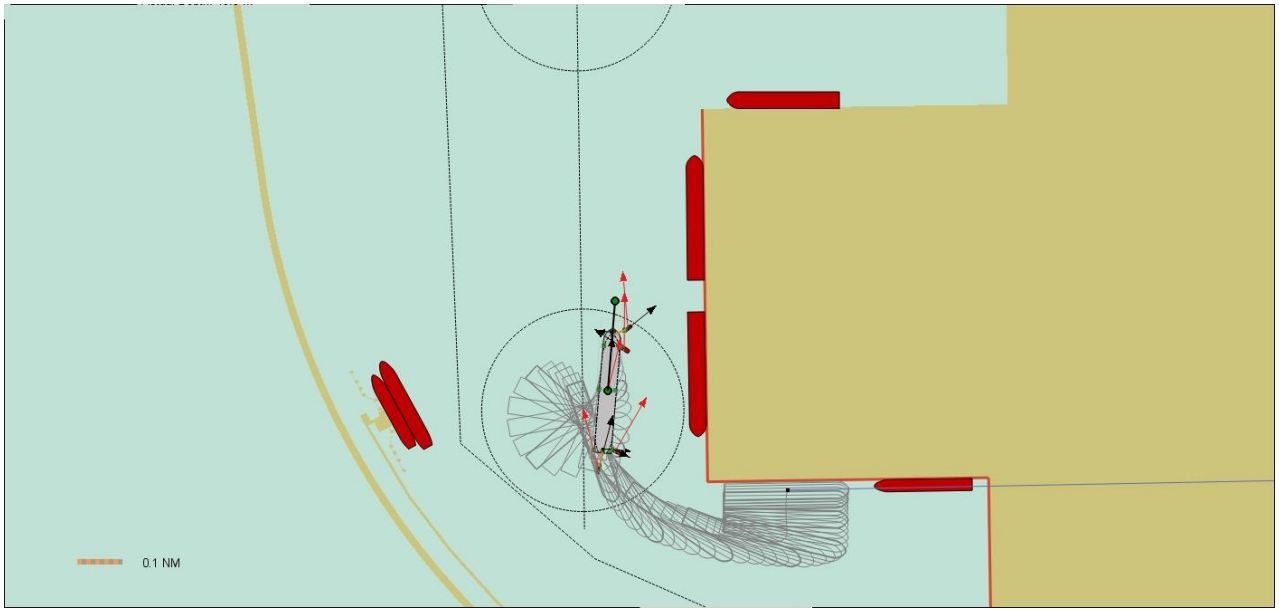




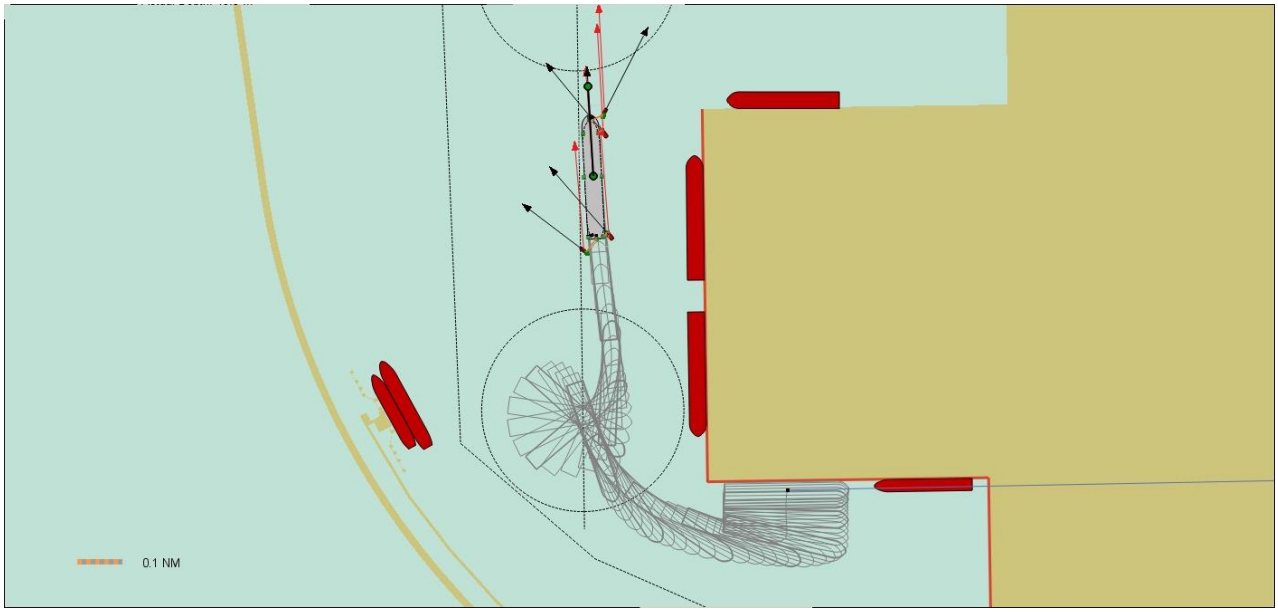
Run No.007

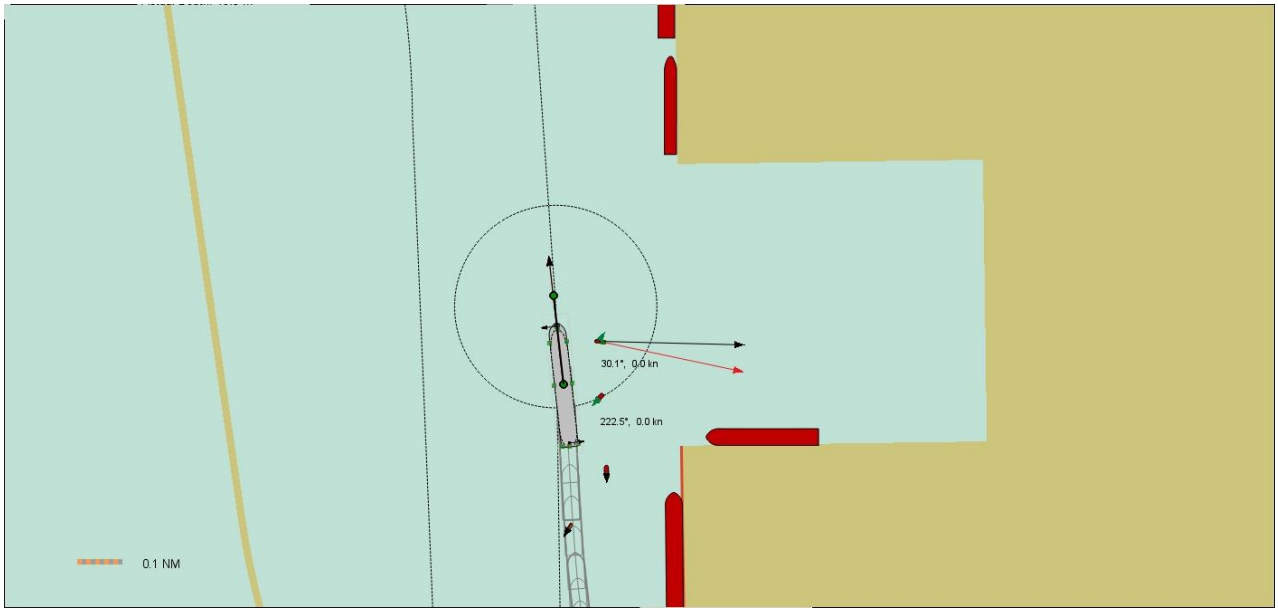


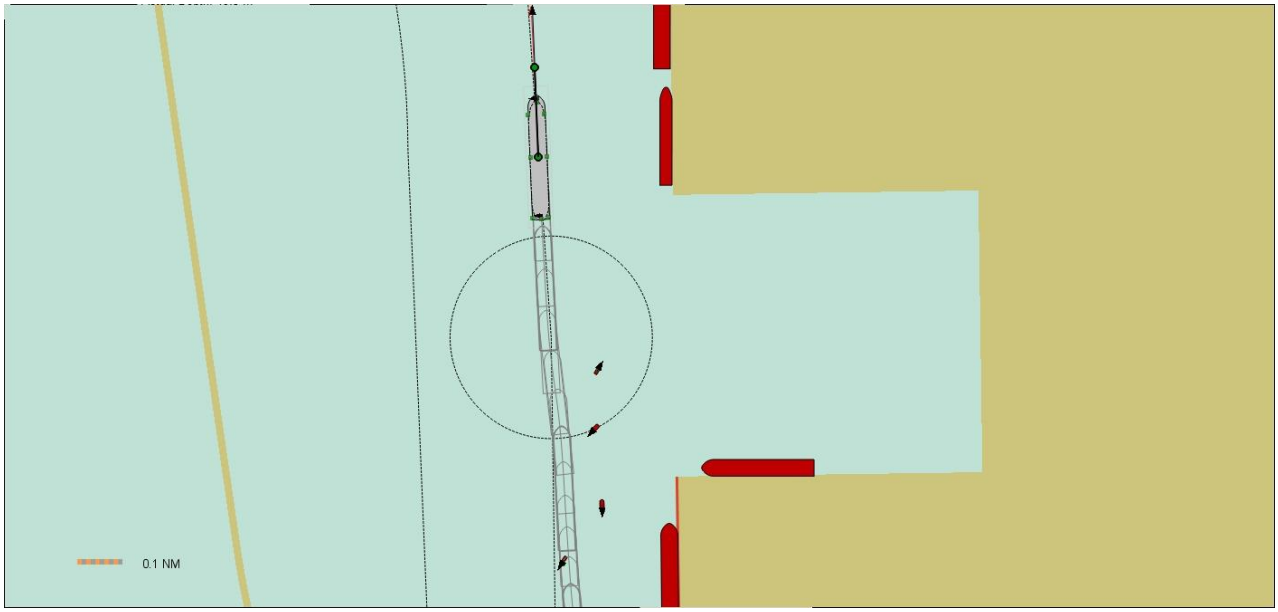




Run No.007







Run No.008

Berth	Container Terminal 1	Route	Depart Stbd side
Wind	045° x 10 knot	Current	Flood (flowing North)
Duration	51 mins	Grade	Successful

Comments

Two 100-ton bollard pull tugs were connected on port side with one at bow shoulder and one at quarter position and two 65-ton bollard pull tugs were connected with one at center lead forward and one at center lead aft. The tugs were used to pull vessel parallel off berth.

When vessel clears the berth by about 3 beam widths, the vessel's engine was used to move the vessel ahead at a controlled speed of about 2 knots.

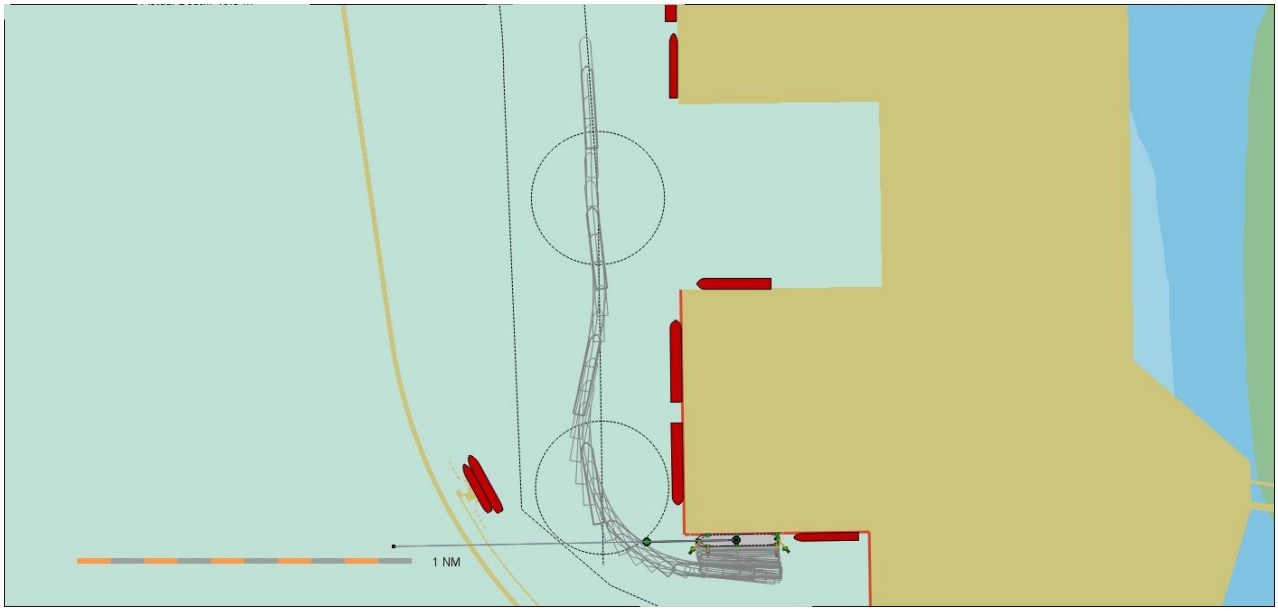
Vessel helm and tugs were used to steer the vessel to clear pass the berth corner at a distance of about 0.5 LOA, and swing the vessel bow northward to the middle of fairway. Vessel engine was then put to slow ahead followed by half ahead to steer the vessel out. All tugs were casted off near the second turning circle.

Vessel had enough resources to un-berth and manoeuver towards the port exit in a controlled manner. There was no significant concern during the manoeuver. The run was comfortable.

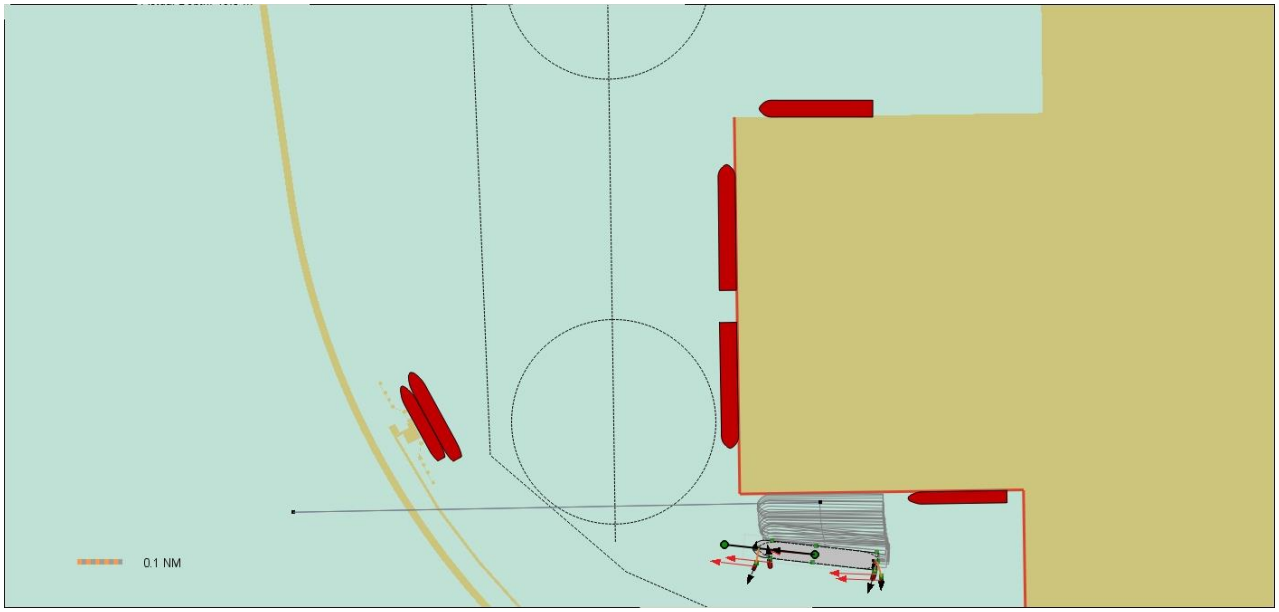
The entire run takes 51 mins till the vessel was in a safe outbound position.

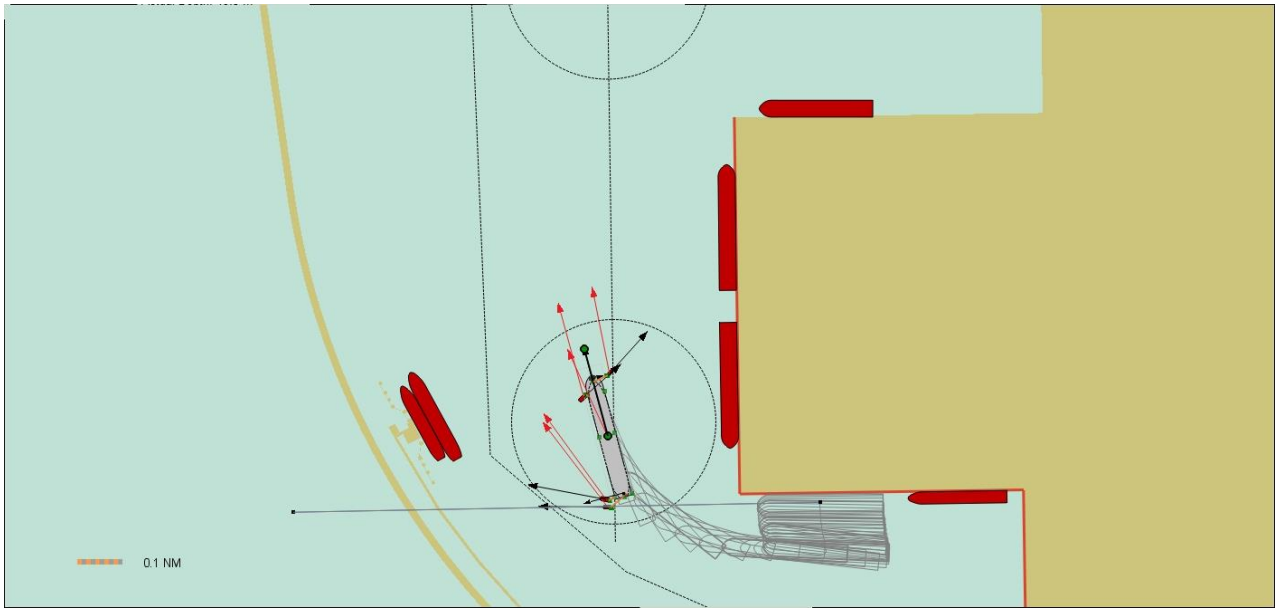
Maximum tug power used was 50%.

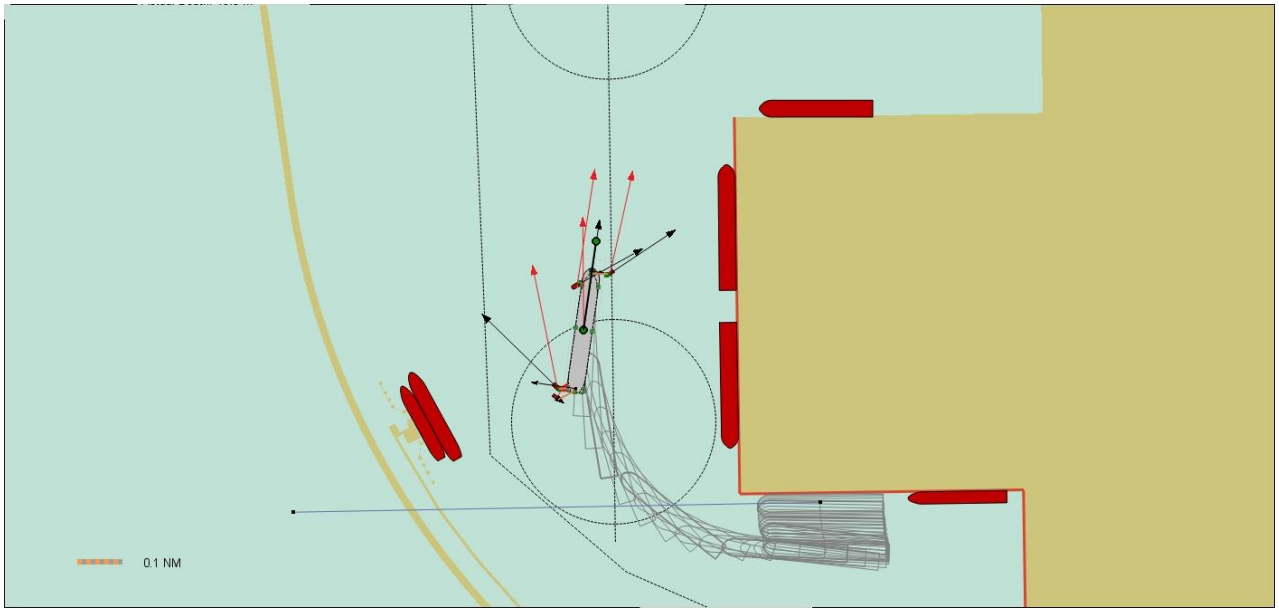
Manoeuver was graded as SUCCESSFUL.



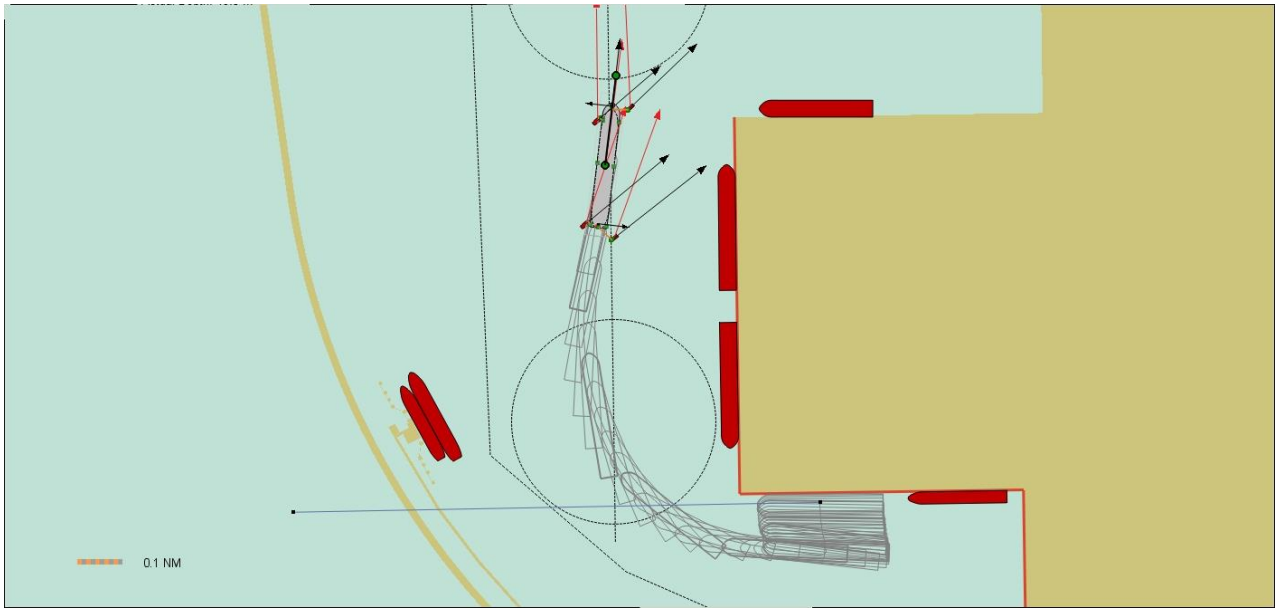
Run No.008

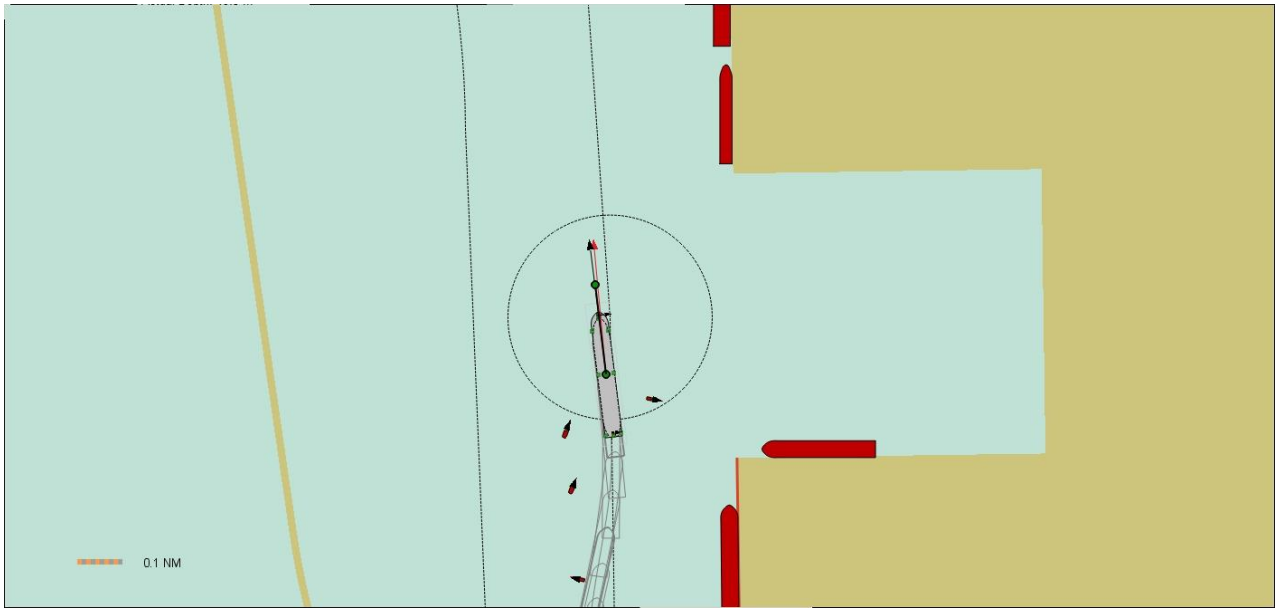


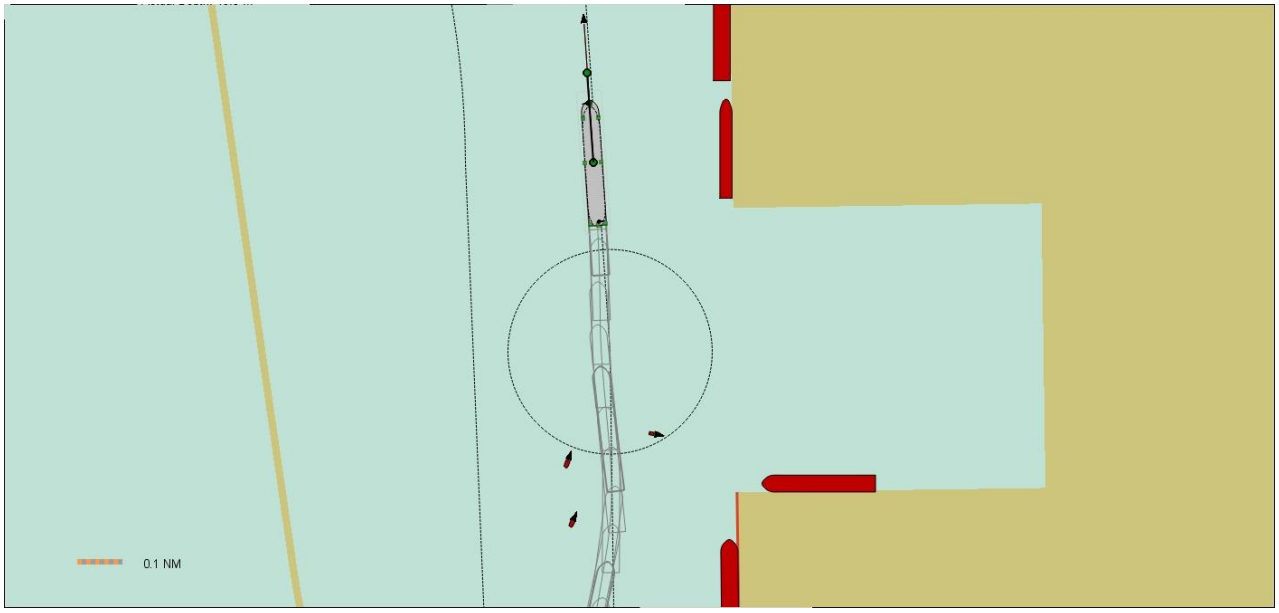




Run No.008







APPENDIX 4

Scenario Report Time Series Log Files

Desktop Navigation Simulations Study for Proposed New Layout of Vadhavan Port

Appendix 4

List of Scenario Report Time Series Log Files

20,000 TEU Container Ship (Model 3749)

Run No. and Scenario	Time Series Log File Name
Run No. 001-Cont.Terminal 2-Arrival-Port	001.pdf
Run No. 002-Cont.Terminal 2-Arrival-Stbd	002.pdf
Run No. 003-Cont.Terminal 2-Depart-Port	003.pdf
Run No. 004-Cont.Terminal 2-Depart-Stbd	004.pdf
Run No. 005-Cont.Terminal 1-Arrival-Port	005.pdf
Run No. 006-Cont.Terminal 1-Arrival-Stbd	006.pdf
Run No. 007-Cont.Terminal 1-Depart-Port	007.pdf
Run No. 008-Cont.Terminal 1-Depart-Stbd	008.pdf

Simflex - Scenario Report

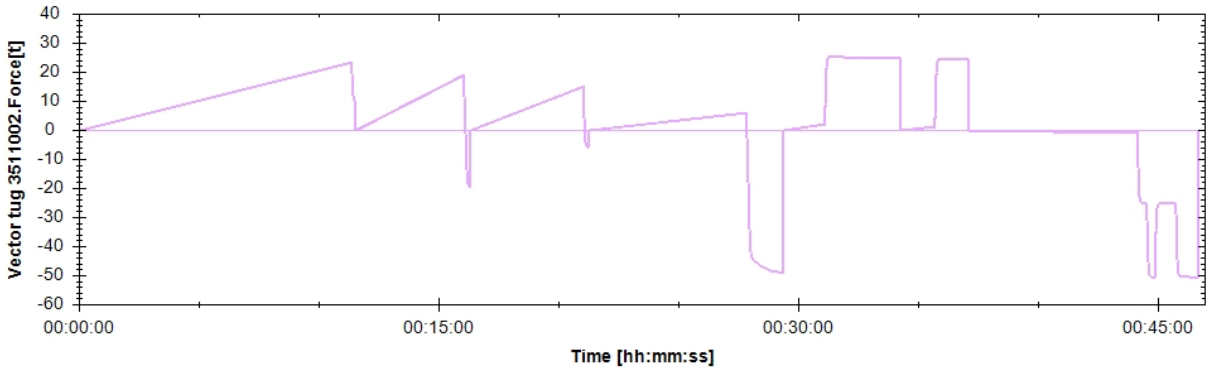
Scenario info

Scenario name: 001-Arr-CT2-Port-Flood-250x15kts

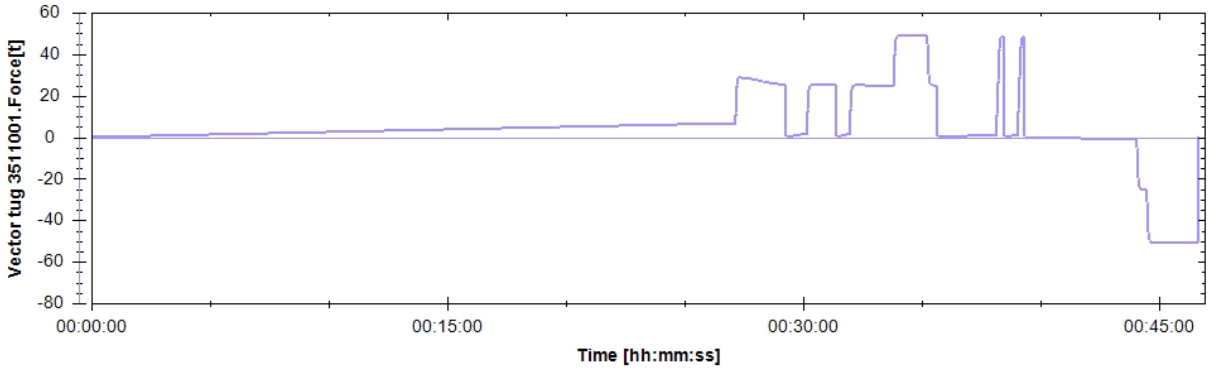
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	7.50	[m/s]
Wind dir.	Constant	250.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

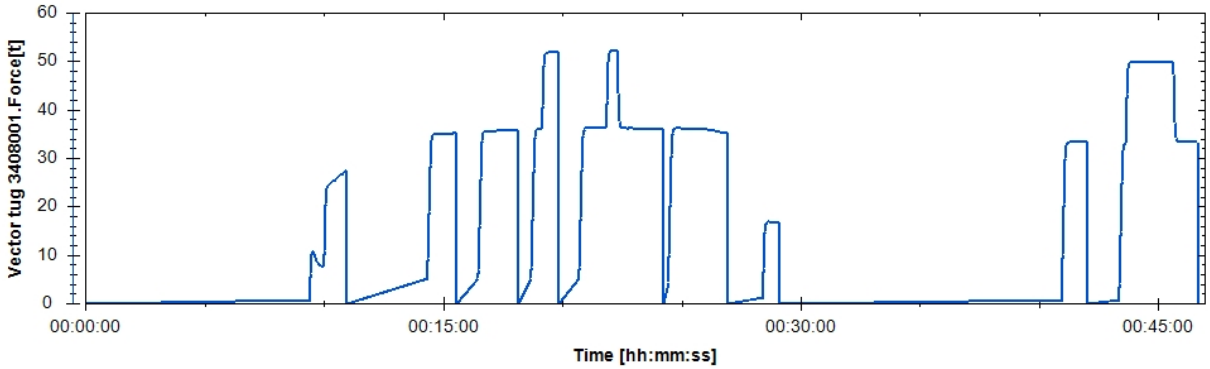
Selected Time Series



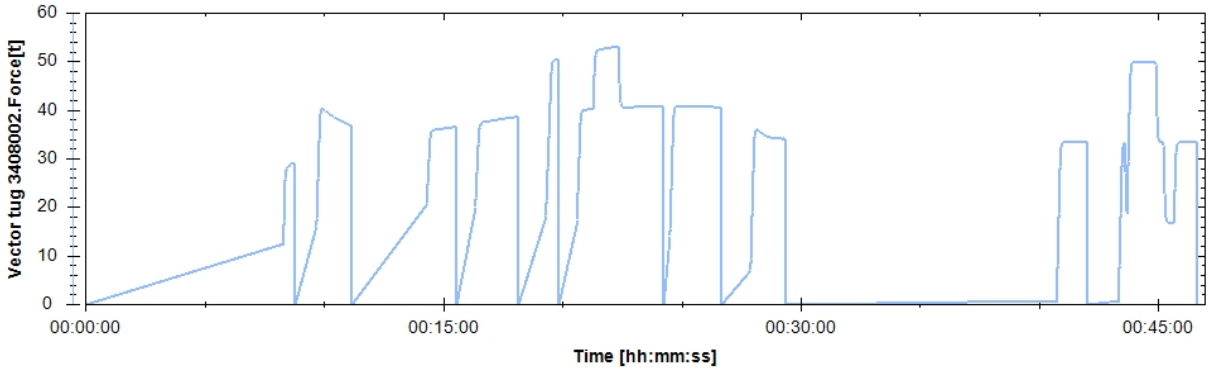
Vector tug 3511002.Force[t] (0.00)



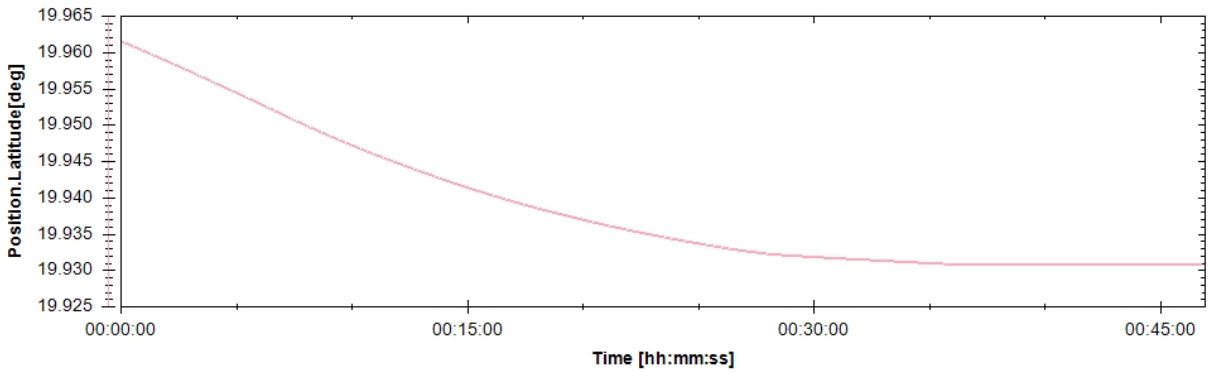
Vector tug 3511001.Force[t] (0.00)



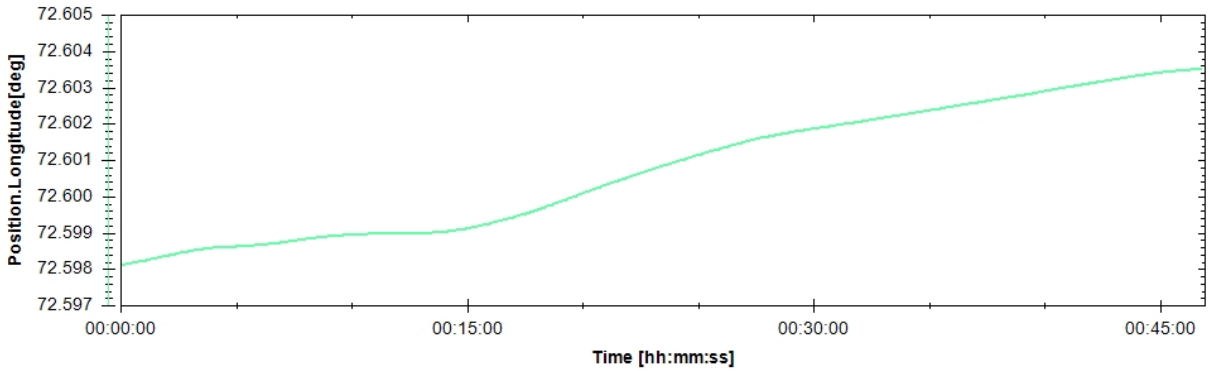
Vector tug 3408001.Force[t] (0.00)



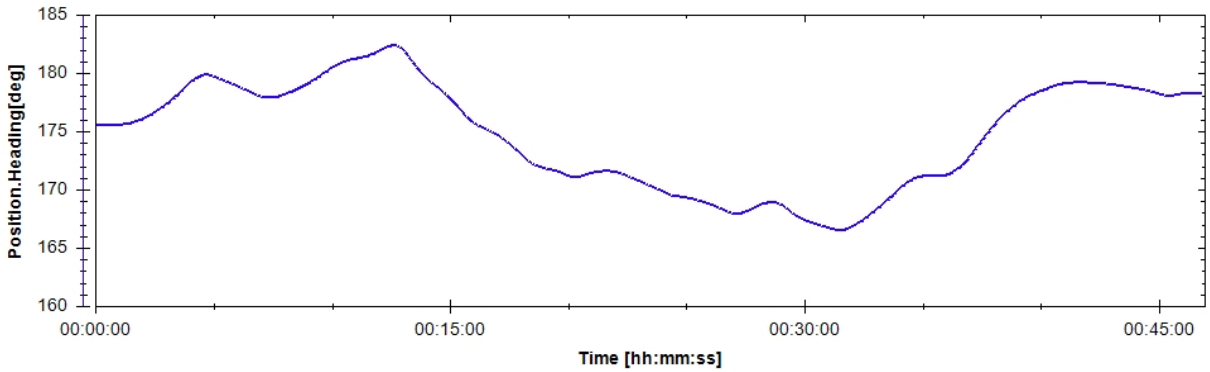
Vector tug 3408002.Force[t] (0.00)



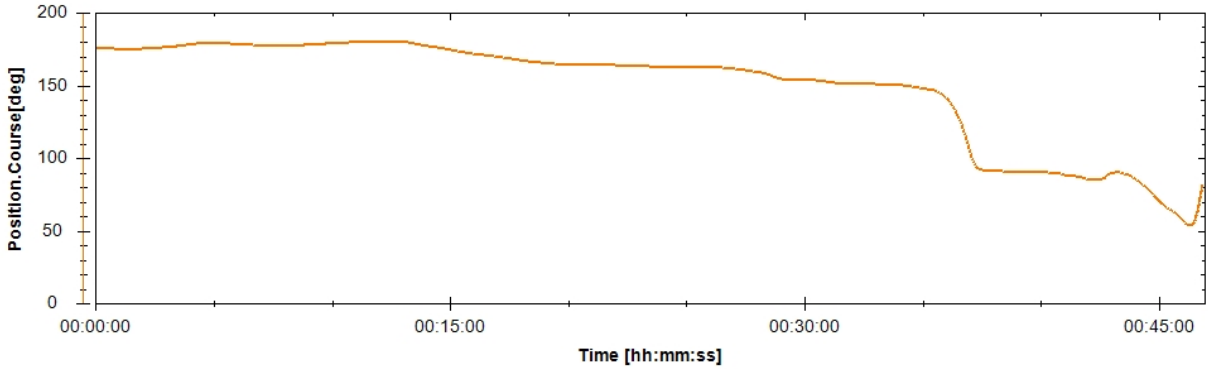
Position.Latitude[deg] (0.00)



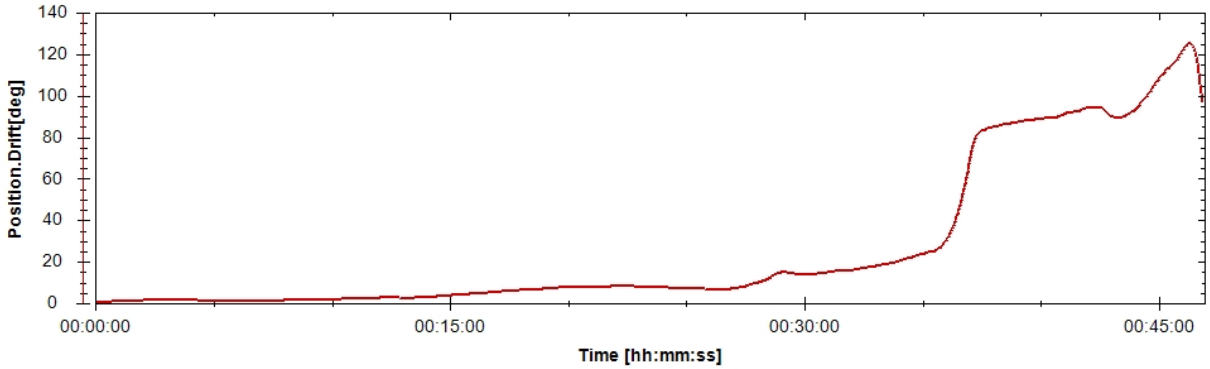
Position.Longitude[deg] (0.00)



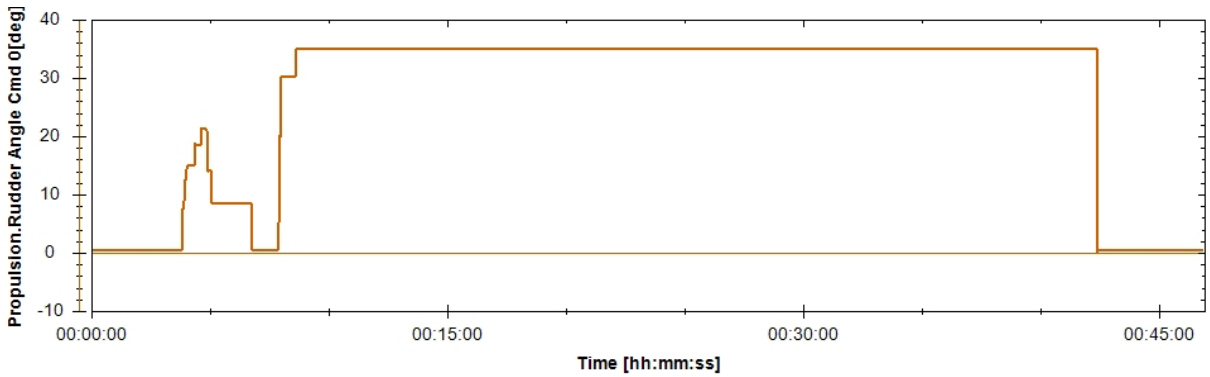
Position.Heading[deg] (0.00)



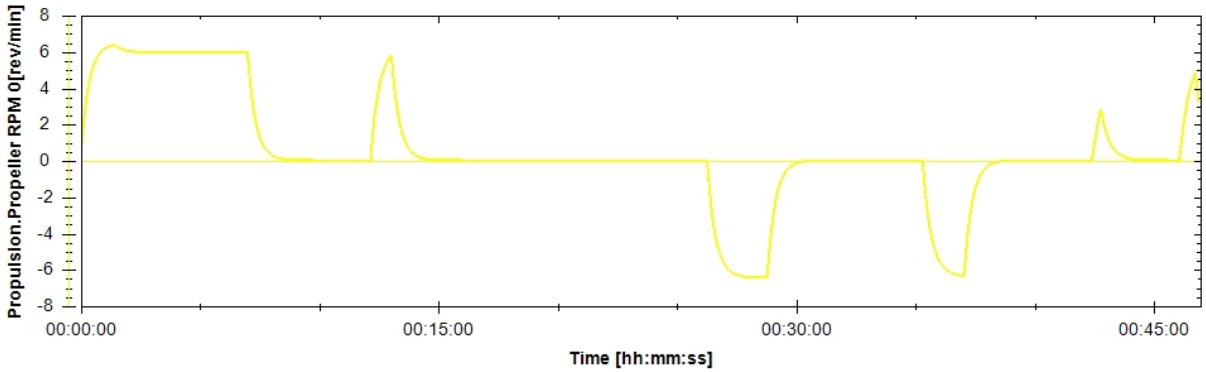
Position.Course[deg] (0.00)



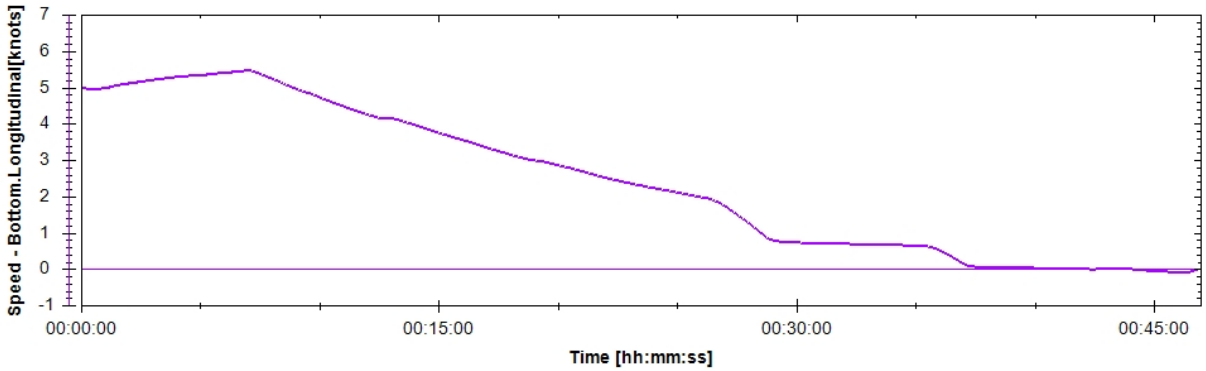
Position.Drift[deg] (0.00)



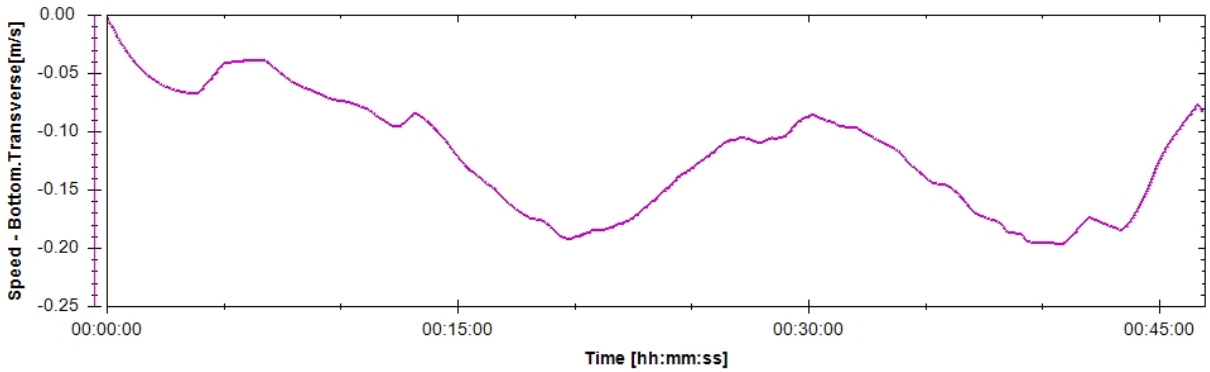
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



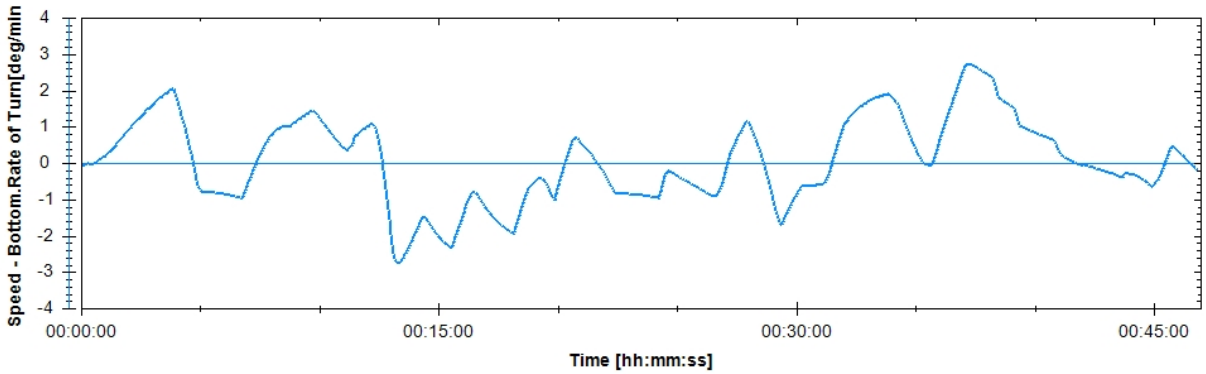
Propulsion.Propeller RPM 0[rev/min] (0.00)



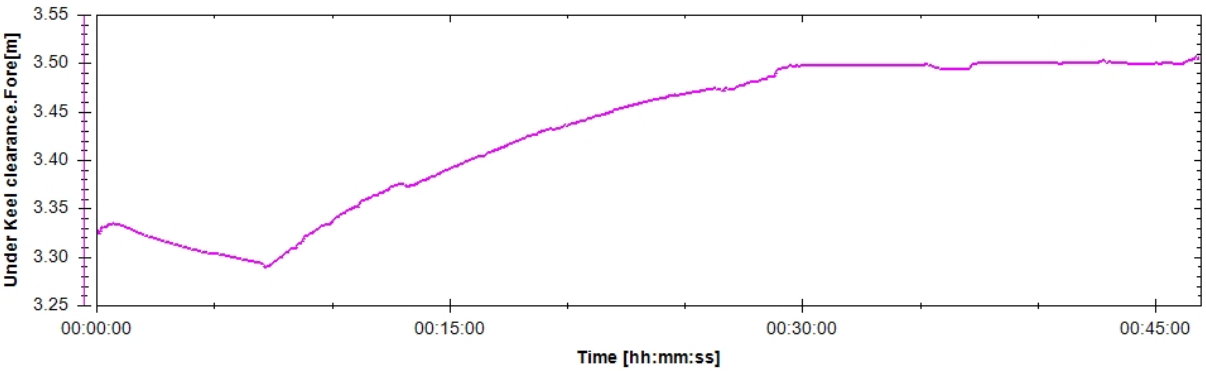
Speed - Bottom.Longitudinal[knots] (0.00)



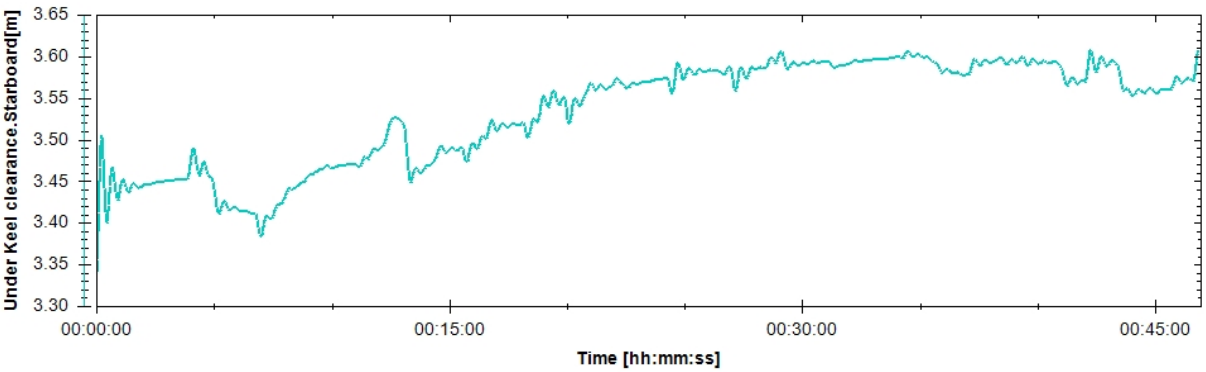
Speed - Bottom.Transverse[m/s] (0.00)



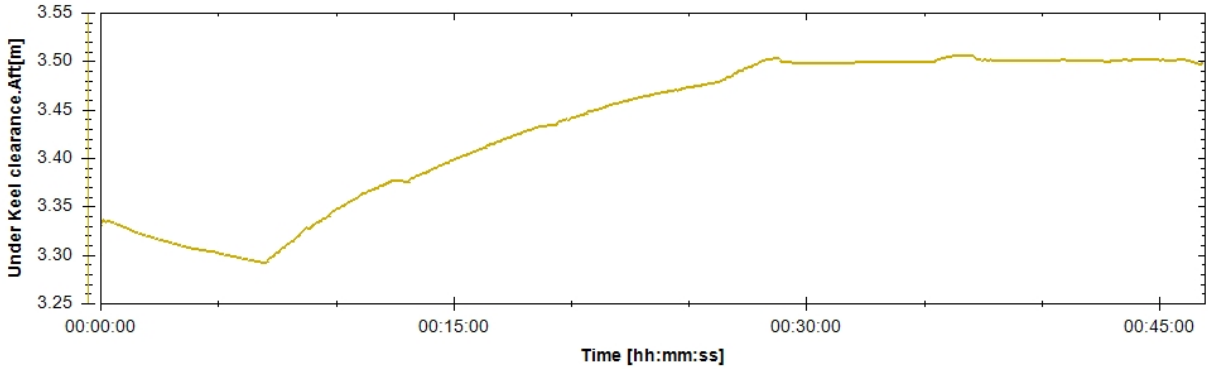
Speed - Bottom.Rate of Turn[deg/min] (0.00)



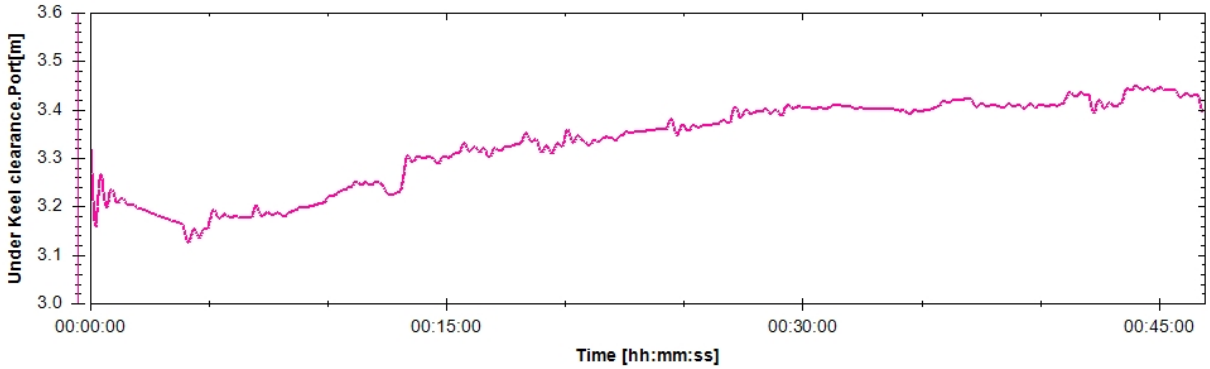
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



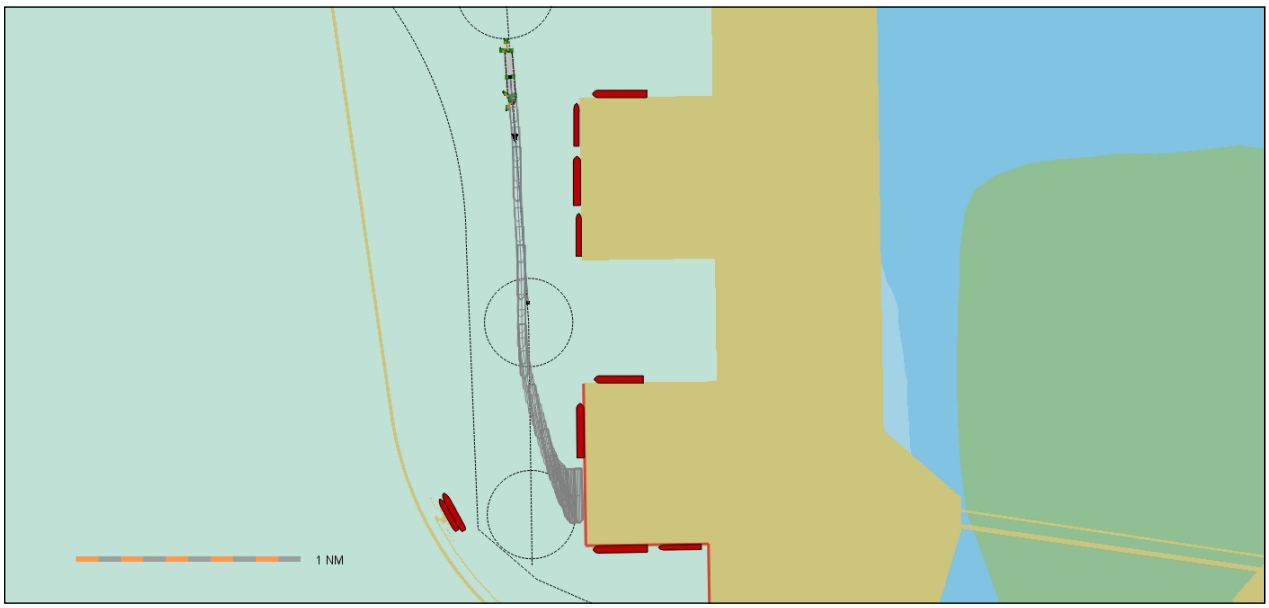
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 58.00195' N 072° 33.51897' E
Bottom right: 19° 55.36065' N 072° 39.41575' E

End-Of-Report

Simflex - Scenario Report

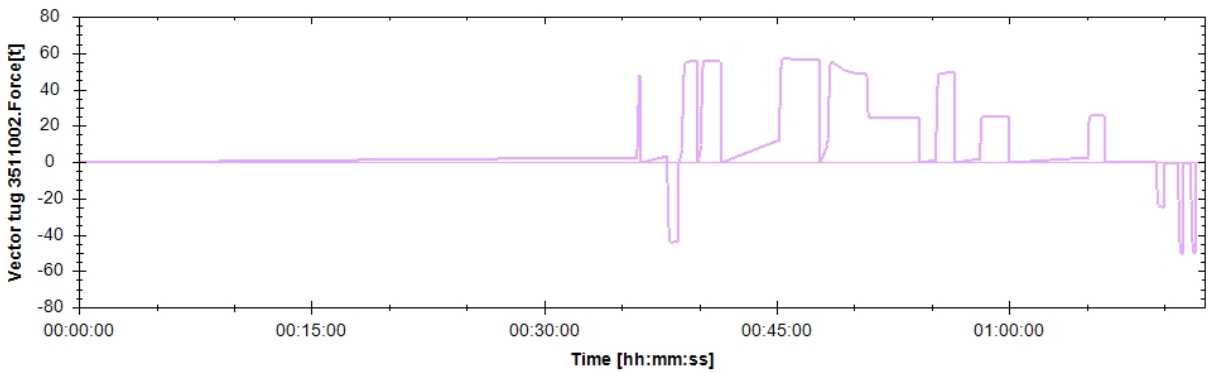
Scenario info

Scenario name: 002-Arr-CT2-Stbd-Ebb-250x15kts

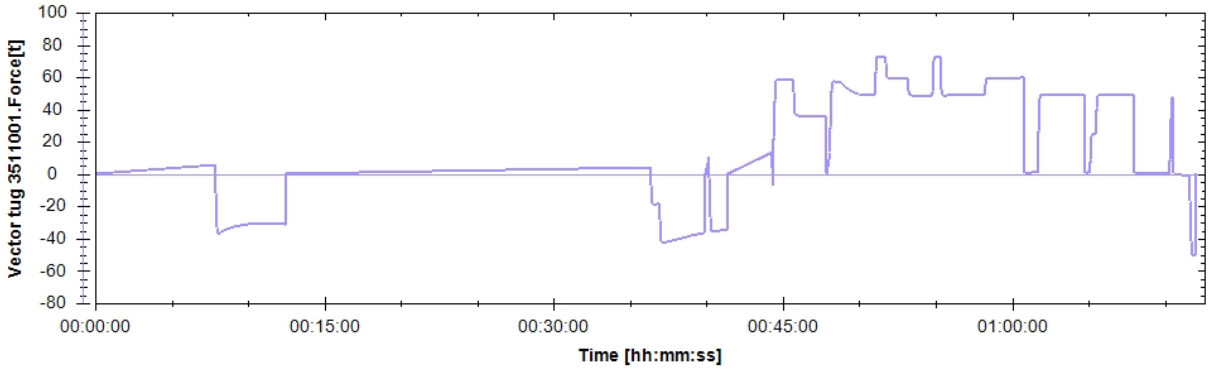
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	7.50	[m/s]
Wind dir.	Constant	250.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

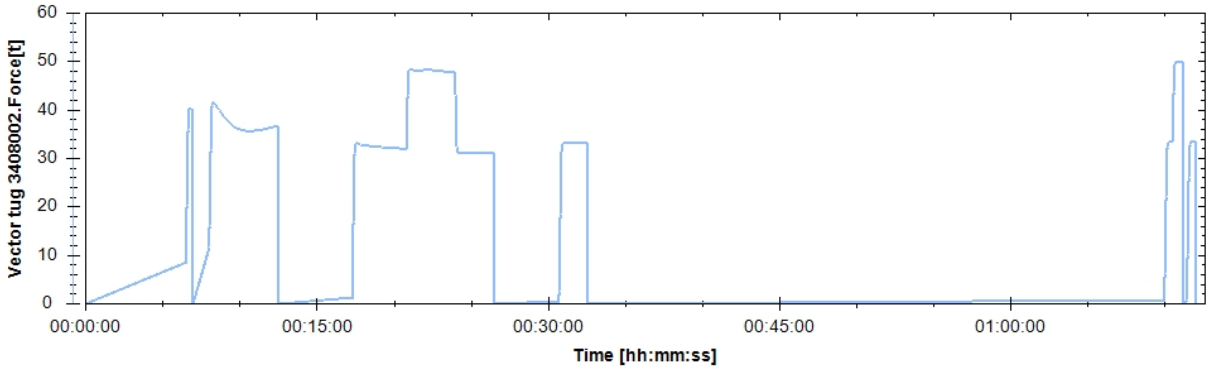
Selected Time Series



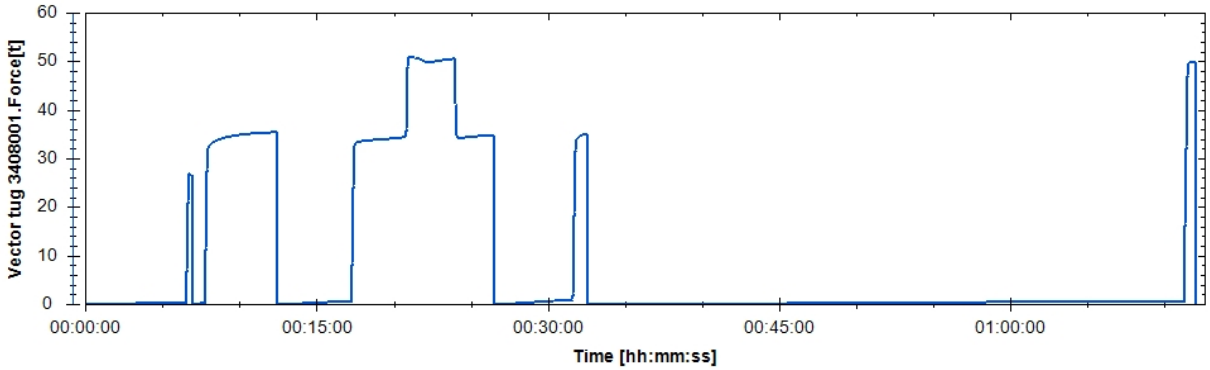
Vector tug 3511002.Force[t] (0.00)



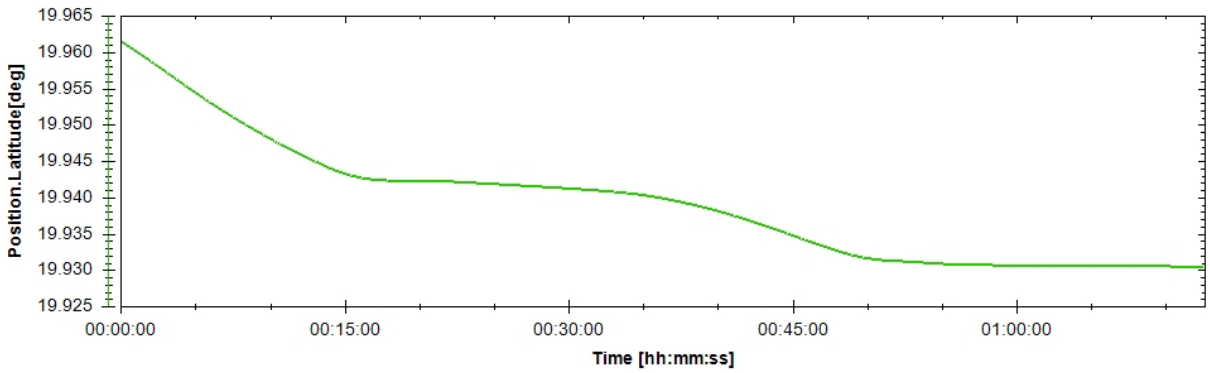
Vector tug 3511001.Force[t] (0.00)



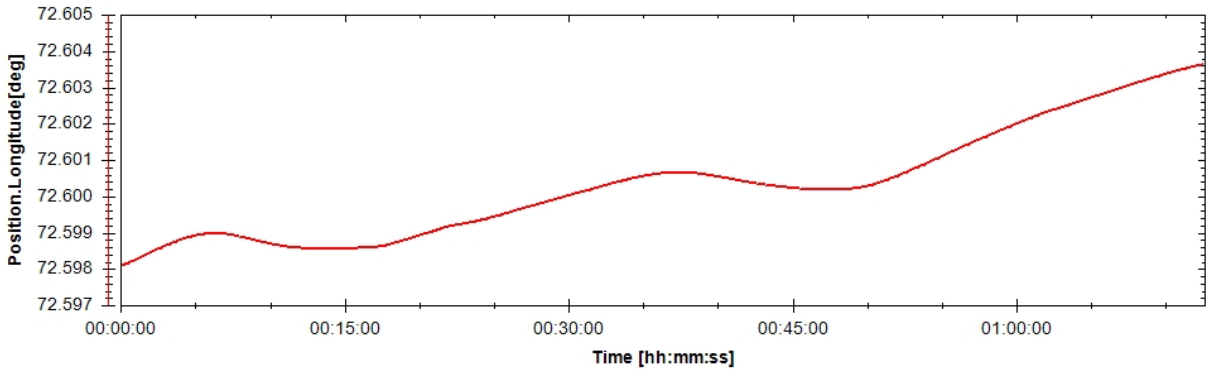
Vector tug 3408002.Force[t] (0.00)



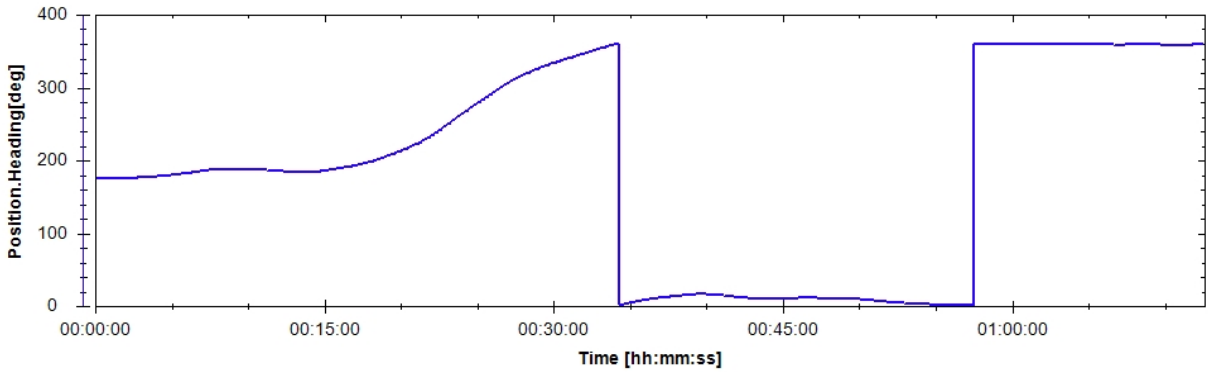
Vector tug 3408001.Force[t] (0.00)



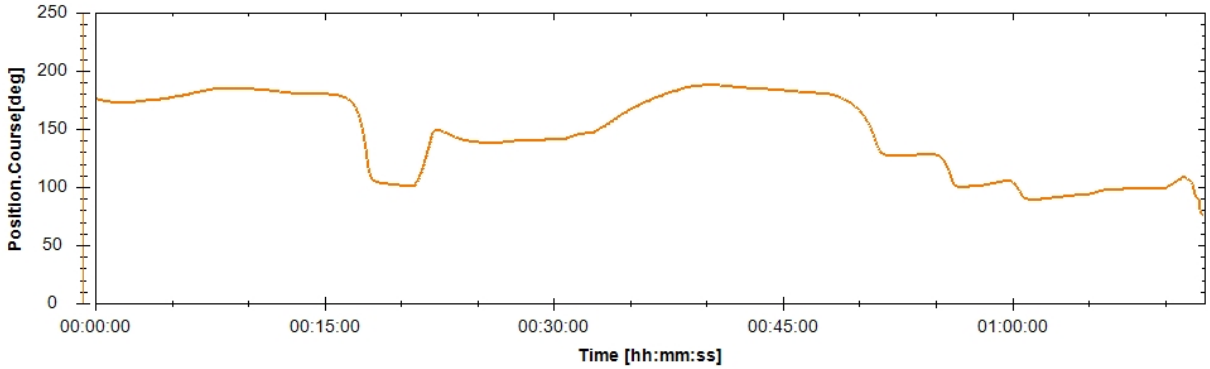
Position.Latitude[deg] (0.00)



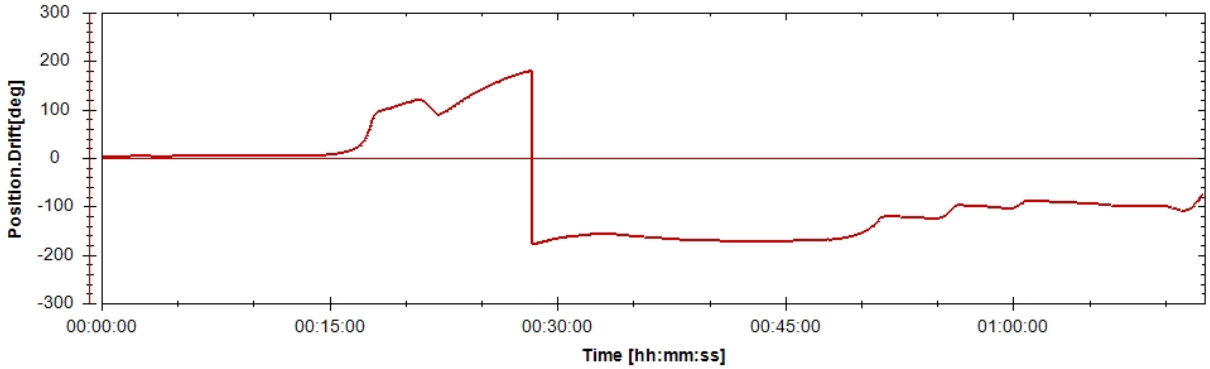
Position.Longitude[deg] (0.00)



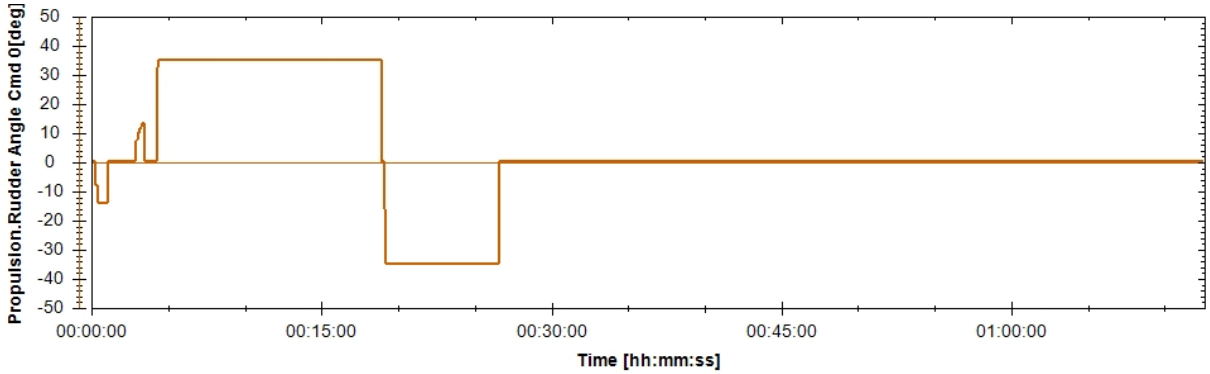
Position.Heading[deg] (0.00)



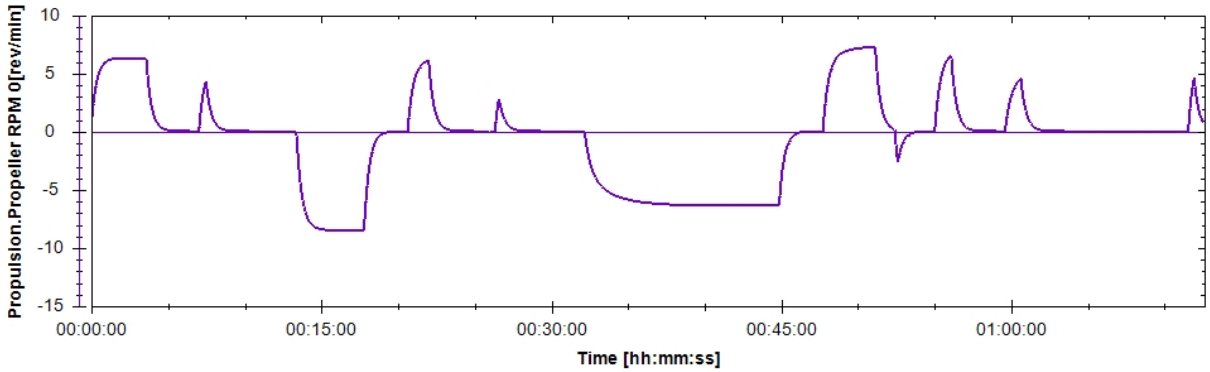
Position.Course[deg] (0.00)



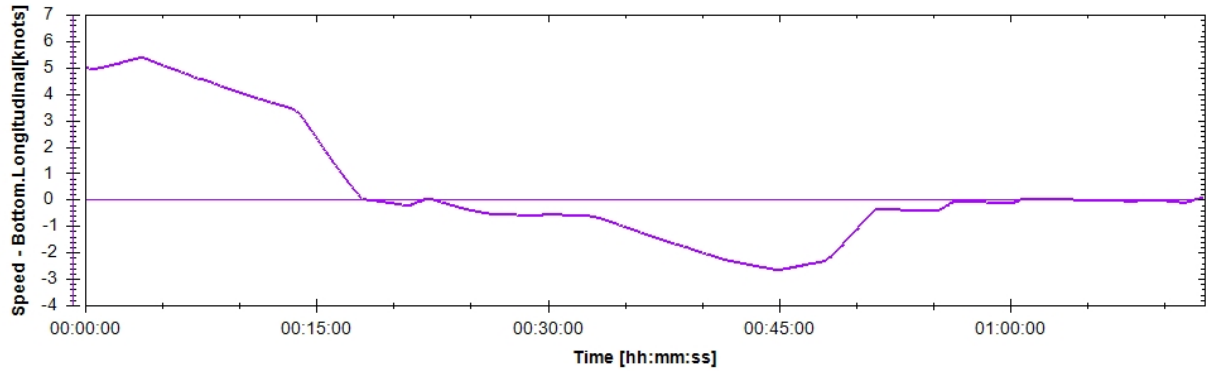
Position.Drift[deg] (0.00)



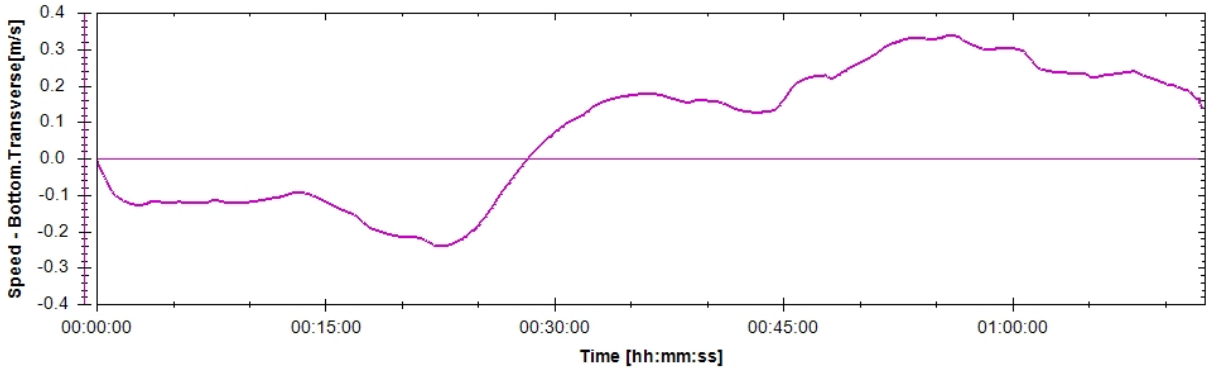
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



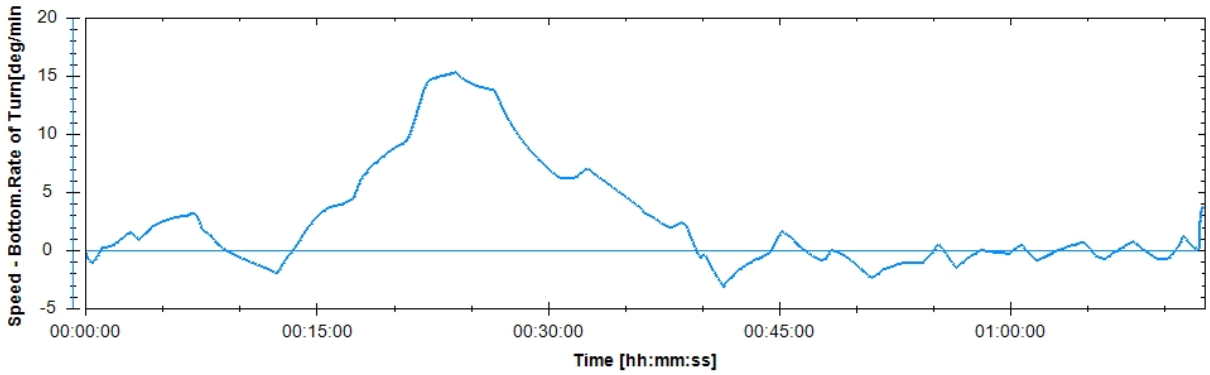
Propulsion.Propeller RPM 0[rev/min] (0.00)



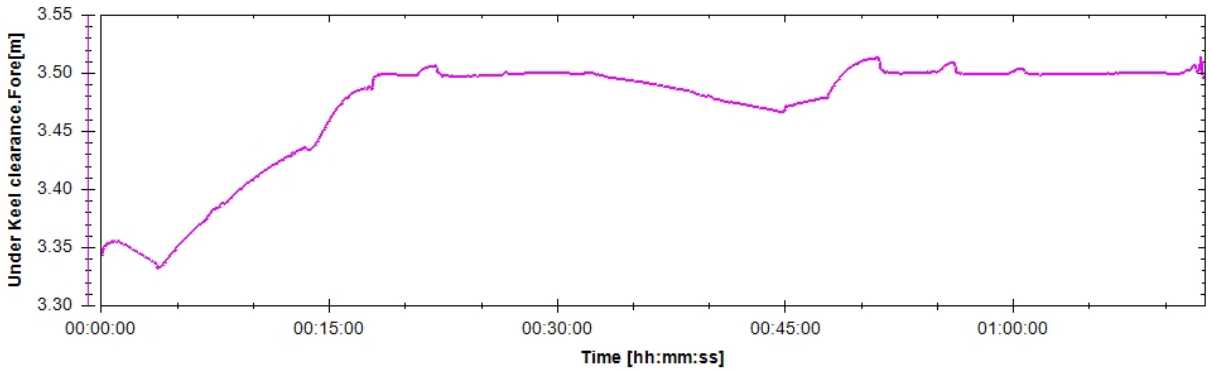
Speed - Bottom.Longitudinal[knots] (0.00)



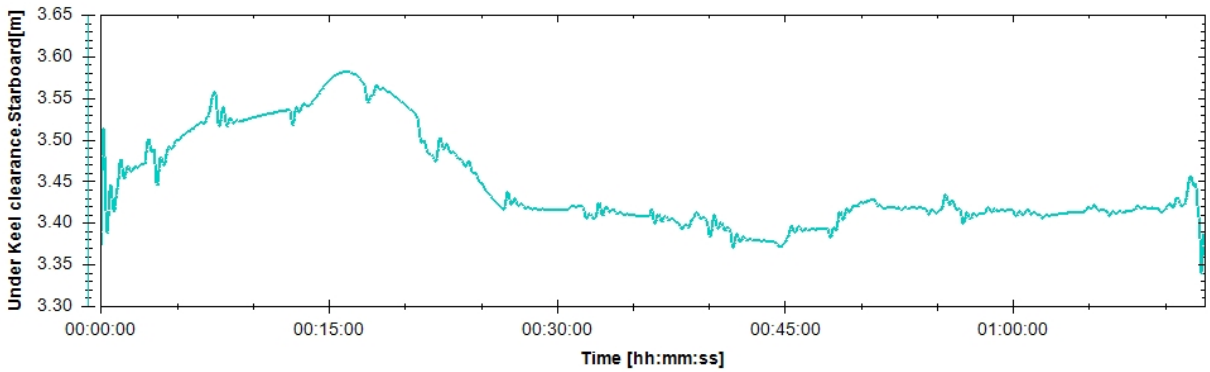
Speed - Bottom.Transverse[m/s] (0.00)



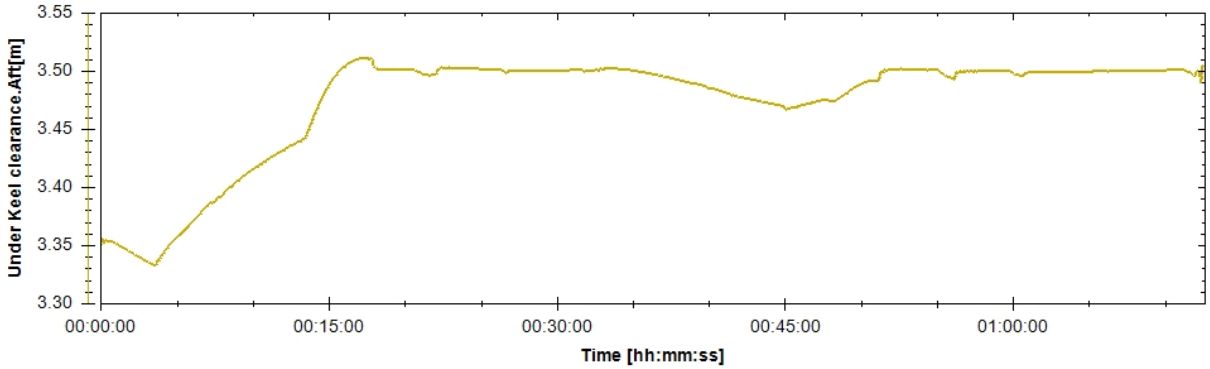
Speed - Bottom.Rate of Turn[deg/min] (0.00)



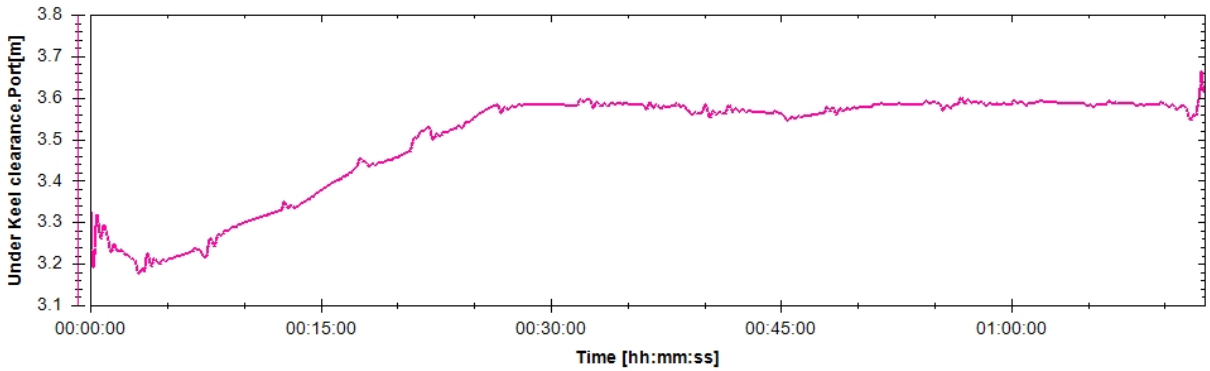
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout

Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.91970' N 072° 33.38922' E
Bottom right: 19° 55.54031' N 072° 38.70118' E

End-Of-Report

Simflex - Scenario Report

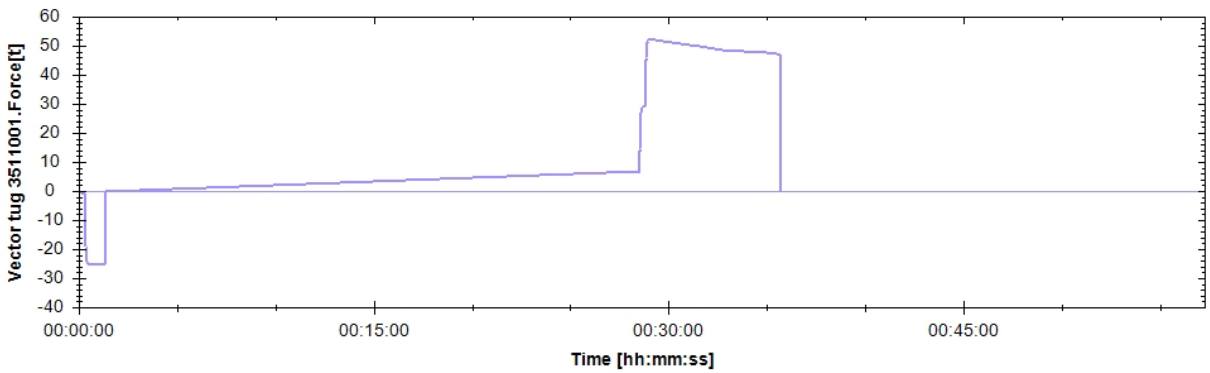
Scenario info

Scenario name: 003-Dep-CT2-Port-Ebb-045x10kts

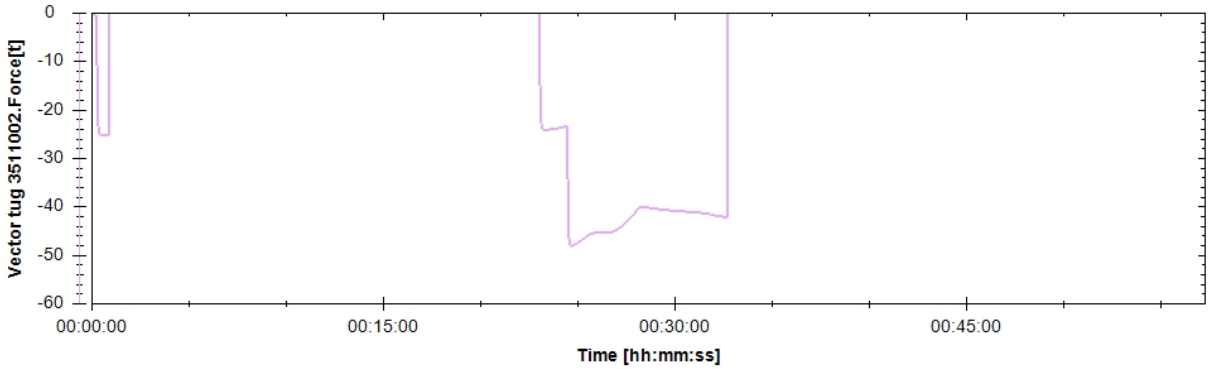
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	5.00	[m/s]
Wind dir.	Constant	45.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

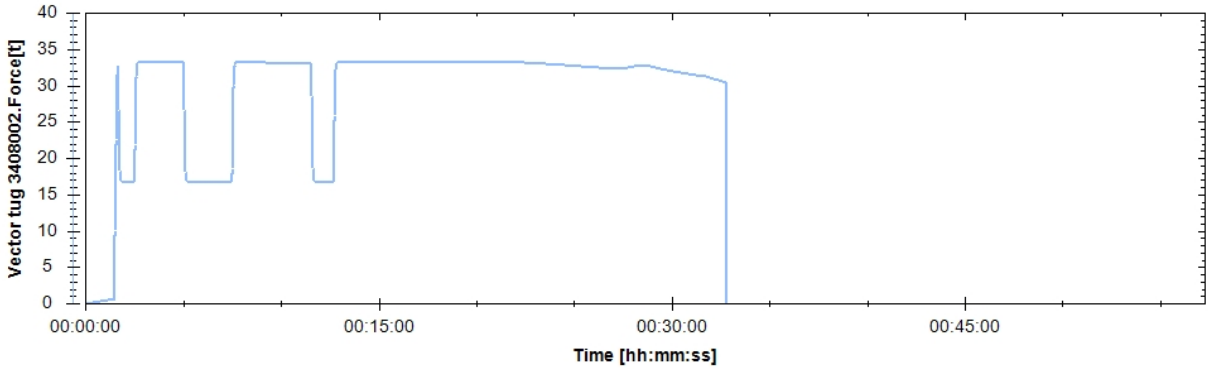
Selected Time Series



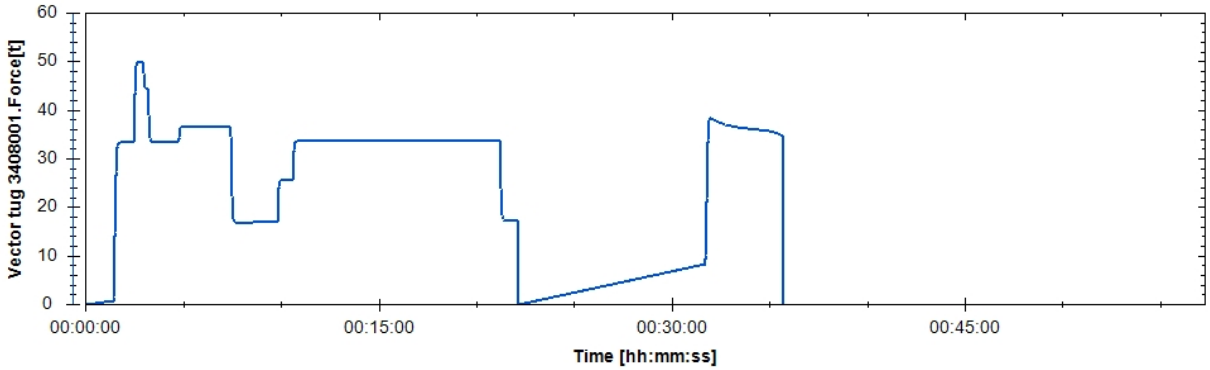
Vector tug 3511001.Force[t] (0.00)



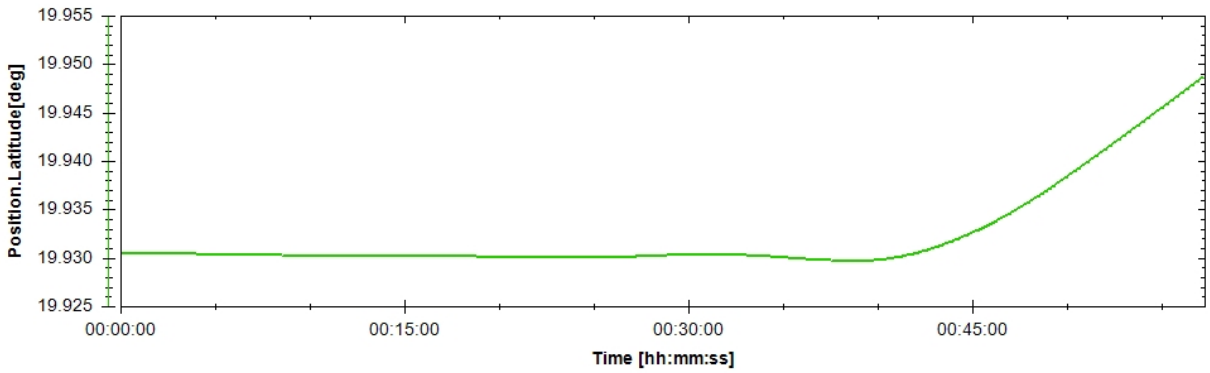
Vector tug 3511002.Force[t] (0.00)



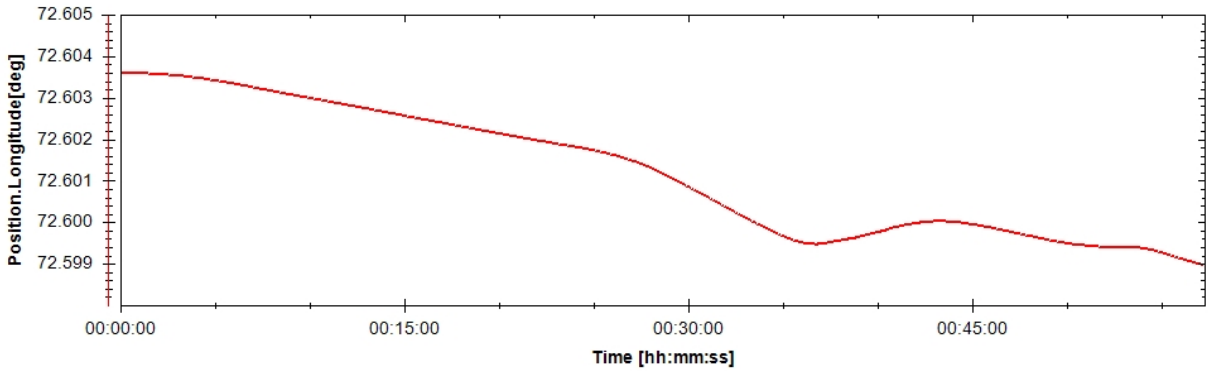
Vector tug 3408002.Force[t] (0.00)



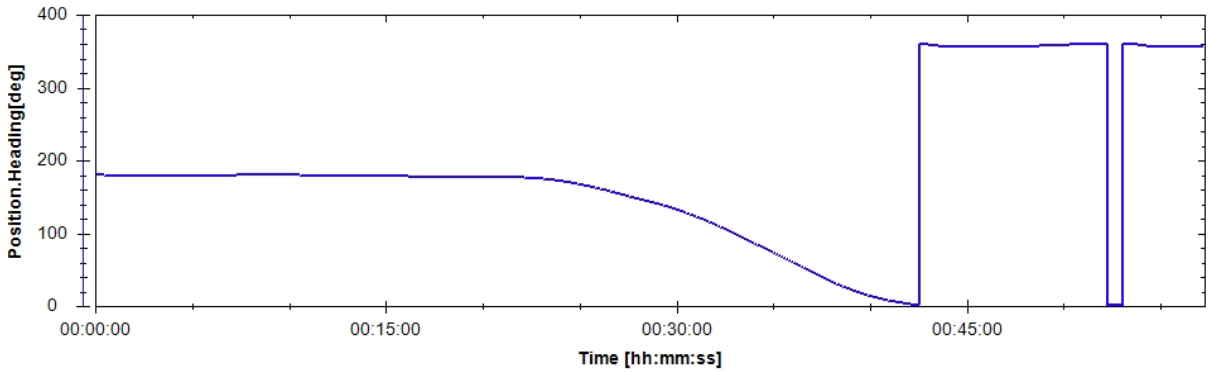
Vector tug 3408001.Force[t] (0.00)



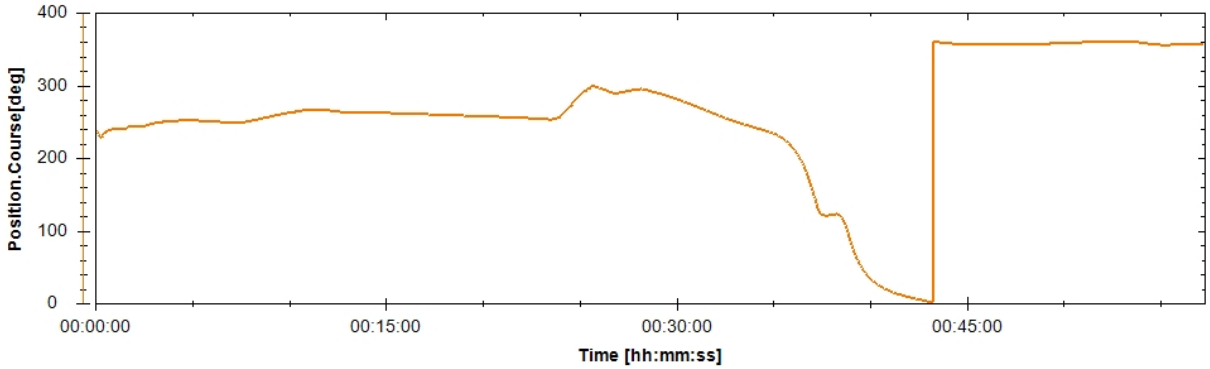
Position.Latitude[deg] (0.00)



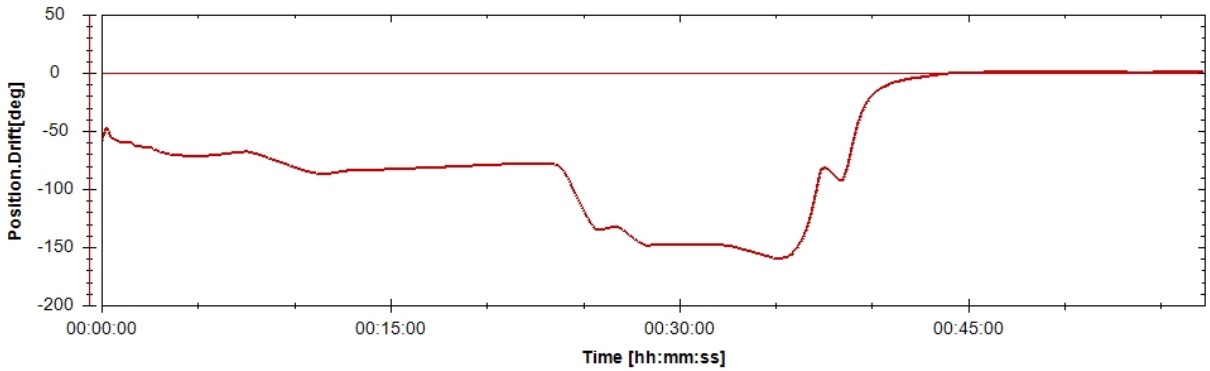
Position.Longitude[deg] (0.00)



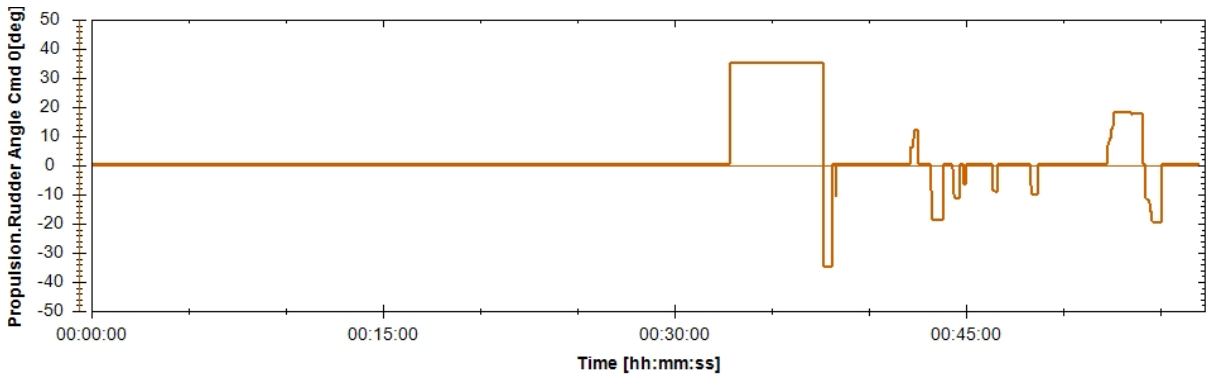
Position.Heading[deg] (0.00)



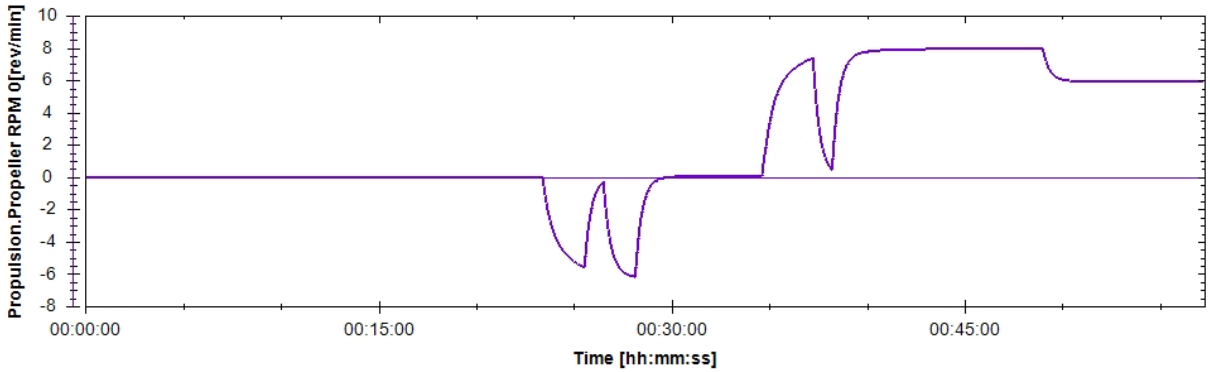
Position.Course[deg] (0.00)



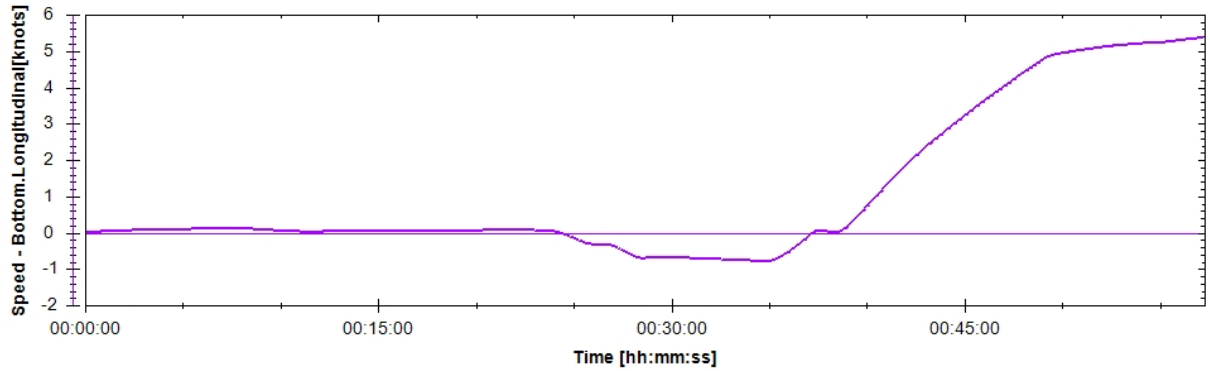
Position.Drift[deg] (0.00)



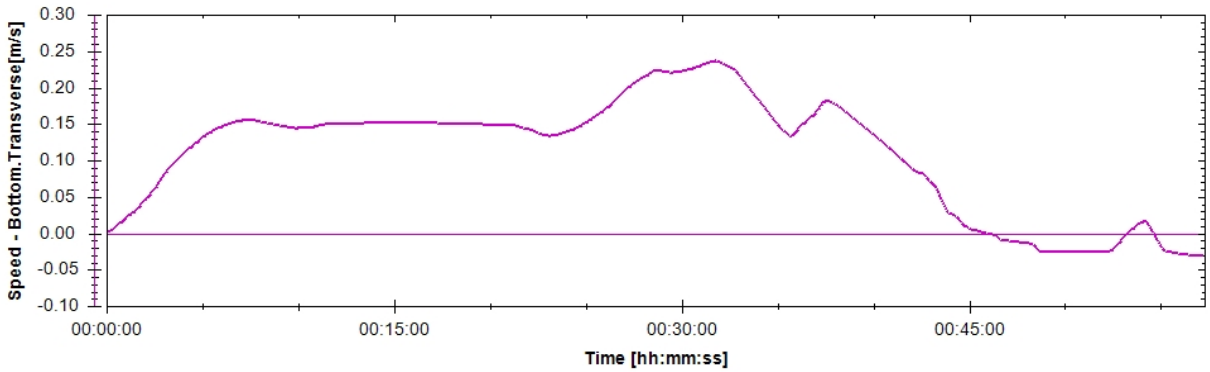
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



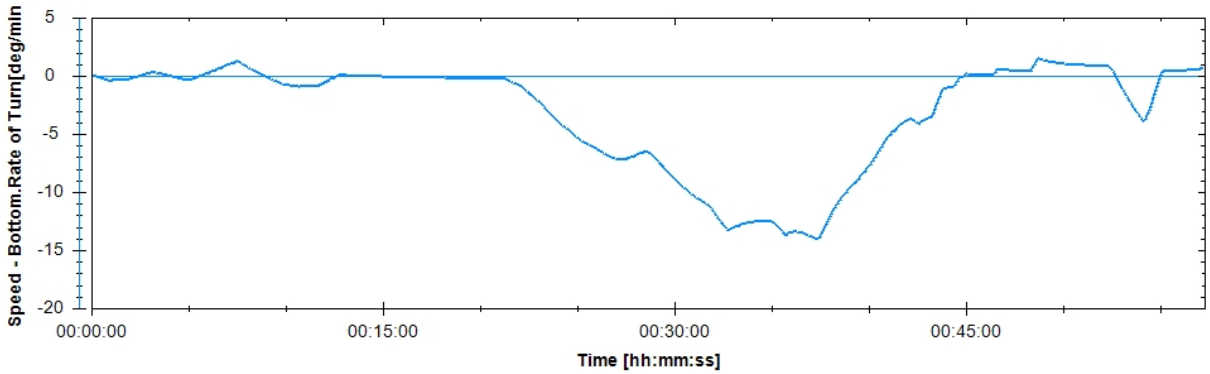
Propulsion.Propeller RPM 0[rev/min] (0.00)



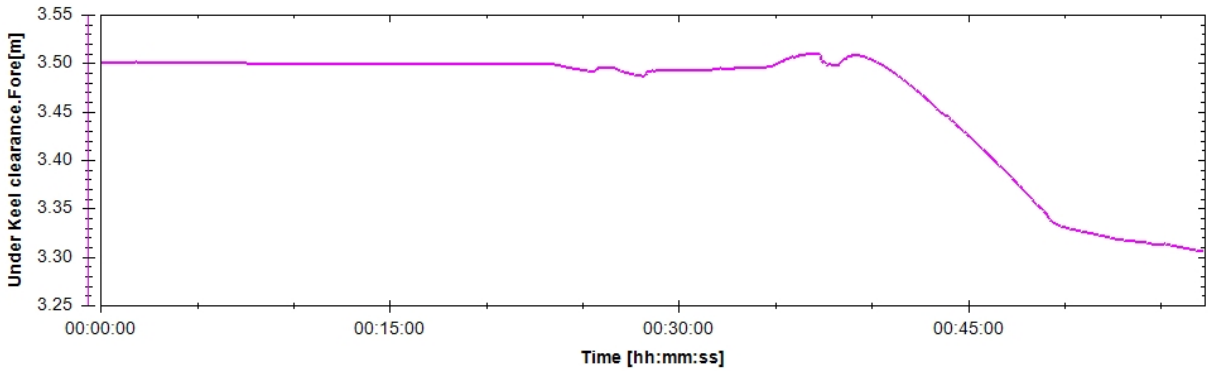
Speed - Bottom.Longitudinal[knots] (0.00)



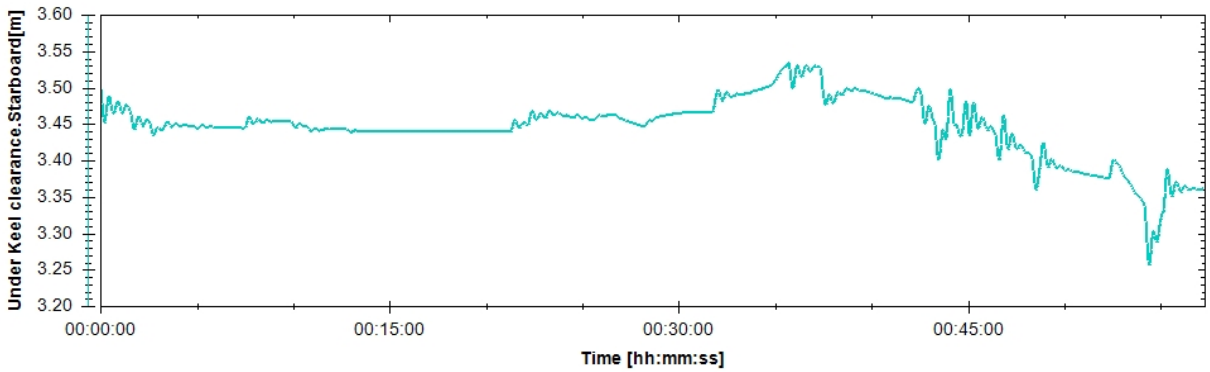
Speed - Bottom.Transverse[m/s] (0.00)



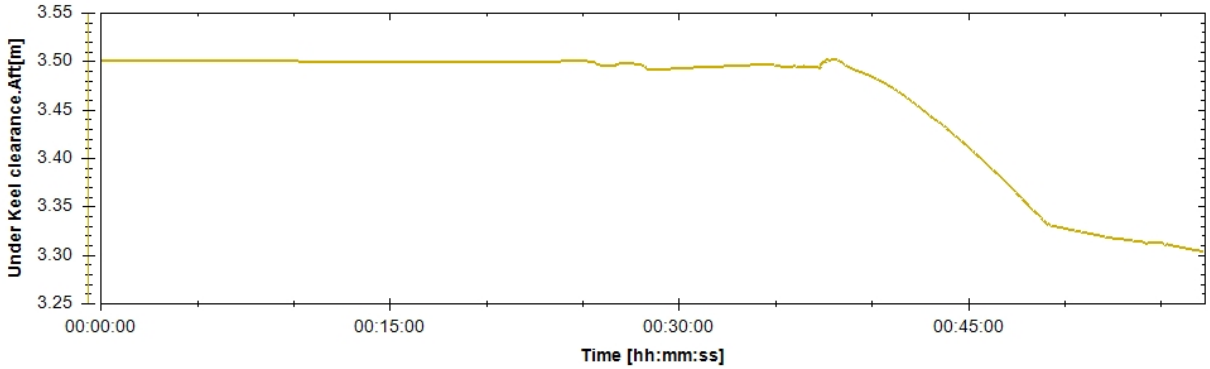
Speed - Bottom.Rate of Turn[deg/min] (0.00)



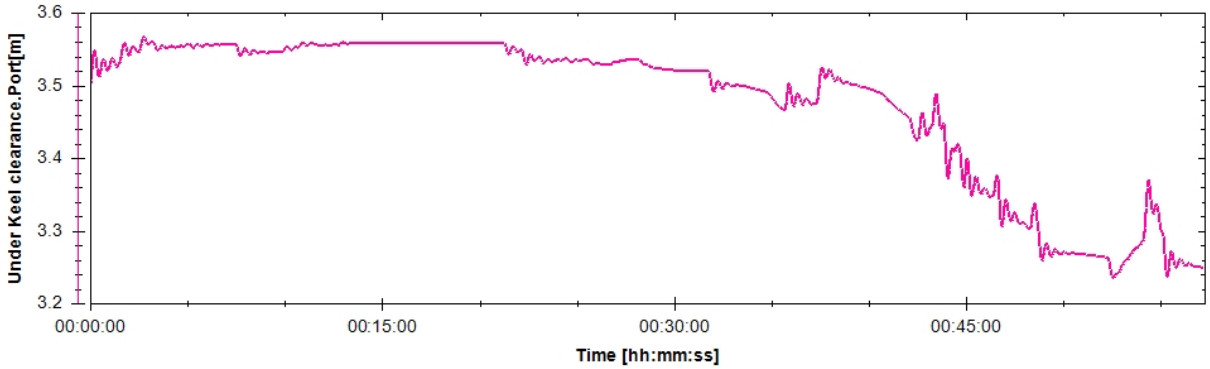
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



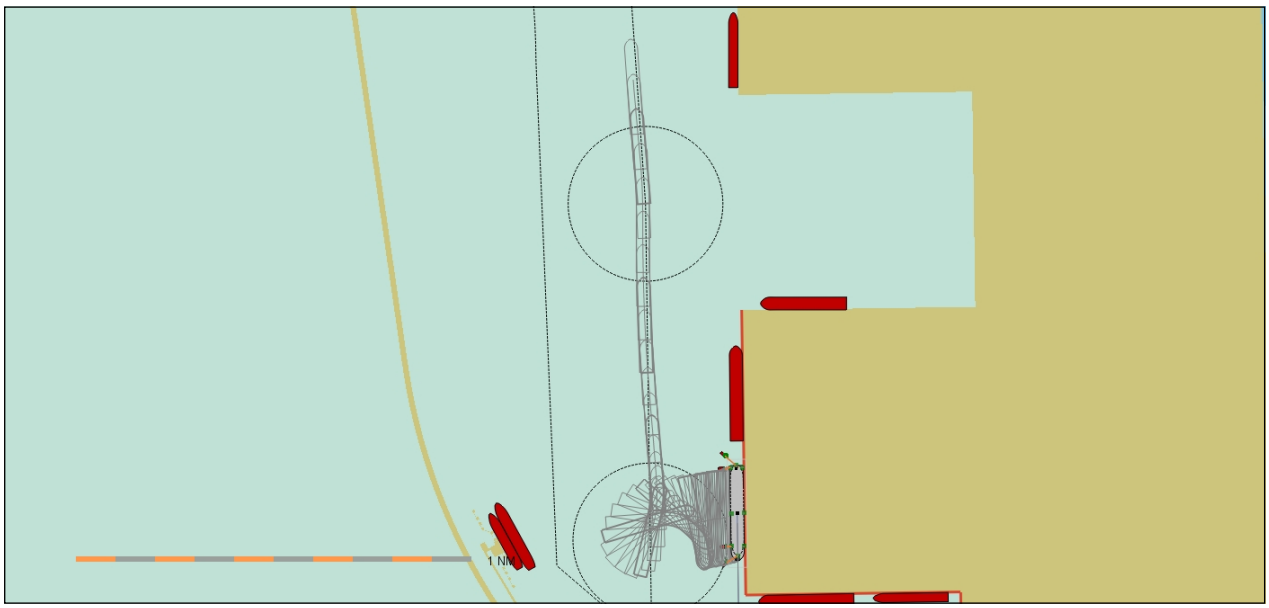
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.10245' N 072° 34.26044' E
Bottom right: 19° 55.59548' N 072° 37.62436' E

End-Of-Report

Simflex - Scenario Report

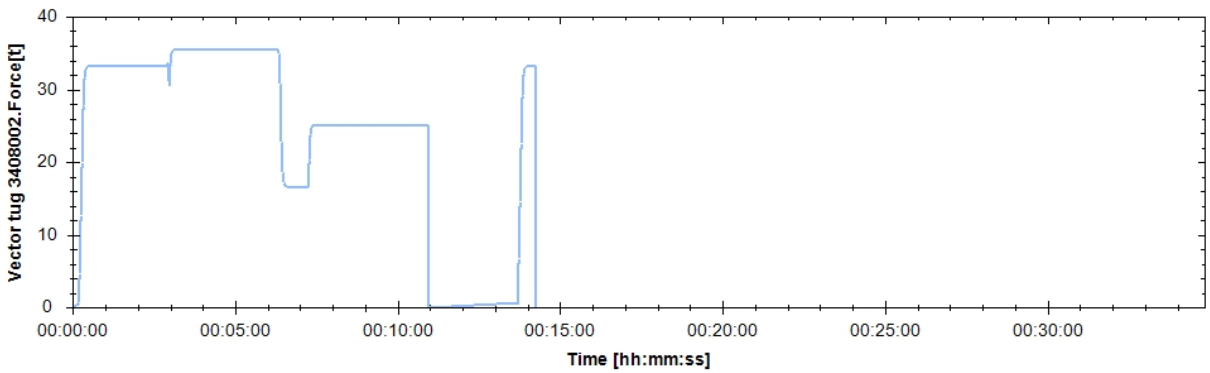
Scenario info

Scenario name: 004-Dep-CT2-Stbd-Flood-045x10kts

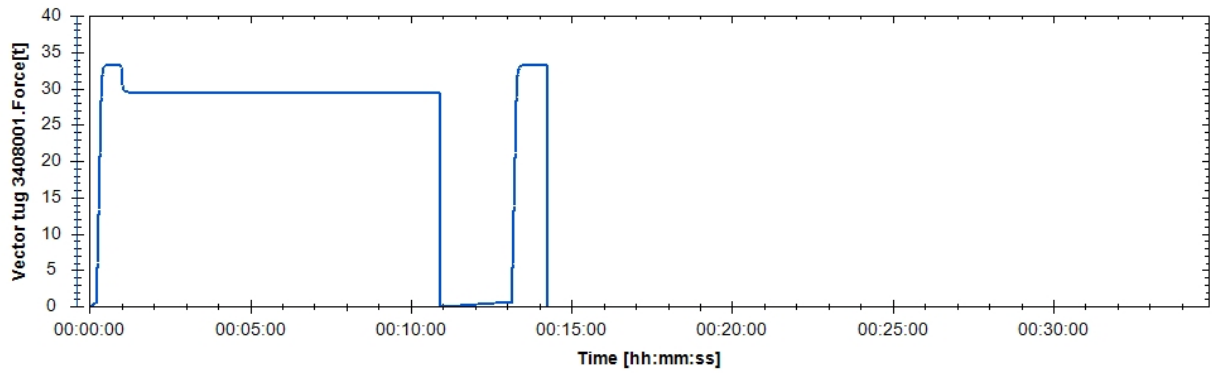
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	5.00	[m/s]
Wind dir.	Constant	45.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

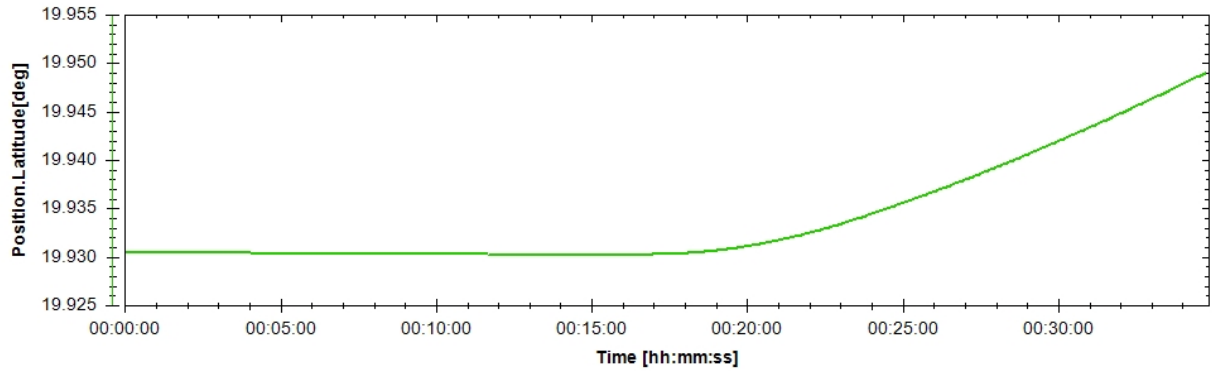
Selected Time Series



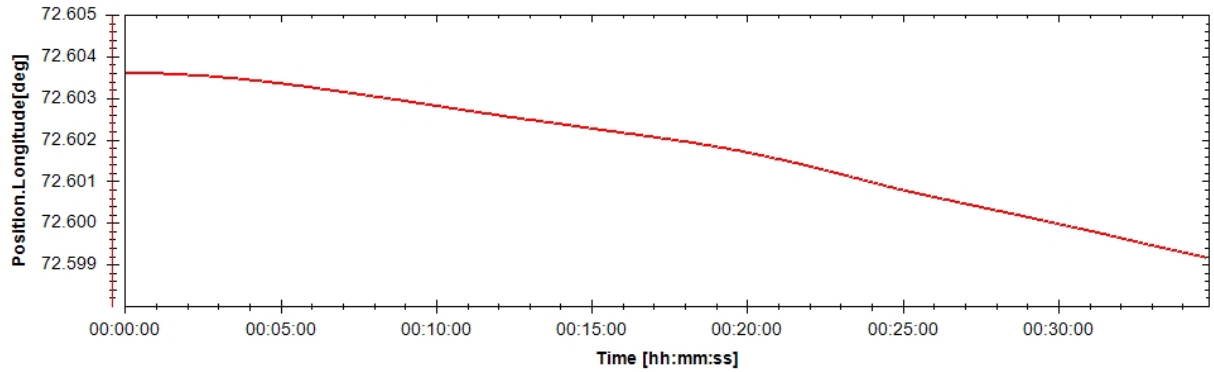
Vector tug 3408002.Force[t] (0.00)



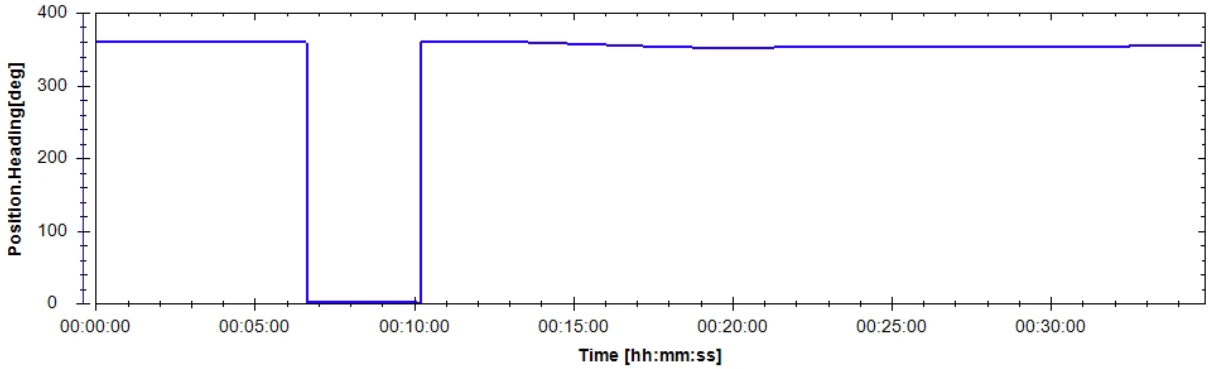
Vector tug 3408001.Force[t] (0.00)



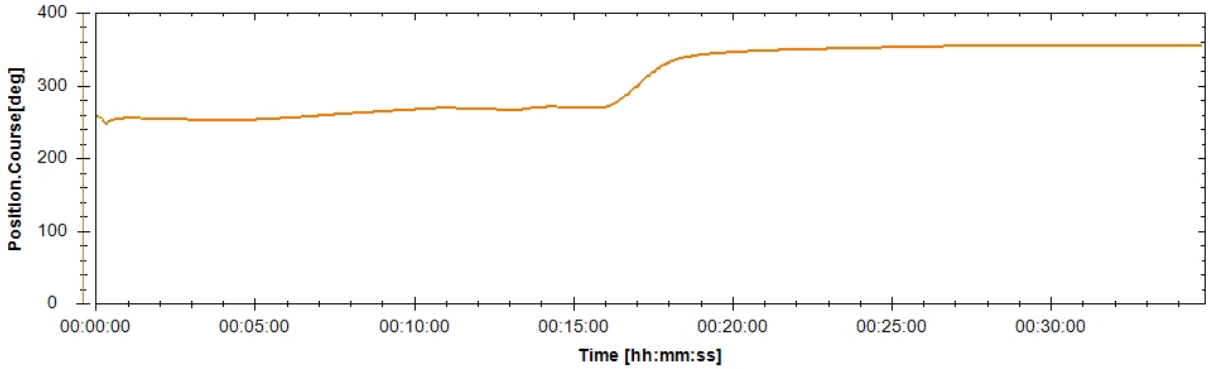
Position.Latitude[deg] (0.00)



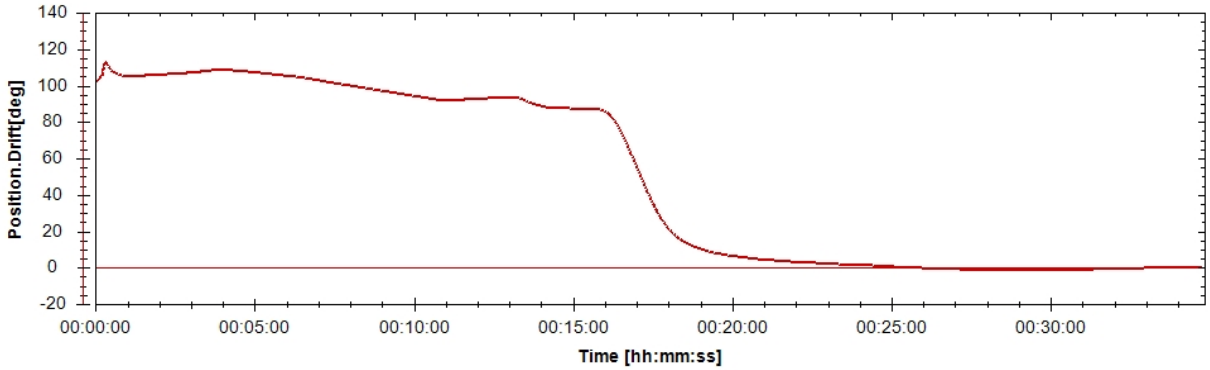
Position.Longitude[deg] (0.00)



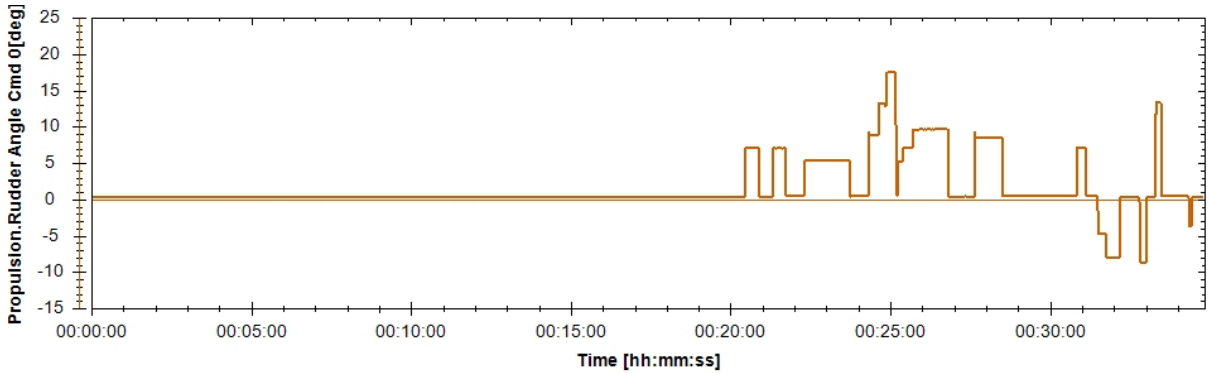
Position.Heading[deg] (0.00)



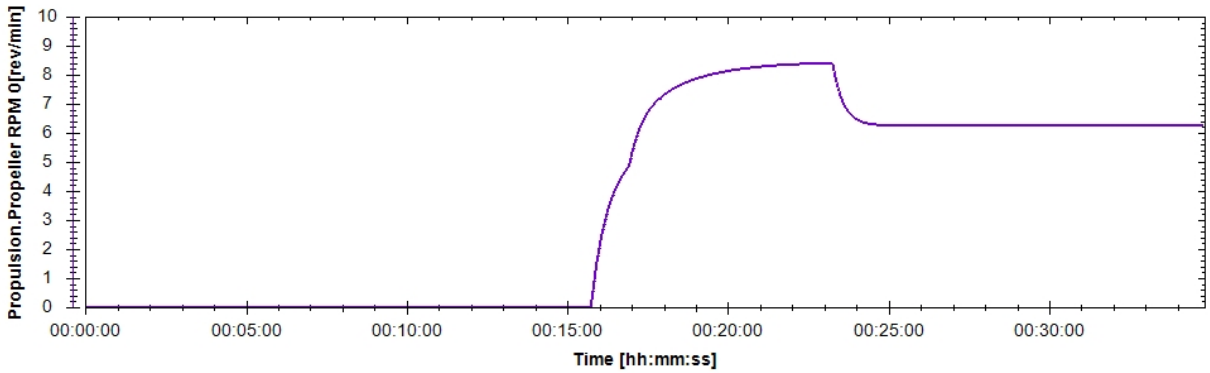
Position.Course[deg] (0.00)



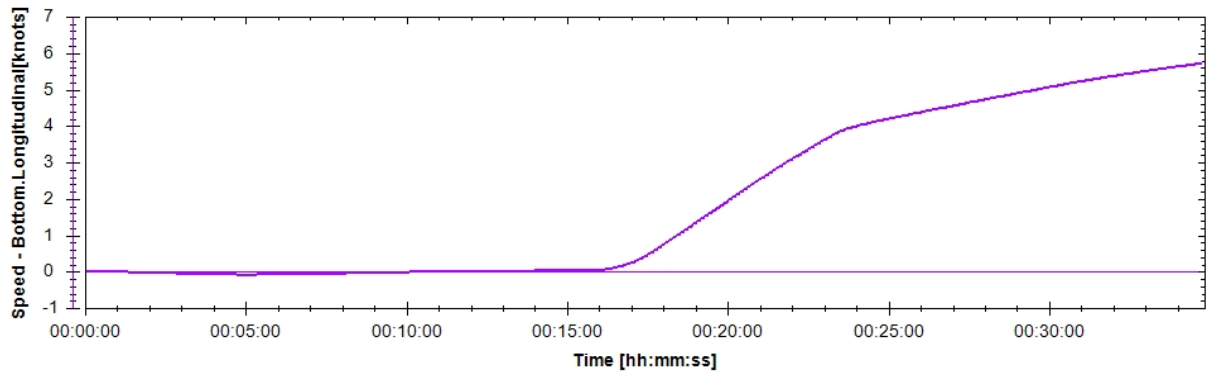
Position.Drift[deg] (0.00)



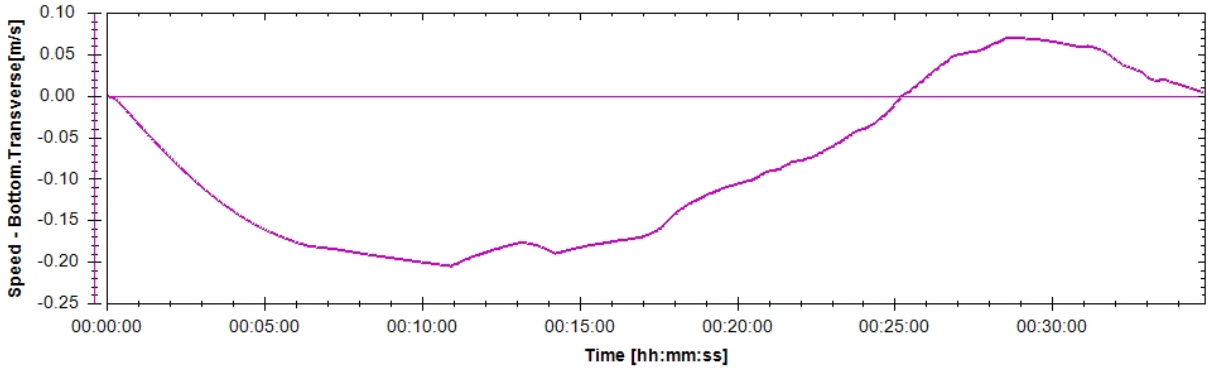
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



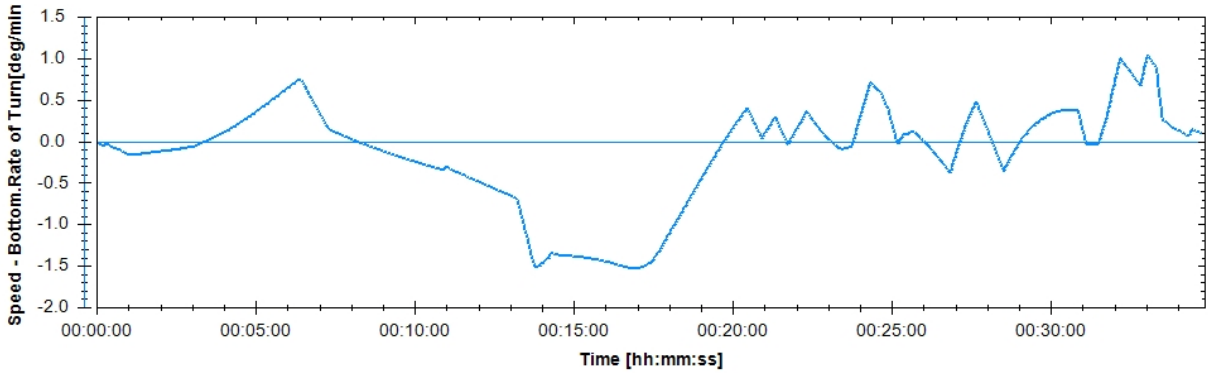
Propulsion.Propeller RPM 0[rev/min] (0.00)



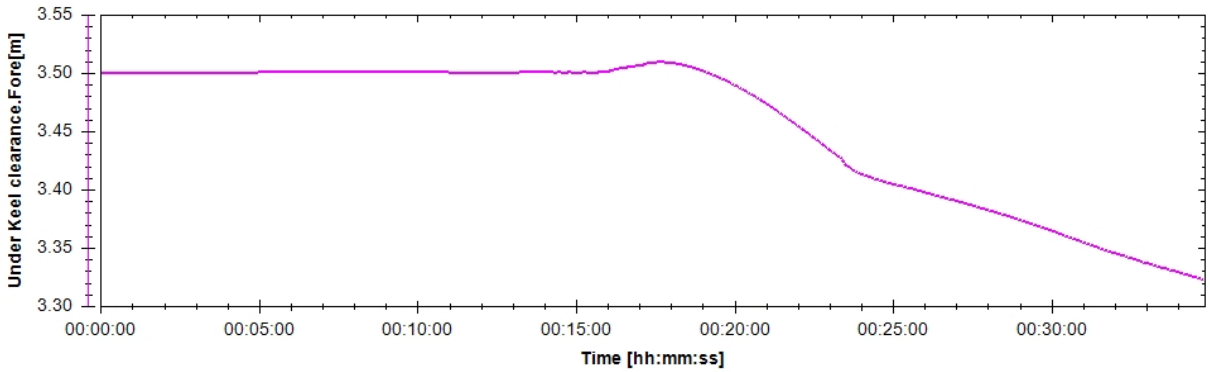
Speed - Bottom.Longitudinal[knots] (0.00)



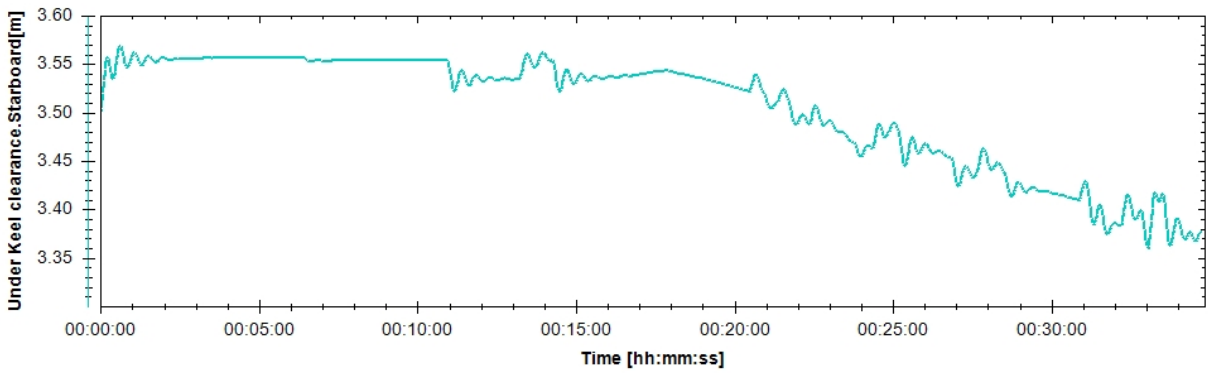
Speed - Bottom.Transverse[m/s] (0.00)



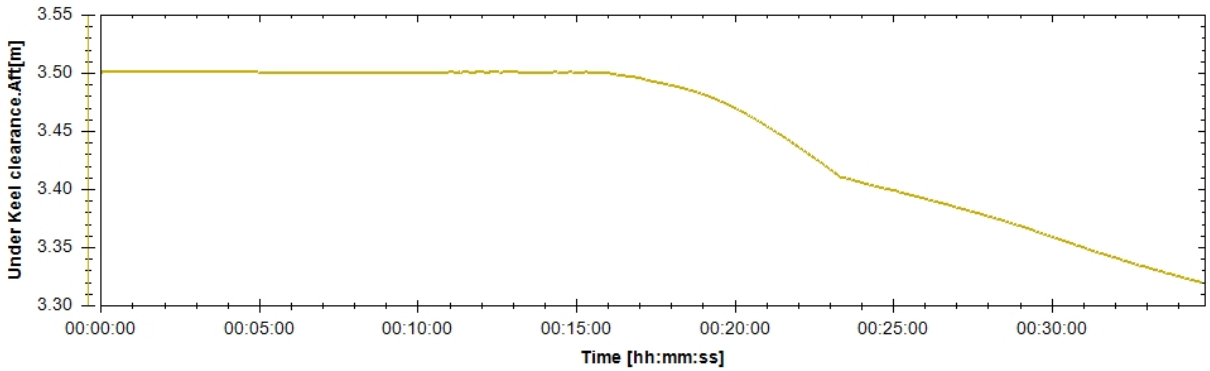
Speed - Bottom.Rate of Turn[deg/min] (0.00)



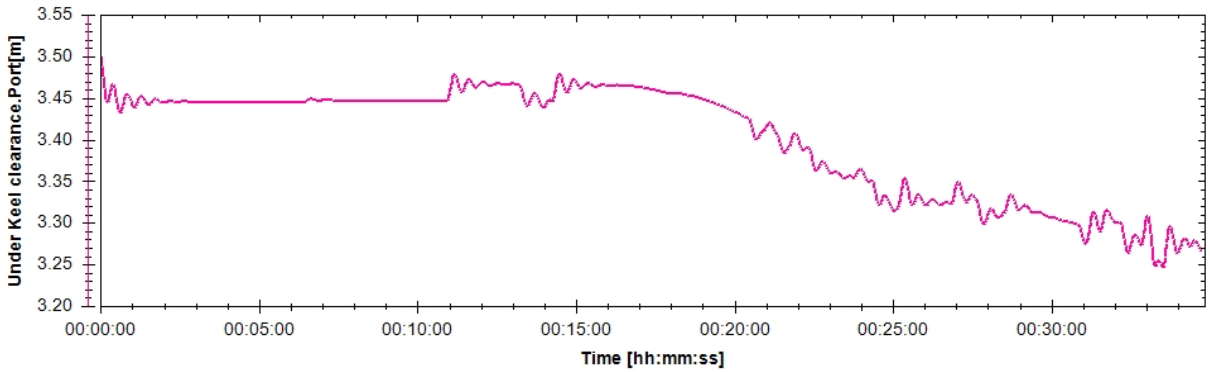
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



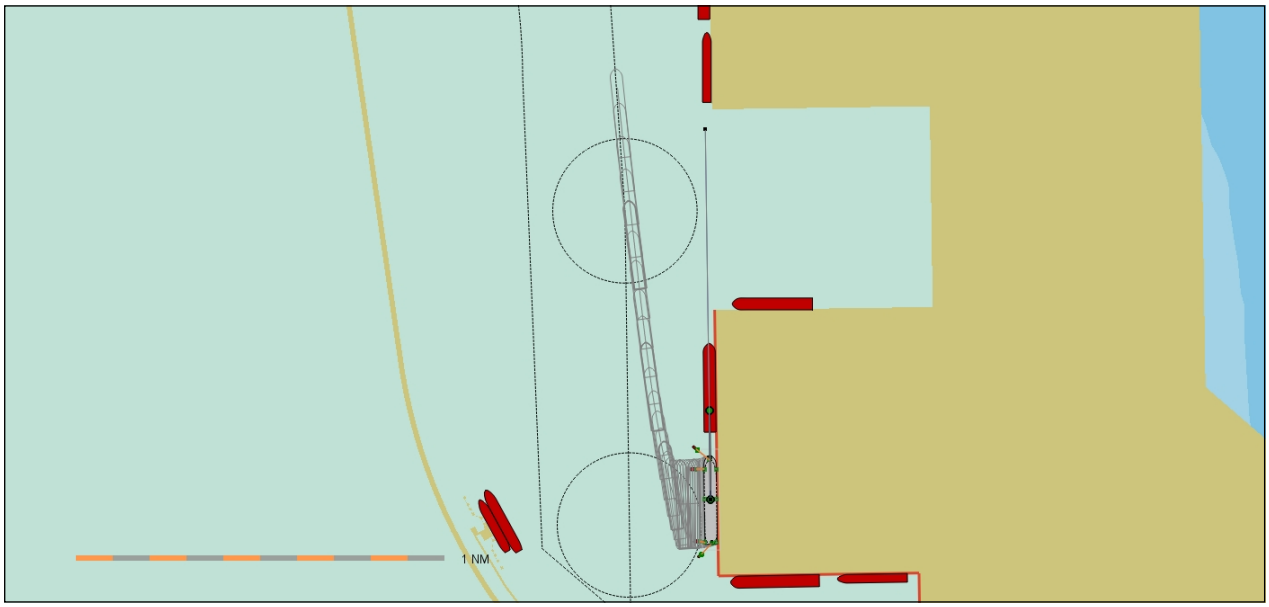
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.15996' N 072° 34.19670' E
Bottom right: 19° 55.54498' N 072° 37.80173' E

End-Of-Report

Simflex - Scenario Report

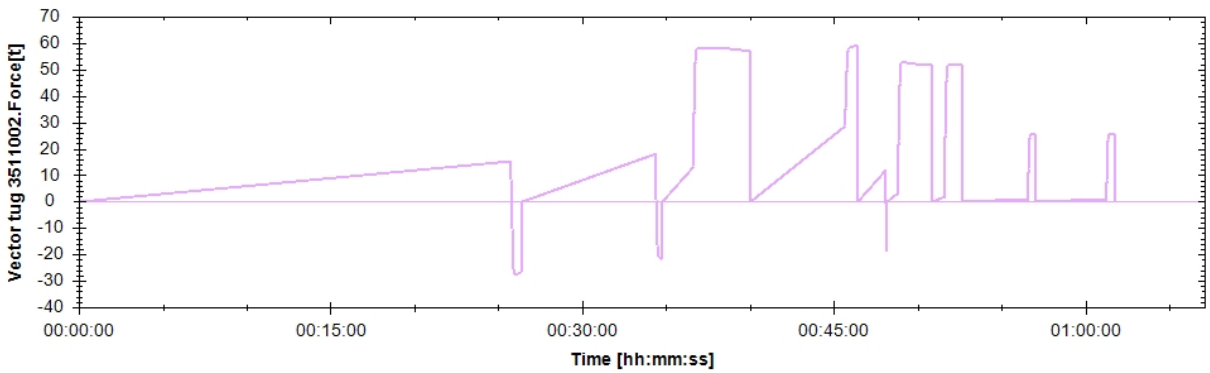
Scenario info

Scenario name: 005-Arr-CT1-Port-Flood-250x15kts

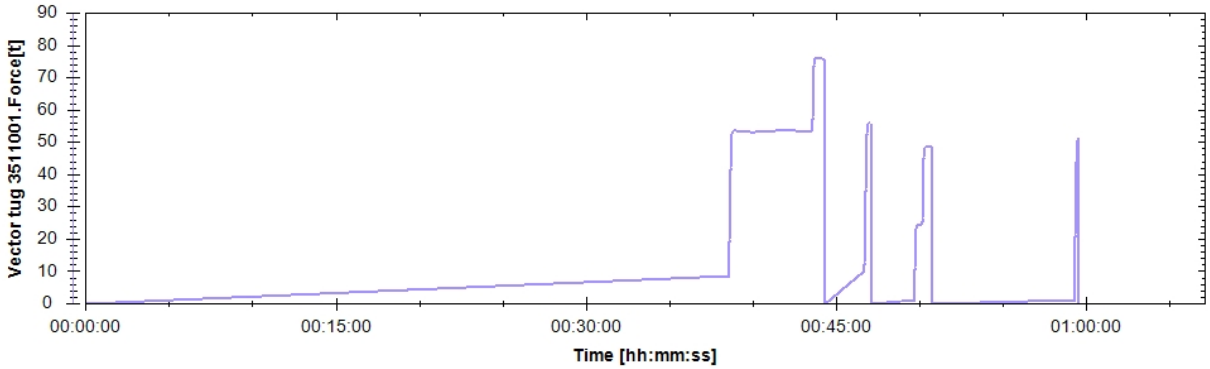
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	7.50	[m/s]
Wind dir.	Constant	250.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

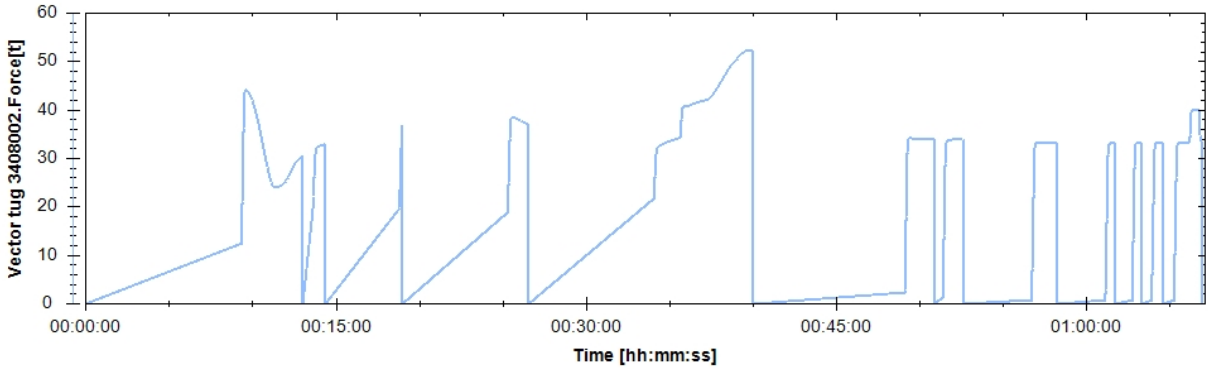
Selected Time Series



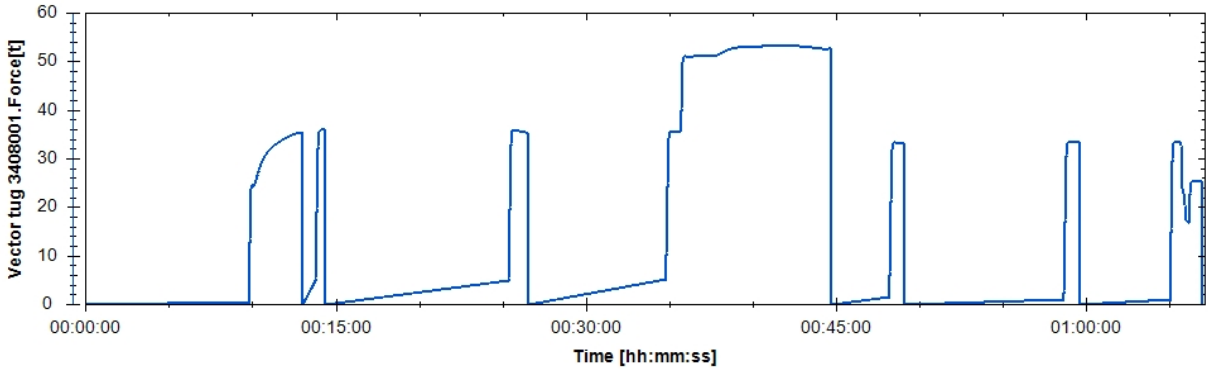
Vector tug 3511002.Force[t] (0.00)



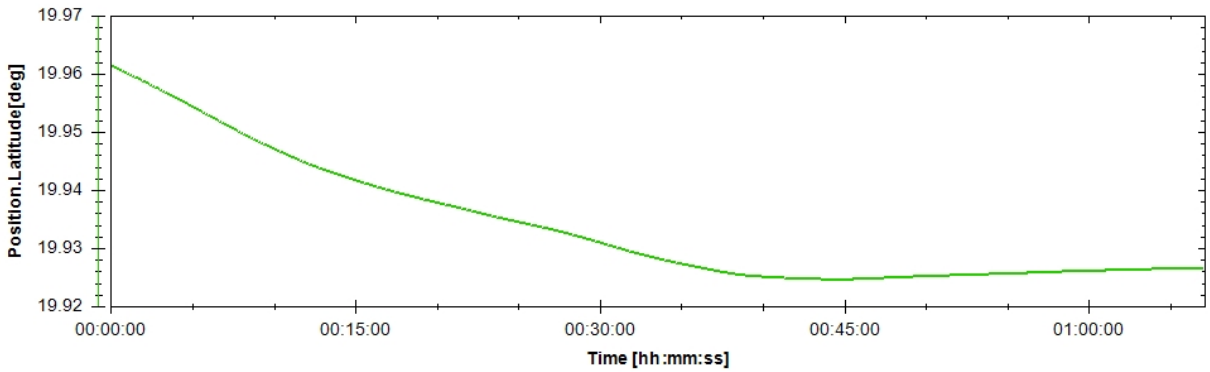
Vector tug 3511001.Force[t] (0.00)



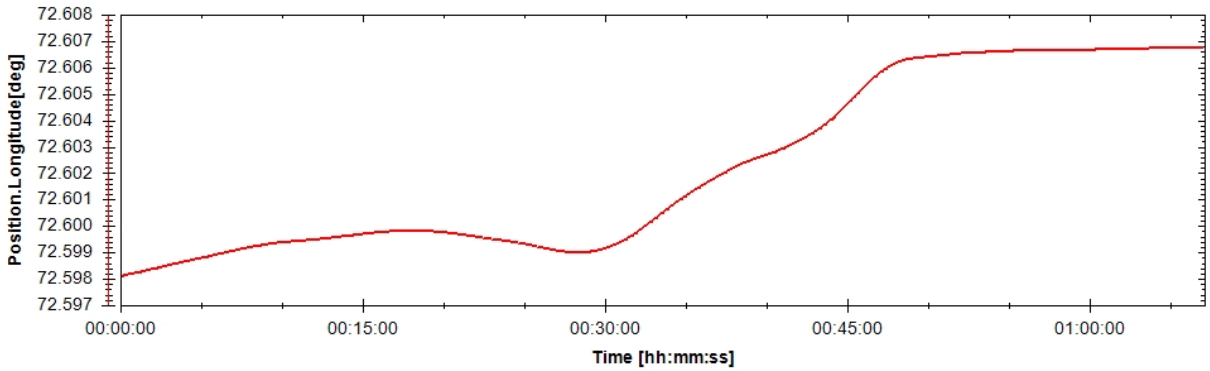
Vector tug 3408002.Force[t] (0.00)



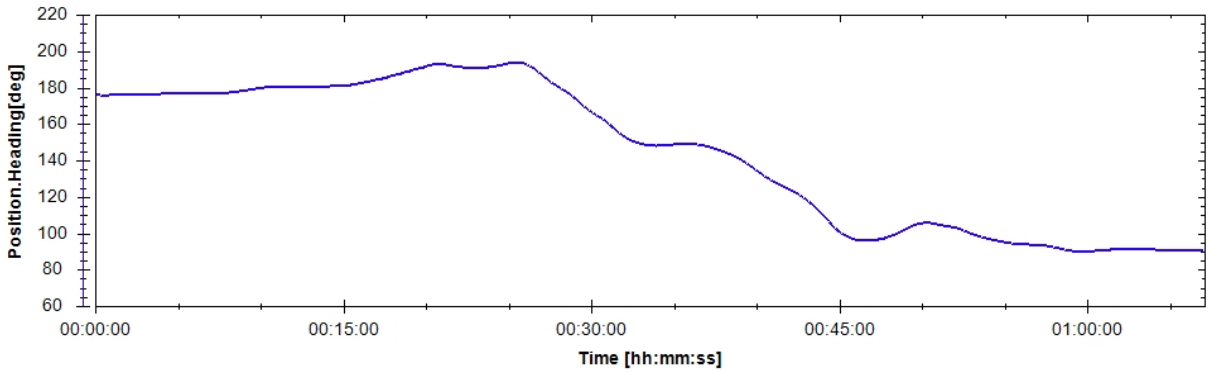
Vector tug 3408001.Force[t] (0.00)



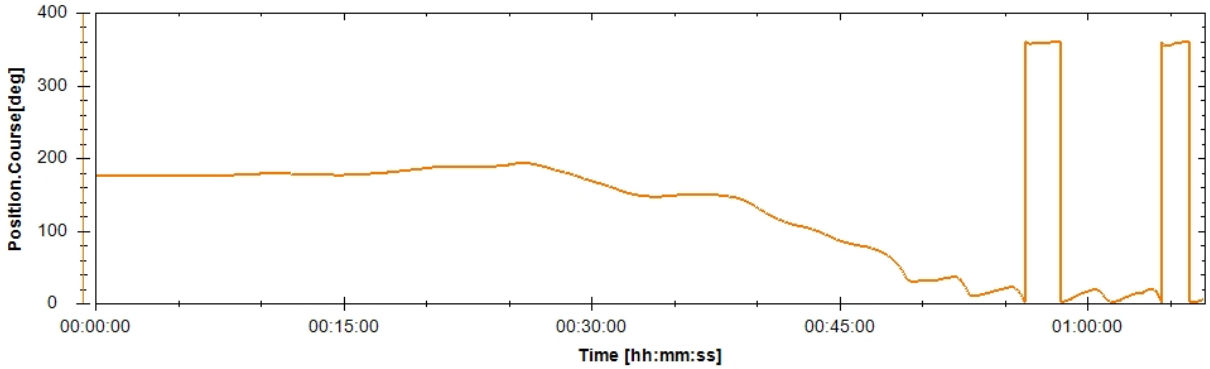
Position.Latitude[deg] (0.00)



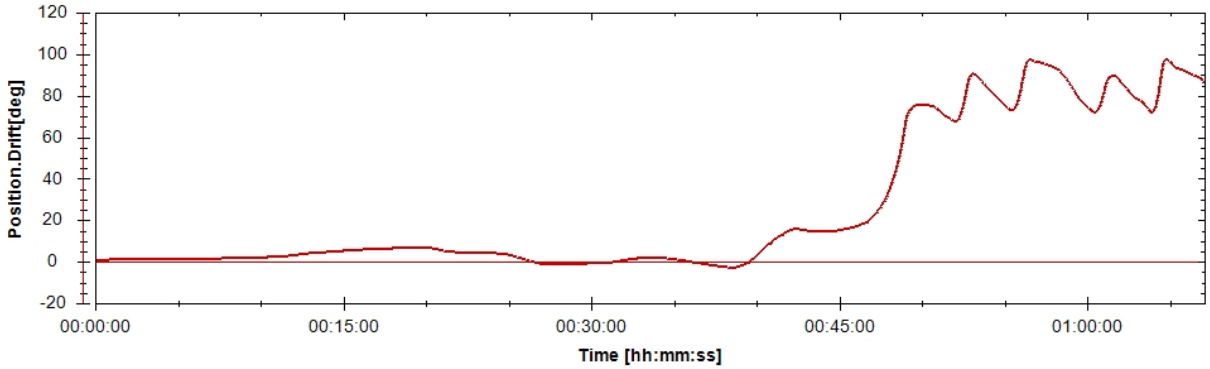
Position.Longitude[deg] (0.00)



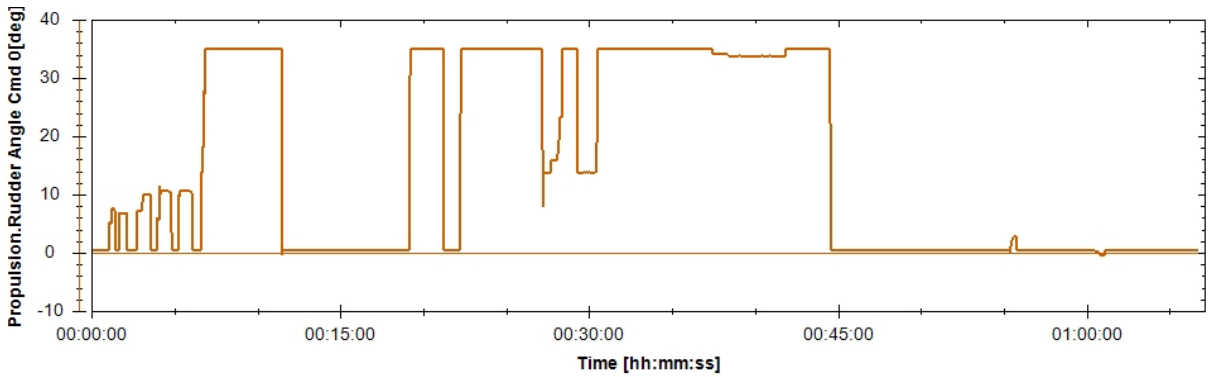
Position.Heading[deg] (0.00)



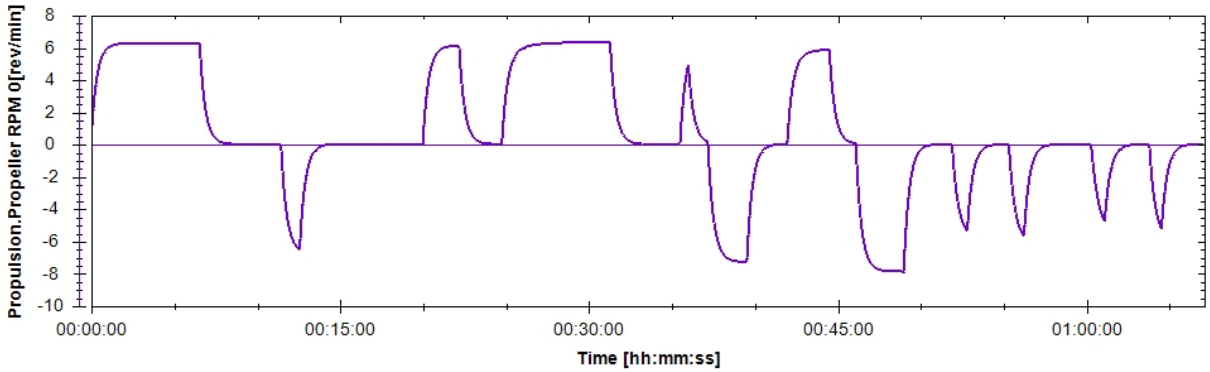
Position.Course[deg] (0.00)



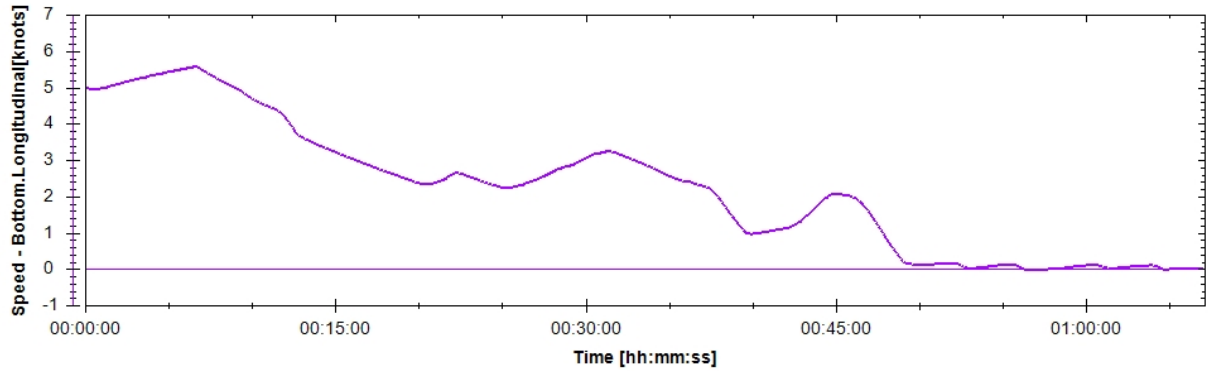
Position.Drift[deg] (0.00)



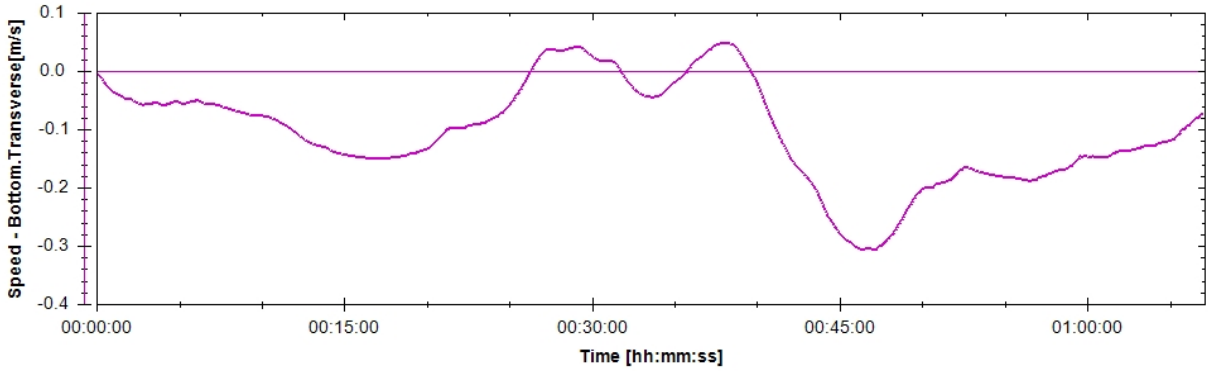
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



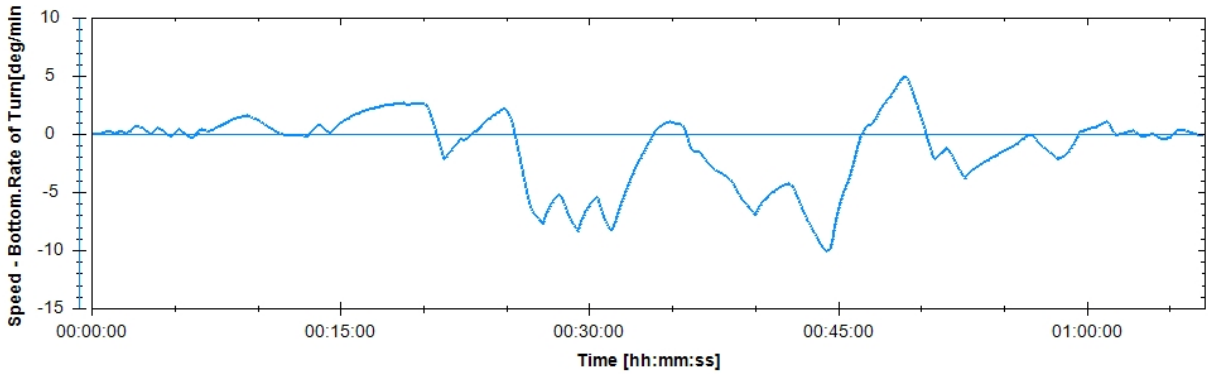
Propulsion.Propeller RPM 0[rev/min] (0.00)



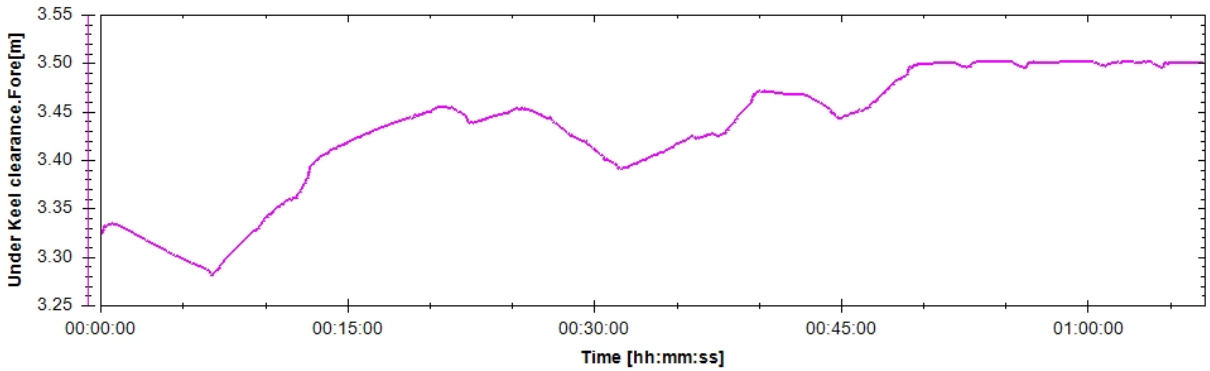
Speed - Bottom.Longitudinal[knots] (0.00)



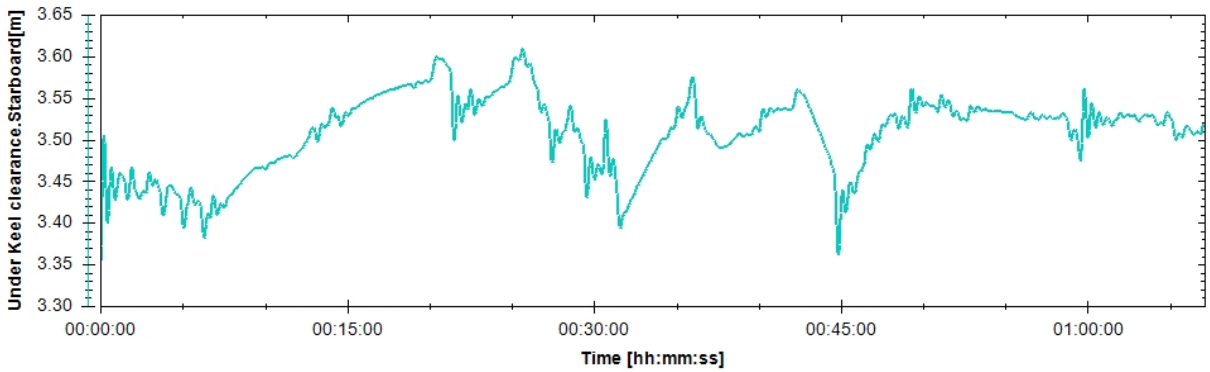
Speed - Bottom.Transverse[m/s] (0.00)



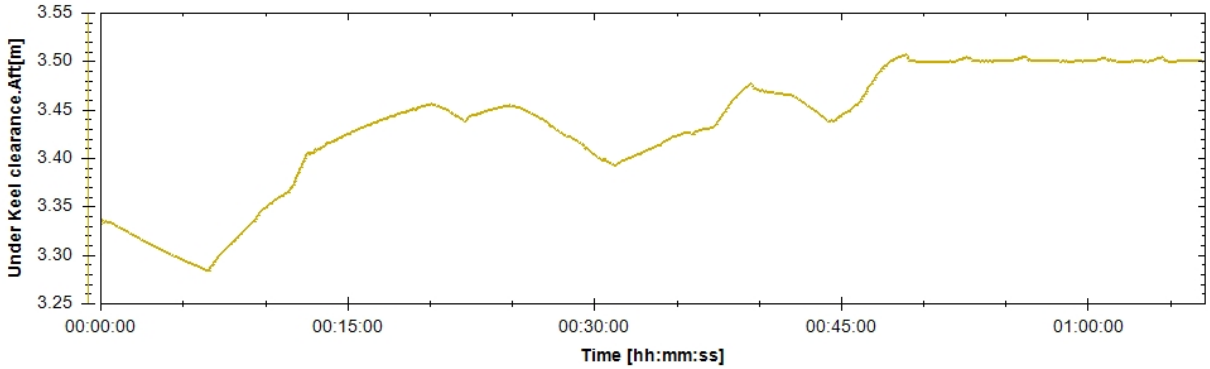
Speed - Bottom.Rate of Turn[deg/min] (0.00)



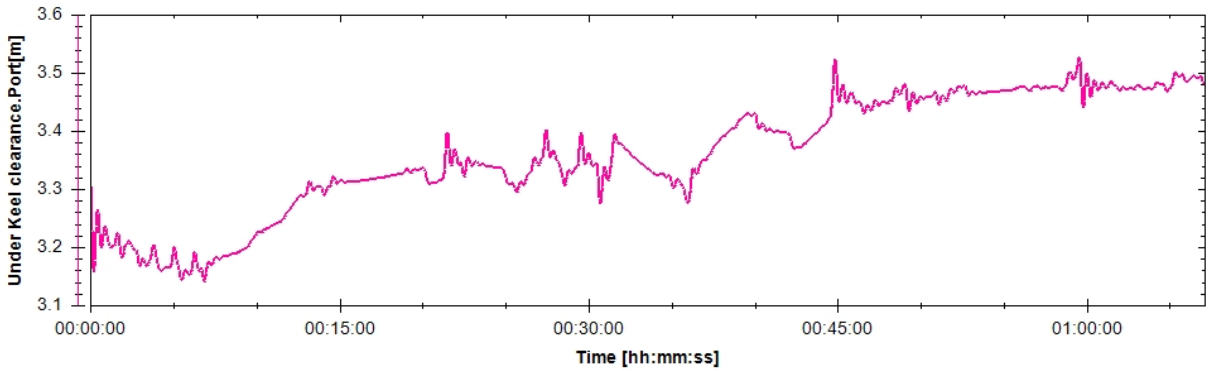
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



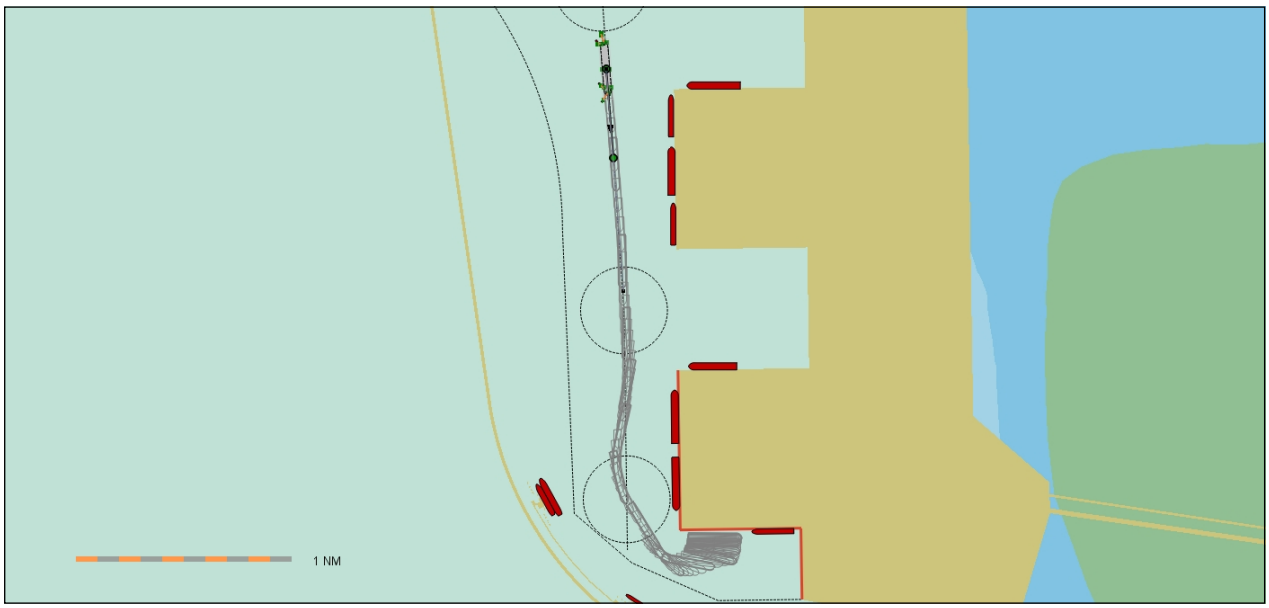
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.97055' N 072° 33.02553' E
Bottom right: 19° 55.28548' N 072° 39.01979' E

End-Of-Report

Simflex - Scenario Report

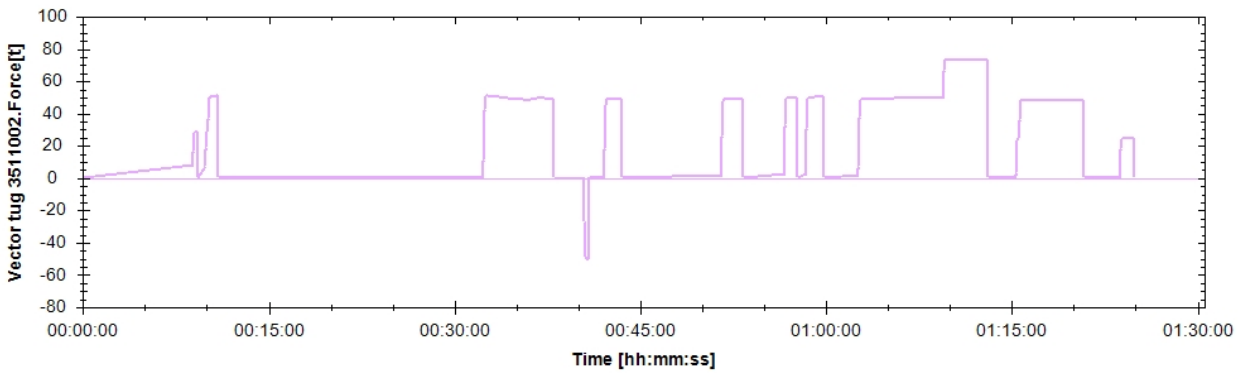
Scenario info

Scenario name: 006-Arr-CT1-Stbd-Ebb-250x15kts

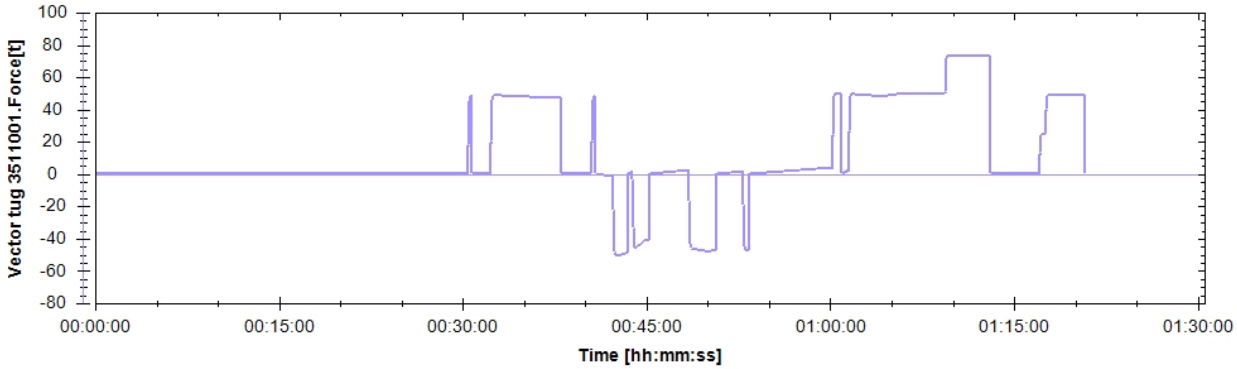
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	7.50	[m/s]
Wind dir.	Constant	250.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

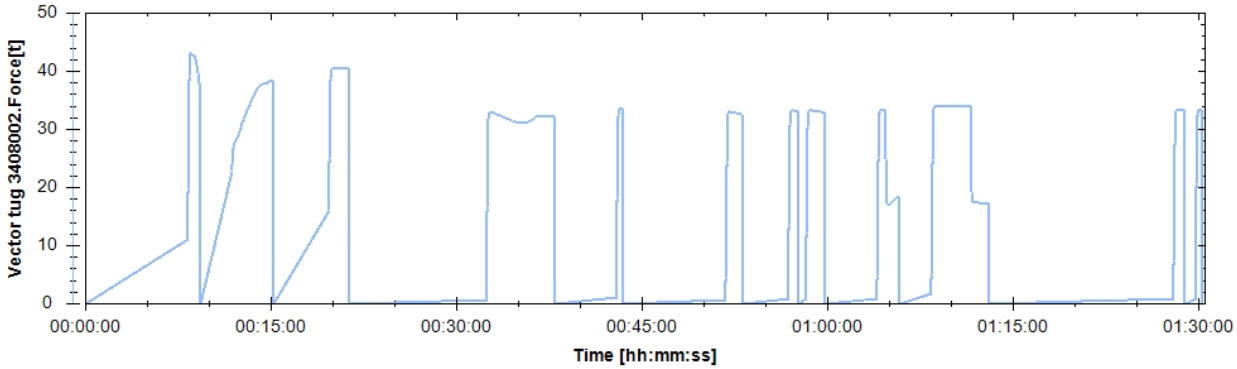
Selected Time Series



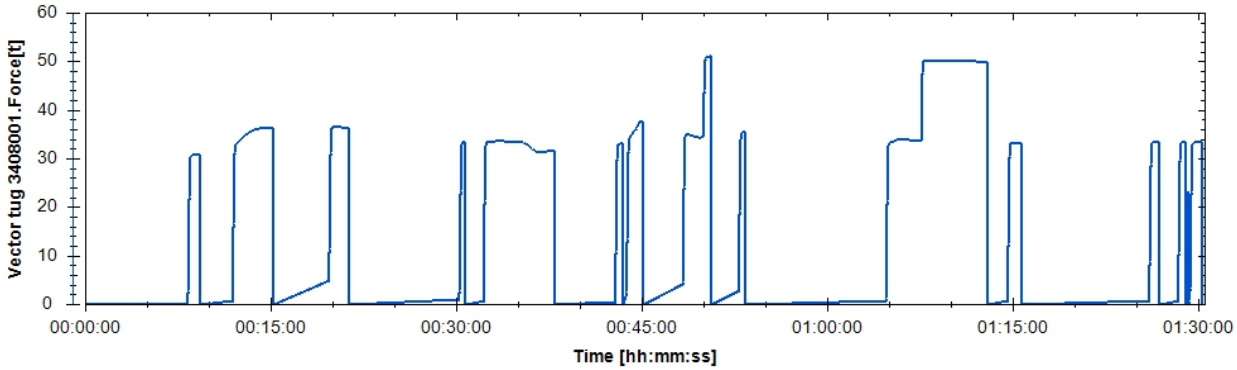
Vector tug 3511002.Force[t] (0.00)



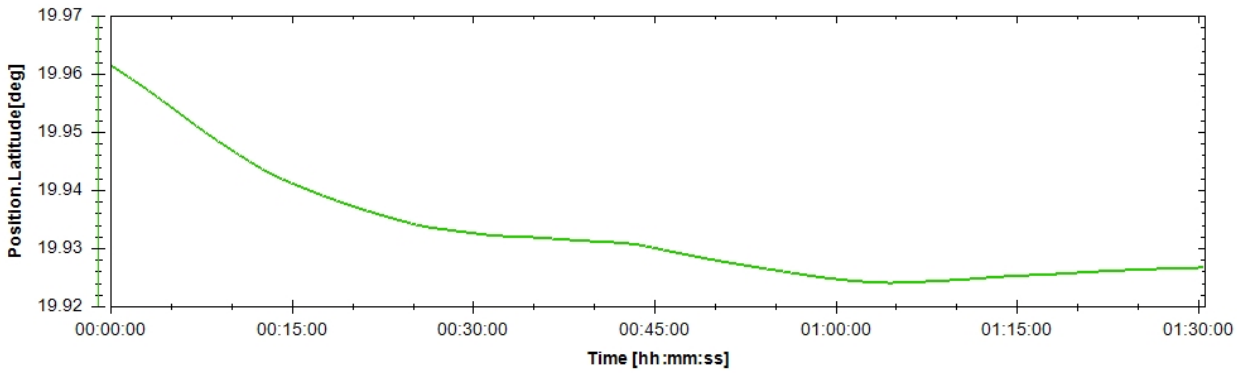
Vector tug 3511001.Force[t] (0.00)



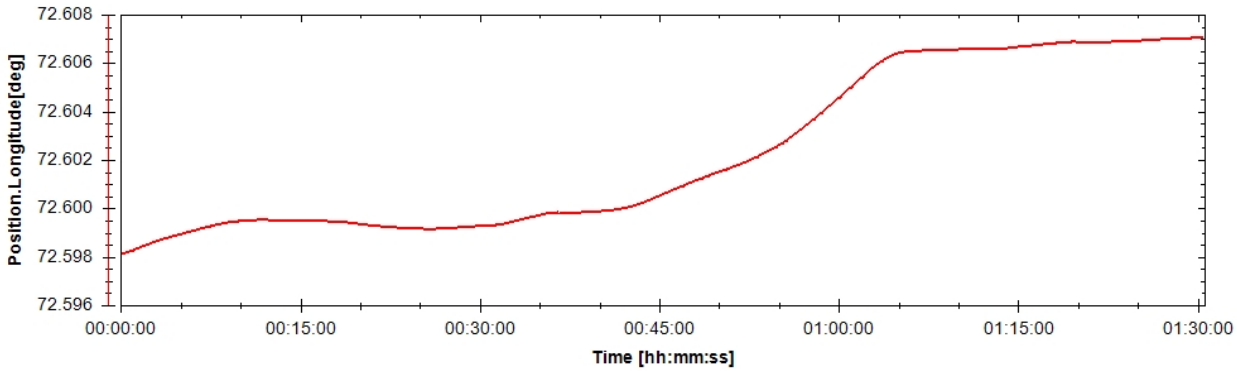
Vector tug 3408002.Force[t] (0.00)



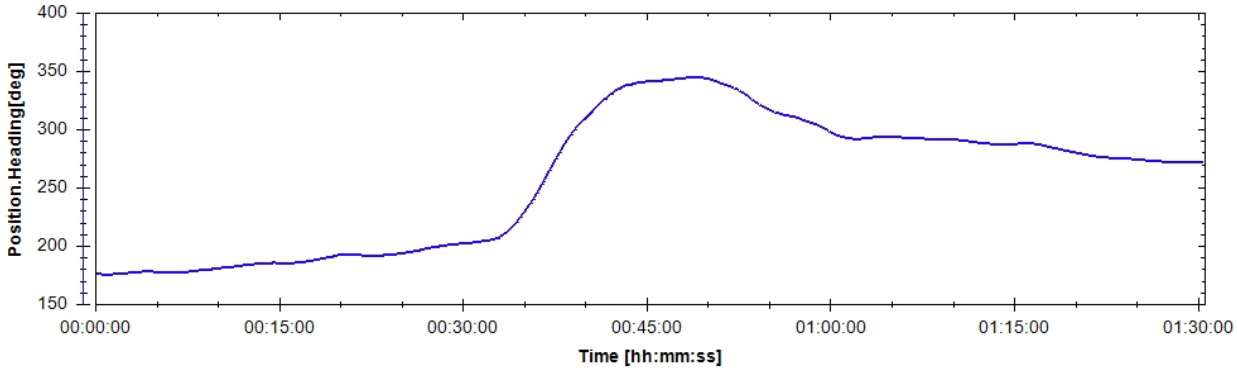
Vector tug 3408001.Force[t] (0.00)



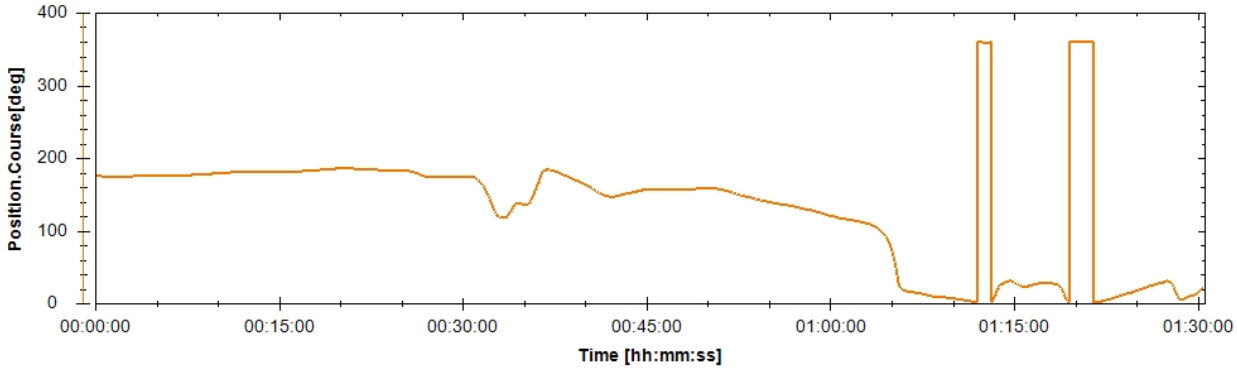
Position.Latitude[deg] (0.00)



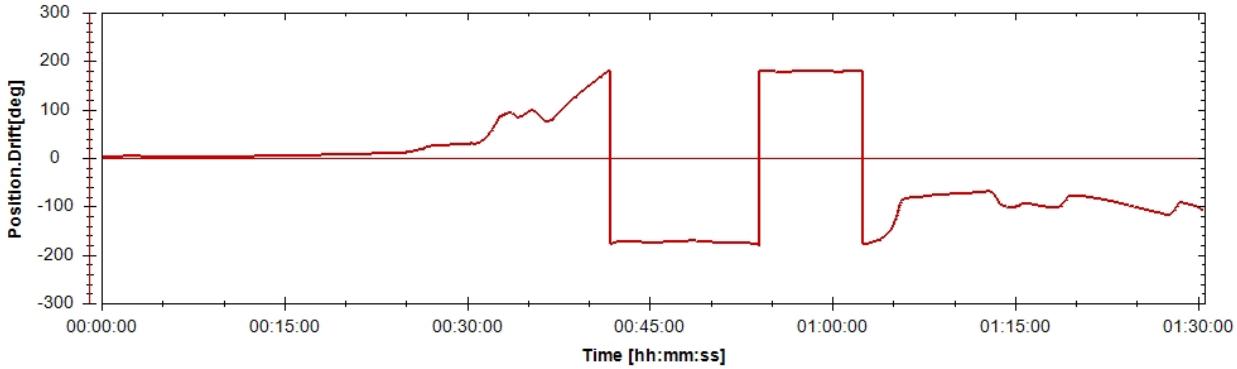
Position.Longitude[deg] (0.00)



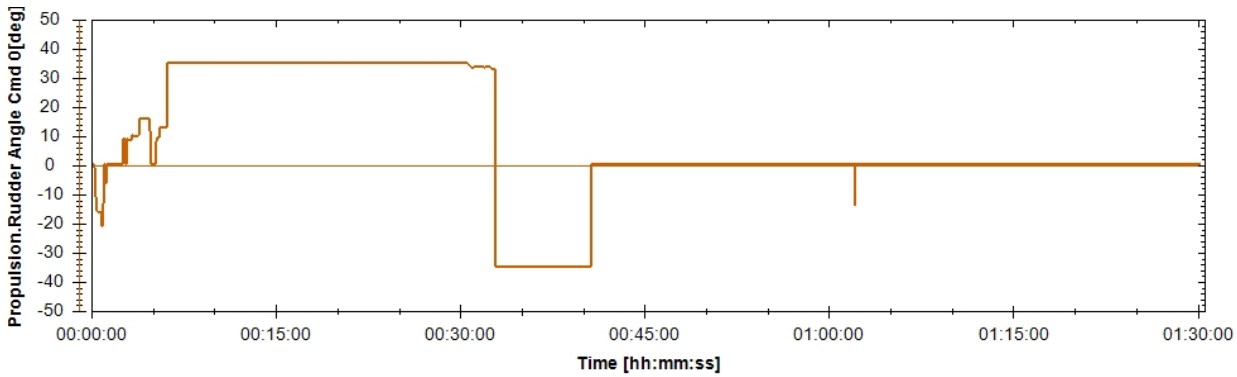
Position.Heading[deg] (0.00)



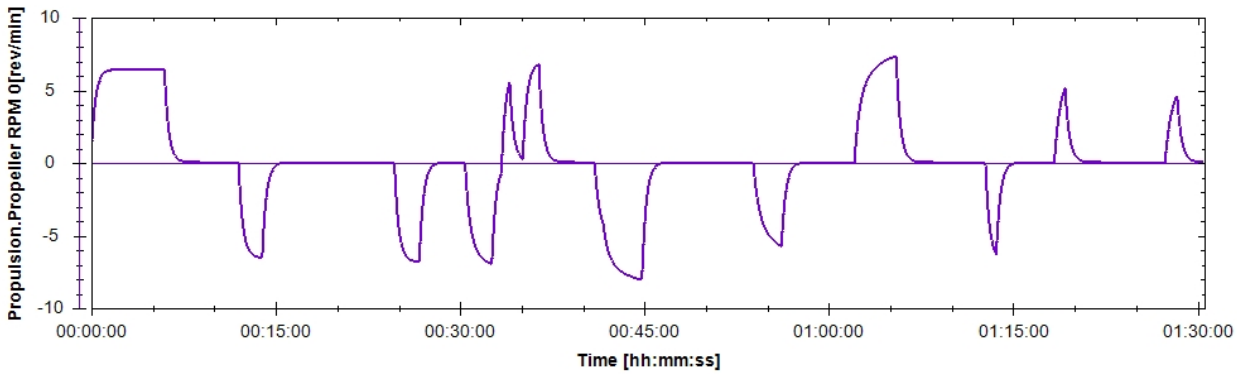
Position.Course[deg] (0.00)



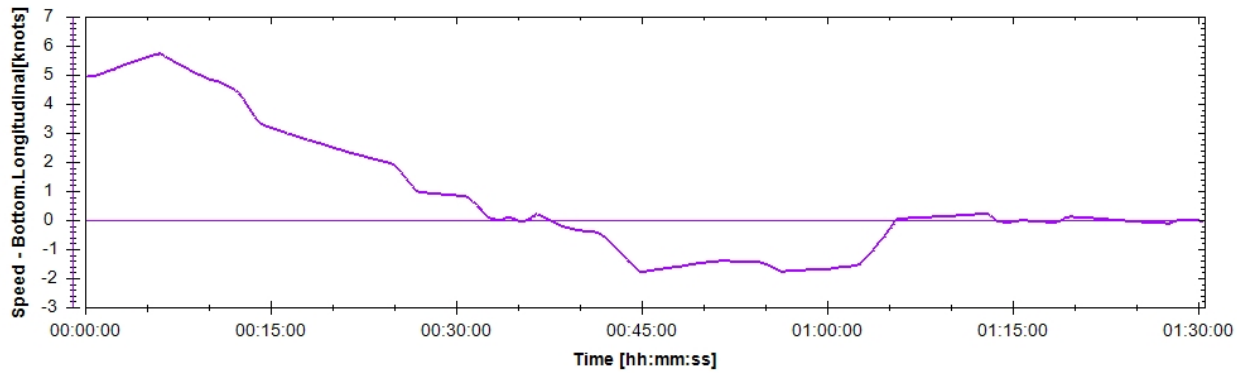
Position.Drift[deg] (0.00)



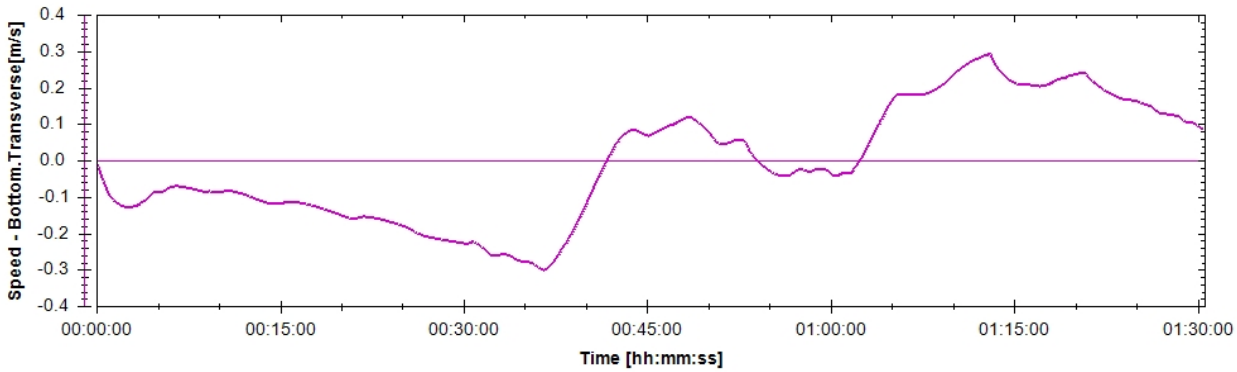
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



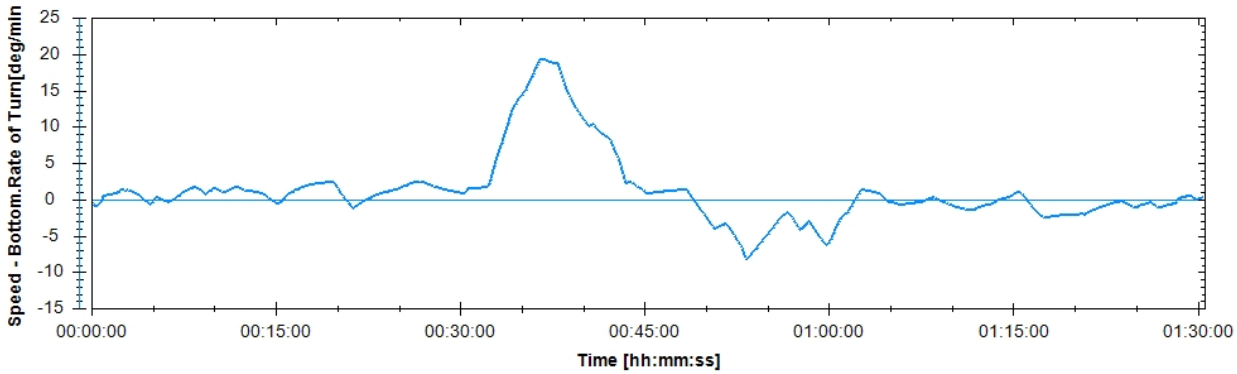
Propulsion.Propeller RPM 0[rev/min] (0.00)



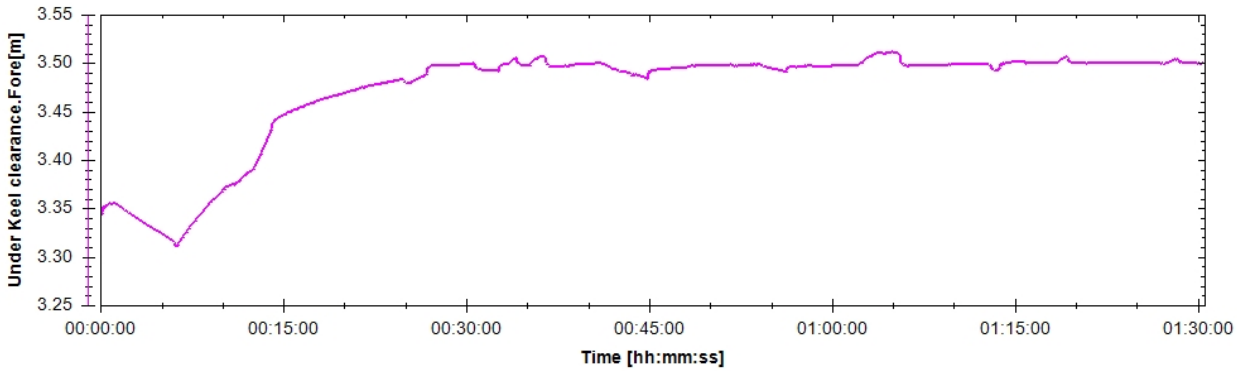
Speed - Bottom.Longitudinal[knots] (0.00)



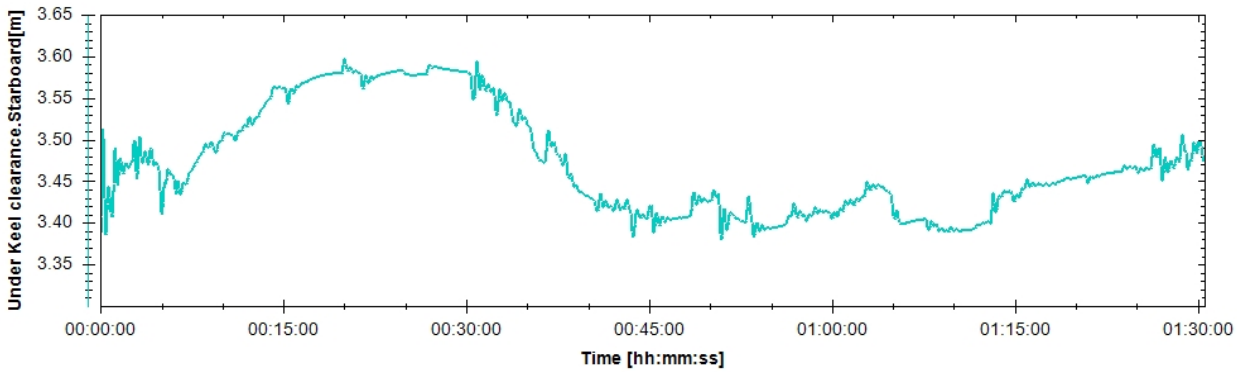
Speed - Bottom.Transverse[m/s] (0.00)



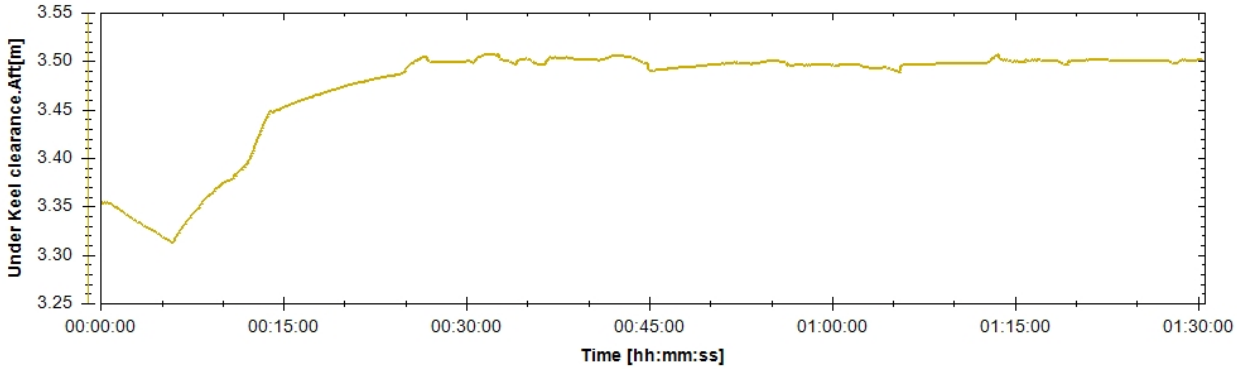
Speed - Bottom.Rate of Turn[deg/min] (0.00)



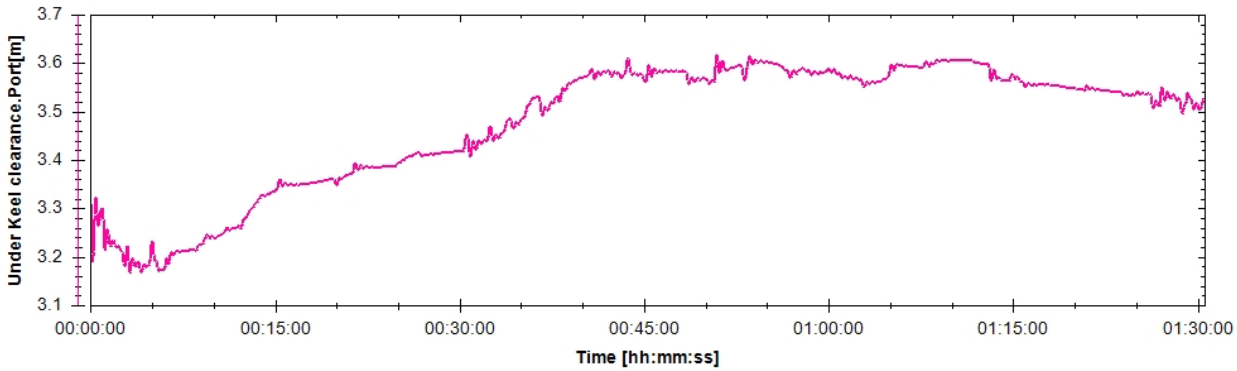
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



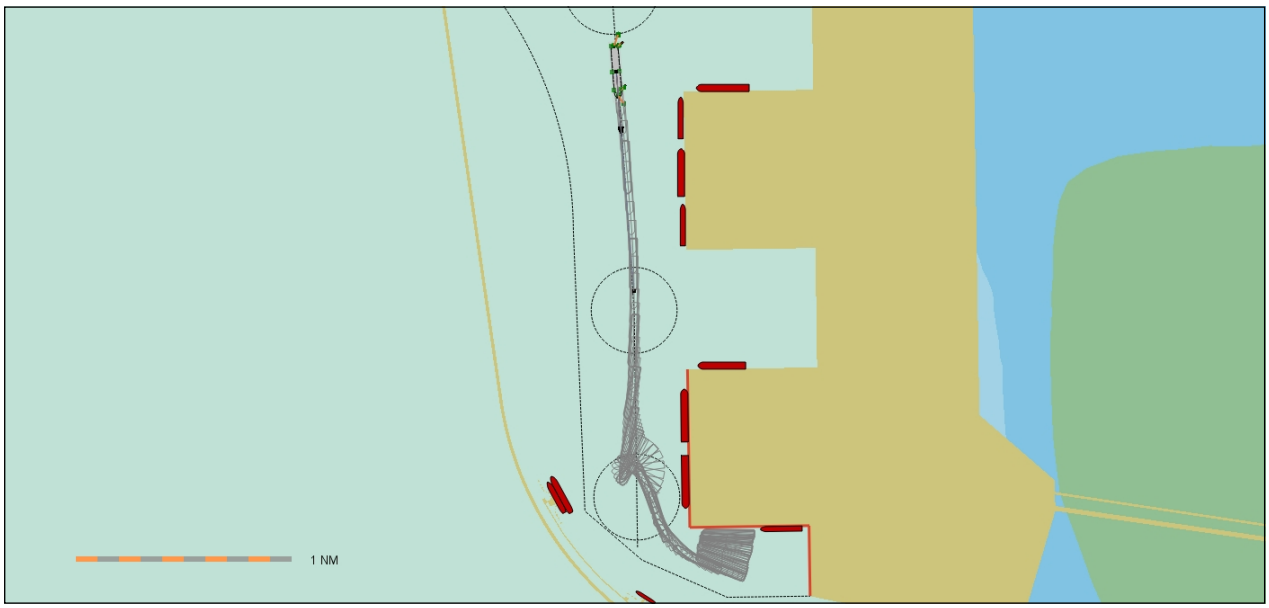
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.98585' N 072° 32.94325' E
Bottom right: 19° 55.27015' N 072° 39.00583' E

End-Of-Report

Simflex - Scenario Report

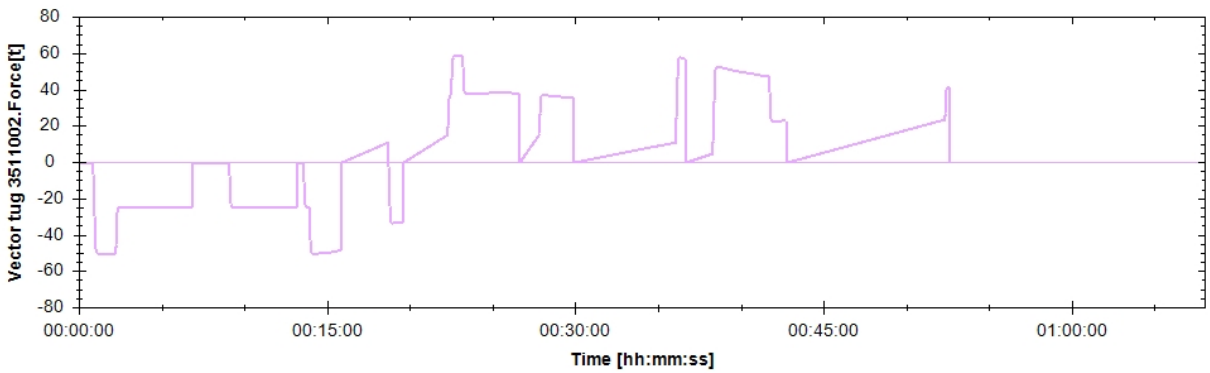
Scenario info

Scenario name: 007-Dep-CT1-Port-Ebb-045x10kts

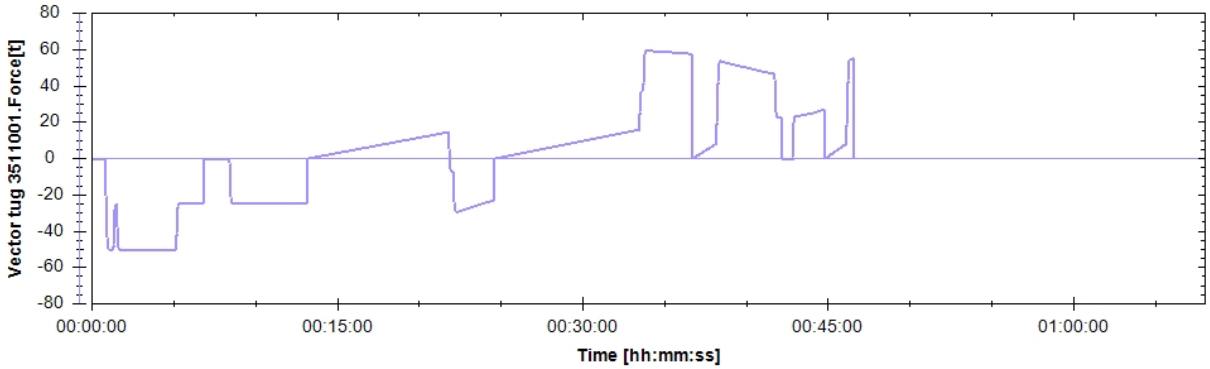
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	5.00	[m/s]
Wind dir.	Constant	45.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

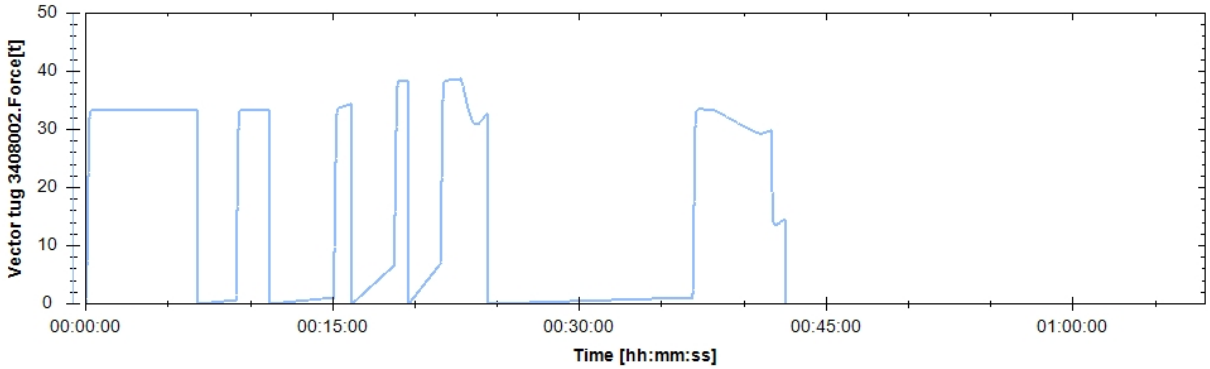
Selected Time Series



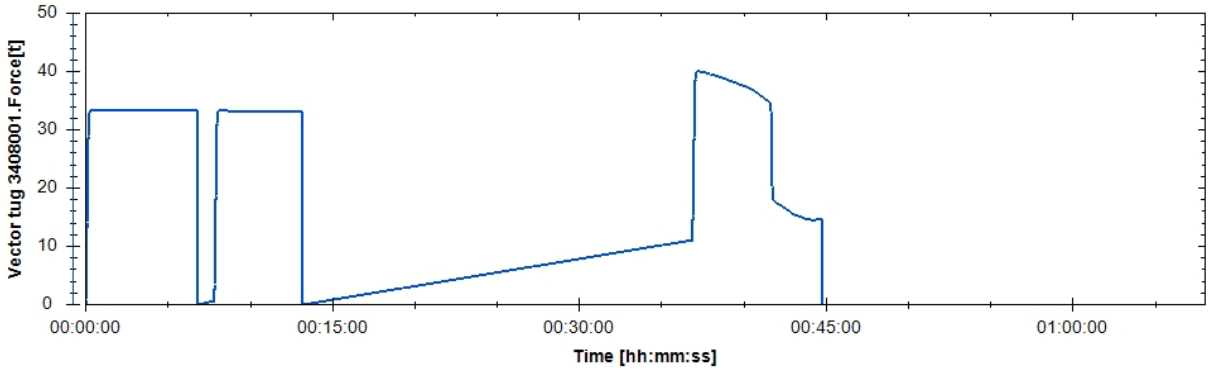
Vector tug 3511002.Force[t] (0.00)



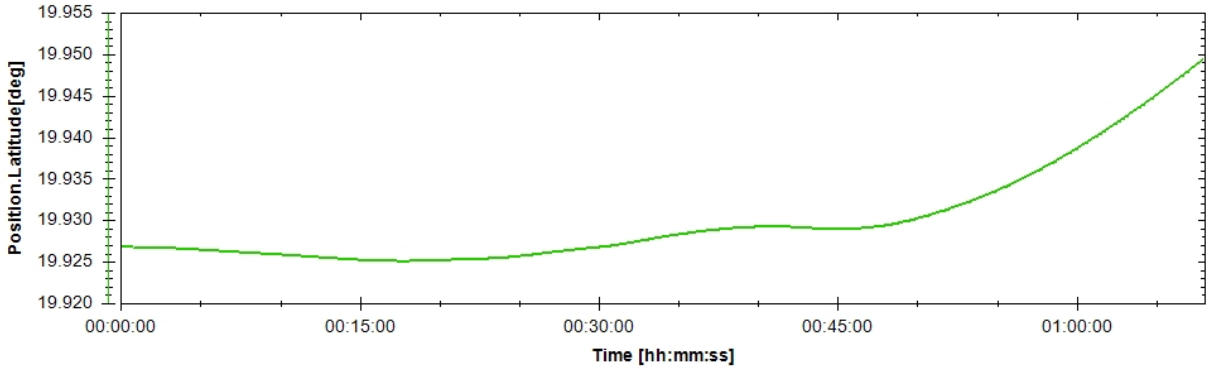
Vector tug 3511001.Force[t] (0.00)



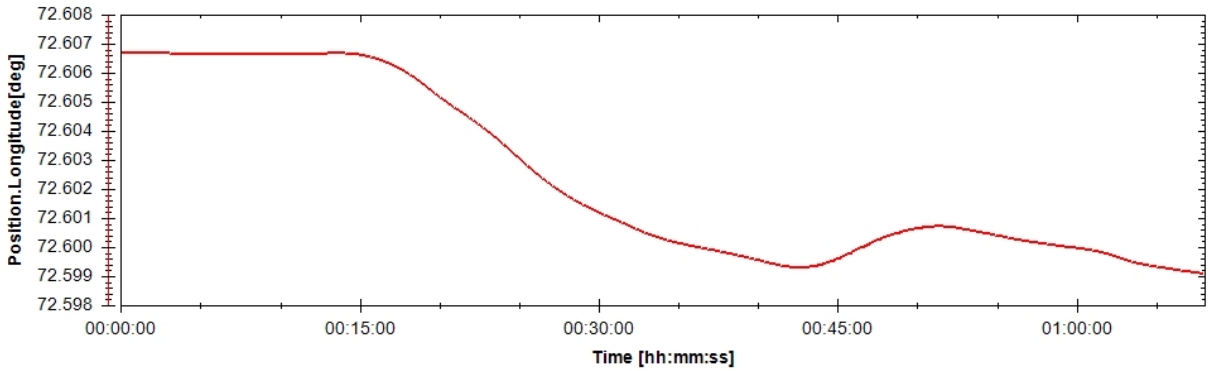
Vector tug 3408002.Force[t] (0.00)



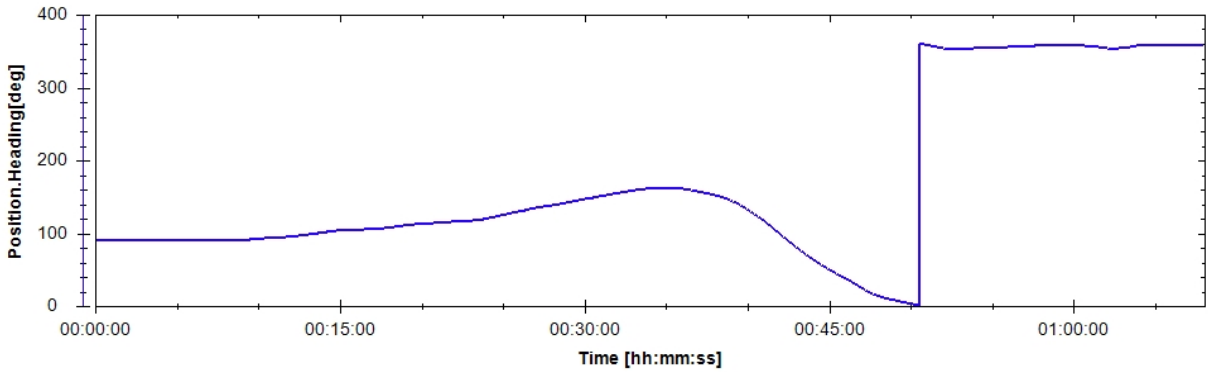
Vector tug 3408001.Force[t] (0.00)



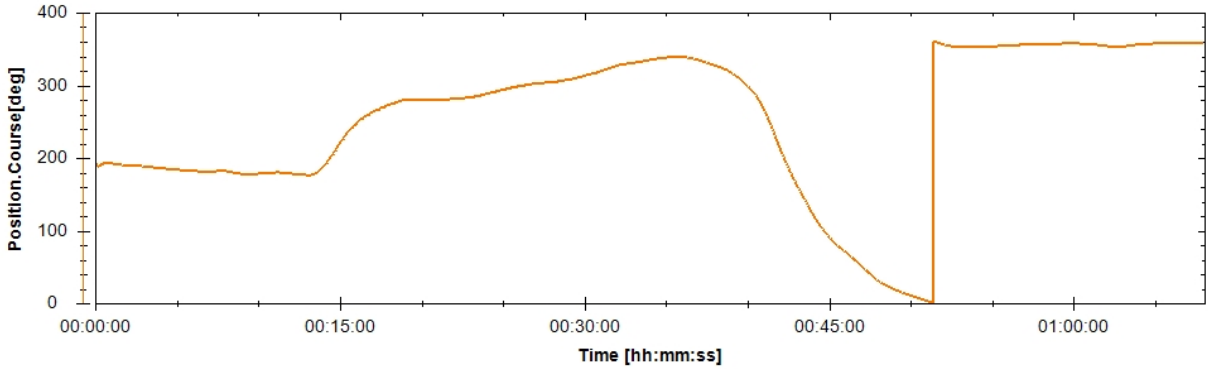
Position.Latitude[deg] (0.00)



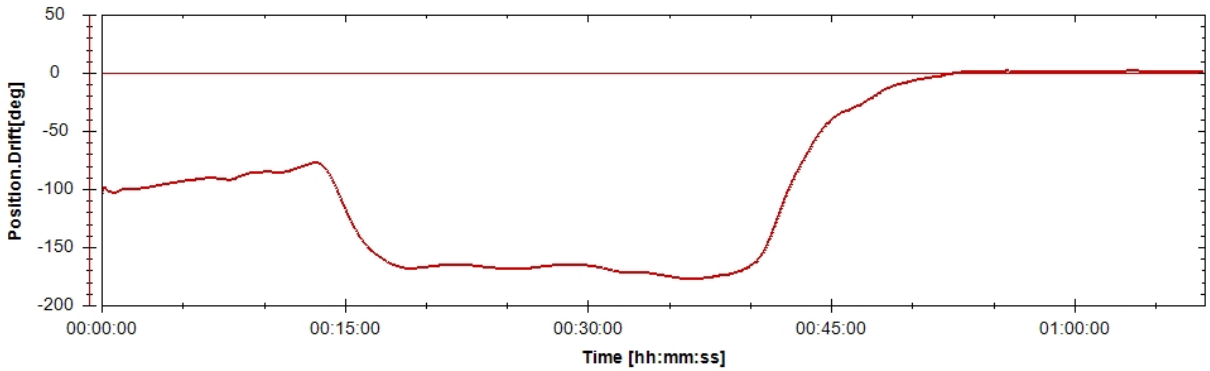
Position.Longitude[deg] (0.00)



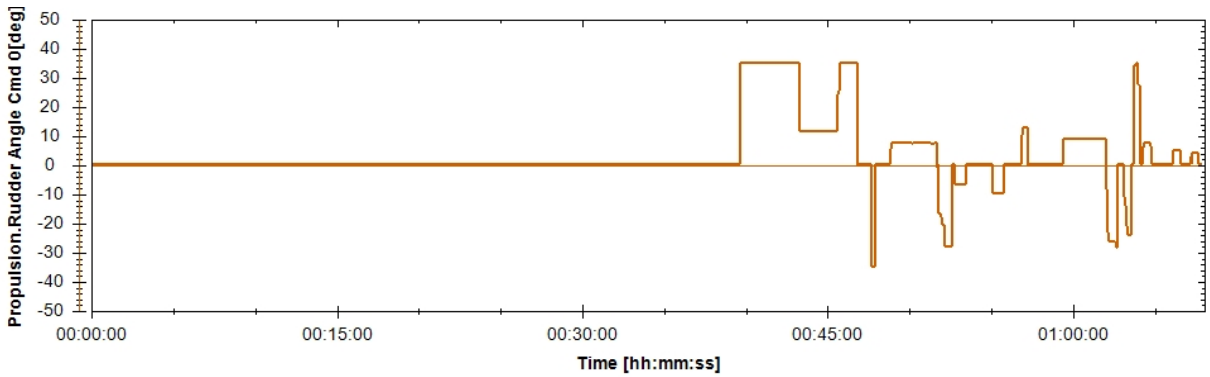
Position.Heading[deg] (0.00)



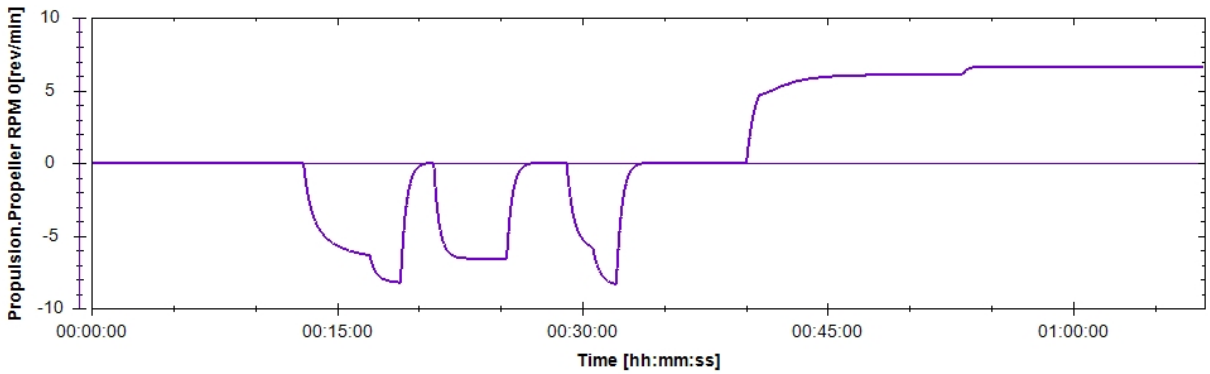
Position.Course[deg] (0.00)



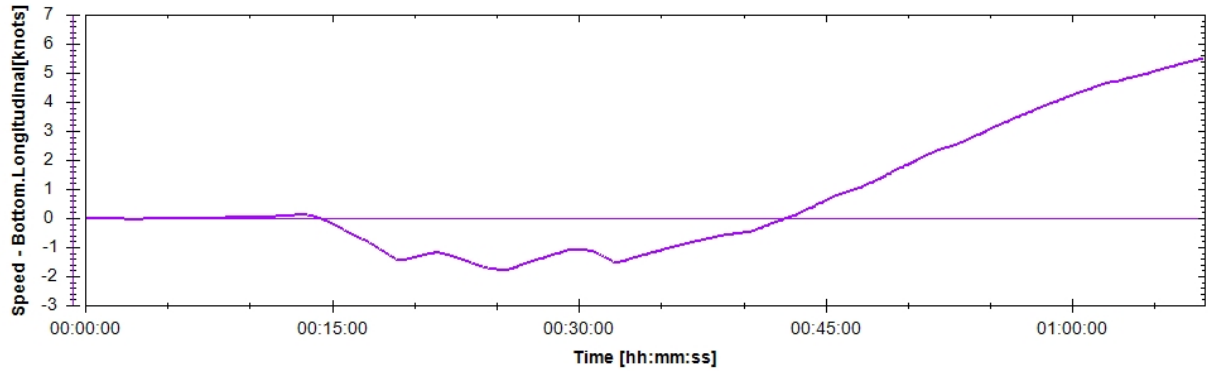
Position.Drift[deg] (0.00)



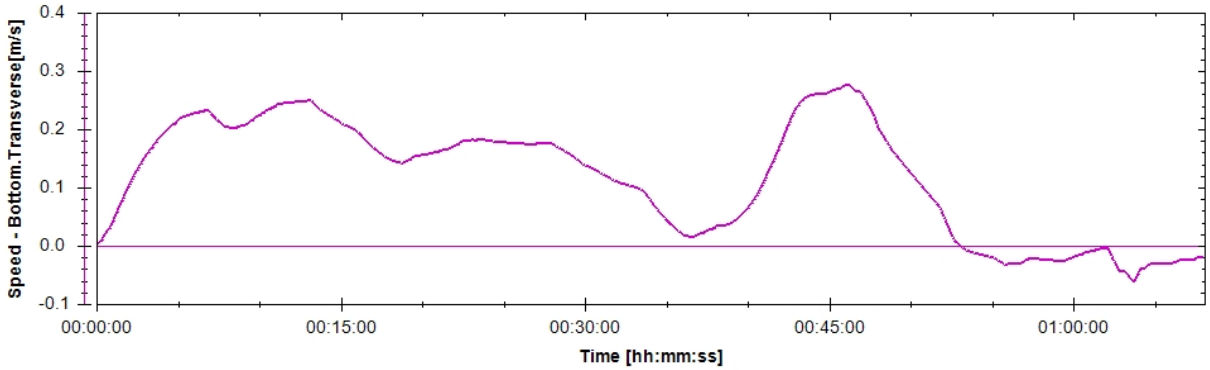
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



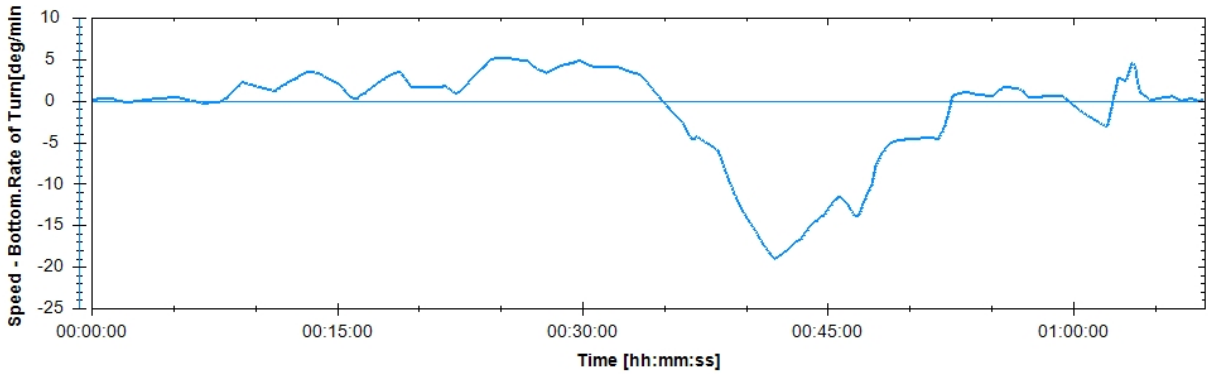
Propulsion.Propeller RPM 0[rev/min] (0.00)



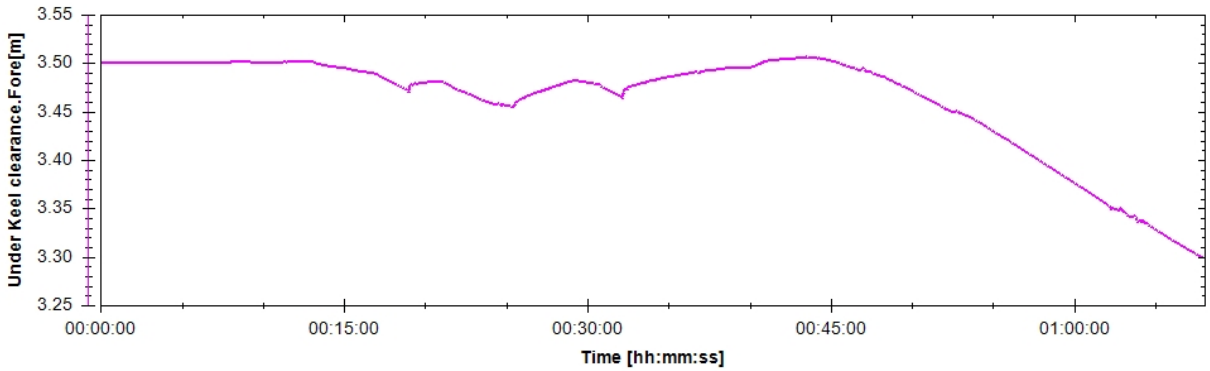
Speed - Bottom.Longitudinal[knots] (0.00)



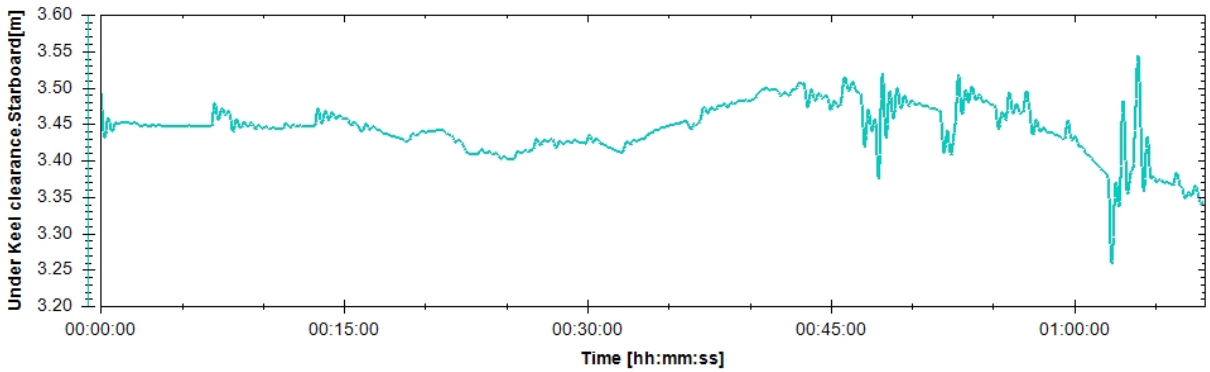
Speed - Bottom.Transverse[m/s] (0.00)



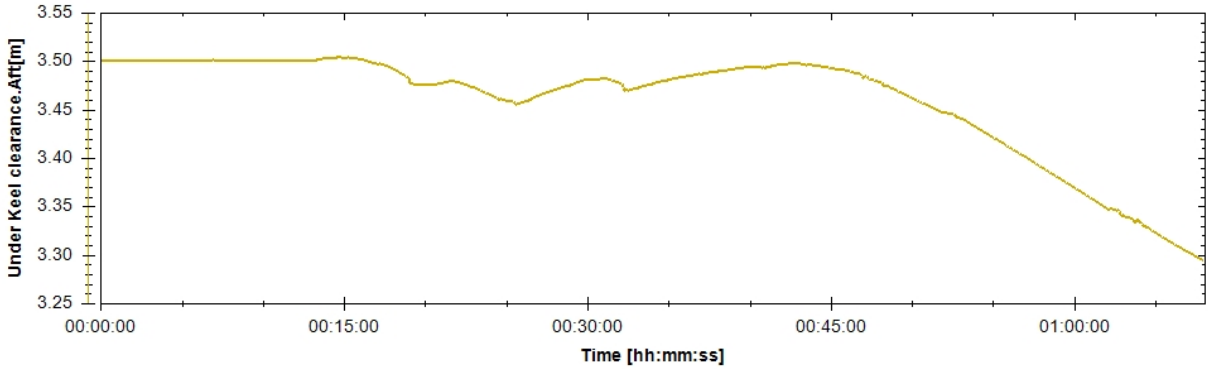
Speed - Bottom.Rate of Turn[deg/min] (0.00)



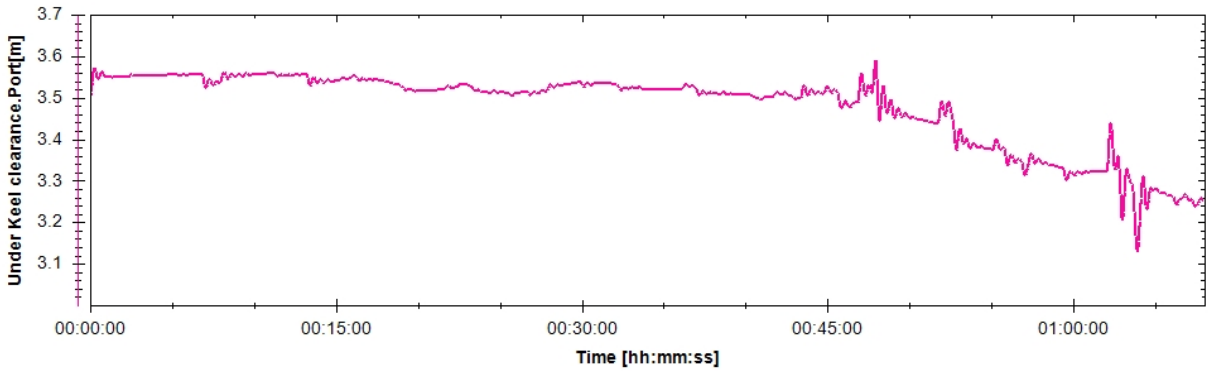
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



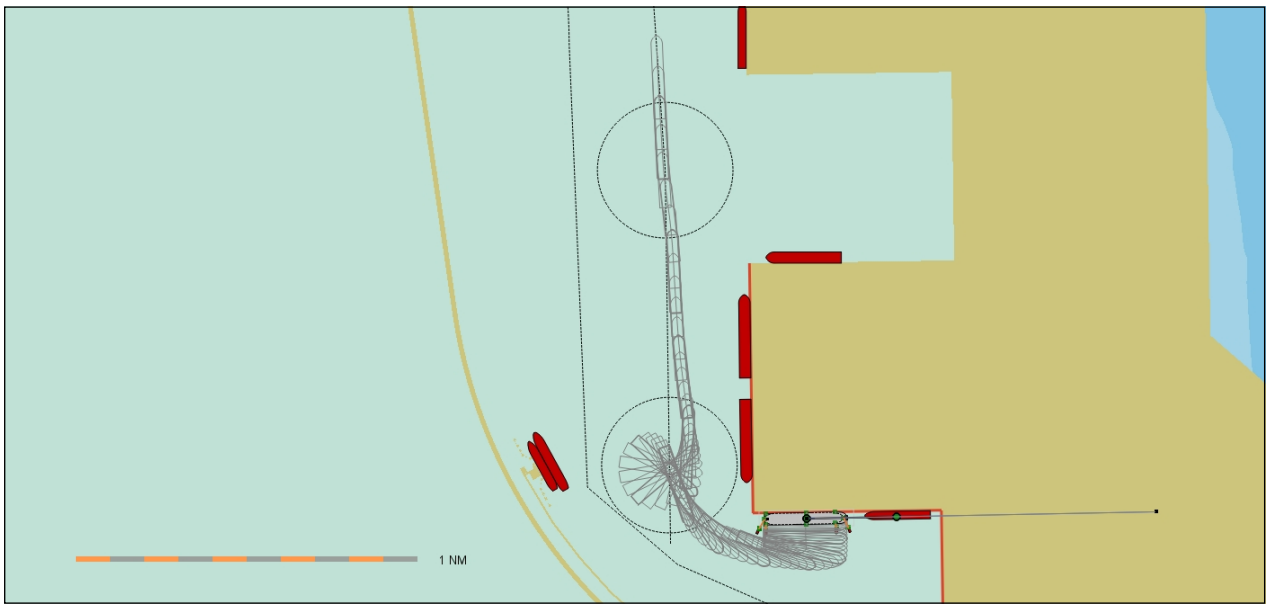
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.07621' N 072° 33.95893' E
Bottom right: 19° 55.35622' N 072° 37.79820' E

End-Of-Report

Simflex - Scenario Report

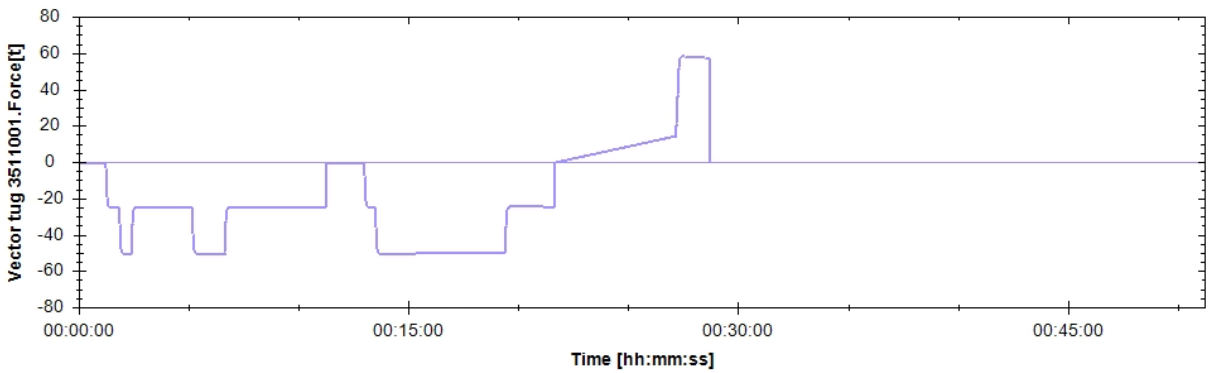
Scenario info

Scenario name: 008-Dep-CT1-Stbd-Flood-045x10kts

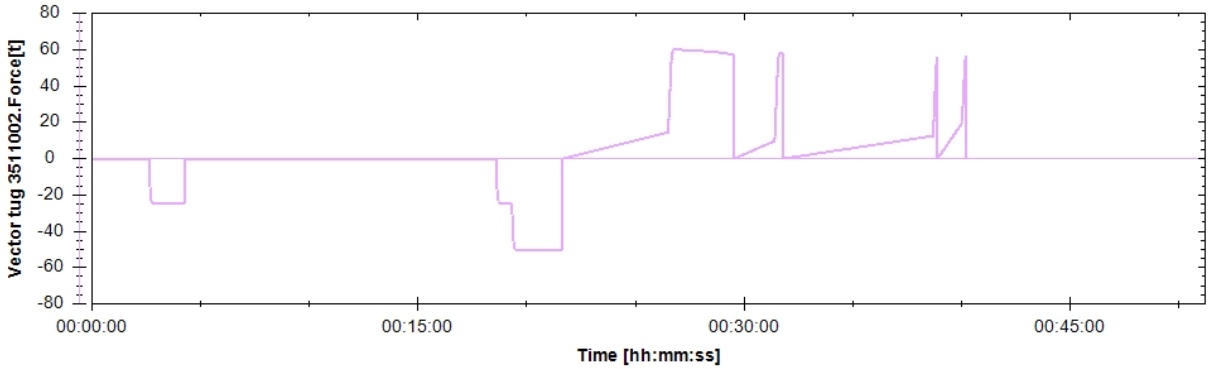
Environment

Parameter	Type	Value	Unit
Depth	Scaled	1.00	
Tide	Constant	0.00	[m]
Current speed	Scaled	1.00	
Current dir.	Scaled	0.00	
Wind speed	Constant	5.00	[m/s]
Wind dir.	Constant	45.00	[deg]
Wave height.	Constant	0.00	[m]
Wave dir.	Constant	0.00	[deg]
Wave period.	Constant	0.00	[seconds]
Wave 2 height.	Constant	0.00	[m]
Wave 2 dir.	Constant	0.00	[deg]
Wave 2 period.	Constant	0.00	[seconds]

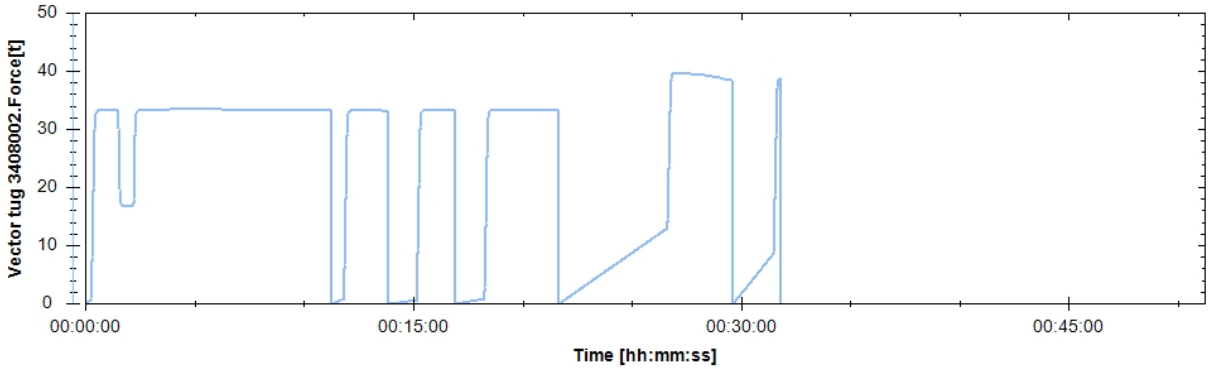
Selected Time Series



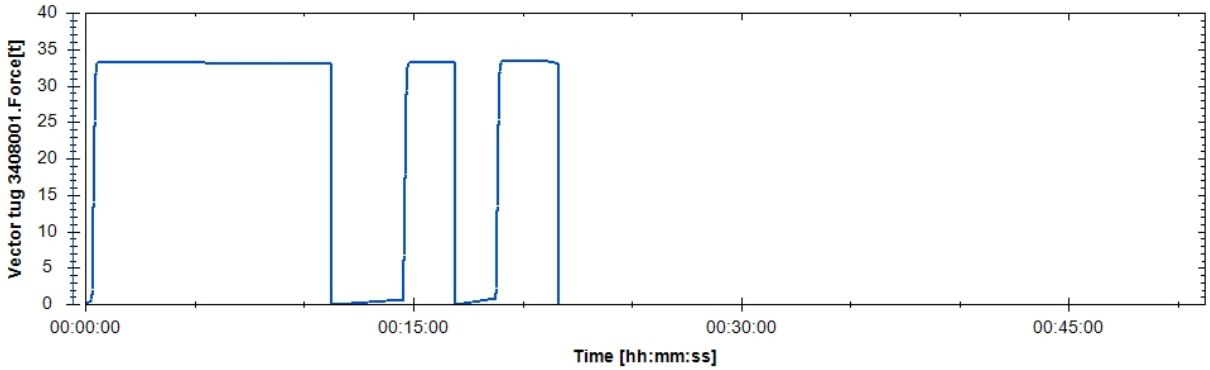
Vector tug 3511001.Force[t] (0.00)



Vector tug 3511002.Force[t] (0.00)



Vector tug 3408002.Force[t] (0.00)



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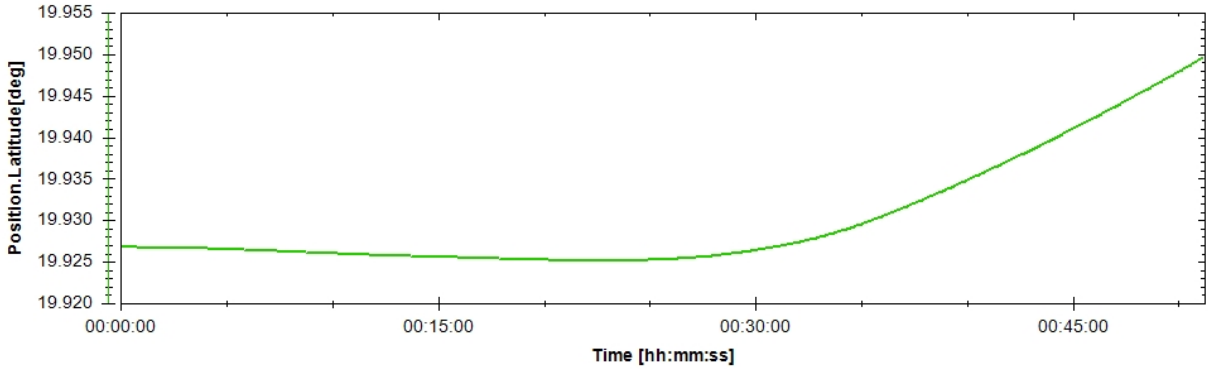
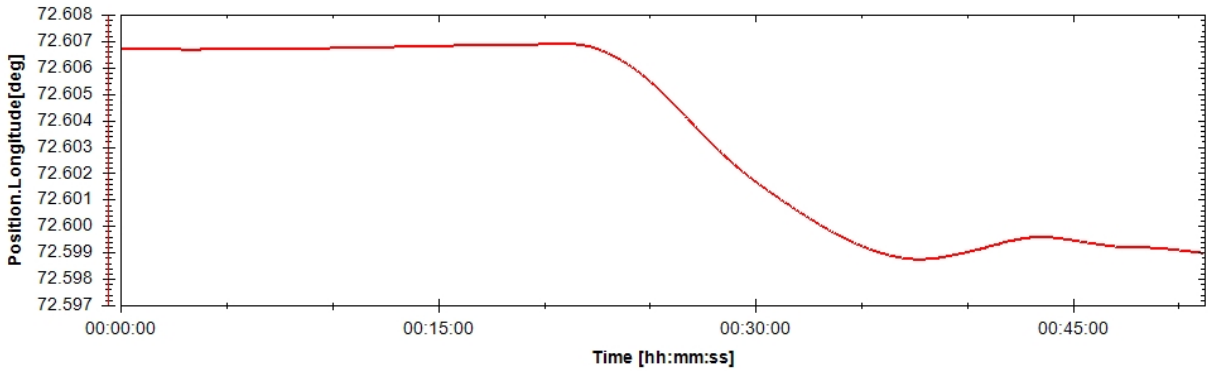
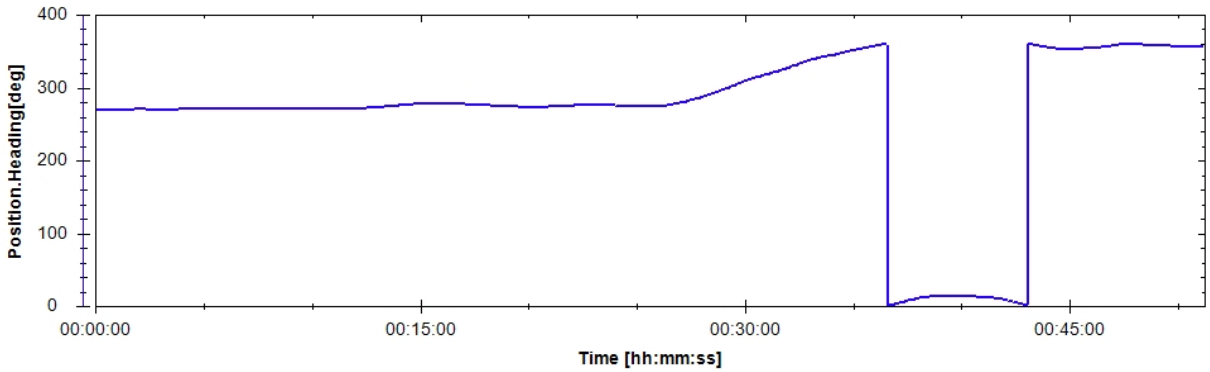


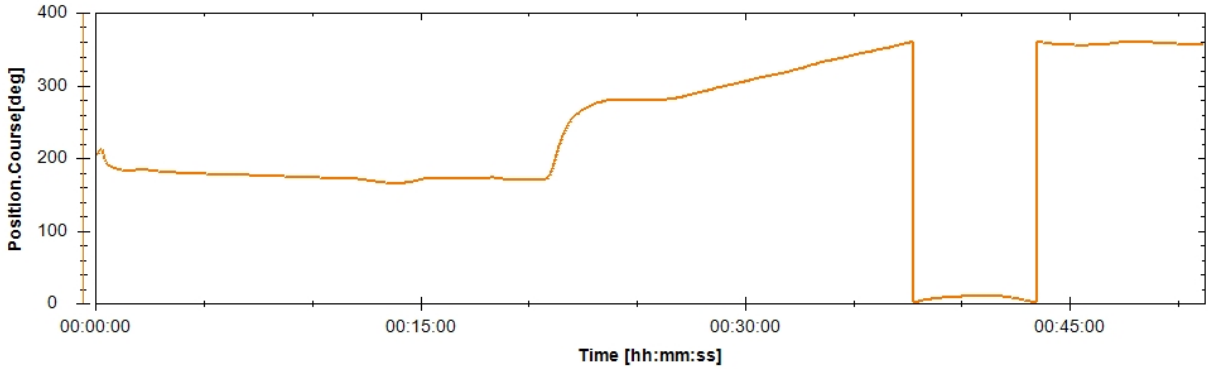
Position.Latitude[deg] (0.00)



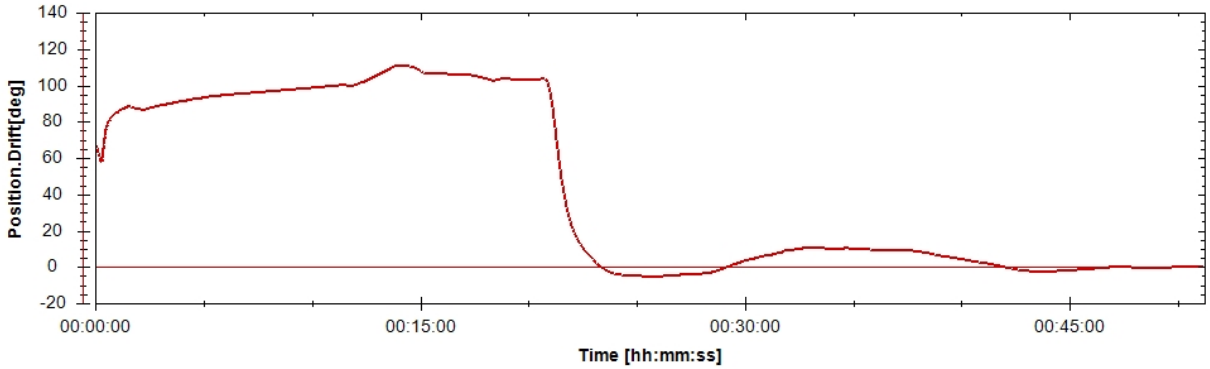
Position.Longitude[deg] (0.00)



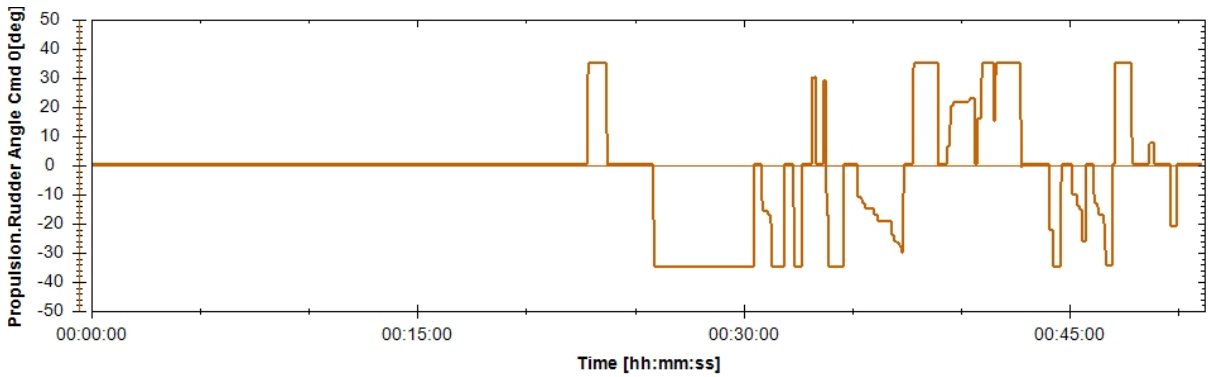
Position.Heading[deg] (0.00)



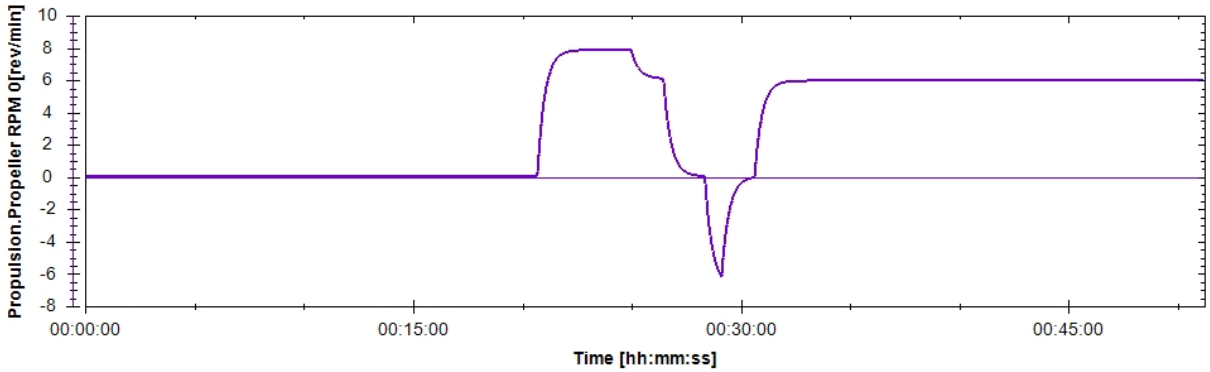
Position.Course[deg] (0.00)



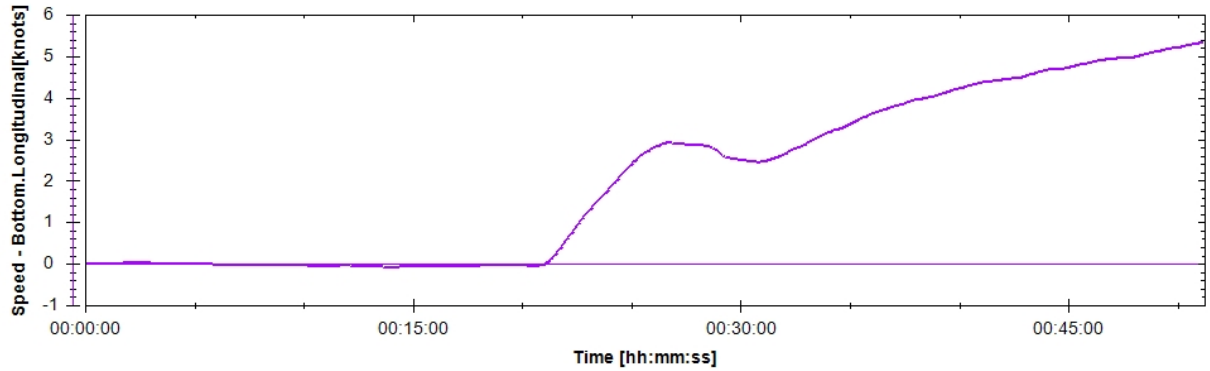
Position.Drift[deg] (0.00)



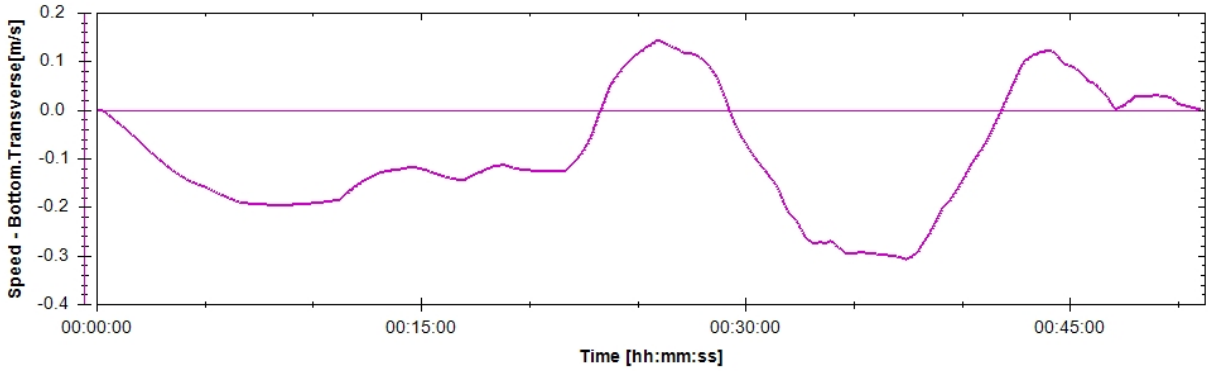
Propulsion.Rudder Angle Cmd 0[deg] (0.00)



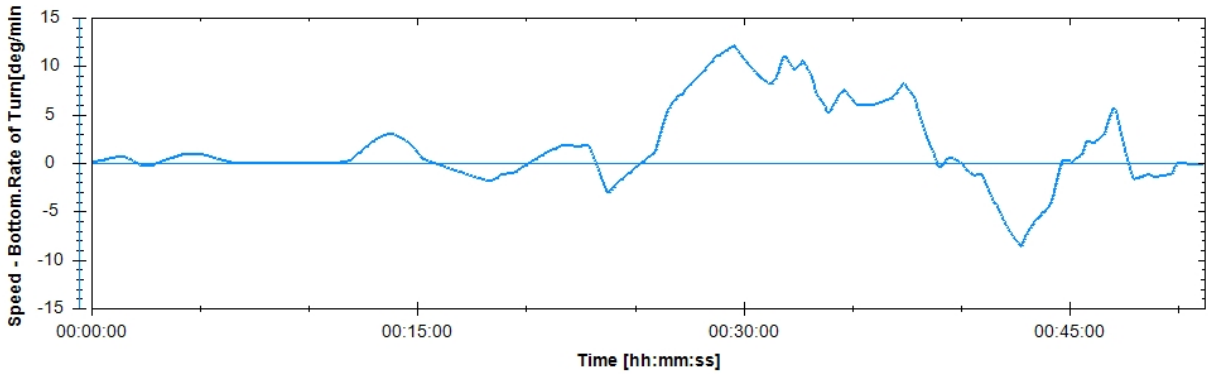
Propulsion.Propeller RPM 0[rev/min] (0.00)



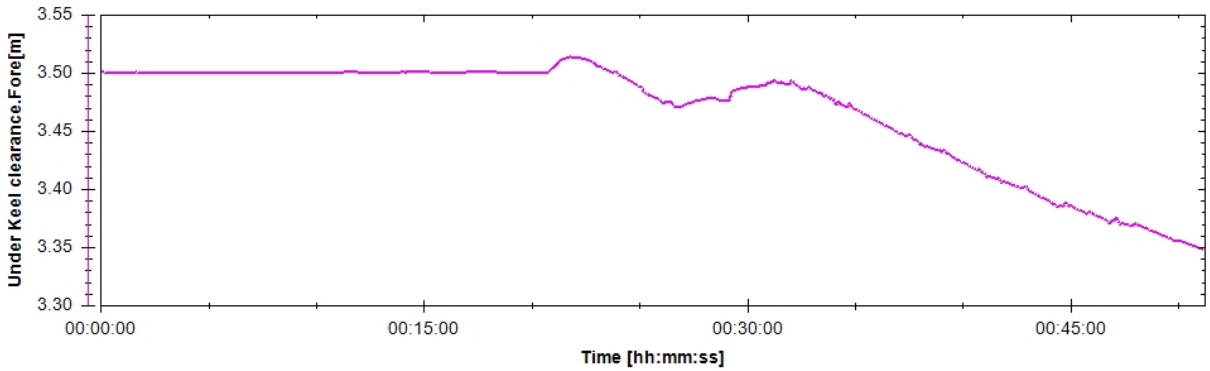
Speed - Bottom.Longitudinal[knots] (0.00)



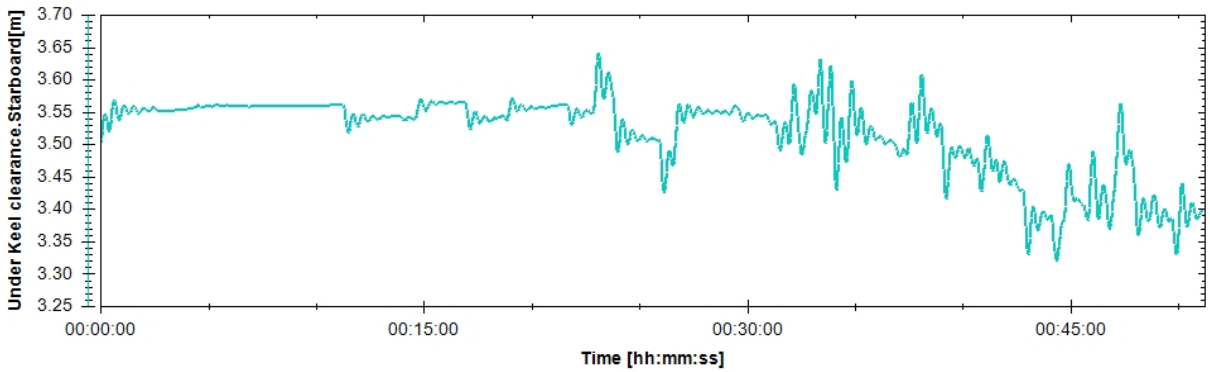
Speed - Bottom.Transverse[m/s] (0.00)



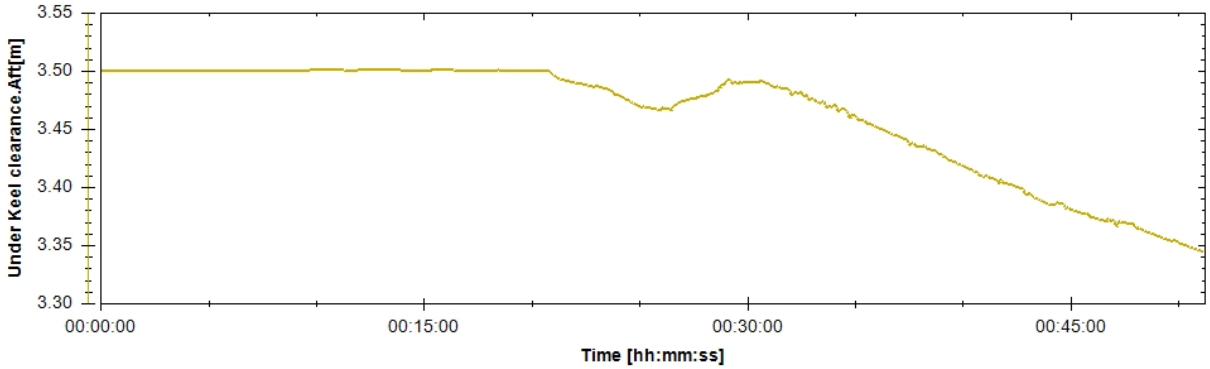
Speed - Bottom.Rate of Turn[deg/min] (0.00)



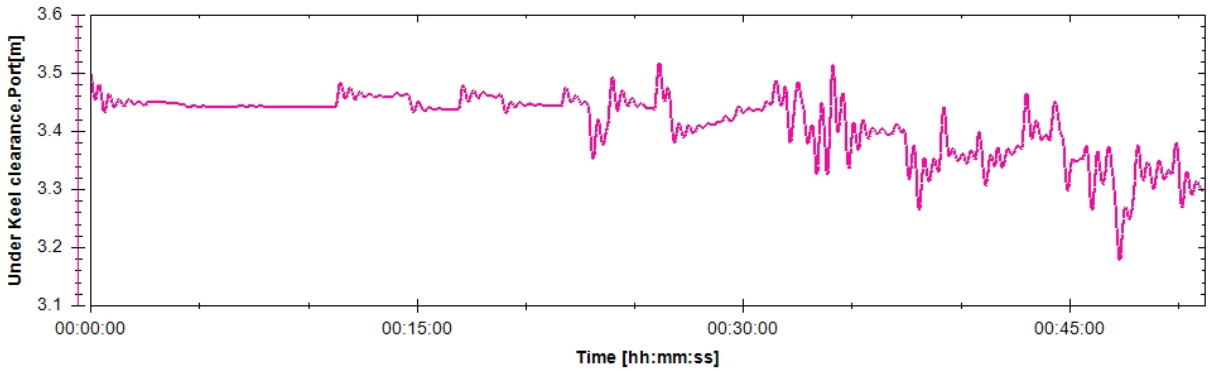
Under Keel clearance.Fore[m] (0.00)



Under Keel clearance.Starboard[m] (0.00)



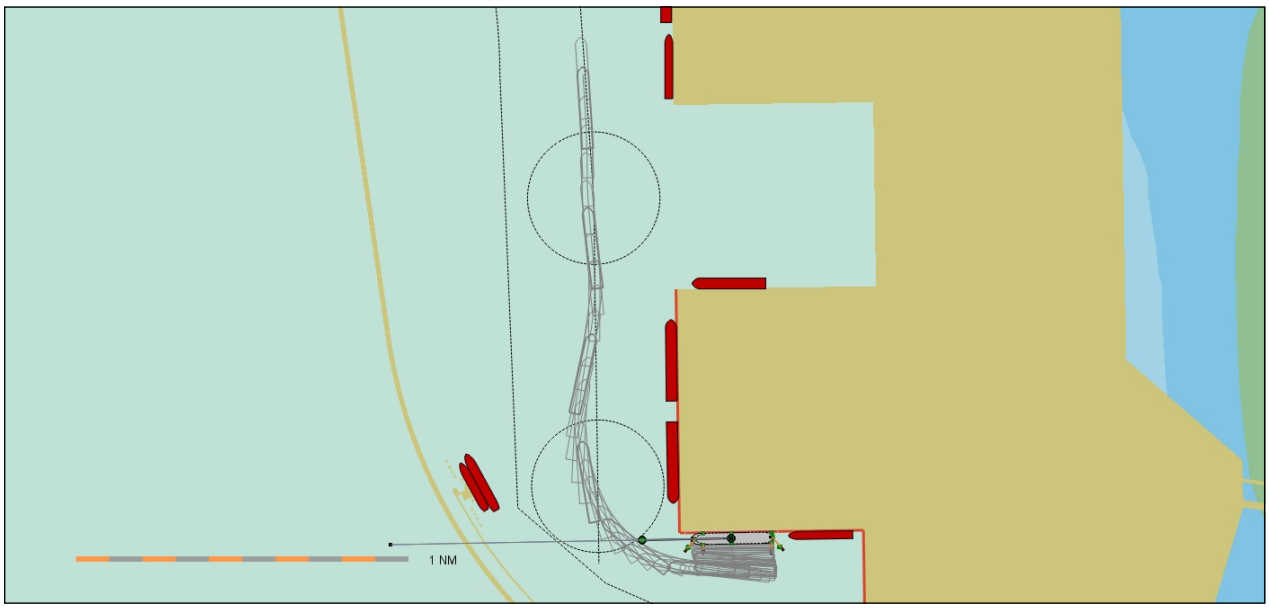
Under Keel clearance.Aft[m] (0.00)



Under Keel clearance.Port[m] (0.00)

Appendix

Chart - Vadhavan_NewLayout



Scenario Time: 23/02/2022 09:38:20
Shown area.
Top left: 19° 57.16974' N 072° 34.13352' E
Bottom right: 19° 55.40865' N 072° 38.06455' E

End-Of-Report

APPENDIX 5

Ship Model Documentation

Mathematical Ship Model No. 3749

"Golden CMS"

FORCE 114-20815 / 2014-07-11

2 Ship Particulars

Type of ship Condition Ship No.		Container Ship Loaded 3749
Length between Perpendiculars	m	418.0
Length overall	m	440.0
Breadth moulded	m	60.0
Depth	m	36.0
Draught fore/aft	m	16.0/16.0
Displacement	m^3	300040
Wetted Surface	m^2	29849
Frontal wind Area	m^2	3182
Lateral wind Area	m^2	19610
Block Coefficient	-	0.748
Trim by the Stern,	%	0.0
Metacentric Height	m	3.08
LCB, % of LPP forw. of LPP/2	%	-2.63
Radius of Inertia, % of LPP	%	25.0
Type of Engine		Diesel
Number of Propellers		1
Type of Propellers		Fixed Pitch
Direction of Rotation		Clockwise
Number of Blades		6
Propeller Diameter	m	9.72
Pitch Ratio at 0.7R		0.919
Area Ratio		0.966
Shaft Power (ahead) total	kW	82.000
Number of Rudders		1
Type of Rudders		Semi Spade
Position off CL	m	0
Area of Rudder	m^2	130.6
100 x total rudder Area/LBP x T		1.95
Turning Velocity of Rudder	deg/s	4.60
Max. rudder Angle	deg	35
Anchor Weight	kg	30497
Chain Weight	kg/m	520
Number of bow Thrusters		2
Nominal bow thruster Power	kW	2 x 1750
Number of stern Thrusters		2
Nominal stern thruster Power	kW	2 x 1750

Table 4-1: Ship Particulars

3 Equilibrium Speeds

Ship Engine Setting	Propeller		Speed, knots	
	RPM	Pitch	1000 m	19.2 m
1.0	98	0.919	23.4	grounded
0.8	70	"	17.0	13.9
0.5	52	"	12.6	11.1
0.25	38	"	8.0	7.4
0.125	30	"	5.7	4.9
-0.125	-30	"	-4.3	-3.1
-0.25	-38	"	-5.4	-4.1
-0.5	-52	"	-8.1	-6.5
-1.0	-70	"	-12.1	-9.2

Table 5-1: Propeller RPM and pitch, and equilibrium speeds for various handle settings for two water depths: deep water and shallow water corresponding to 1.2 times the aft draught.

Title of report and Project No.:

Ship Description

Ship 3408

30 m ASD Tug, 65 t BP

Service Condition

"Svitzer Mars"

Client:	***Ref.:*** DMI 2006212
Author(s): Ole Tersløv	***Date:*** 2006-10-13
	Approved by:

Revision	***Description***	***By:***	***Checked:***	***Approved:***	***Date:***
1	Original version	OT	KA		2006-10-13

Keywords:

Manoeuvring characteristics
Ship characteristics
Equilibrium speeds
Standard manoeuvres
Other characteristic manoeuvres

Classification:

Open
Internal
X Confidential

2 Ship Characteristics

Type of ship Condition Ship No.		**30 m ASD Tug, 65 t BP Service 3408**
Displacement	m3	647.9
Length between Perpendiculars	m	25.6
Length overall	m	30.0
Breadth moulded	m	11.0
Depth to main Deck	m	6.9
Draught fore/aft	m	4.60/4.60
Wetted Surface	m²	396.7
Frontal wind Area	m²	69.5
Lateral wind Area	m²	150.5
Block Coefficient	-	0.500
Trim by the Stern,	%	0.0
Metacentric Height	m	1.7
LCB, % of LPP forw. of LPP/2	%	-3.11
Radius of Inertia, % of LPP	%	25
Type of Engine		Diesel
Number of Propellers		2 Azimuth thrusters
Type of Propellers		CP in nozzle
Distance from Centreline	m	2.88
Direction of Rotation		Inwards
Propeller Diameter	m	2.4
Pitch Ratio at 0.7R		0.908
Area Ratio		0.700
Shaft Power (ahead) total	kW	2 x 1800
Bollard pull	t	65
Number of Rudders		2
Type of Rudders		Azimuth thrusters
Position		aft
Area of Rudder	m²	-
100 x total rudder Area/LBP x T		-
Turning Velocity of Rudder	deg/s	20.0
Max. rudder Angle	deg	+/- 180
Anchor Weight	kg	262.5
Chain Weight	kg/m	9.3
Number of bow Thrusters		1
Nominal bow thruster Power	kW	1 x 370

Table 2-1: Ship characteristics

3 Equilibrium Speeds

Engine Setting	Propeller		Speed, Knots	
	RPM	PITCH	1000 m	1.2 Tm = 5.52 m
1.0 Ahead	266	1.02	13.8	Grounded
0.8 Ahead	266	0.91	13.5	Grounded
0.5 Ahead	209	0.64	10.5	9.2
0.25 Ahead	160	0.27	5.4	5.2
0.125 Ahead	160	0.15	3.6	3.5

Table 3-1: Propeller RPM and pitch, and equilibrium speeds for various handle settings for two water depths: deep water and shallow water corresponding to 1.2 times the mean draught.

Title of report and Project No.:

Ship Description

Ship 3511

36m ASD Tug, 100t BP

Departure Condition

Client:	***Ref.:*** DMI 108-29100
Author(s): Kristian Agdrup	***Date:*** 2009-03-16
	Approved by:

Revision	***Description***	***By:***	***Checked:***	***Approved:***	***Date:***
1	Original version	KA			2009-03-16

Keywords:

Manoeuvring characteristics
Ship characteristics
Equilibrium speeds
Standard manoeuvres
Other characteristic manoeuvres

Classification:

Open
Internal
X Confidential

2 Ship Characteristics

Type of ship Condition Ship No.		36m ASD Tug, 100t BP Departure 3511
Displacement	m^3	1191.1
Length between Perpendiculars[1]	m	29.15
Length overall	m	35.8
Breadth moulded	m	14.5
Depth moulded	m	7.7
Draught (maximum, incl. skeg)	m	6.15
Wetted Surface	m^2	600.5
Frontal wind Area	m^2	120
Lateral wind Area	m^2	234
Block Coefficient based on Lpp	-	0.458
Trim by the Stern	%Lpp	0.00
Metacentric Height	m	2.48
LCB, % of LPP forw. of LPP/2	%	3.0 %
Radius of Inertia, % of LPP	%	25 %
Type of Engine		Diesel
Number of Propellers		2
Type of Propellers		CP
Direction of Rotation		Outwards
Number of Blades		4
Propeller Diameter	m	3.00
Pitch Ratio at 0.7R		1.10
Area Ratio		0.68
Shaft Power (ahead) total	kW	2 x 3060
Bollard Pull (ahead/astern)	ton	100 / 95
Number of Rudders		2
Type of Rudders		azimuth thrusters
Position (offset from centre line)	m	3.25
Area of Rudder	m^2	-
100 x total rudder Area/LPP x T		-
Turning Velocity of Rudder (two Pumps)	deg/s	12
Max. rudder Angle	deg	+/- 180
Anchor Weight	kg	817
Chain Weight	kg/m	19.8
Number of bow Thrusters		1
Nominal bow thruster Power (each)	kW	200
Number of stern Thrusters		0
Nominal stern thruster Power (each)	kW	-

Table 2-1: Ship characteristics

[1] Aft perpendicular is here defined to be at the location of the turning axis of the azimuth thrusters.

3 Equilibrium Speeds

Direction	Ship Engine Setting	Propeller		Speed, knots	
		RPM	Pitch P/D	1000 m	7.38 m
Ahead	1.0	218	1.10	13.9	11.2
	0.8	199	0.86	12.3	10.3
	0.5	173	0.71	10.1	9.2
	0.25	137	0.55	7.0	6.7
	0.125	106	0.43	4.6	4.4
Astern[2]	-0.125	106	-0.09	-1.7	-1.4
	-0.25	137	-0.19	-3.8	-3.6
	-0.5	173	-0.38	-6.9	-6.7
	-1.0	218	-0.55	-9.9	-9.2

Table 3-1: Propeller RPM and pitch, and equilibrium speeds for various handle settings for two water depths: deep water and shallow water corresponding to 1.2 times the mean draught.

[2] Note that sailing astern is normally done by turning the azimuth thrusters 180 deg instead of using negative pitch as shown here.