IMMINGHAM EASTERN RO-RO TERMINAL

Navigation Simulation Study December 2021 (Part 1)

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Summary

Associated British Ports (ABP) Humber are considering additional RoRo berth capacity to the east of the Immingham dock, this will be known as Immingham East RoRo Terminal.

HR Wallingford were commissioned to undertake a real time navigation simulation study in support of ABP's development process, with the following conclusions and recommendations made as a result of the study:

- The proposed infrastructure is acceptable to operate a 240m RoRo vessel safely.
- The design width between the 2 jetties can be reduced to 120m between fender lines without reducing the operational availability of the berth.
- Any amendment to the design which reduces the distance between IOT and the new infrastructure, or sets the new infrastructure at a different aspect to the existing alignment of IOT6/8 will make the operations at IOT more difficult to achieve safely. Any such change should be checked through navigation simulation before being adopted.
- Layout 2, with 94m between new infrastructure and IOT8, should be adopted to minimise disruption to operations at IOT8.
- The 3 berth design (Layout 2) should be adopted with the option to extend to a 4 berth hybrid layout in due course.
- Operations at the berths need small, relatively agile and powerful tugs to assist manoeuvres. Tugs of approximately 25m in length with at least 60tBP will be required.
- Based on the minimum observed under keel clearance (UKC) in the dredged box of 4.5m during the simulation runs, it might be appropriate to reduce the dredged depth to -8mCD, as long as the design draught remains no greater than 7m and, until demonstrated otherwise, special consideration is given to any manoeuvre where the predicted UKC is less than 2m.

Overall it should be noted that manoeuvring to and from the new infrastructure is challenging, requiring precise positing of the vessel, tugs and their attitude to the tidal flow and the wind. Mitigating the inherent risk in the manoeuvring operations will require a robust training solution to be in place.

Additional assessment will be required to identify the detail of recommended procedures and limits for all classes of vessel and a wider range of environmental conditions. This will be particularly pertinent to developing appropriate limits for an initial operating capability.

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1 Introduction

1.1 Background

Associated British Ports (ABP) Humber are considering additional RoRo berth capacity to the east of the Immingham dock, this will be known as Immingham East RoRo Terminal.

HR Wallingford were commissioned to undertake a real time navigation simulation study in support of ABP's development process. As part of the initial analysis of the baseline designs provided by ABP, a short design review was undertaken to refine the setup for the navigation simulation study. Details of the design review is provided in Reference 1. The design review included updating an existing tidal flow model to account for additional dredging, analysis of the location and orientation of the berths to minimise environmental concerns and to maximise the functionality of the berths from an operational perspective.

The design review recommend the real time navigation study should consider the following:

- A berth design orientated across the general direction of tidal flow should be discounted;
- The design of the new infrastructure should be orientated to 297°N which is assessed as the general direction of peak tidal flow in the berthing area;
- It is challenging to accommodate 4 berths without significant dredging in the intertidal area, so options for 3 and 4 berth layouts should be considered;
- It may be possible to reduce the distance between the main jetties to around 120m, so options for a reduced manoeuvring area should be included which create either more space between the new infrastructure and adjacent berths to the north, or reduce the dredging footprint to the south;
- Consider 4 options for the proposed berths at Immingham, as follows and as shown in Figure 1.1:
  - Layout 1 represents an option which provides 4 new RoRo berths, including a 140m (fender to fender) manoeuvring area between the inner berths;
  - Layout 2 represents an option which provides 3 new RoRo berths including a 120m (fender to fender) manoeuvring area between the inner berths. The additional space is used to increase the distance between the new infrastructure and the adjacent IOT8 berth to 94m;
  - Layout 4 represents an option which provides 4 new RoRo berths including a 120m (fender to fender) manoeuvring area between the inner berths. The additional space is used to move the new infrastructure north and reduce the dredging. The distance between the new infrastructure and the IOT berths is the same as for Layout 1;
  - Layout 4 provides 3 new RoRo berths including a 140m (fender to fender) manoeuvring area between the inner berths. The distance between the new infrastructure and the IOT berths is the same as for Layout 1.

This report describes the real time navigation simulation study that was carried out to assess these options and the recommendations provided to ABP as an outcome of the study.

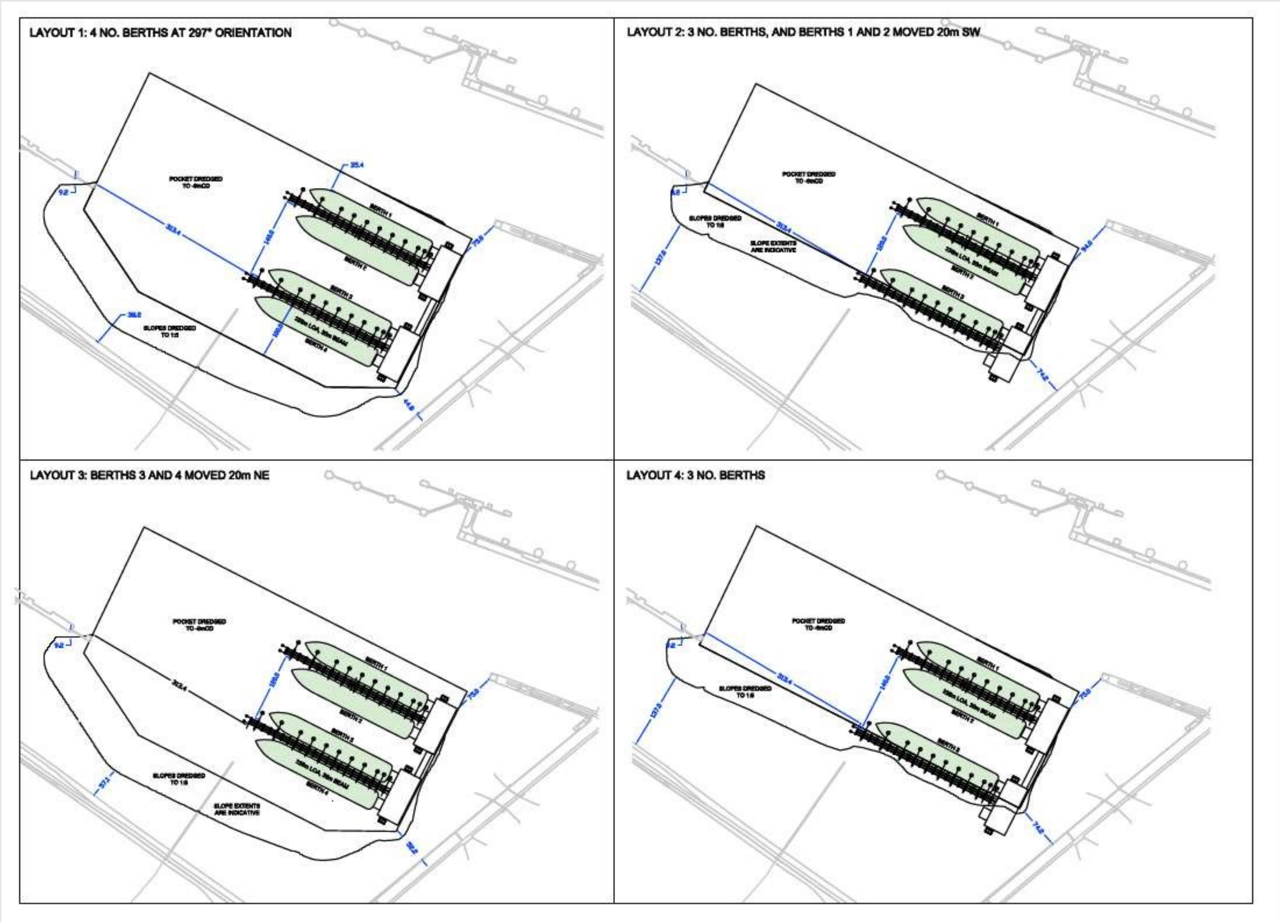

Figure 1.1: Proposed layouts for RoRo berths at Immingham

1.2 Objectives

The study addressed the following key objectives:

- Assess potential for safe operations of the design vessel (240m long RoRo vessel) to and from all proposed berths during strong tidal flows and with strong beam winds;
- Assess potential for safe operations of the design vessel to the inner berths (Berths 2 and 3), during strong tidal flows and with strong beam winds;
- Consider the distance between Berths 1 and 2 (fender to fender) and if it can be reduced to 120m from the original design specification of 140m;
- Assess potential for safe operation of the design vessel to the inner most berth (Berth 4), during strong tidal flows and with strong beam winds;
- Assess if vessels that typically operate from IOT6 and 8 at present can continue to operate safely with the new infrastructure in place, during strong tidal flows and with strong beam winds.

These were examined during the real time navigation simulation session. The conditions for the simulation runs were deliberately selected to represent the likely limiting conditions for safe operations, and so they can be considered to provide a conservative assessment of the viability of the new infrastructure. However, throughout the session it was noted that further simulation work would be required to fully examine the procedures and appropriate limits for the berths.

1.3 Orientation of infrastructure

The proposed new RoRo berths are to be situated within the Immingham East Harbour, as shown in Figure 1.2, with details of the new infrastructure depicted in Figure 2.1. The berths will be located between the Immingham East Jetty and the Immingham Oil Terminal (IOT).

The main navigational fairway for the river Humber runs parallel to IOT, and vessels using the new facilities will be expected to arrive and depart via this fairway.

Immingham East Jetty is due west of the new facility. It is predominately used by large tankers, which places a further restriction on vessels approaching the new facility due to decreased manoeuvring space on approach.

Immingham Dock is accessed via a lock system approximately 500m NW of the new facility. Vessels approaching the lock approach at slow speed, transiting across the tidal flow. Consequently, there will need to be some management of vessel movements between approaching the new facility and those arriving or departing the lock.

Relatively small tankers operate at IOT6 and 8. Manoeuvring at the berths is to flood conditions only. Operations at IOT6 and 8 are expected to continue alongside the new facilities, hence again, vessel movements will need to be carefully managed between the two facilities.

Figure 1.2: Immingham Harbour layout

Source: Google Earth 2021

2 Simulator configuration

2.1 Port approaches and proposed development

HR Wallingford previously developed a detailed simulation model of the River Humber and the approaches to Immingham in conjunction with ABP Humber. The model has been validated by professional pilots and masters and used for various training courses and navigation assessment studies during 2021. This model was used to represent the approaches to the new facilities and surrounding features.

ABP provided HR Wallingford with CAD drawings (References 1 and 3) which detailed the proposed new infrastructure. These drawings were used to undertake the initial design review and produce the layouts shown in Figure 1.1. The details from these drawing were including into the simulation for this study.

The key features of the layouts from a navigational perspective are presented in Table 2.1 and the general arrangement can be seen in Figure 2.1.

Table 2.1: Overview of the four berth configuration options considered

Particulars	Layout 1	Layout 2	Layout 3	Layout 4
Number of berths	4	3	4	3
Proximity to IOT	75m	94m	75m	75m
Distance between Berths 2 and 3	140m	120m	120m	140m

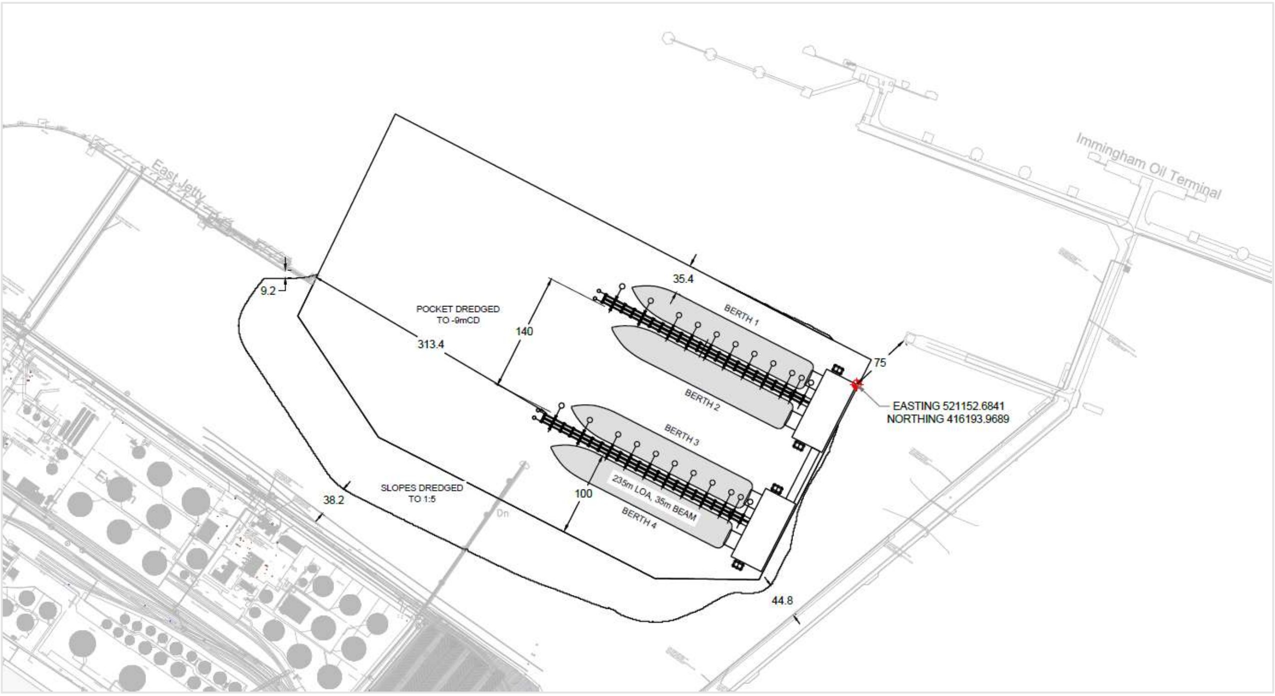

Figure 2.1: Layout 1 general arrangement drawing

2.2 Environmental considerations

2.2.1 Bathymetry

The general bathymetry that was used in the simulation was exported from HR Wallingford's detailed 2D flow model of the river Humber. The raw bathymetric data was previously provided by ABP Humber, and verified by comparison with recent Admiralty charts and during Continuous Professional Development courses attended by the Humber Pilots.

The extent and orientation of the dredged boxes was considered as part of the design review, as described in Reference 1. There were two dredged area designs proposed and considered in the real time navigation simulation study as follows:

- A four berth option which required dredging into the intertidal area;
- A three berth solution which required minimal dredging into the intertidal area.

The depth of the dredged area was set at -9mCD on advice from ABP Humber and the side slope of the dredged areas was determined in conjunction with ABPMer.

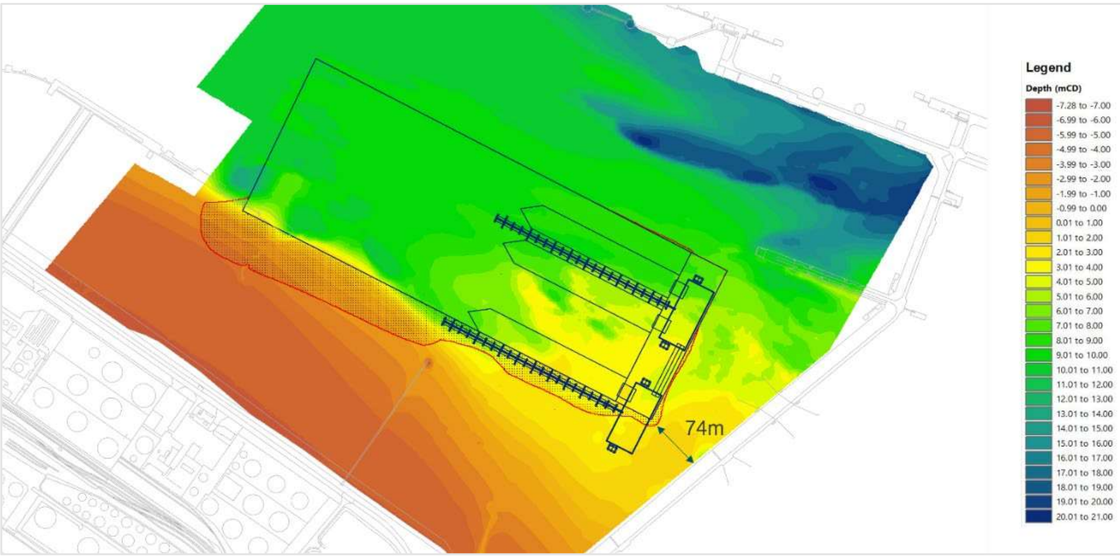

Figure 2.2: The 3 berth only solution, showing dredging required to achieve 1:5 side slopes

2.2.2 Current flows

HR Wallingford have an existing TELEMAC flow model for the River Humber and its approaches. This model was verified against an Automatic Wave and Current (AWAC) sensor deployed in the vicinity of the proposed infrastructure between November 2019 and June 2020, as follows:

- Considering the directional distribution of currents, the peak flows are aligned on 297°T and 117°T (Figure 2.3).
- HR Wallingford compared the flows recorded by the AWAC device over 2 measurement periods with output from the 2D tidal flow model, based on tidal ranges similar to mean spring (Figure 2.4 to Figure 2.7). The model results showed a good comparison to the observed values of flow speed, except around slack water, when the flows were negligible and directions highly variable. This comparison provides confidence that the predicted flows in and around the proposed infrastructure were representative of those that can be anticipated at the site.

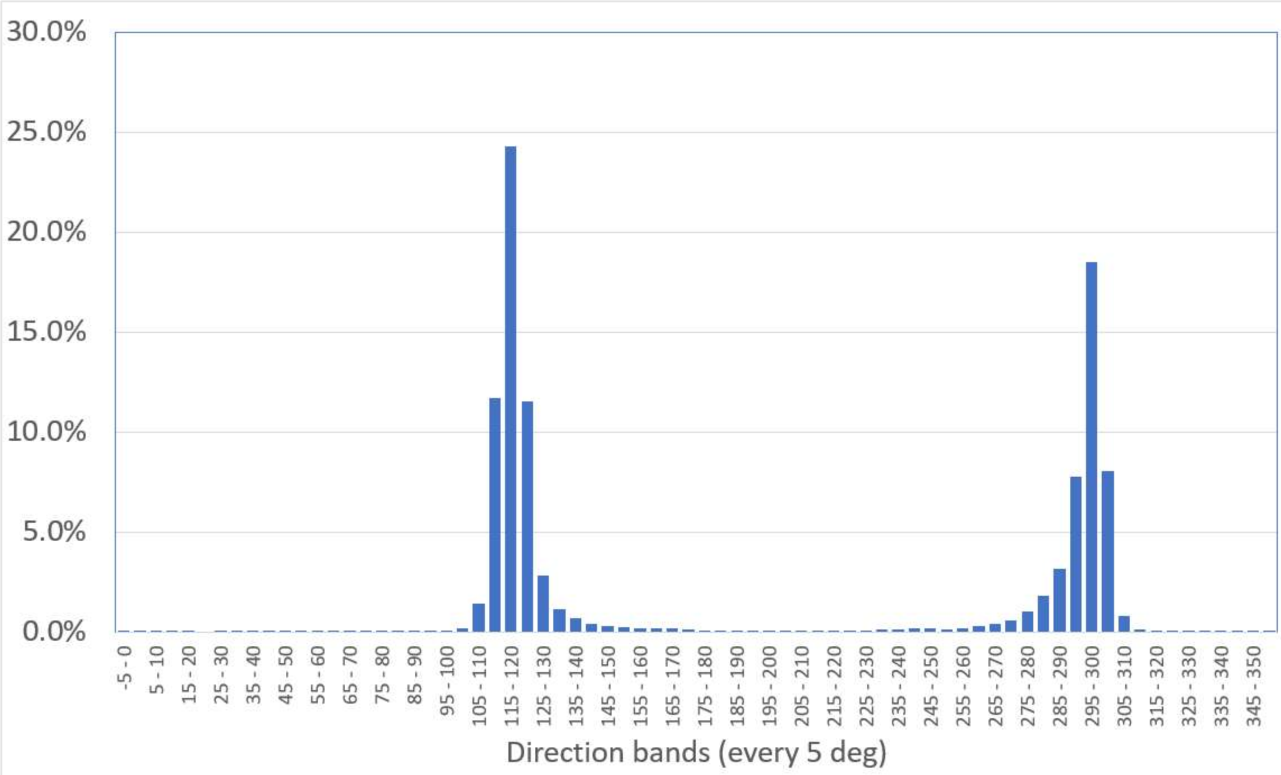

Figure 2.3: Directional distribution of currents from AWAC device

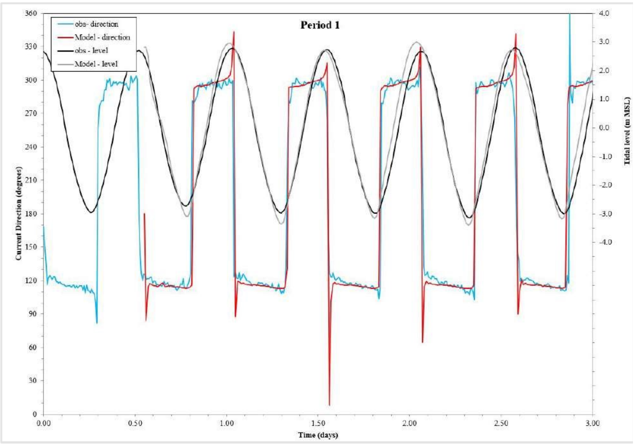

Figure 2.4: Comparison of HR Wallingford flow model direction with AWAC data flow direction

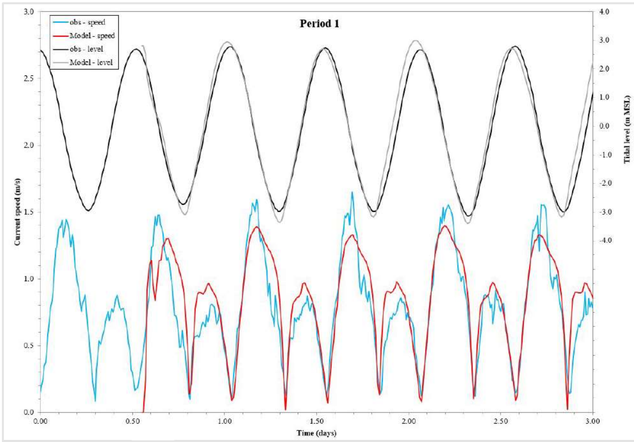

Figure 2.5: Comparison of HR Wallingford flow speed with AWAC flow speed

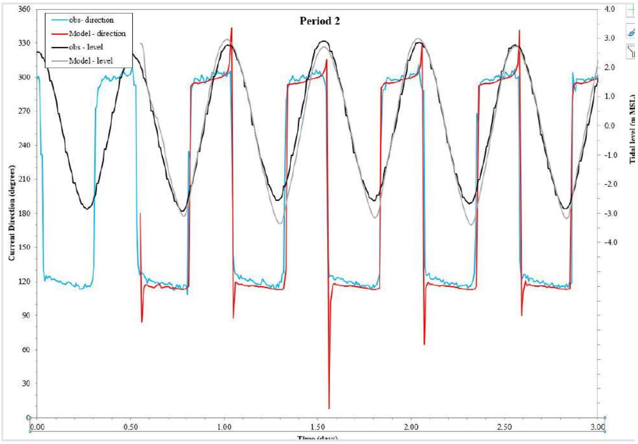

Figure 2.6: Comparison of HR Wallingford flow model direction with AWAC data flow direction

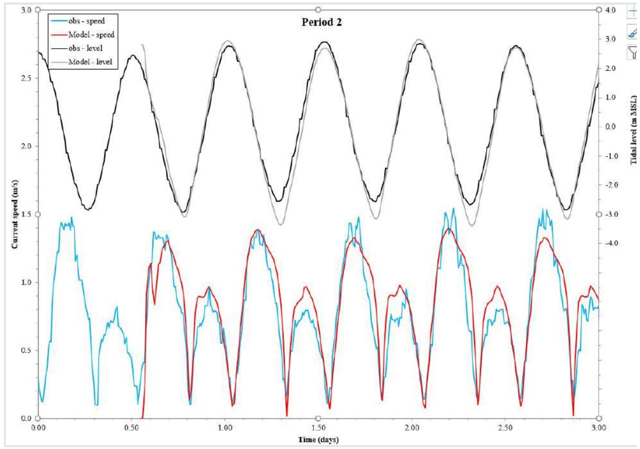

Figure 2.7: Comparison of HR Wallingford flow speed with AWAC flow speed

The bathymetry within the TELEMAC model was updated with the proposed dredged areas and their side slopes, as described in Section 2.2.1. The TELEMAC model was subsequently re-run to produce flow data which were considered representative of the currents which will be experienced after any dredging works are completed. The adjusted flows were determined for 2 cases based on MHWS and a peak spring range.
A total of 4 sets of flow model data were therefore available for the simulation session, as follows:

- Peak spring tide with the 4 berth layout;
- MHWS tide with the 4 berth layout;
- Peak spring tide with the 3 berth layout;
- MHWS tide with the 3 berth layout.

The flow model took into account disturbances in the flow due to new infrastructure, but not the effect of other vessels which might be moored on the berths.

Figure 2.8 and Figure 2.9 show the model output for the MHWS ebb and flood tides for the 4 berth options and Figure 2.10 and Figure 2.11 show the model output of MHWS ebb and flood for the 3 berth options.

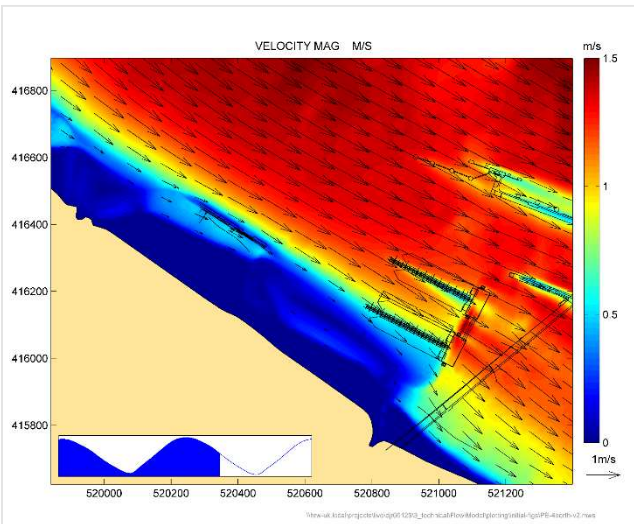

Figure 2.8: MHWS ebb 4 berth option

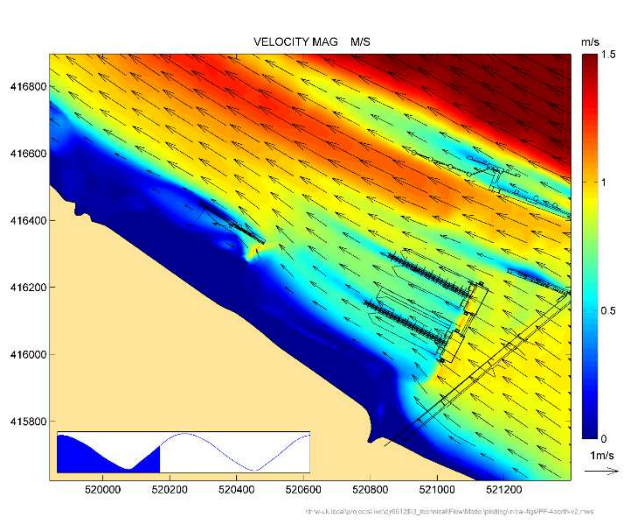

Figure 2.9: MHWS flood 4 berth option

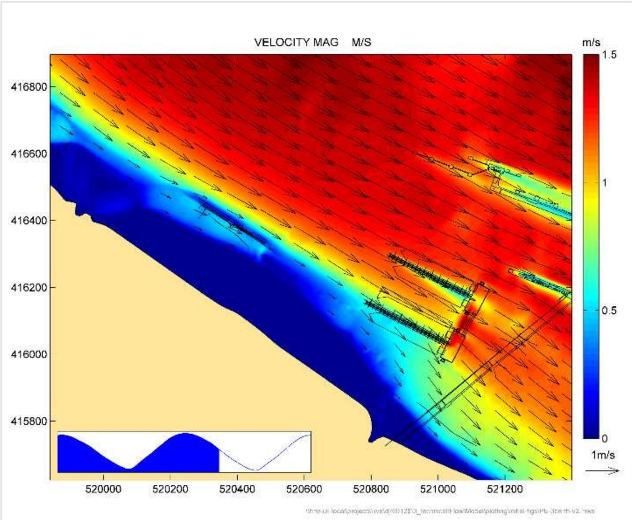

Figure 2.10: MHWS ebb 3 berth option

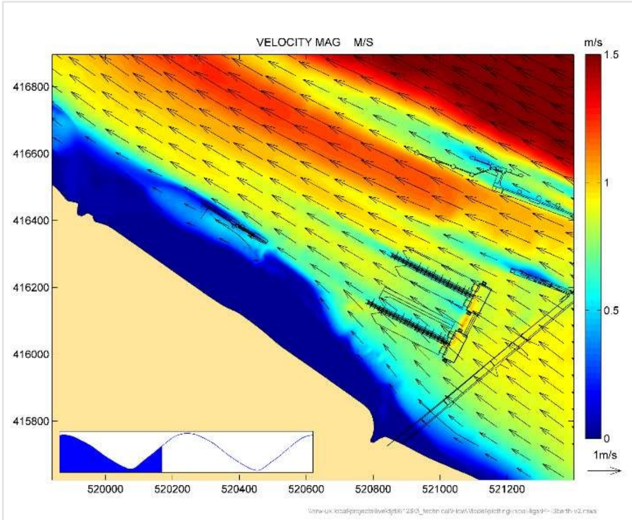

Figure 2.11: MHWS flood 3 berth option

Comparing Figure 2.8 to Figure 2.11 shows how the currents in the southern part of the new facility follow the contours of the intertidal zone, producing a set across the inner berths during the flood tide in the 3 berth option layout. The deeper dredging required for the 4 berth option allows the flows to remain more parallel to all berths.

Figure 2.8 to Figure 2.11 indicates that the strength of the tide that will affect manoeuvres at the new berths, particularly during, the swing and final approach. During a mean spring tide the ebb flow will exceed 1.5m/s (3 knots).

It was noted that in both designs, during the flood tide, the floating pontoons at the eastern end of the new infrastructure significantly shelter the dredged pocket from the prevailing current.

2.2.3 Wind

ABP Humber provided wind data collected from the Immingham Maritime Control Centre (at a height of 24m) between August 2020 and 2021. The data was analysed by HR Wallingford, as shown in Figure 2.12 and Figure 2.13.

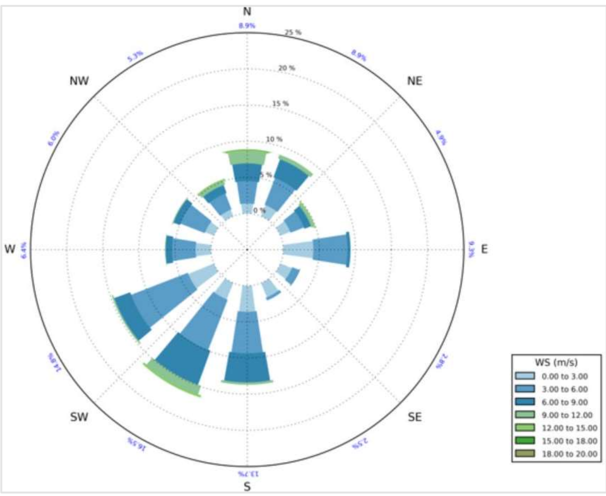

Figure 2.12: Wind rose showing distribution and strength of wind at IOH

Source: ABP/HR Wallingford

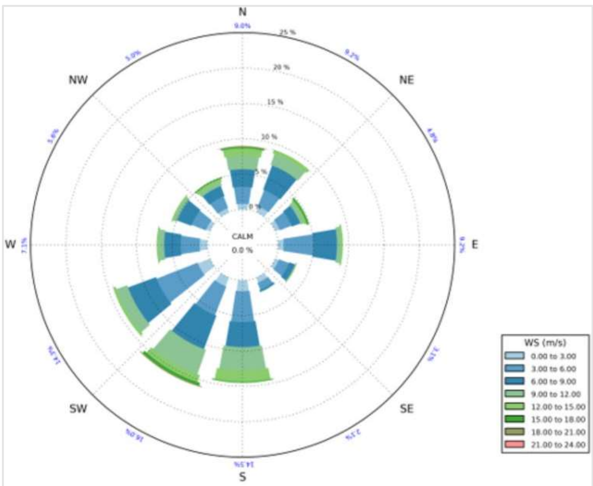

Figure 2.13: Wind rose showing distribution and strength of wind gusts at IOH

Source: ABP/HR Wallingford

These wind roses show that the prevailing wind conditions at Immingham East are SW, however, the strongest winds are experienced from NNE, and are often associated with an unstable air flow and gusts. These directions were expected to be the most problematic for ship manoeuvring at Immingham East, as they set directly across the berth.

HR Wallingford's ship manoeuvring models usually assume that the wind speed is taken at an elevation of 10m above sea level. Adjusting the wind speed from an elevation of 24m to 10m resulted in a 10 to 15% reduction from the observed value. This was taken into account in the analysis.

The two maximum wind conditions established for the study from the observations provided by ABP Humber were therefore as follows:

- SW winds up to 30 knots (about 12.5m/s) with gusts up to 35 knots (about 17.5m/s);
- NE winds up to 30 knots (about 15m/s) with gusts up to 35 knots (about 17.5m/s).

These wind limits were considered to be a conservative assessment and also reflected the conditions at the likely maximum operational envelope for the new facility.

During the simulation runs, wind sheltering was not explicitly modelled. It was acknowledged that ships on adjacent berths would provide some sheltering and reduce the lateral forces experienced by a manoeuvring vessel, depending on the wind direction. However, such an effect from adjacent vessels and jetty infrastructure or equipment cannot be considered to be consistent, nor can it be guaranteed, so it was agreed that potential wind sheltering would not be represented, as it represented a conservative case.

2.2.4 Waves

The proposed facilities at Immingham East will benefit from their sheltered location in the Humber and are not expected to experience significant wave activity, especially with regard to navigation of the size of vessels operating and those providing assistance at the new berths. Consequently, wave effects were not considered further.

2.3 Design vessels

2.3.1 237m RoRo ferry

ABP intend that the new berths should be capable of handling vessel of up to 240m in length.
HR Wallingford previously created a ship manoeuvring model for ABP representing a 237m long RoRo vessel, the Hollandia Seaways, as shown in Figure 2.14.

Figure 2.14: Hollandia Seaways ship manoeuvring model image

This ship manoeuvring model was extensively tested by masters with experience of manoeuvring the vessel at Immingham, who considered it representative of such a vessel, and it was used as the primary design vessel. The vessel characteristics are summarised in Table 2.2.

Table 2.2: Vessel characteristics for the RoRo design vessel

Characteristic	Unit	237m RoRo	
Ship type		RoRo	
Length overall	m	237.4	
Length between perpendiculars	m	233	
Beam overall	m	33	
Distance bridge to stern	m	74.5	
Draught forward	m	7	
Draught aft	m	7	
Block coefficient		0.634	
Displacement	t	35,000	
Propulsion			
Main engine type		2 x MAN BW 8S50ME-C9.5	
Engine power (total)	kW	23600	
No. of propellers, type		2 x CPP	
Bow thrusters	t	65.6	
Stern thrusters	t	none	
Rudder type		Becker twisted flap	
Max rudder angle	°	65	
Manoeuvring engine order		**RPM**	**Speed (knots)**
Full Ahead		100	19.2
STOP		0	0
Full Astern		100	- 16.3
Windage			
Windage lateral	m²	6,200	
Windage frontal	m²	1,208	
Wind speed (knots)		**Beam wind force (t)**	
15		23	
20		40	
25		63	
30		90	

2.3.2 Products tanker

Relatively small tankers operate at Immingham Oil Terminal (IOT) berths 6 and 8 up to a maximum length of around 100m. These vessels are usually products tankers of a modern design with relatively responsive engines, effective rudders and bow thrusters designed to operate self-sufficiently in European ports. At IOT the vessels are normally assisted by an 11t work boat, the Spurn Sand, which is used to push the vessels alongside.

HR Wallingford already has a ship manoeuvring model of a 104m long products tanker which was considered to be representative of the larger type of vessels handled at IOT6 and 8. The 104m tanker model was not particularly responsive or powerful, and, as such, was considered to be a conservative vessel. Its characteristics are shown in Table 2.3 and Figure 2.15.

Table 2.3: Vessel characteristics for the products tanker design vessel

Characteristic	Unit	104m x 15m products tanker	
Ship type		Product tanker	
Length overall	m	103.46	
Length between perpendiculars	m	98.35	
Beam overall	m	15	
Distance bridge to stern	m	15	
Draught forward	m	3.5	
Draught aft	m	4.9	
Block coefficient		0.787	
Displacement	t	5000	
Propulsion			
Main engine type		CAT MAK 6M25	
Engine power (total)	kW	2430	
No. of propellers, type		1 x CPP	
Bow thrusters	t	4	
Stern thrusters	t	none	
Rudder type		Spade	
Max rudder angle	°	35	
Manoeuvring engine order		**RPM**	**Speed (knots)**
Full Ahead		100	13.3
STOP		0	0
Full Astern		100	- 8.0
Windage			
Windage lateral	m²	894.3	
Windage frontal	m²	189.8	
Wind speed (knots)		**Beam wind force (t)**	
15		3	
20		6	
25		9	
30		13	

Figure 2.15: Products tanker manoeuvring model image

2.3.3 Tugs

It was considered that a small powerful ASD tug would be appropriate to provide support to the manoeuvres at the new Immingham RoRo berths. The SMS tug ‘Superman’ was selected as the design tug for the simulation runs, because it is small and relatively powerful, and representative of the types of tug increasingly used on the Humber.

HR Wallingford already had a tug manoeuvring model of a 70tBP 2411 tug, which was based on the ‘Superman’ and had used been extensively used previous simulation work with SMS masters with experience of the vessel, who considered it to be highly representative.

Consequently, throughout the simulation session, 2 x 70tBP 2411 ASD were available to provide assistance.

The simulation session for this work was attended by an SMS tug master, and so a separate but integrated tug bridge simulator was used, controlled by the master, to represent one of the tugs. The response of this tug was therefore inherently represented by the tug master’s response to, for example, orders over the radio, his experience and the time taken to appropriately position the tug.

All other tugs were centrally controlled by the Simulator Operator, following the Pilot’s commands. These tugs were also manoeuvred in a realistic manner and had realistic time delays applied, as summarised in Table 2.4. These delays account for the period between an order given by the Pilot to the actual full force being delivered to the tow-line or push. This accounts for human response and mechanical control lag. The delay periods are derived from live trials and are under constant review. During the sessions the response time of interactively controlled tug bridges were used as a comparison to ensure that the values are appropriate.

Table 2.4: Simulated tug delay times

Tug response delay			Delay
Time to attach and secure			5 minutes (+ 3 minutes line pay-out)
Time to react to new thrust level command			30 second
Time to react to change in thrust level			3% / second
Time to change thrust direction	Direct		Up to 30 second
	Indirect	Roll into assist	Up to 30 seconds
		quarter to quarter	Up to 1 minute
Time to detach	Push/pull mode		1 minute
	Working on line		3 minutes

Further details are shown in Figure 2.16 and Figure 2.17, and in Table 2.5.

Figure 2.16: Tug ‘Superman’

Source: SMS Towage

Figure 2.17: Tug model ‘70t 2411’

Source: HR Wallingford Ship Simulation System

Table 2.5: Tug characteristics for ‘70t ASD 2411’

Characteristic	Unit	70t ASD 2411 - Tug 2021
Ship type		Tug
Length overall	m	24.55
Length between perpendiculars	m	22.16
Beam overall	m	11.33
Distance bridge to stern	m	13.525
Modelled conditions		
Draught forward	m	5.56
Draught aft	m	5.56
Main engine type		2 x Caterpillar 3516C TA HD
Engine power (total)	kW	4200
No. of propellers, type		2 x Azipod

As previously mentioned, manoeuvres at IOT6 and 8 are usually assisted by the work boat, ‘Spurn Sands’, as illustrated in Figure 2.19. This vessel was simulated, as shown in Figure 2.18, and its effect was adjusted such that it was similar to the Spurn Sands, noting that it only provides push assistance.

This vessel was simulated as a centrally controlled tug.

Figure 2.18: Work boat

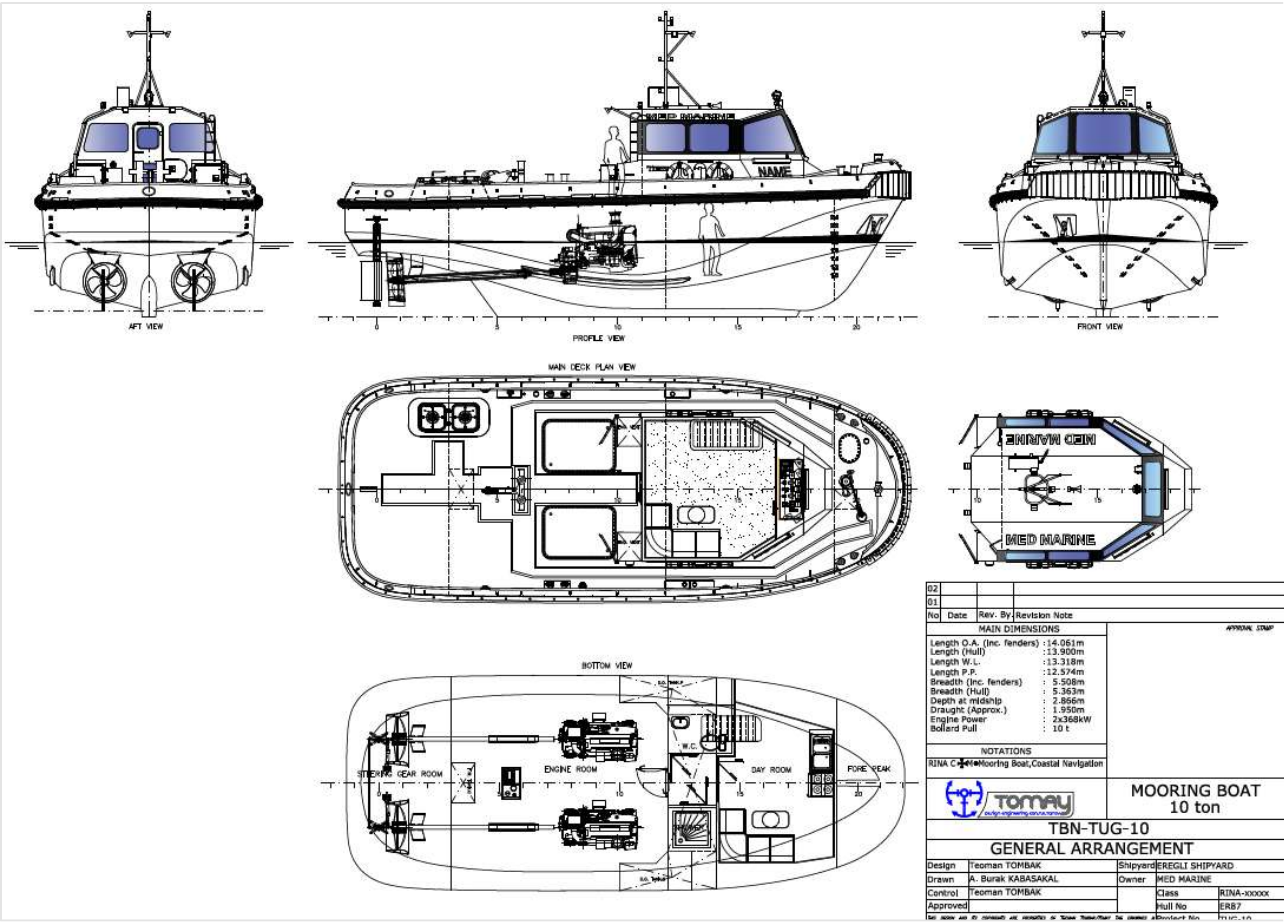

Figure 2.19: General arrangements for workboat

Source: ABP Humber

2.3.4 Tug effectiveness

Tug effectiveness is significantly degraded by waves and water speed. It is not expected that waves will cause much degradation in the vicinity of the proposed new RoRo berths, but the berths are situated in an area where the tidal flows regularly exceed 3 knots. When this is the case a significant proportion of the tug's available power will be used to maintain its position relative to the vessel, and its effectiveness will be degraded as shown in Figure 2.20.

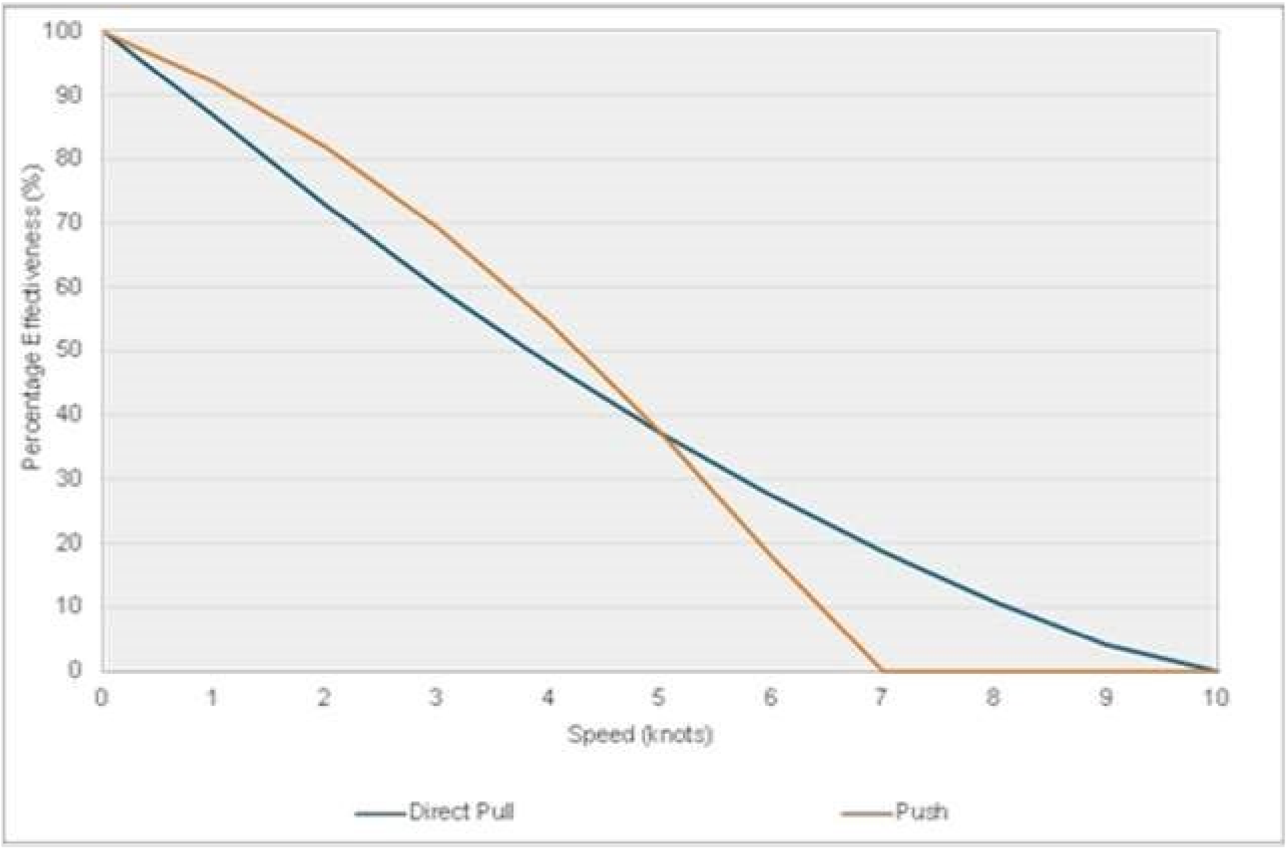

Figure 2.20: Tug effectiveness underway

3 Navigation simulation

3.1 Overview

The study was supported by a real time navigation simulation session that was carried out over a 3 day period from 20 to 22 December 2021. During this session a series of simulation runs were performed using one ship and one integrated tug bridge simulators at HR Wallingford's UK Ship Simulation Centre. The simulators presented experienced pilots and tug masters the visual cues and other information, such as the coastline, aids to navigation and port infrastructure, which they would experience in approaching a marine terminal. In this way the essential features of the human input can be retained.

As previously mentioned, in addition to the 2 integrated and interactively controlled bridge simulators used, additional centrally controlled tugs and other ships were used to assist or provide additional realism to the simulations.

Ship manoeuvring models of the design ships and tugs were available so that the pilots and tug masters received realistic positioning cues during manoeuvres. The vessels were consequently undertaken in a realistic manner. In each simulation comprehensive manoeuvring information was recorded so that the environmental limits and the optimal manoeuvring areas could be evaluated in support of the study.

3.2 Simulation Team

The Simulation Team for the session was formed of personnel representing ABP Humber, Stena Line and SMS Towage and HR Wallingford. The team was reduced from the original plan due to coronavirus situation in the UK at the time.

Table 3.1: Composition of the Simulation Team

Company	Name	Role
HR Wallingford	Dr Mark McBride (MMCB)	Project Director
	Mike Parr (MPA)	Project Lead
	Morgan Robinson (MRO)	Simulator Operator
	Siobhan Vaughan (SHV)	Simulator Operator
ABP Humber	Gary Wilson (GW)	Head of Marine
	Joseph Smith (JS)	Simulation Project Coordinator; and Pilotage Operations Manager
	Ian Cousins (IC)	VLS Pilot
Stena Line	Geert Jan Feringa (Stena) (GF)	Master (Day 1 and 2 only)
	Richard Wagt (Stena) (RW)	Master (Day 1 and 2 only)
SMS Towage	Simon Gutterless (SG)	Tug Master (Day 1 and 2 only)

Additional technical support was provided by HR Wallingford personnel during the study, as required.

The Simulation Team agreed all assumptions outlined in this report before the start of the sessions and collectively determined the result of individual runs and the overall direction of the sessions.

3.3 Briefing and debriefing

The Pilots and Tug Masters were briefed on the simulation run conditions and objectives before each run. At the end of each run a debrief and discussion was used to capture their views, and any other members of the Simulation Team, the relevant aspects of which were recorded in the run summary.

A discussion considered the events of the run and key conclusions, including any need for repeat runs or alter the run schedule. Expertise from across the whole Simulation Team contributed to this important element of the study.

A daily summary discussion was held at the end of each day of the simulation session.

3.4 Simulation run summary

Following each run, a summary table entry is completed see Table 4.1. This details the set-up of the run including the vessel(s) used, the manoeuvre conducted, the tug configuration and the environmental conditions. It also describes key aspects of the manoeuvre and captures the remarks and comments made by the Pilot and the rest of the Simulation Team.

3.5 Grading of results

Each simulation run was graded by the Simulation Team as Successful, Marginal or Fail, according to the following evaluation criteria:

Successful

Standard manoeuvres:

- The ship remains under full control at all times without resorting to aggressive manoeuvring techniques;
- The ship stays within safe water areas with acceptable clearances to all port and other structures, and other berthed ships;
- Tugs are operating safely and within sustainable limits;
- For berthing manoeuvres, the ship ends the run alongside, or in such a position that lines would be ashore without appreciable difficulty, at zero speed, with an acceptable sway velocity and no appreciable yaw rate;
- For departure manoeuvres the ship exits smoothly, without risk of drifting onto port structures or other ships.

Emergency/failure situations:

- The ship is brought back under full control without encountering significant hazards, with the risk of only minor damage;
- The ship may leave the designated manoeuvring area boundaries, but still has acceptable under keel clearance and maintains acceptable clearances to other ships/structures throughout the recovery;
- Tugs are neither endangered nor asked to operate in an unsafe manner;
- The ship can be moved into safe, deep water or to a position suitable to anchor safely, where the equipment failure can be investigated/resolved.

Marginal

Standard manoeuvres:

- The Pilot considers the ship is at the limit of control during standard manoeuvres;
- The ship stays within the safe water area boundaries, but with unacceptable clearances;
- The ship clears all port structures, and other berthed ships, but with unacceptable clearances;
- Tugs are operating safely, but approaching their sustainable operating limits (e.g. being used at 100% power for more than 15 minutes);
- For approach manoeuvres, the ship ends up alongside, but may have a high approach velocity. The manoeuvre can be concluded, but minor damage may occur;
- On departure, the ship is manoeuvred off the berth but with some difficulty. The manoeuvre is completed with the potential for minor damage only.

Emergency/failure situations:

- The ship is at the limits of control during the recovery from the failure;
- The ship has marginal under keel clearance or marginal clearances to other ships/structures during the recovery;
- Tugs operate at the limits of safety;

- The ship is at the limits of controllability as it is moved into safe, deep water or to a position suitable to anchor safely, where the equipment failure can be investigated/resolved.

Fail

Standard manoeuvres:

- The Pilot loses control of the ship;
- The ship strays outside the safe water area boundaries and/or grounds;
- The ship either contacts, or has a near-miss with port structures and/or other berth ships;
- Tugs are required to operate in an unsafe manner, or exceed sustainable operating limits (e.g. being used at 100% power for more than 30 minutes);
- For approach manoeuvres, the ship cannot get alongside at all, or contacts the berth with sufficient force that severe damage may have occurred;
- On departure, the ship either cannot be manoeuvred off the berth, or encounters significant difficulty in manoeuvring, such that severe damage may have occurred.

Emergency/failure situations:

- The Pilot cannot regain control of the ship before the ship is endangered;
- The ship cannot be prevented from entering dangerously shallow water and/or grounds;
- The ship either contacts or has a near-miss with a known hazard, port structures, and/or other berth ships;
- Tugs are endangered or are asked to operate in an unsafe manner;
- The ship cannot be moved into safe, deep water or to a position suitable to anchor safely.

3.6 Simulation track and data plots

The results of each navigation simulation run are available in the form of plots of the vessel tracks and graphs of key data parameters recorded during the run. These data are presented in Appendix A.

The vessel data and track plots show:

- The position of the ship and the tugs at one minute intervals is indicated by a succession of black and blue vessel outlines. Red vessel outlines indicate the vessel's position every 10 minutes from the start of the run;
- The positions of port structures and aids to navigation;
- A north arrow;
- A scale bar;
- Seabed contours (bed levels in m NGT).

The data graphs plot the variation of various key parameters against elapsed simulation time and graphs have been included for all vessels in all of the runs. These graphs are presented by vessel, starting with the ship, and then the independent tug (where applicable). The vessel ID is identified in the text block on the bottom right of each page.

The ship graphs comprise:

- Ship's under keel clearance(s) in metres and speed over the ground (knots). The data plotted in these UKC graphs does not take account of wave-induced ship motions;
- Speed (knots) and direction (°N) of the wind acting on the ship;

- Lateral wind force acting on the ship (tonnes);
- Ship's rate of turn (°/min) and heading in °N;
- Ship's course over the ground and drift angle in degrees;
- Ship's speed (over the ground and through the water) in knots, expressed in terms of longitudinal and lateral components relative to the ship's head;
- Ship's rate of turn (°/min);
- Ship's rudder angle (degrees);
- Ship's bow and/or stern thruster power (%);
- Number of ship's engine restarts.

Where there are no plots for a particular parameter, for example for bow thruster power, this indicates that the particular parameter was not relevant for the particular run or no bow thruster was available.

4 Discussion of results

4.1 General

The simulation run plan was developed by the Simulation Team to address the aims and objectives of the study, as described in Sections 1.1 and 1.2.

A total of 43 simulation runs were completed during the 3 day real time navigation simulation session, which focused on challenging, and limiting conditions aimed at assessing the overall viability of the proposed infrastructure.

Of these 6 runs were assessed as either marginal or fail, although these were subsequently repeated successfully. This reflected the level of testing applied to the planned infrastructure and the difficulty of the manoeuvres undertaken.

4.2 Environmental conditions

In general the manoeuvres were conducted at a peak MHWS flow, before increasing the flow to reflect a faster current speed, as would be expected with a large spring range.

Similarly the wind was increased run by run, once the Pilots gained some familiarisation with the basic approach for each manoeuvre. The wind was always applied perpendicular to the berth to provide the most onerous conditions for assessing the proposed berth layouts.

4.3 Adjacent berths

Other vessels were represented as being moored on the adjacent berths to simulate the most restrictive manoeuvring/berthing conditions. The overall situation is illustrated in Figure 4.1, and as follows:

- A 243m x 42m product tanker was moored on the north side of the main IOT berth to restrict the Pilot's freedom to pass close to the facility before swinging into the East Immingham Harbour.
- A 258m x 37.5m bulker was moored on the north side of the Immingham East Jetty to restrict the freedom of the Pilot to swing within the East Immingham Harbour area. The Vessel was chosen by the simulation team to provide the most constrained approach to the new infrastructure. It is recognised that vessels of this type or size rarely use this berth.
- 237m long RoRo ferries were moored on adjacent berths within the new berths to minimise the available space on the final approach to each berth.

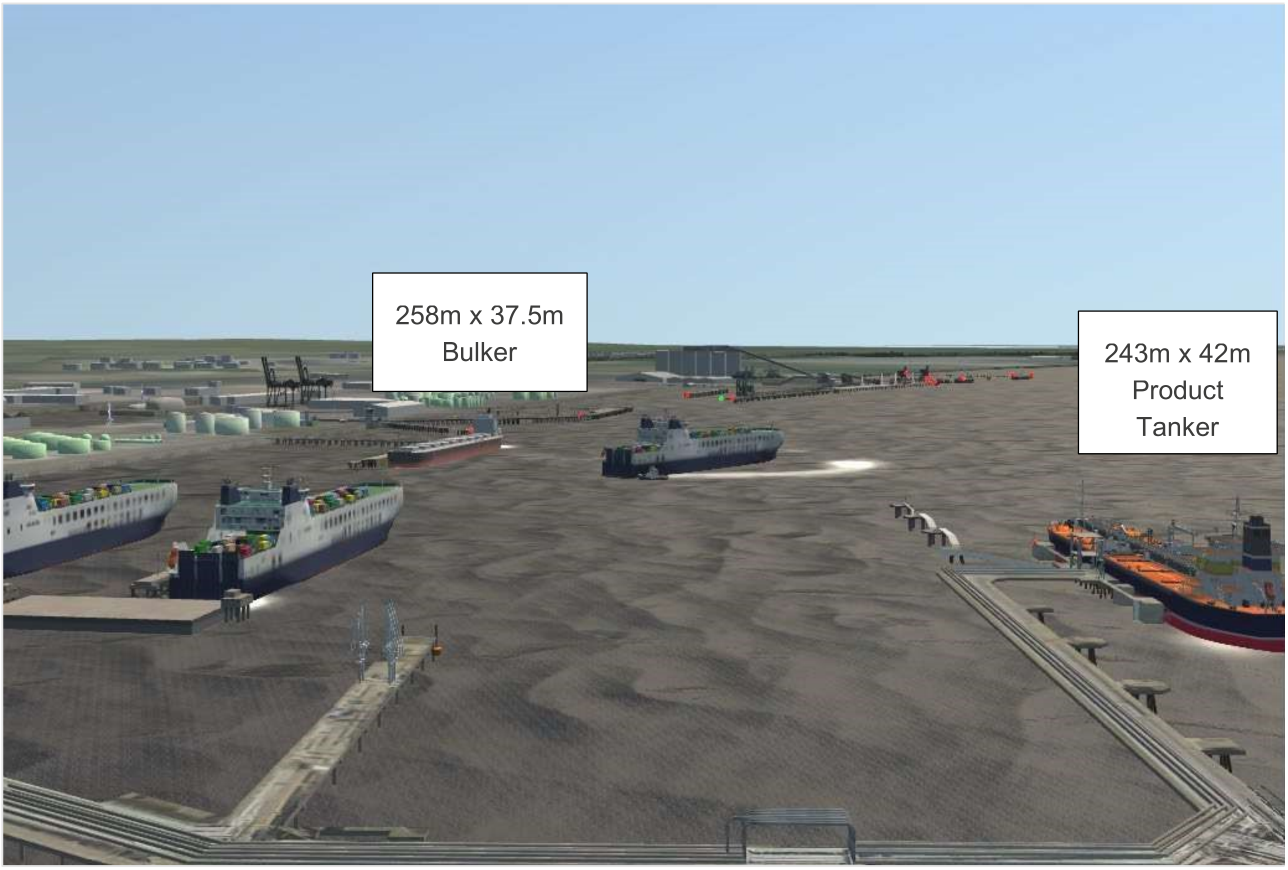

Figure 4.1: General berthing situation during session, with adjacent moored vessels

4.4 Simulation runs

The following provides an outline of the simulation runs carried out. Further details can be found in the Appendix B and Table 4.1:

- Runs 1 and 2 were runs to allow the Pilots to become familiar with the new layout, the simulator configuration, the ship manoeuvring model and the modelled environment.
- Runs 3 to Run 16 considered the 237m RoRo vessel arriving at the new inner berths (Berths 2 and 3), and Runs 17 to Run 19 considered it departing from them, as follows:
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum under keel clearance (UKC). Typically a minimum UKC of 4 to 5m was observed in the dredged area;
  - Layout 2 with a 120m fender to fender spacing. The 3 berth dredged area also results in a small set across the berths so was considered more challenging;
  - The intent of these runs was to establish whether the proposed facility would be operationally feasible or not with a reduced distance between berths;
  - The runs also developed an understanding of the overall manoeuvring strategy for the berths, and the general effects of the combined wind and tide on ship manoeuvring. This understanding helped inform later runs and decisions.
- Runs 20 to Run 22 considered the 237m RoRo vessel departing the new inner berths (Berths 2 and 3), and Runs 23 to 24 considered it arriving at them, as follows:

- During the ebb flow, with a tidal condition of HW+4 hours used to ensure the maximum current speed and minimum UKC in the dredged area, which was typically 4 to 5m;
- Layout 2 with a 120m fender to fender gap;
- Again, the intent of these runs was to establish whether the proposed facility would be operationally feasible or not with a reduced distance between berths.

- Runs 25 to 26 considered the 237m RoRo vessel arriving at the new Berth 4, as follows:
  - During the ebb flow, with a tidal condition of HW+4 hours used to ensure the maximum current speed and minimum UKC in the dredged area, which was typically 4 to 5m;
  - Layout 1 with a 140m fender to fender spacing and 4 berths in use;
  - The intent of these runs was to establish whether the proposed inner Berth 4 would be operationally feasible or not with a reduced distance between berths.
- Runs 27 to 29 considered the 237m RoRo vessel departing the new Berth 4, as follows:
  - During the ebb flow, with a tidal condition of HW+4 hours used to ensure the maximum current speed and minimum UKC in the dredged area, which was typically 4 to 5m;
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum UKC, which was typically 4m;
  - Layout 1 with a 140m fender to fender spacing and 4 berths in use;
  - The intent of these runs was to establish whether or not there was sufficient space between the new facility, East Immingham Jetty and the limit of the dredged area to safely conduct these manoeuvres.
- Runs 30 to 31 considered the 237m RoRo vessel arriving the new berth 1, as follows:
  - During the ebb flow, with a tidal condition of HW+4 hours used to ensure the maximum current speed and minimum UKC in the dredged area, which was typically 4 to 5m;
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum UKC, which was typically 4 to 5m;
  - Layout 1 with a 140m fender to fender spacing and 4 berths in use;
  - The intent of these runs was to establish that the layout at Berth 1 presented no unexpected operational challenges.
- Runs 32 to 33 considered the 237m RoRo vessel operating to and from the new Berth 1, as follows:
  - During the ebb flow, with a tidal condition of HW+4 hours used to ensure the maximum current speed and minimum UKC in the dredged area, which was typically 4 to 5m;
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum UKC, which was typically 4 to 5m;
  - Layout 1 with a 140m fender to fender spacing and 4 berths in use;
  - The intent of these runs was to establish that the layout at Berth 1 presented no unexpected operational challenges.
- Runs 35 to 36 considered the 104m long tanker arriving and departing at IOT8, as follows:
  - During the ebb flow with a tidal condition of HW+4 hours used to ensure the maximum current speed and minimum UKC in the dredged area;
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum UKC;
  - Layout 1 with a 140m fender to fender spacing and 4 berths in use. This design provides the least distance of 75m between IOT8 and the new facilities;
  - The intent of these runs was to establish that the new facilities did not prevent normal operations at IOT6 and 8;

- The runs concentrated on manoeuvres to and from IOT8 as it is significantly more constrained in relation the new facilities than IOT6.

- Run 37 considered the 104m tanker arriving at IOT8. A new layout was adopted to provide more space between IOT8 and the new infrastructure, with the other run conditions as follows:
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum UKC;
  - Layout 2 with a 120m fender to fender spacing and 3 berths in use. This design increases the distance between IOT8 and the new facilities to 94m;
  - The intent of these runs was to establish that the new facilities did not prevent normal operations at IOT6 and 8;
  - Runs concentrated on manoeuvres to and from IOT8 as it is significantly more constrained in relation the new facilities than IOT6.
- Runs 38 to 42 considered the 104m tanker arriving at IOT8. Again the new layout adopted provided more space between IOT8 and the new infrastructure, with the other run conditions as follows:
  - During flood flows, with a tidal conditions of HW-5 hours to ensure the maximum current speed and a minimum UKC;
  - Layout 2 with a 120m fender to fender spacing and 3 berths in use. This design increases the distance between IOT8 and the new facilities to 94m;
  - The intent of these runs was to establish that the new facilities did not prevent normal operations at IOT6 and 8;
  - Runs concentrated on manoeuvres to and from IOT8 as it is significantly more constrained in relation the new facilities than IOT6;
  - With the wind increased to gusting 30 knots and above, an additional ASD tug was provided to assist as required.

4.5 Approach requirements

It became clear early in the simulation session that manoeuvring from the main navigation fairway to the approaches to Immingham Harbour, such that the vessel is correctly aligned to make a controlled approach to the new infrastructure, is challenging. Controlling the swing and the early part of the approach was found to be more difficult on the flood tide than with an ebb tide.

There are 2 options on a flood tide as follows:

- As demonstrated in Run 4, once clear of IOT, take a course towards the entrance to Immingham Lock. Then swing the vessel to starboard when stopped, aligning the stern across the tide to track astern towards the berth, with the current assisting. This approach is slow, as the vessel effectively make 2 half swings. It also requires precise control to stop the return swing at the correct angle to the flow to allow a safe approach to be made to the new facilities. This method is shown in Figure 4.2.
- As demonstrated in Run 3, once clear of IOT, swing the bow to port and stop the vessel, then manoeuvre astern across the tide, using the tidal flow to assist the lateral movement towards the berth, before moving astern to the jetty. This is also a slow manoeuvre and could result in the vessel impeding other traffic in the fairway. The delay to other traffic in the channel is comparable to that of an East or West Jetty arrival. As such minimal delays are expected by ABP. Movements will continue to be managed through VTS and LPS. The manoeuvre is shown in Figure 4.3 and Figure 4.4.

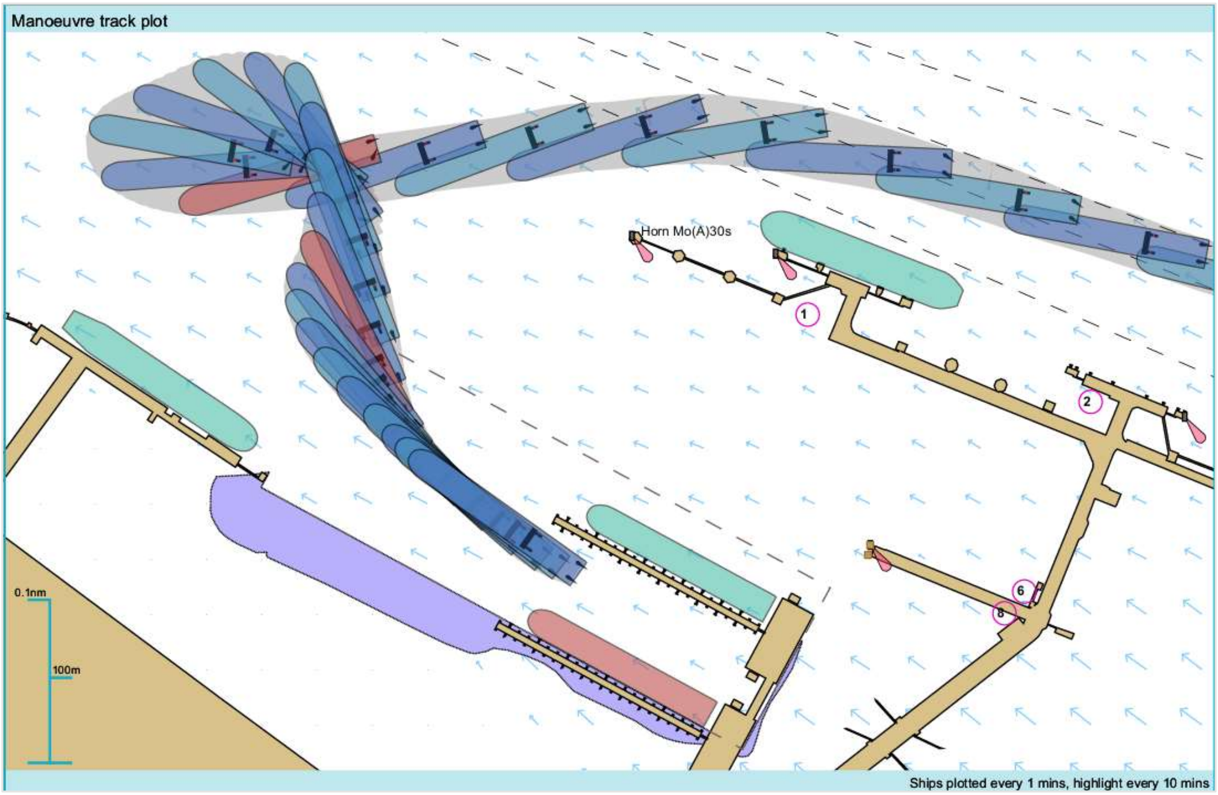

Figure 4.2: Run 4 track plot

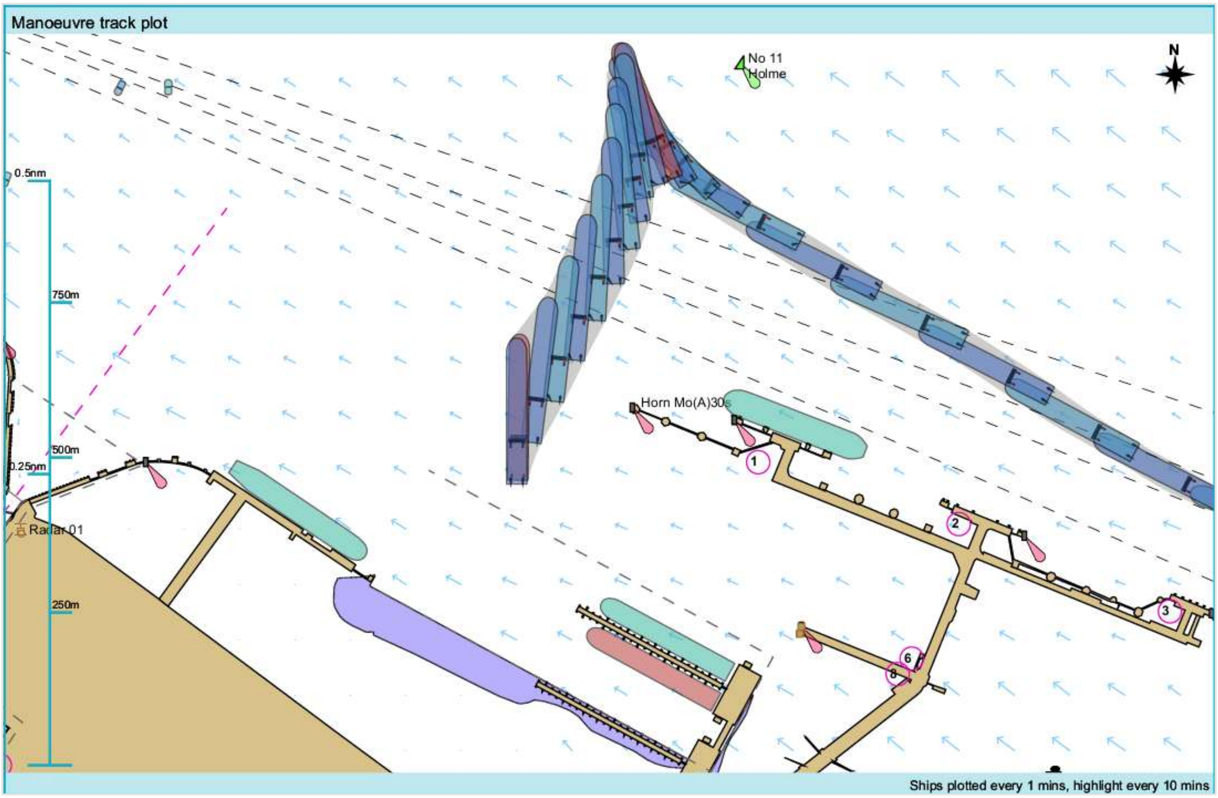

Figure 4.3: Run 3 track plot

Figure 4.4: Balancing tide and wind to manoeuvre RoRo ship laterally towards the new infrastructure

In general, the first approach seemed to be more difficult to achieve, particularly as the wind was increased run by run. The angle of the vessel to the current and the berth needs to be precisely balanced against the wind to allow the ship to be manoeuvred into a position between Immingham East Jetty and the new berths. Once in this position the Pilot can manoeuvre parallel to the berth and the current to make a stern-board approach to the jetty (see Figure 4.5 to Figure 4.8). Overall, because the swing was quite dynamic, finding the balance between wind and tide was found to be challenging.

The correct position at which to start the final stern-board approach is predicated by the prevailing conditions and the Pilot needs to adjust the angle of the vessel such that the effect of current and tide are balanced. With strong winds and tides this needs excellent pilotage judgment and experience.

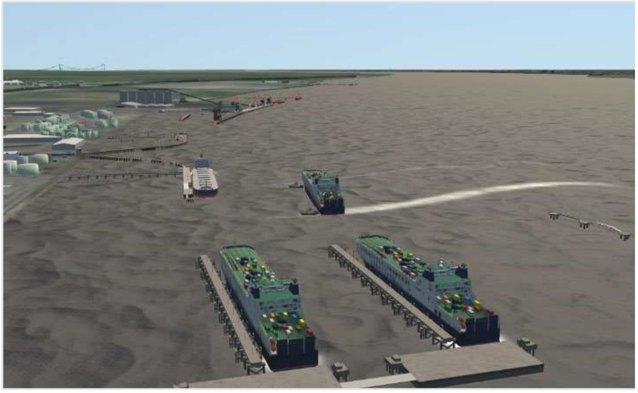
Figure 4.5: Vessel with wind and current balanced manoeuvring laterally towards the berthing pocket

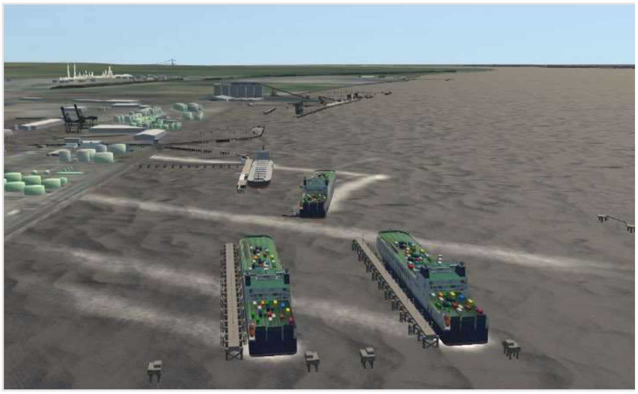
Figure 4.6: Vessel adjusting angle to be parallel with berth and current


Figure 4.7: Vessel manoeuvring astern to berth


Figure 4.8: Vessel arriving on berth with tug assistance

The difficulty of the manoeuvre can be exacerbated by the reduction in effective power of the assisting tugs when the vessel is manoeuvring into a strong current. The effective water speed is the sum of the current and the vessel's speed, so can exceed 5 knots, so significantly reducing the available power from the tug to assist the vessel (see Figure 2.20).

Runs 4 to 10 are examples of the 237m RoRo making relatively straightforward approaches to the berths in peak flow conditions, with winds increasing up to 25 knots and gusts of 30 knots.

Because of the proximity of the Immingham East Jetty and other vessels moored at it, in conditions when wind and tide are both setting the manoeuvring ship towards the south west, the manoeuvre becomes extremely challenging.

Run 11 is an example where the Pilot did not quite have the setup right, consequently, tugs were required to operate at full power for extended periods and there was limited reserve, despite eventually completing the berthing manoeuvre.

Run 13 shows a more challenging manoeuvre with north easterly winds of 30 gusting 35 knots (see Figure 4.9). The vessel comes too close to the ship moored at Immingham East Jetty and the run is assessed as a fail. The simulation was re-run twice and successfully completed in Run 15 with the wind limit reduced to 25 knots gusting 30 knots (see Figure 4.10).

It should be noted that the winds (of 30 to 35 knots) and tides (with a peak flood flow of 3.5 knots) are considered a relatively extreme operational combination. Although the manoeuvre was assessed as possible, for an initial operating capability it was considered that the operating wind limit of the berths will need to be closer to 25 knots during a peak flood tide. Further navigation simulation work will be required at a future date to define those limits more precisely.

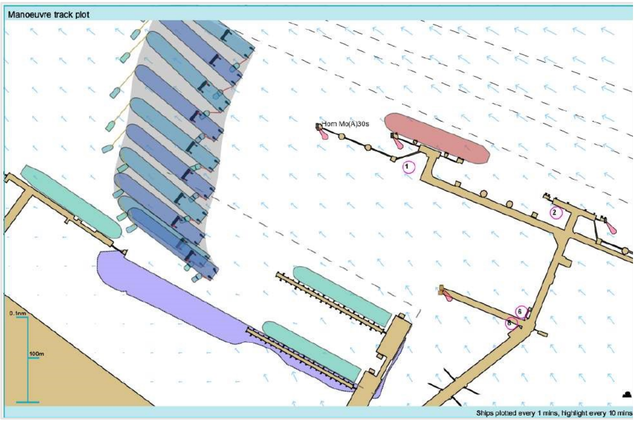

Figure 4.9: Run 13 track plot

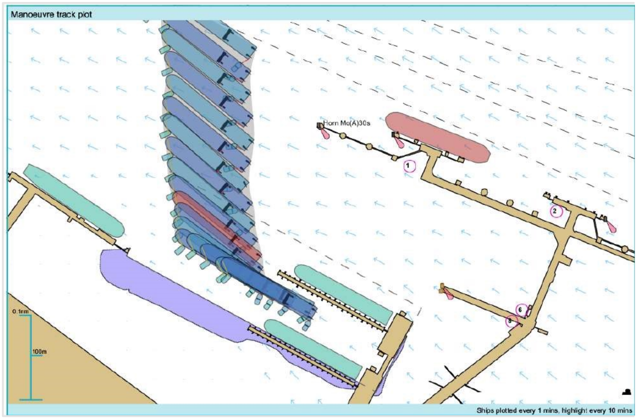

Figure 4.10: Run 15 track plot

Approaches to the new berths on the ebb were more straightforward to control, even with winds at 30 knots. The Pilot is able to balance the current on the bow against the beam wind to hold the vessel with more precision. Runs 23 and 24 (see Figure 4.11 and Figure 4.12) show a controlled manoeuvre to position the vessel between Immingham East Jetty and the new infrastructure, before making a safe final approach to the berths.

Also the effective water speed for the tug is much reduced on the ebb, making the tug assistance more effective.

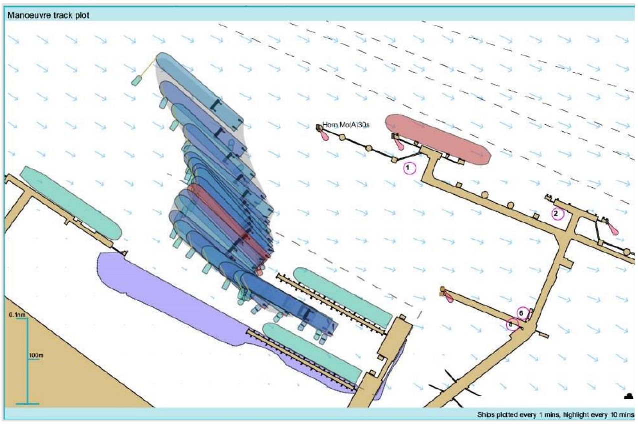

Figure 4.11: Run 23 track plot

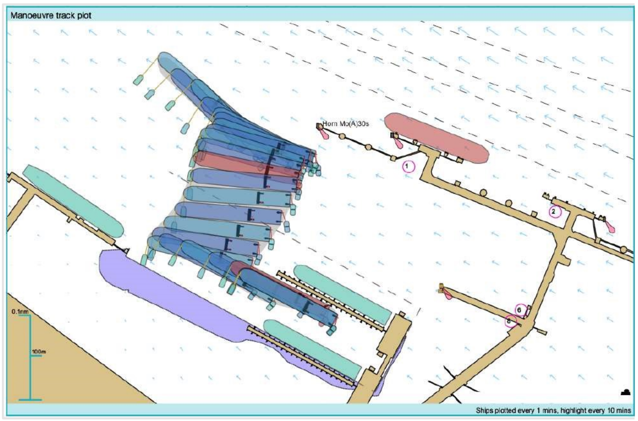

Figure 4.12: Run 24 track plot

No significant difficulties were experienced in the approaches to Berth 1 in peak ebb with winds in excess of 30 knots.

4.6 Departure manoeuvres

Departure manoeuvres from the inner berths during the flood tide required careful management. The first main departure, Run 17, resulted in a situation where once the vessel had been lifted off the berth with tug assistance, it was set quickly towards a vessel moored on the east jetty. With strong north easterly winds (of 30 knots) the Pilot was not able to develop sufficient control to avoid a close quarters situation with the moored vessel (see Figure 4.13). The tugs were operating at full power and still unable to help prevent the close quarters situation.

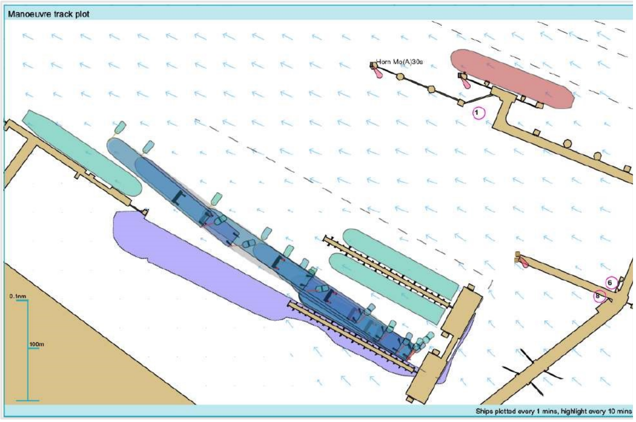

Figure 4.13: Run 17 track plot

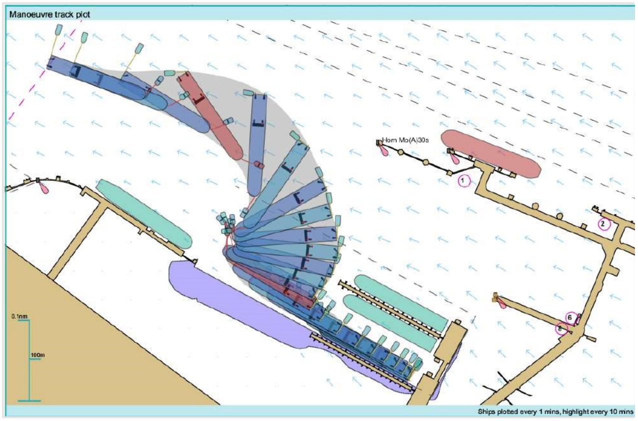

Figure 4.14: Run 18 Track plot

The Pilot adopted an alternative strategy in the same conditions for Run 18 (see Figure 4.14). Here, once clear of the new infrastructure, the stern was brought across the tide with tug assistance, allowing the vessel to be swung whilst making very slow sternway against the current. The Pilot is much better able to balance the elements in this manoeuvre, keeping the stern up to windward and using the tide to assist. This manoeuvre will require training and experience to enable safe flood departures in strong north easterly winds.

Run 19 shows a similar strategy being used in lighter winds (see Figure 4.15), with the Pilot able to manoeuvre the vessel across the tide for departure.

Figure 4.15: Run 19 showing limited manoeuvring space between new infrastructure and end of Immingham East Jetty

Departures on the ebb tide were more straightforward again, with the Pilot able to use the current across the bow to assist the manoeuvre. Run 20 indicated that with a 20 knot north easterly wind, tug assistance might be required to assist during departure, although there was insufficient time in this study to enable the manoeuvre to be repeated to obtain a definitive result.

No significant issues were experienced with departures from Berth 1.

4.7 Reduced manoeuvring space between Berths 2 and 3

Manoeuvres to Berths 2 and 3 were all conducted with a reduced distance of 120m between fenders. The runs showed that, even in relatively extreme operational conditions, the reduced distance between jetties did not cause any significant issues. The Pilots who had significant experience operating to Killingholme Terminal stated that the manoeuvre was very similar.

The difficulties in manoeuvring to the new infrastructure was assessed as due mainly to:

- The requirement to balance wind and tide in strong conditions, with little scope to adjust once the stern-board manoeuvre is commenced;
- Manoeuvring into the tide with reduced tug efficiency at the same time as attempting to counter strong cross winds.

These factors mean that the setup for the final stern-board manoeuvre has to be precise. The most difficult situation was with a strong north easterly wind and flood tide, such as in Run 14 (see Figure 4.16). Here the Pilot did not account enough for a strong set to the south and started the final manoeuvre to the berth too late, consequently passing close to the moored vessel on Berth 3. Widening the distance between the jetties, particularly by only 20m, would not remove this issue. Instead it will be important that pilots and masters are well acquainted, through training, with the potential for strong southerly set that can be encountered with a flood tide and north easterly winds.

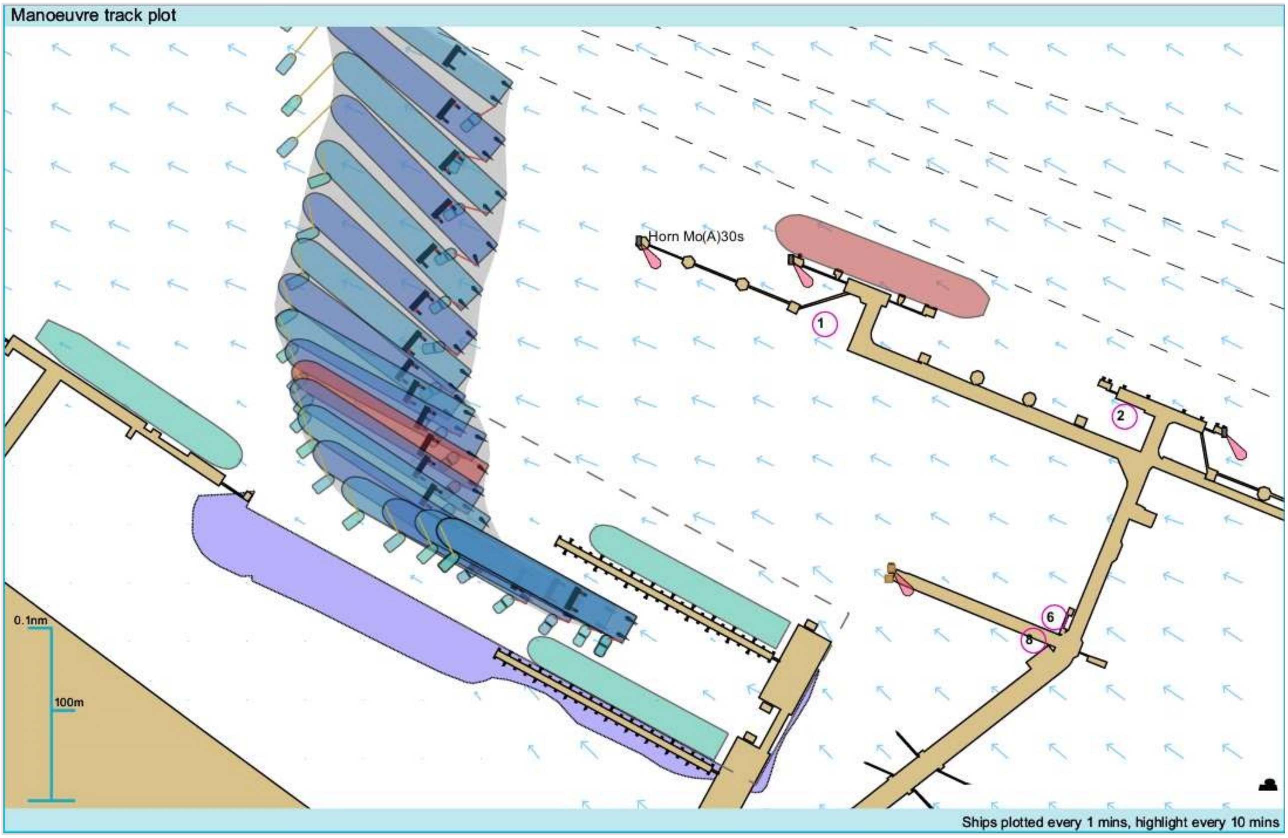

Figure 4.16: Run 14 track plot

The 120m fender to fender spacing between jetties means that relatively small, agile and powerful tugs will be required to support manoeuvres at the new infrastructure. Figure 4.17 and Figure 4.18 illustrate the limited space available. Throughout the simulation session, the Tug Master was asked for his assessment on the available space. At all times he considered there to be sufficient space for safety, and he was able to provide the assistance requested. He also noted he had options to escape if the situation changed. It will be important to include Tug Masters and considerations for the use of tugs in future Pilot and PEC training for these berths.

Figure 4.17: View showing 2411ASD tugs assisting berthing with 120m jetty option

Figure 4.18: View showing 2411ASD tugs assisting berthing with 120m jetty option

4.8 Inner Berth 4

Manoeuvres to and from Berth 4 were conducted in peak flood and peak ebb tides, with cross winds up to 30 knots, gusting to 35 knots. The key aspects of the manoeuvres were similar to the approaches to Berths 2 and 3, as follows:

- The setup to the final manoeuvre needs to be as precise as the approaches to Berths 1 to 3, and the same strategy can be employed;
- Particular care needs to be taken on departure with a flood tide, so that the vessel is not set onto the Immingham East Jetty;
- Manoeuvres in ebb conditions are more straightforward and on the flood.

The Pilots all noted that the proximity of the East Jetty means the space to access and depart Berth 4 (at less than 40m clearance ahead and astern) is small relative to the size of vessel (see Figure 4.19). This distance is difficult to judge and the so manoeuvre was assessed as highly challenging.

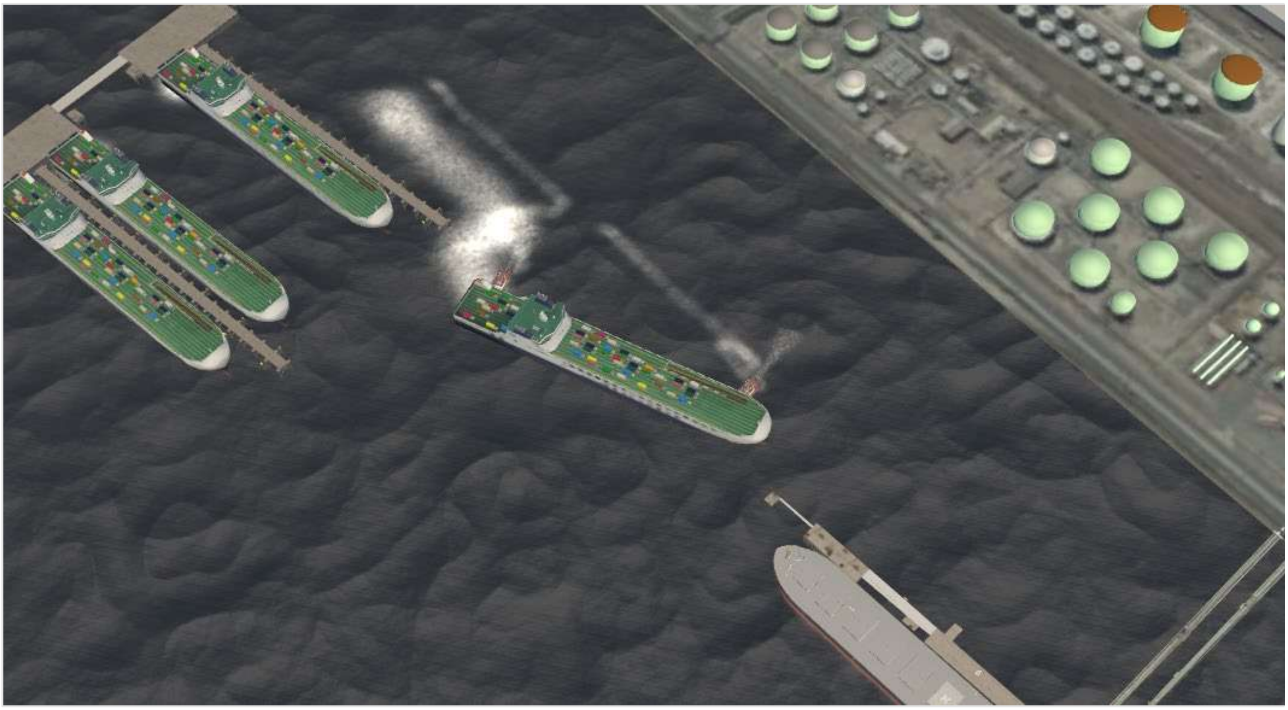

Figure 4.19: Departure from Berth 4 showing limited space to manoeuvre

4.9 Operations from IOT8

There were 8 simulation runs used to examine manoeuvres of a 104m products tanker to and from IOT8 jetty.

Initial attempts at arrival with a flood tide and 15 knot cross wind were attempted with Layout 1 which has 75m distance between the new infrastructure and the IOT8 berth (Run 35, see Figure 4.20). There were 2 attempts made (Runs 35 and 36) and the Pilot assessed that, even with the relatively benign conditions, the manoeuvre could not be completed with the limited space.

The layout was amended to Layout 2 which provided a 94m distance between the IOT8 berth and the new infrastructure. The additional 20m (at more than 1 beam width of the product tanker) made the manoeuvres significantly more achievable (Run 37, see Figure 4.21).

Further approaches to and from IOT8 were conducted with increasing wind. The assessment was that the increase in space allows operations at the IOT Berths. With the wind above 25 knots, gusting to 30 knots, more assistance than can be provided by the workboat Spurn Sands is required, and a single 70tBP ASD2411 was made available to assist.

It should be noted that the runs to and from IOT8 were conducted at the end of an intensive series of simulations and it is possible that Pilot fatigue was an element in some of these runs.

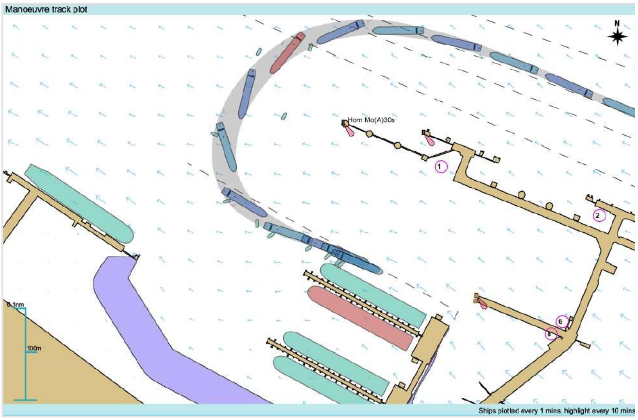

Figure 4.20: Run 35 track plot

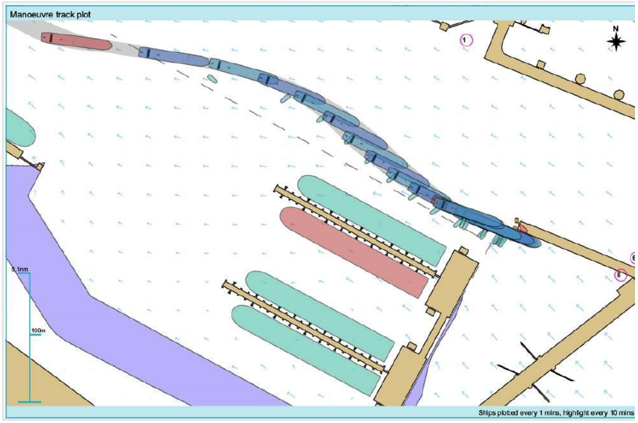

Figure 4.21: Run 37 track plot

Figure 4.22 and Figure 4.23 provide views which show the proximity of the new infrastructure, IOT8 and the 104m vessel with tug assistance.

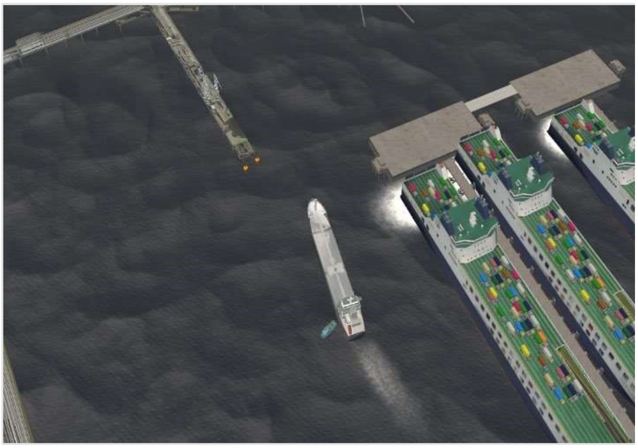

Figure 4.22: 108m Tanker approaching IOT8

Figure 4.23: Tug providing assistance to 108m Tanker approaching IOT8

The runs showed clearly that a reduced width of 120m fender to fender between Berths 2 and 3 to increase the distance between IOT and new infrastructure (to 94m) is strongly recommended.

The manoeuvres to IOT were then achieved in challenging conditions. A further series of similar runs in more regular operational conditions are recommended, as these will provide confidence in the continued operational safety of IOT8.

4.10 Under keel clearance

The state of tide was adjusted at the beginning of each run such that the flow rate was maximised and the UKC would be at its lowest. This was to ensure that the ship manoeuvring models experienced the maximum effect of the current flow during the simulations.

During these peak tidal periods, the minimum UKC observed within the dredged area was 4.5m, during approaches to Berths 1, 2 and 3.

The original design assumed the dredged area would need to be to -9mCD based on ABP Humber advice, although the runs indicated that dredged depth of -8mCD would be appropriate.

Although it was not tested in the simulation, and noting that real time navigation simulation is not the most appropriate tool for assessing UKC in detail, it was, however, considered that a reduction in dredged depth to -8mCD for the dredged area would be appropriate, based on the evidence of the runs conducted to date, as long as:

- The draught of the design vessel remains at a maximum of 7m;
- Until checked during future work, consideration is given to the risk of higher current forces affecting manoeuvres in the case of the predicted UKC being less than 2m.

4.11 Alignment of berths

The simulation runs were all conducted with a berth design in which the jetties were as closely aligned to the general direction of the tidal flows as possible (297°N). The simulations revealed that balancing the vessel during the approach to berth in situations where the wind and current are strong will be challenging. It was considered, in particular, that the final part of the manoeuvre, where the vessel is pushed to the berth, is only achievable where there is good alignment of the jetties with the flow direction.

The length of the berths and the proximity to the existing IOT infrastructure means that the separation between the two is sensitive to any change in alignment. In particular, any rotation of the infrastructure to the north should be supported by some additional navigation simulation work to demonstrate that the operability of IOT8 is not adversely affected.

4.12 General comments

Operating to and from the new infrastructure will be challenging in the upper end of environmental conditions regularly experienced on the River Humber, not least the strong tidal flows.

The simulation session showed that experienced Pilots can manoeuvre large vessels up to 237m in length, marginal conditions, safely to and from the berths.

A further simulation session will be required to design appropriate training for future operators including:

- Most efficient manoeuvring strategy in normal operating conditions and, in particular, at lower flow speeds;
- Guidance on minimum number of tugs required based on state of tide and wind conditions;
- Guidance on operational limits for wind and tide at the berths;
- Consideration of emergency scenarios and abort locations;
- Consideration of requirements for simulation based Pilot familiarisation and training;
- Guidance for VTS on the management of vessels manoeuvring around East Immingham Harbour during departures and arrivals to the new infrastructure.

The nature of the new infrastructure and the associated manoeuvres are such that failure to adequately address training and operating procedures might lead to serious incidents.

Table 4.1: Simulation run summary

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
1	IC	None	237m RoRo	Arrival to Berth 3	Mean spring HW-5	SW 15	Pass	Between 9A and Horn buoy	Familiarisation run. Swing resulted in vessel arriving in approach further north than intended, therefore lateral movement slow. Rudders were locked so the turn in the berth was not representative.
2	IC	None	237m RoRo	Departure Berth 3	Mean spring HW-5	SW 15	Pass	Berth 3	Vessel lifted from berth and made straightforward departure. As soon as vessel was across the flow, the tide started to set the vessel towards IOT.
3	GJF	None	237m RoRo	Arrival to Berth 3	Mean spring HW-5	SW 15	Aborted	Between 9A and Horn buoy	Started approach at 5 to 6 knots, reducing to 3 to 4 knots (ground speed) adjacent to the Holme buoy where a starboard swing was initiated. Around 12 minutes in vessel started going astern. Run aborted as the vessel was too close to IOT structures and it was clear that the approach should not be recommended.
4	GJF	None	237m RoRo	Arrival to Berth 3	Mean spring HW-5	SW 15	Pass	Between 9A and Horn buoy	Swing initiated after Holme buoy, but adjusted to more SW in channel. When adjacent to end of IOT jetty at 2 to 3 knots astern. Speed reduced to 2 knots once fully within the berthing area. Vessel attitude across the tide enabled a straightforward approach to the berth.
5	IC	None	237m RoRo	Arrival to Berth 2	Mean spring HW-5	SW 15	Aborted	Between 9A and Horn buoy	Run aborted due to a simulation issue.
5B	IC	None	237m RoRo	Arrival to Berth 2	Mean spring HW-5	SW 15	Pass	Between 9A and Horn buoy	Course adjusted towards Immingham Bellmouth at IOT2 whilst in the white sector light. Port side of the vessel came to within 45m of the vessel on IOT1 (at 5 knots). Once stern clear of IOT1 dolphins started swing to starboard, with stern-board manoeuvre conducted at 1 to 2 knots. Good control of vessel throughout and straightforward berthing achieved.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
06	IC	1 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Mean spring HW-5	SW 25	Pass	Between 9A and Horn buoy	Tug secured on starboard quarter/CL aft when passing IOT. Port turn initiated adjacent to IOT1 maintaining >150m separation from the IOT1 to vessel's port side. Tug assisted swing to starboard. Once vessel stopped, tug continued to assist in push/pull mode during the stern-board approach. Controlled and straightforward berthing manoeuvre.
07	IC	1 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 3	Mean spring HW-5	SW 25	Pass	Between 9A and Horn buoy	Vessel turned towards Immingham Lock, aiming to swing 130m off the vessel berthed on Immingham East Jetty. Tug attached starboard quarter in push/pull mode and assisted controlling the leeward drift during the manoeuvre. Once the vessel's stern was heading towards the berth, the tug was moved to midships to assist pushing the vessel to Berth 3.
08	GY	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 3	Peak spring, HW-5	SW 25	Pass	Between 9A and Horn buoy	Tugs attached at starboard shoulder and quarter, with additional tug required for peak flow. Vessel stopped when bow was 100m from vessel on East Jetty and starboard swing initiated with aft tug mainly assisting. Both tugs continued pushing as coming alongside the berth. Pilot said it would have been beneficial to have been approaching berth at a shallower angle to avoid the contact at min. 20. Tug Master said 6m clearance astern comfortable as had space and freedom to manoeuvre. The approach highlights the precision required in setting up this manoeuvre after the swing and before entering the berthing area. Fine control of drift angle and heading are required to manage the attitude of the vessel as it manoeuvres to the jetty.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
09	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	SW 25	Pass	Between 9A and Horn buoy	Tugs on CL forward and starboard quarter when passing IOT1. Port turn initiated when passing IOT1. Starboard swing started 140m off E jetty with aft tug pushing full. Forward tug assisting with minor pull (10-25%) to control the swing. ABP commented that they were content with the approach, but Pilots should be wary of getting too close to the E jetty before swinging. Tug master commented that he was content with proximity to other vessels throughout, and drift at all times was away from closest point of danger and plenty of options available.
10	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	SW 25 gusting 30	Pass	Between 9A and Horn buoy	Tugs on CL forward and starboard quarter when passing IOT1. Aft tug assisted with swing to starboard, with forward tug controlling rate of turn. Tugs continued to check the ship throughout the berthing manoeuvre. Angle of approach was closer to the 297°N berth bearing than previous runs. ABP commented that aft tug connected at starboard (inboard) quarter is ideal to stay away from the vessel on the opposite berth. Tug master commented that although tug stern passes close to the vessel berthed on no. 3 jetty, the movement is always away and there are plenty of options to adjust position to increase separation if deemed necessary.
11 Day 2	GW	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	NE 25 gusting 30	Marginal (full power tugs and limited reserve)	Between 9A and Horn buoy	Tugs assisted with starboard swing and continued to provide assistance during manoeuvre towards the berth At times both tugs required full power to provide effective lift. Assessment that this is due to relatively high water speed, at 4 knots, reducing the effectiveness of tugs and thrusters. Pilot said that although the tugs were used at full power an alternative approach using reserve lift available from the rudder is possible. Tug master commented that although tug stern passes close to the vessel berthed on no. 3 jetty, the movement is always away and there are plenty of options to adjust position to increase separation if deemed necessary.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
12	GW	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	NE 25 gusting 30	Pass	Between 9A and Horn buoy (N of green sector)	Repeat of Run 11 with tugs on CL forward and port quarter. Rather than swing the vessel before making stern-board manoeuvre, vessel attitude adjusted across the flow and tide with wind used to assist the lateral movement of the vessel towards the berthing area. Both tugs assisted by pulling the vessel south and then checking drift once ready to approach he berth. The manoeuvre provides greater control and requires less precision in setting up.
13	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	NE 30 gusting 35	Fail	Min. 12 of Run 12	Tugs on CL forward and port quarter, pulling vessel south. Tugs started pushing as the vessel approached the E jetty, but the bow of the ship (and fore tug) came close to the E jetty ship (6m clearance for the tug). Run aborted due to proximity to berthed vessel with fore tug/bow not completely under control.
14	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	NE 25 gusting 30	Marginal	Min. 12 of Run 12	Tugs on CL forward and port quarter, though ship maintained an approach more E of the E jetty. Difficult to control the speed of lateral drift with stronger wind and unable to stop stern setting towards vessel on Berth 3. Issue is setup not gap between berths and Pilot needs to stop leeward set earlier.
15	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring, HW-5	NE25 30	Pass	Min. 12 of Run 12	Tugs on CL forward and port quarter, similar approach to Runs 13 and 14, but Pilot started the process of removing lateral set earlier, manoeuvring into the appropriate position to commence stern-board manoeuvre into the berthing area with more control. The effect was to create a situation where the combined lift of thruster, rudders and tugs is able to safely manoeuvre the vessel into the berthing area.
16	GJF	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 3	Peak spring, HW-5	NE 25 gusting 30	Pass	Min. 12 of Run 12	Tugs attached CL forward and port quarter to control vessel lateral speed as elements set it laterally towards the berth. Once aligned with the berthing area straightforward stern-board manoeuvre alongside.
17	GW	2 x 70t ASD 70t 2411	237m RoRo	Departure from Berth 3	Peak spring, HW-5	NE 30 gusting 35	Fail	Berth 3	Tugs on CL fore and port quarter to lift vessel off the berth. As vessel manoeuvred into the main channel, wind and tide rapidly set the vessel onto the East Jetty. Assisting tugs able to provide limited additional lift due to flow speed. Run aborted due to proximity to vessel berthed on east wall.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
18	GW	2 x 70t ASD 70t 2411	237m RoRo	Departure from Berth 3	Peak spring, HW-5	NE 30 gusting 35	Pass	Berth 3	Vessel lifted from jetty with tug assistance and manoeuvred into the berthing area. Once the stern was clear of the jetties a slow swing to port swing was initiated, this enabled the Pilot to steady the vessel's stern into the wind and use a combination of tide and power to manoeuvre clear of the east jetty and complete the swing. Pilot said it was a challenging manoeuvre, which was possible, but uncomfortable. Note that there was 75m on the bow and 50m on stern, which is the limit.
19	GW	No tugs	237m RoRo	Departure from Berth 3	Peak spring, HW-5	NE 20	Pass	Berth 3	Slowly edged the vessel forward, started a port swing once the stern was clear of the Berths 1 and 2, and used the elements to advantage to swing the vessel. Pilot said it went well, as they were patient. It was slow to lift the vessel clear of the jetty, adding around 20 minutes.
20	IC	No tugs	237m RoRo	Departure from Berth 3	Peak spring HW+4	NE 20	Marginal	Berth 3	Pilot was able to lift the bow into tide, but when he applied lift to the stern the associated yaw and 20 knot wind brought the bow back towards the jetty causing the vessel to slide along the jetty, so the run was aborted and wind reduced to 15 knots from NE for next run.
21	IC	No tugs	237m RoRo	Departure from Berth 3	Peak spring HW+4	NE 15	Pass	Berth 3	Required bow thruster at 100% for the whole run, but able to lift the vessel clear of the berth and manoeuvre into open water.
22	GJF	No tugs	237m RoRo	Departure from Berth 3	Peak spring HW+4	SW 15	Pass	Berth 3	Vessel slowly came away from berth. Straightforward departure with wind assisting lift.
23	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring HW+4	NE 30 gusting 35	Pass	Min. 12 of Run 12	Tugs on port shoulder and CL aft (port side). Both tugs used to hold vessel into the wind until clear of the jetty. Utilising the tide across the bow to provide additional lift gives great control and makes the ebb approach more straightforward to manage than the flood condition.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
24	GJF	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 2	Peak spring HW+4	SW 25-30	Pass	Min. 12 of Run 12	Tugs on CL fore and aft (portside), offering 50-75% pull at the start of the run to help settle the vessel to windward. The Pilot is able to control the approach angle to make the manoeuvre steady and controlled to the berth.
25	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 4	Peak spring HW+4	SW 25-30	Pass	Min. 12 of Run 12	Change to Layout 1 to examine Berth 4. Tugs attached CL forward and starboard aft giving control throughout. Only 35m and 40m clearance either end of the ship between the new infrastructure and east jetty so felt tight to pilot. There is a point of no return as the bow clears vessel on the E jetty.
26	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 4	Peak spring HW+4	NE 30 gusting 35	Pass	Min. 12 of Run 12	Tugs connected CL forward and port aft. Tugs used to check lateral speed as vessel sets to the south. As the attitude of the vessel changes to be parallel with berth, more power is required to check the vessel and push it back towards the jetty. Winds of 30 gusting 35 knots look to be the maximum from the NE for this berth.
27	GJF	2 x 70t ASD 70t 2411	237m RoRo	Departing Berth 4	Peak spring HW+4	NE 30 gusting 35	Pass	Berth 4	Tugs connected CL forward and port aft. Both tugs and bow thruster initially at 100% to hold the ship into wind. Once the bow was across the tide, the tide assisted the manoeuvre. Thereafter a straightforward manoeuvre moving laterally across the tide to the north.
28	GJF	2 x 70t ASD 70t 2411	237m RoRo	Departing Berth 4	HW-5	SW 25-30	Pass	Berth 4	Tugs on CL forward and starboard quarter. Just controllable, with tugs necessary to lift vessel and then check lateral movement across the entrance.
29	IC	2 x 70t ASD 70t 2411	237m RoRo	Departing Berth 4	HW-5	NE 30 gusting 35	Pass	Berth 4	Tugs connected at CL forward and port aft quarter. Both initially pushing on to check set to windward, aft tug came close to leaving the dredged area extents. Port swing started once clear of jetty. Once stern across the tide, the flood flow assisted the vessel opening laterally to the north against the prevailing wind. Pilot said it was harder than previous runs with limited room to come forward, so very challenging.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
30 Day 3	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 1	HW-5	SW 25-30	Pass	IOT2 within sector lights	Tugs secured on CL forward and starboard aft. Vessel swung 180m NW of IOT A1 beacon. Then set stern across tide to make slow controlled stern-board manoeuvre to vicinity of berth. Tugs provided assistance pushing to windward. Straightforward manoeuvre. Pilot said he could have swung further W increasing clearance on IOT. Vessel was well balanced once south of IOT1.
31	IC	2 x 70t ASD 70t 2411	237m RoRo	Arrival to Berth 1	HW-5	NE 30 gusting 35	Pass	As previous, N of green sector	Tugs connected CL forward and port quarter. Vessel tracked beyond IOT then adjusted stern across the flow to allow wind and current to set the vessel laterally towards the berth. Tugs assisted checking the lateral movement to windward. Up to full power was used and the balance point was achieved late in the manoeuvre, consequently the stern of the vessel passed close to the end of Berths 1/2. This could be avoided with Pilot adjusting strategy to check lateral movement earlier.
32	IC	2 x 70t ASD 70t 2411	237m RoRo	Depart Berth 1	HW-5	NE 30 gusting 35	Marginal	Berth 1	Tugs connected CL forward and port aft quarter with 50 to 75% power required to assist lift off the berth, increasing to 100% power, to assist in maintaining clearance from the vessel on East Jetty. Forward tug assisted with swinging the bow to starboard. As the speed increased (reaching 3 knots), the aft tug kept the stern from drifting too close to the E Jetty (though it came 35m of the E Jetty vessel) and helped stop the swing.
33	IC	2 x 70t ASD 70t 2411	237m RoRo	Depart Berth 1	HW-5	NE 30 gusting 35	Pass	Berth 1	Vessel departed berth much slower than in Run 32 and instead a port swing (with the aft tug pulling) was initiated between the Berth 1/2 jetty and E jetty. Once the vessel swung through 90°, the Pilot used the starboard bow thruster to complete the swing (maintaining a separation distance of 115m from the E jetty vessel). Forward tug assisted in stopping the swing, and pushing the bow to turn out of IOT.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
34	IC	2 x 70t ASD 70t 2411	237m RoRo	Depart Berth 1	HW-5	SW 25 gusting 30	Pass	Berth 1	Utilised a swing methodology similar to Run 33, though the swing was completed closer to Berth 1/2 jetty. The tugs only assisted in pulling the vessel off the berth as once away from the berth the tide assisted the vessel away to the west. A 62m separation distance from IOT1 dolphins was maintained throughout.
35	IC	16t workboat	104m tanker	Arrival IOT8	HW-5	NE 15	Aborted	IOT3	Vessel successfully turned wide of IOT1, but had picked up speed (4 knots) when coming around and so it was a challenge to maintain distance from Immingham East Berth 1 vessel. Tug secured on port quarter and assisted with push/pull as the vessel straightened up out of the turn, however, the tug was unable to avoid contact with the Immingham East Berth 1 vessel.
36	IC	16t workboat	104m tanker	Arrival IOT8	HW-5	NE 15	Aborted	IOT3	Similar to Run 35 and was aborted before contact would have occurred between the tug and Berth 1 vessel.
37	IC	16t workboat	104m tanker	Arrival IOT8	HW-5	NE 15	Pass	IOT2	Pilot took a more conservative approach (compared with Runs 35 and 36), providing time to line up west of IOT and to reduce speed to below 2 knots before passing Immingham East Berth 1. The subsequent approach was controlled (not requiring tug assistance) and resulted in safely arriving in a berthing position.
38	IC	16t workboat	104m tanker	Arrival IOT8	HW-5	NE 30 gusting 35	Aborted	Min. 12 of Run 37	Tug secured on starboard quarter and provided push assistance as approaching Immingham East Berth 1. This was, however, insufficient to avoid contact with the tug/stern of the vessel. Initial position regarded to be too close to correct and to be revised in the next run.
39	IC	16t workboat	104m tanker	Arrival IOT8	HW-5	NE 30 gusting 35	Aborted	E of min. 12 of Run 37	Initial position revised to further E of previous run providing more clearance from Immingham East Berth 1. Vessel tracked SE towards IOT8, however, contacted the rolling fender at the end of the IOT pier.
bn	IC	16t workboat 45t ASD	104m tanker	Arrival IOT8	HW-5	NE 30 gusting 35	Pass	E of min. 12 of Run 37	As run started, 45t ASD secured on starboard beam and the workboat on the starboard quarter. The forward tug (the ASD) started pushing 25 to 50% once S of the pier to keep vessel away from Immingham East Berth 1. Satisfactory berthing manoeuvre.

Run ID	Pilot	Tugs	Vessel	Manoeuvre	Tide/ current	Wind dirn, speed (knots	Outcome	Initial position	Comments and pilot/tug master remarks
41	IC	16t workboat 45t ASD	104m tanker	Departure IOT8	HW-5	NE 30 gusting 35	Pass	IOT8	Tugs initially secured as Run 40. Both tugs pushing as vessel came away from the berth (achieving a 20m separation distance from the Immingham East Berth 1 dolphin). Vessel tracked out satisfactorily.
42	IC	16t workboat	104m tanker	Arrival IOT8	HW-5	SW 25 gusting 30	Pass	N corner of dredged area	Vessel initially on a ESE course, with the tug providing push assistance on the port quarter, just before the bow reached the IOT8 pier.

Note: 16t workboat limited to 66% of its capacity

5 Conclusions

The following conclusions and recommendations were made as a result of the study:

- The proposed infrastructure is acceptable to operate a 240m RoRo vessel safely.
- The design width between the 2 jetties can be reduced to 120m between fender lines without reducing the operational availability of the berth.
- Any amendment to the design which reduces the distance between IOT and the new infrastructure, or sets the new infrastructure at a different aspect to the existing alignment of IOT6/8 will make the operations at IOT more difficult to achieve safely. Any such change should be checked through navigation simulation before being adopted.
- Layout 2, with 94m between new infrastructure and IOT8, should be adopted to minimise disruption to operations at IOT8.
- The 3 berth design (Layout 2) should be adopted with the option to extend to a 4 berth hybrid layout in due course.
- Operations at the berths need small, relatively agile and powerful tugs to assist manoeuvres. Tugs of approximately 25m in length with at least 60tBP will be required in the most extreme conditions, additional sensitivity testing once the design and operational plan are finalised will be required to determine tug requirements in more normal operating conditions.
- Based on the minimum observed under keel clearance (UKC) in the dredged box of 4.5m during the simulation runs, it might be appropriate to reduce the dredged depth to -8mCD, as long as the design draught remains no greater than 7m and, until demonstrated otherwise, special consideration is given to any manoeuvre where the predicted UKC is less than 2m.

Overall it should be noted that manoeuvring to and from the new infrastructure is challenging, requiring precise positing of the vessel, tugs and their attitude to the tidal flow and the wind. Mitigating the inherent risk in the manoeuvring operations will require a robust training solution to be in place.

Additional assessment will be required to identify the detail of recommended procedures and limits for all classes of vessel and a wider range of environmental conditions. This will be particularly pertinent to developing appropriate limits for an initial operating capability.

6 References

1. HR Wallingford, “Project Sugar - ABP Humber - Immingham East Development - Design review and navigation studies”, Report no. DJR6612-RT01-00-04,10 Dec 2021.
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3. ABP, Drawing “Red Line Boundary 3 Berths”, Baseline 3 berth layout, 16 Nov 21.
4. ABPmer, “Report of survey AWAC buoy deployment”, 15 Jul 20.
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Appendices

A Ship and tug simulation at HR Wallingford

Ship and tug simulation at HR Wallingford

Overview

At HR Wallingford, we operate ten real time simulators from our Ship Simulation Centres in Wallingford, UK and Fremantle, Australia. Our simulators are full bridge, real time manoeuvring simulators specifically designed for port design and ship operations applications, but are also used for training and pilot familiarisation purposes.

They have been developed over 25 years and have been used successfully in over 350 studies world-wide in the last 15 years alone. They have proved to be reliable, flexible and cost-effective design and evaluation tools that can be used for optimising harbour layouts, establishing operational strategy, and training in safe manoeuvring procedures.

We operate a combination of ship simulators and dedicated tug simulators, and to maximise the flexibility of our simulation capability, all of our ship simulators can also be adapted to represent tugs with suitable consoles and controls.

Our simulators are fully integrated such that they can be used to represent one or more piloted ships, or a ship and independently manned tugs, all within the same simulated environment. Alternatively the simulators can be used independently, which enables more "hands-on" time for pilots and tug masters during training or familiarisation sessions. When operating in this mode, an independent ship can also be controlled from another simulators to maximise the training opportunities for tug masters.

The system is capable of real time simulation of vessel behaviour in a range of environmental conditions making the simulators suitable for a wide range of design, assessment and training tasks including:

- Pre-feasibility studies, in the form of desk studies or simulation aided desk studies
- Optimisation of site specific terminal/port/harbour and approach channel designs
- Assessment of safety standards and procedures for shipping and port management operations
- Feasibility studies for new vessels using existing harbours / ports
- Effective training in manoeuvring procedures for pilots, tug masters and ships' officers

A mobile version of the real-time simulator can be used for on-site pilot training and port design.

Ship Simulation Centres

Our Ship Simulation Centres in the UK and Australia house the simulators within a dedicated suite of rooms including separate ship's bridges with their own briefing/observation rooms, control rooms, a dedicated tug bridge, and a conference room.

The ship simulator bridges

For the Ship Simulators the main room in each facility provides a representation of the bridge of a ship. From the bridge, a pilot can view and control ship manoeuvres and monitor the vessel's status throughout the simulation. A wide range of controls can be provided to represent conventional, azipod or other ship specific control systems. The console also provides radar and electronic chart display (ECDIS).

Ship Simulator bridge

Visual scene

The visual scene is a major component of navigation simulation, as piloting a ship or tug is essentially a visual process. Most manoeuvring decisions are made by interpretation of the view from the bridge windows. It is therefore essential that this information is presented in a realistic manner.

Photograph taken at study site

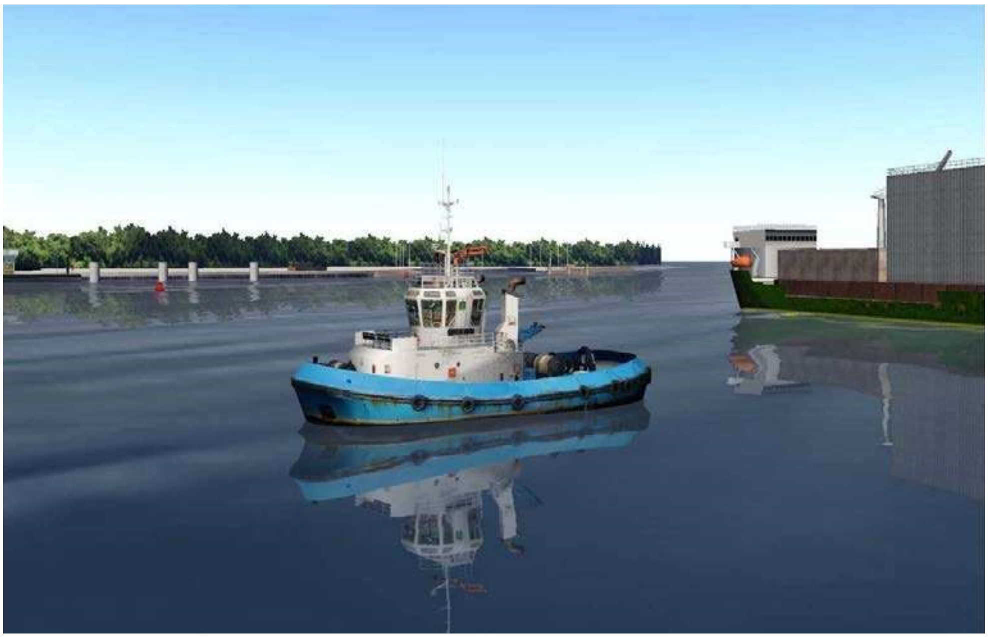
Simulator visual scene

Example visual scene for LNG terminal from ship's starboard bridge wing

Example visual scene for cruise terminal

The screens wrap around the bridge console and provide a continuous visual angle of 280°, in addition to an astern view presented on a 42" TFT monitor. A "look-around" facility is also incorporated that allows the pilot's viewpoint to be moved from the centre of the bridge to either bridge wing, and all around the ship allowing 360° vision, along with viewing down along the ship's side.

Example visual scene for container terminal



Realistic tug modelling

The lighting level can be adjusted between full daylight and full night time, in a range of visibility conditions, from excellent, long range visibility to thick fog. In night time simulations, shore lights and other vessel lights can be included, and all navigation marks can be set with the correct light configuration and characteristics.

Example visual scene of bulker terminal at night, with ship lights in distance

Example visual scene in mist

Control consoles

The control console on each bridge is flexible, but the conventional configuration has ship helm, engine and thruster controls along with instrument, radar, ECDIS/situation displays.

A range of helm and engine controls are available including:

- Wheel, tiller or joystick or twin rudder controls
- Single or twin engine telegraph controls
- Azipod propulsor controllers
- Bow and stern thruster controls.

Alternative control consoles can also be provided if required.

The instrument display presents information on the ship status including:

- Ground or water speed ahead and athwartships at midships or at bow, stern and midships
- Heading
- Rate of turn in graphical or digital display form
- Depth under the keel in graphical or digital display form
- Relative wind speed and heading
- Engine settings
- Helm indicator, showing applied wheel
- Rudder indicator, showing actual rudder angle.

There is also an electronic situation display available, in place of the ECDIS, where required, which enables the pilot to monitor the ship's position relative to key features. This displays information in the form of a plan view, similar to an electronic chart/ECDIS display, and includes a scaled ship outline and any planned developments in the area of interest.

Tug bridges

The dedicated Tug Simulators comprises a bridge with a chair and two consoles. Similarly to the Ship Simulators, from the bridge a tug master can view and control tug manoeuvres in a realistic manner and can monitor the vessel's status throughout the simulation.

A wide range of controls can be provided to represent ASD, (Aquamaster) type controls, throttle and joystick or Voith Schneider type controls. The consoles also provide radar and electronic chart display (ECDIS), along with line tension meters, where applicable.

In addition, a winch control panel is also provided and the simulated winch can represent a standard, static type winch or a dynamic, render recovery type winch.

As with the Ship Simulators, the tug visual scene is generate using three dimensional, fully textured, computer generated graphics, which are projected onto three large screens at the front of the bridge, and an array of 13 x 50" plasma monitors, to provide a full 360 degree view.

A 3 channel intercom system is available to enable communications with the central Control Room, and the simulated ship when operating in the integrated mode.

Tug Simulator bridges

Tug Simulator bridges

Simulator control room

Each simulation scenario is configured and initiated by a Simulator Operator, who is stationed at a dedicated console in one of the Control Rooms, immediately adjacent to the bridge on each of the Ship Simulators. There is a window and intercom system between the bridge and Control Room allowing full visual and verbal communications at all times. During a simulation run, the operator can monitor the simulation but can also control the application of the tugs (that are not independently controlled), anchors and mooring lines, and adjust light and environment settings as required. The operator can also introduce failures at any time, along with other vessels in the simulation.

Briefing / observation and meeting rooms

Immediately adjacent to each bridge are Briefing/Observation Rooms, with a suite of monitors that relay the instrument and situation displays from the bridge control console, along with simulation visuals, as seen from the bridge.

These enables project team members to observe and monitor the simulation runs without disturbing either the pilot. There are also meeting rooms nearby, which can act as a base for the Client's project team, and where all members of the Simulation Team can gather to discuss each simulation in detail and to consider any issues raised by the runs.

Ship and tug manoeuvring models

Within the simulators, the behaviour of the ship or tug, in terms of its response to any helm and engine actions and the local environmental effects, is governed by a mathematical manoeuvring model which includes the following effects:

- Shallow water effects including increase in turning radius and drag
- Squat
- Bank effects
- Wind response allowing for both lift and drag
- Response to waves
- Response to current
- Tug operations
- Ship to ship interaction
- Collision/contacts with any fixed structure or another vessel
- Mooring lines
- Anchors
- Lock blockage.

Mathematical manoeuvring models are tailored to particular studies based on the design ship(s)/tug(s) dimensions, drawings and, whenever possible, ship trials data. HR Wallingford also has an extensive library of ship and tug models for vessels of different sizes and hull forms.

All ship manoeuvring models are verified by professional mariners/pilots and navigation experts.

Real time navigation simulation runs

During the simulation runs, a professional mariner or pilot is in command of the simulated ship. This may be either a visiting, local pilot, who is familiar with the particular ship or study site, or one of HR Wallingford's experienced pilots.

At the start of each run, the desired scenario (vessel, port layout, tidal state, wind and wave conditions, lighting level and visibility) are configured within the simulator and the ship is initialised with a suitable position, heading, and forward and transverse speeds. During the run, the wind, waves, light levels and visibility can be altered as required. Furthermore, the pilot can call upon the assistance of tugs, which are controlled in response to verbal commands from the pilot.

Effective and appropriate use of tugs is often essential to safe manoeuvring at slow speed. Consequently the performance of assisting tugs needs to be realistically simulated. This is achieved in the Ship Simulators by representing the interaction of a complex series of factors including the type of tug, the number, type and position of the tug's propulsors, the prevailing wind and wave conditions, the location of the tug with respect to the ship (ie. it may be protected from some wave activity by the ship), the ship's speed, the current speed and direction, and the operating mode of the tug.

Alternatively, the Ship Simulator(s) can be integrated with the Tug Simulator so that one or two of the tugs are operated independently by a tug master.

Of particular importance at many sites is the effectiveness of tugs in waves. HR Wallingford has considerable experience of this issue based on detailed discussions and simulated trials with a range of tug operators. This has resulted in a series of tug efficiency curves for varying wave heights and periods for each operational mode.

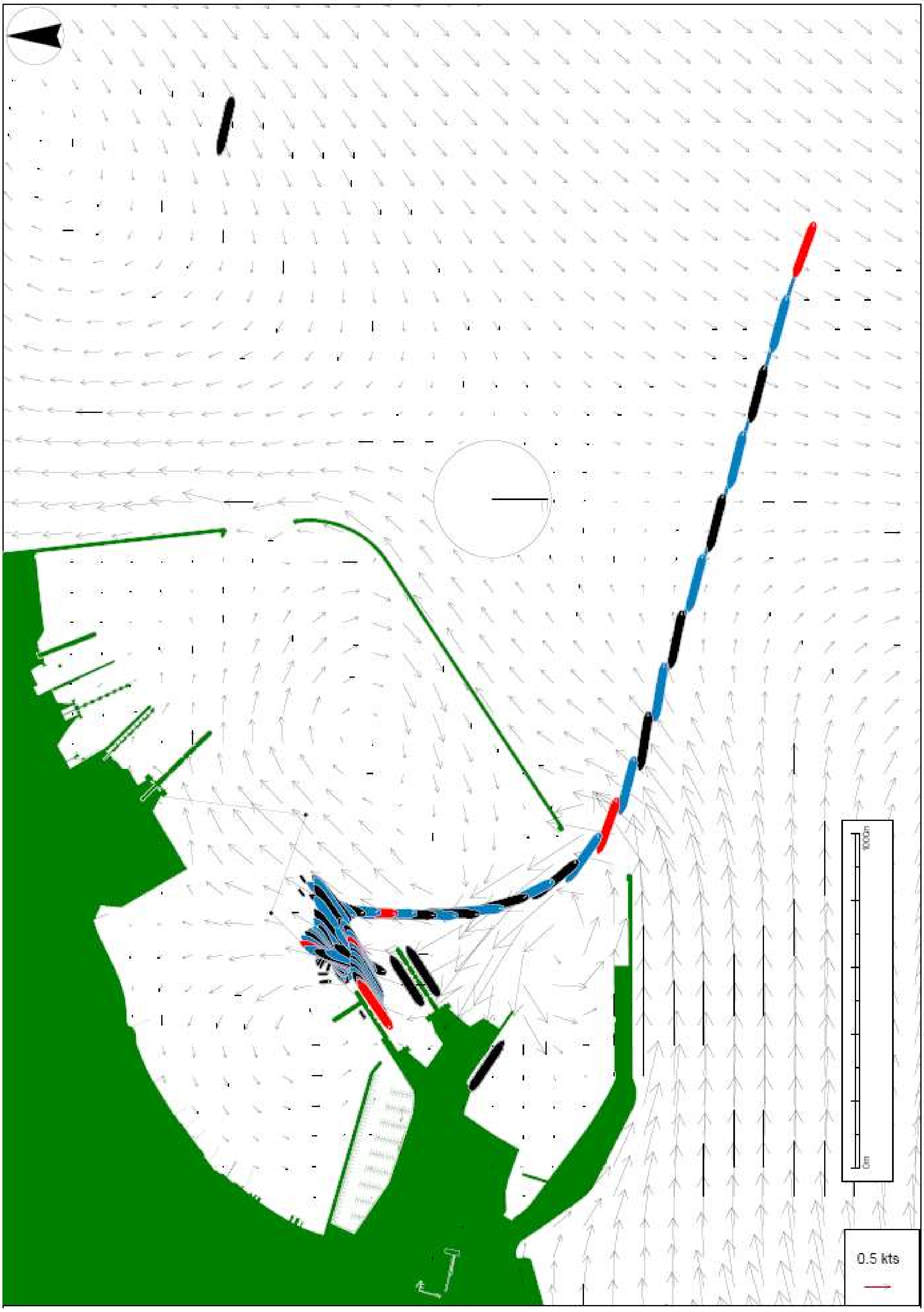
Any number of other vessels can also be present in the simulation. These can be used as vessels on berths or in passing ship manoeuvres. The position and behaviour of these ships are either controlled in a simplified manner or the two Ship Simulators can be integrated so that a pilot can operate the other ship from other Ship Simulator bridge.

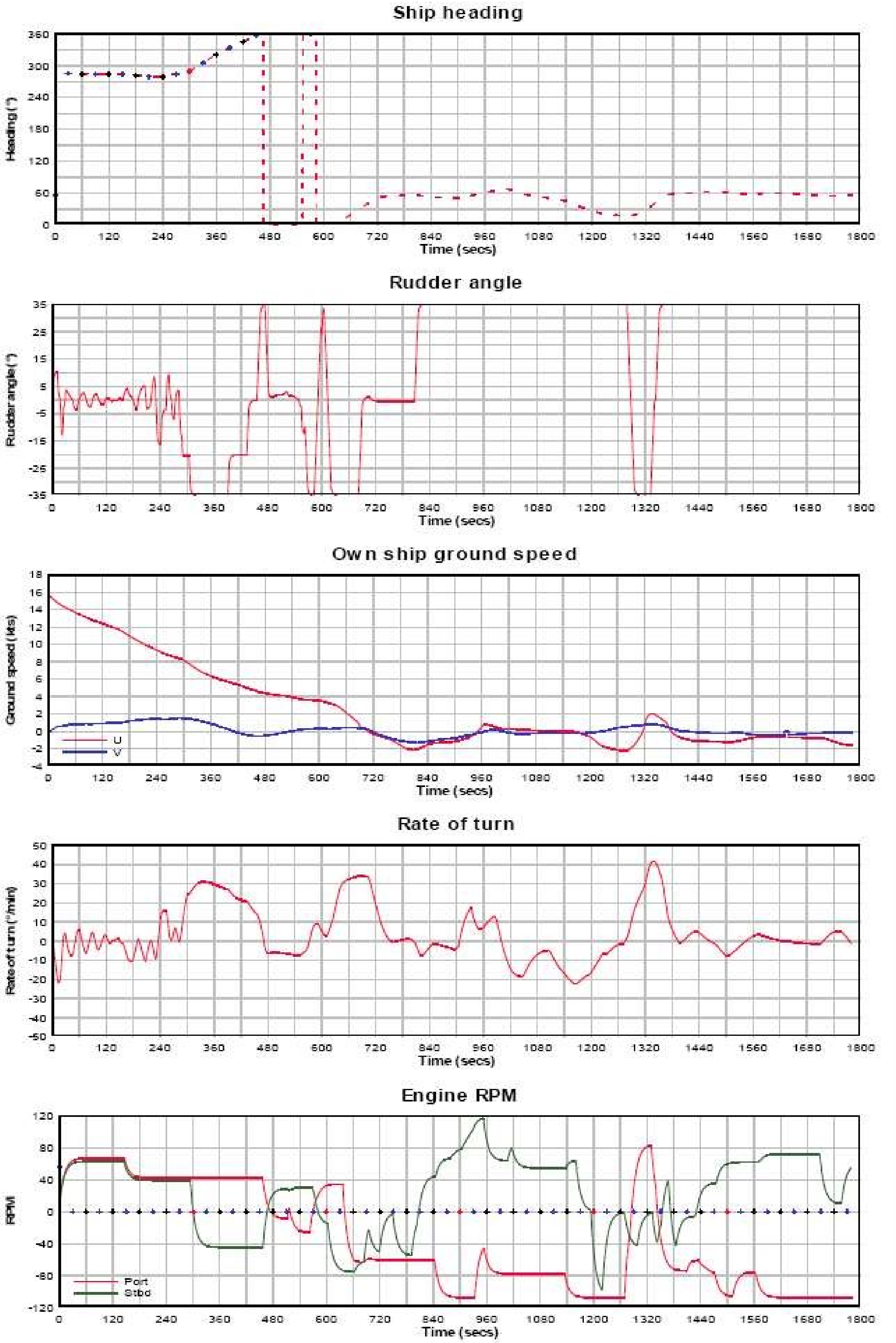
As each simulation run proceeds, the pilot is presented with the visual and other information that allow representative ship handling decisions to be made, based on accepted navigation practice, skill and experience. In particular, the use of experienced mariners ensures that realistic limits of ship controllability are reproduced and accounted for within the simulation.

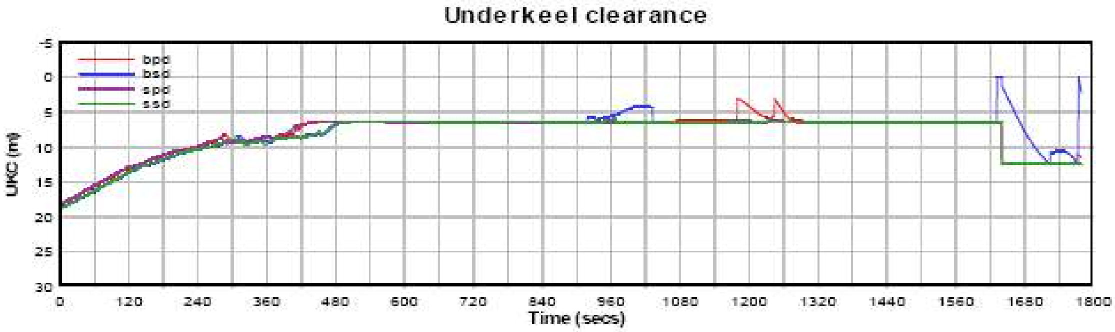
Simulation data is recorded at an appropriate frequency (typically every 1 second) for later analysis and reporting. The list of data parameters recorded can vary, but typically includes:

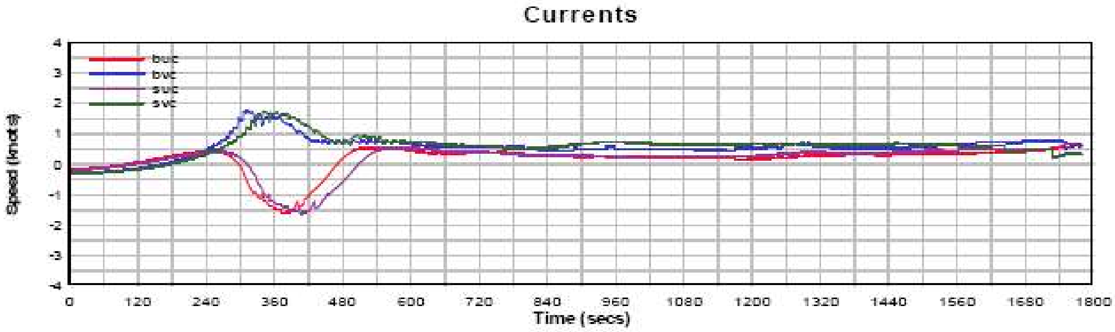
- Elapsed time
- Ship position and heading
- Speed and rate of turn
- Rudder and engine settings
- Under keel clearance
- Tug and thruster activity
- Current and wave conditions at the ship
- Position and heading of any target ships.

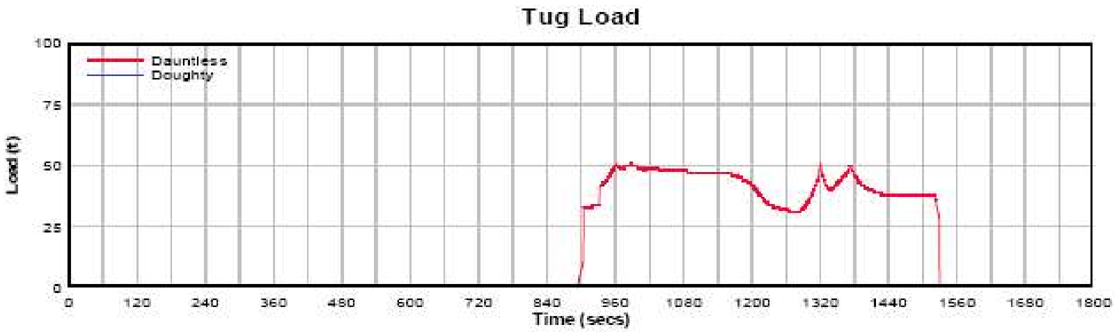
This information is presented in a series of vessel track and data plots as shown in the Figures below.

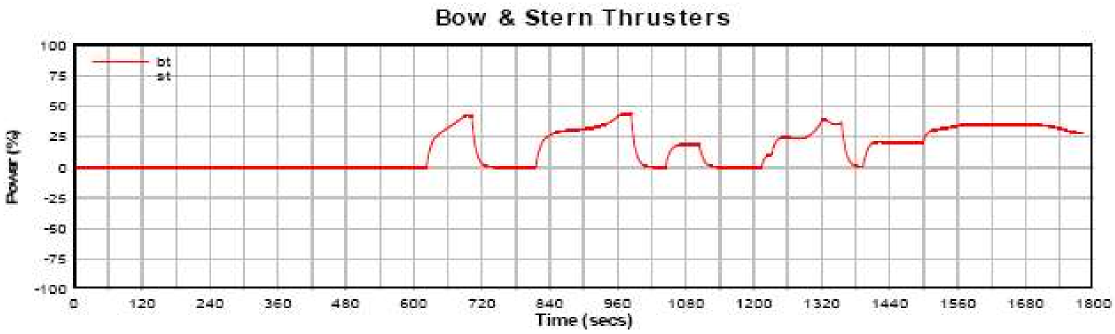

1000m
0m
0.5 kts


Ship heading
Heading (°)
Time (secs)
Rudder angle
Rudder angle (°)
Time (secs)
Own ship ground speed
Ground speed (kts)
U
V
Time (secs)
Rate of turn
Rate of turn (°/min)
Time (secs)
Engine RPM
RPM
Port
Stbd
Time (secs)


Underkeel clearance
bpd
bsd
spd
ssd
UKC (m)
Time (secs)

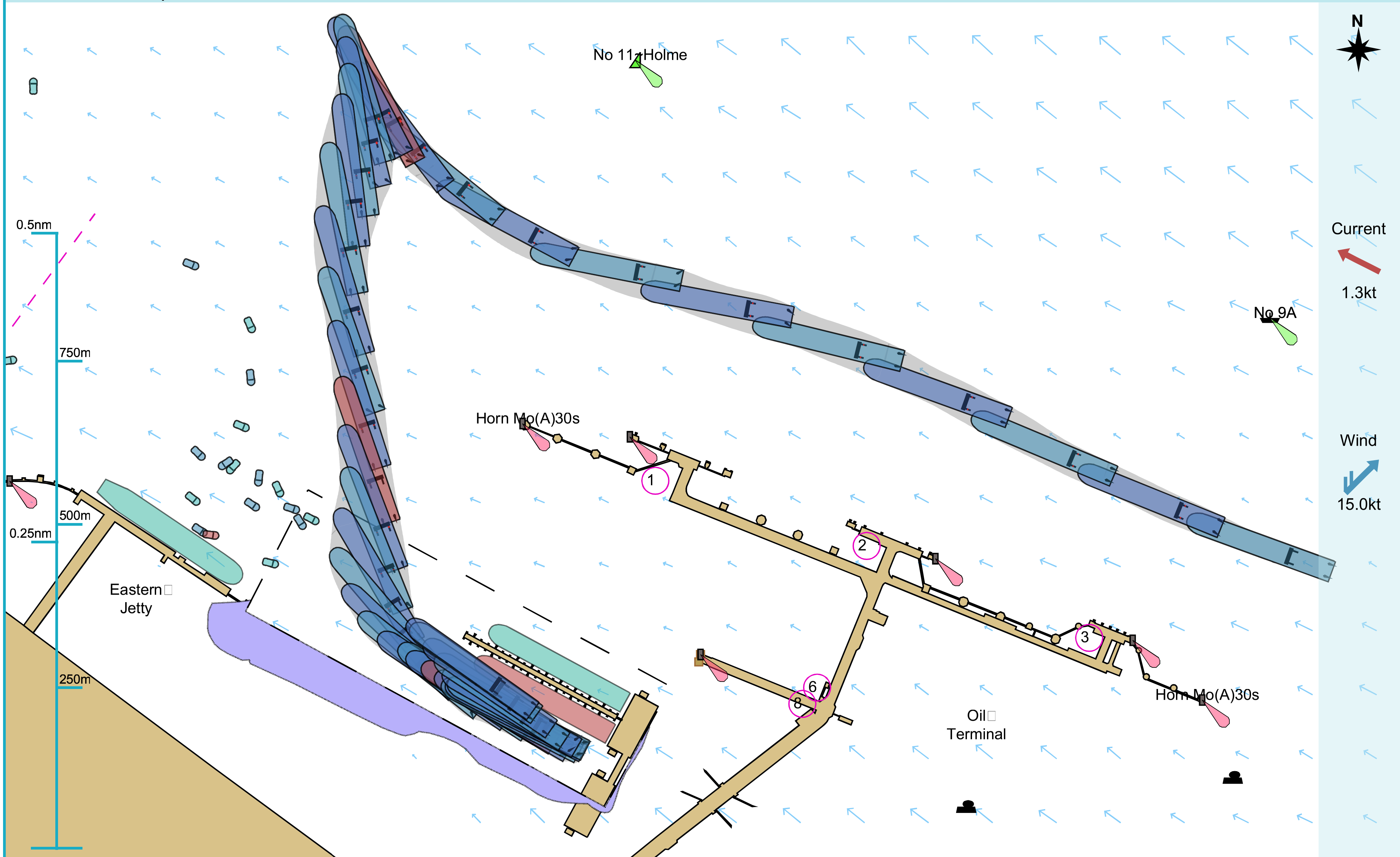

Currents
buc
bvc
suc
svc
Speed (knots)
Time (secs)


Tug Load
Dauntless
Doughty
Load (t)
Time (secs)


Bow & Stern Thrusters
bt
st
Power (%)
Time (secs)

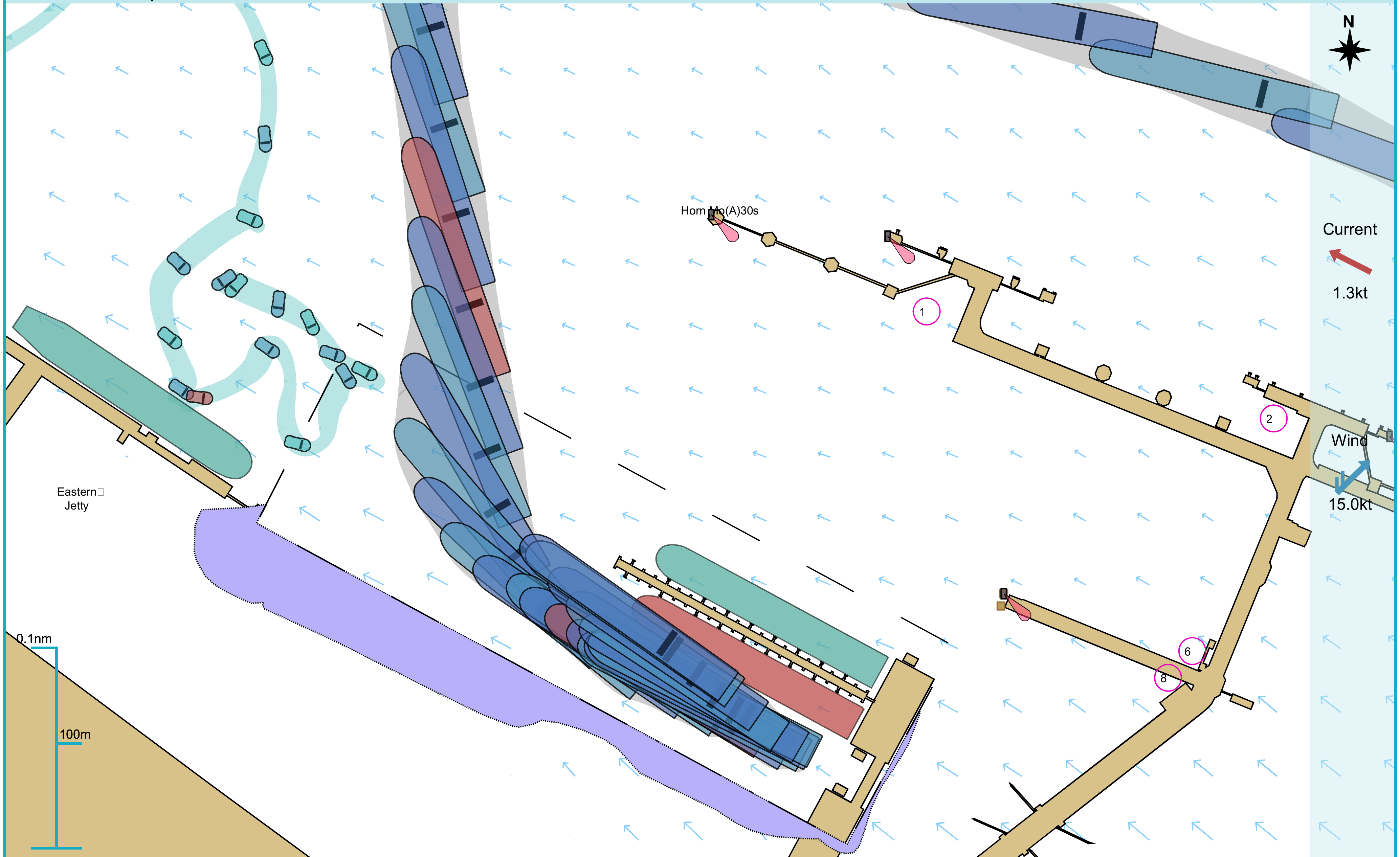
B Simulation track and data plots

Manoeuvre track plot



Ships plotted every 1 mins, highlight every 10 mins

Manoeuvre track plot



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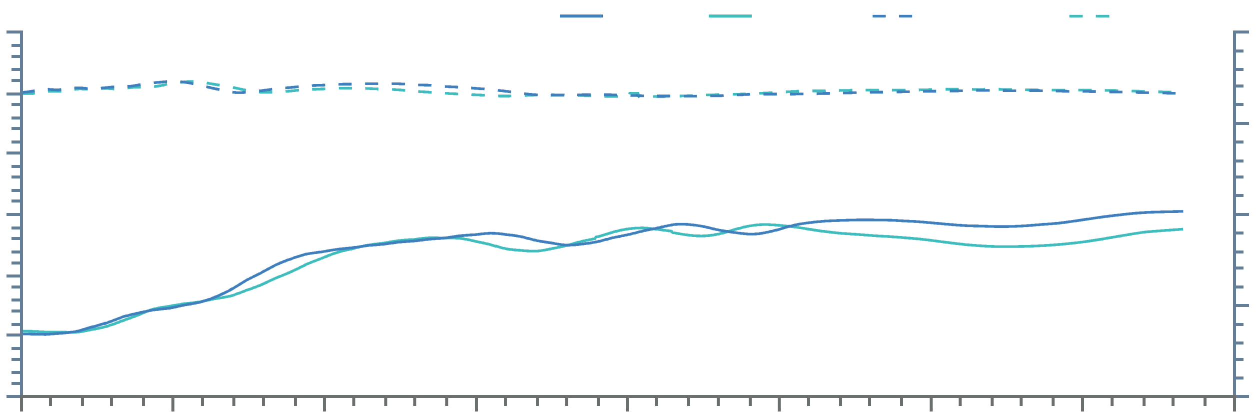
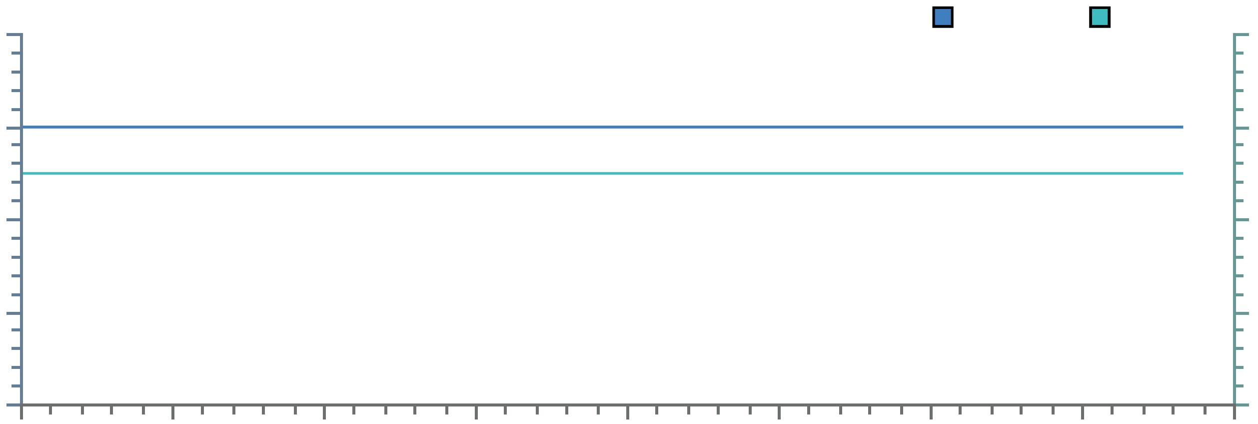
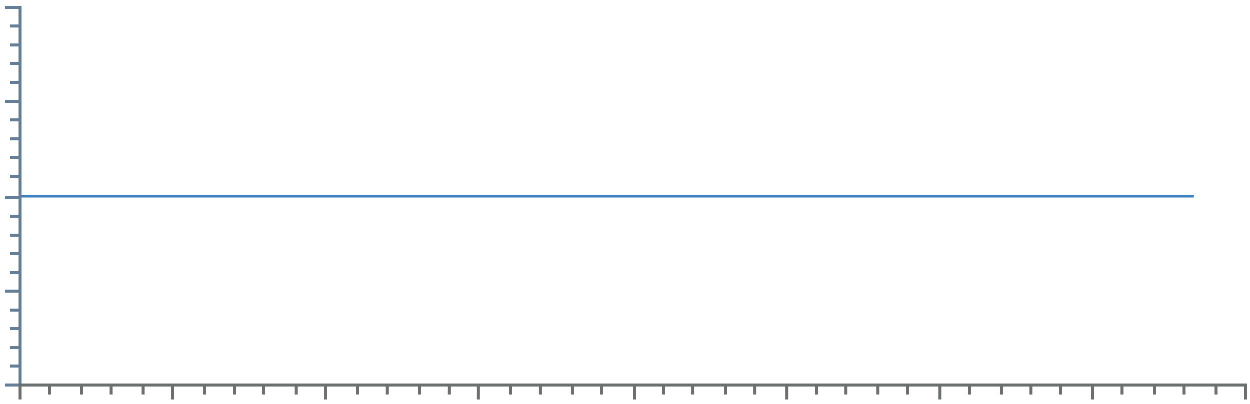
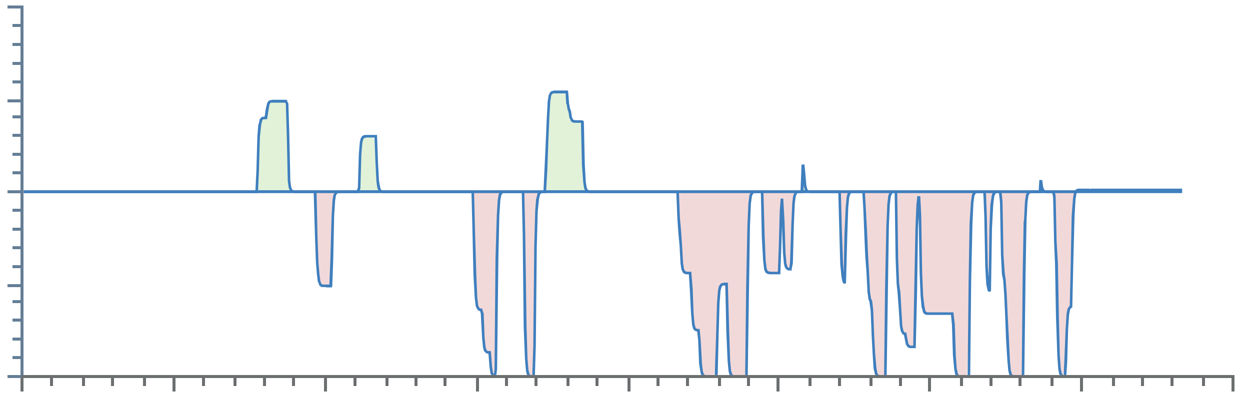
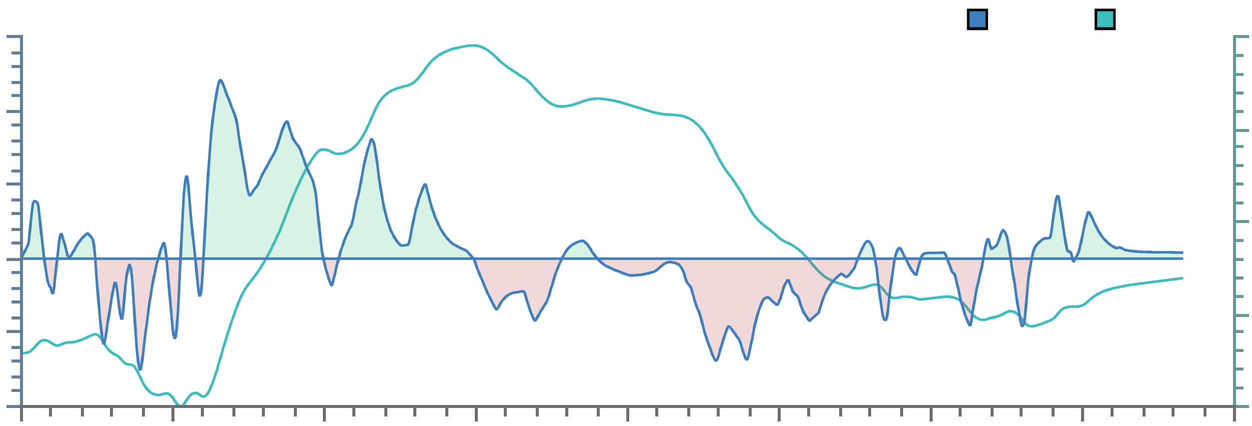
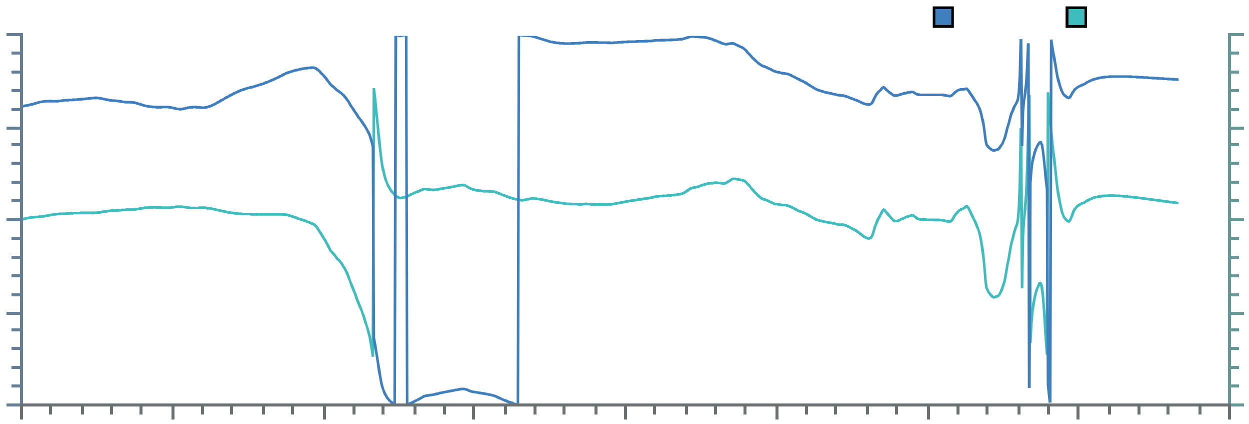


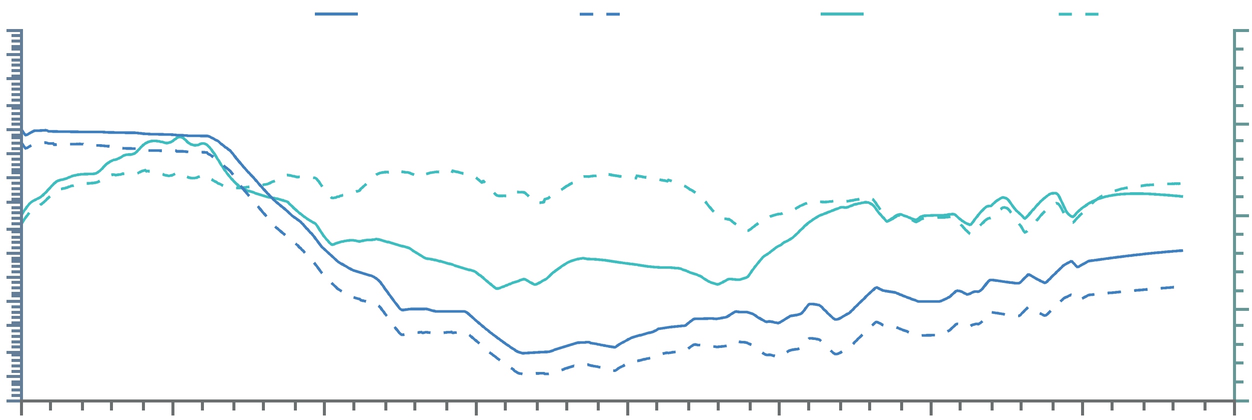


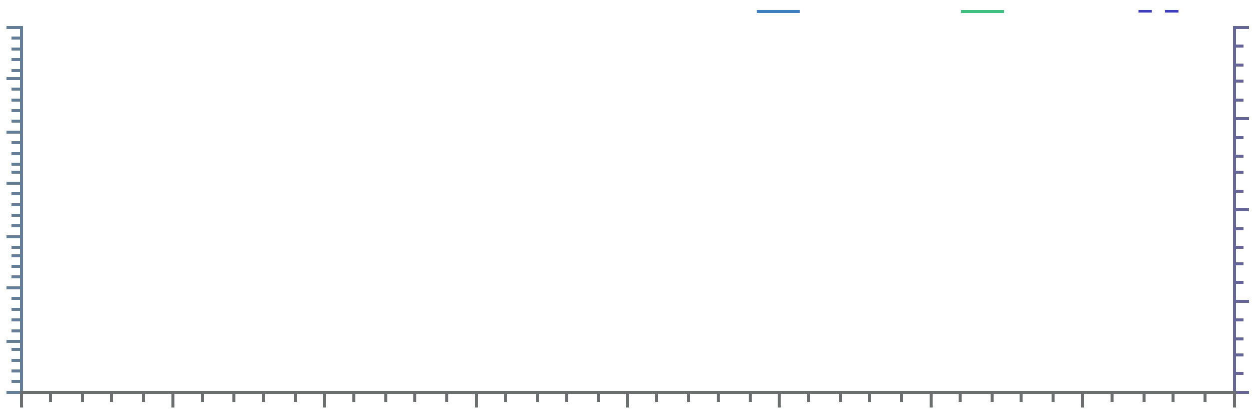


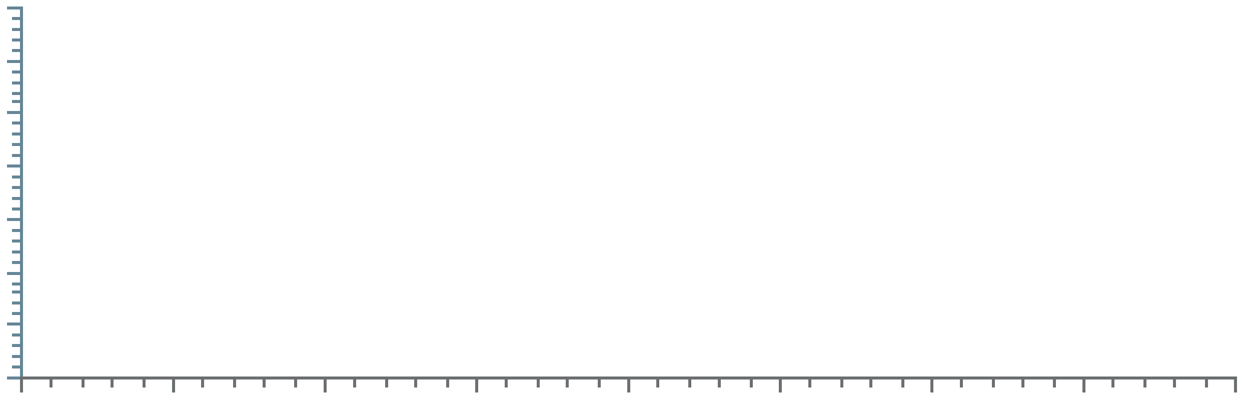




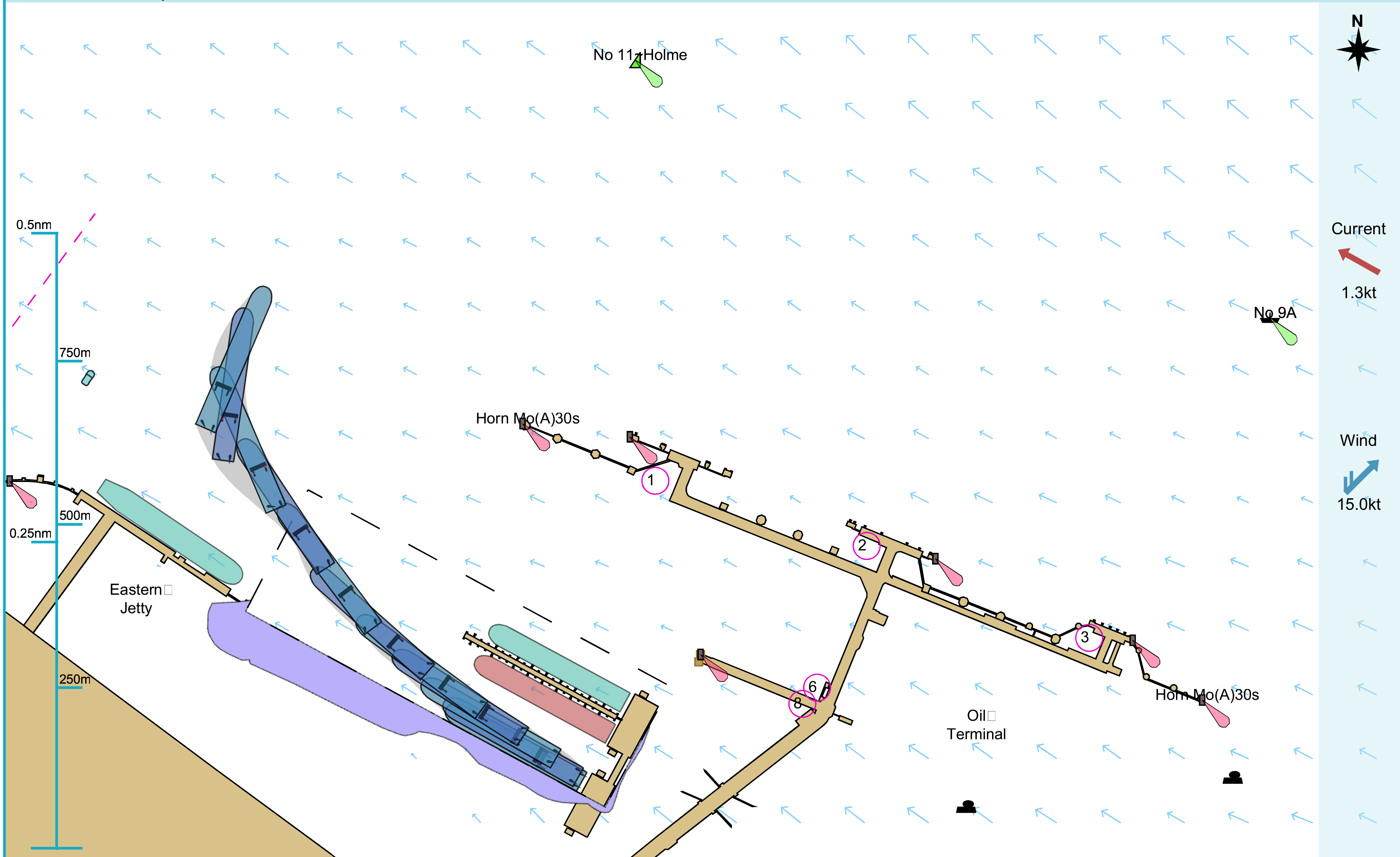








Manoeuvre track plot



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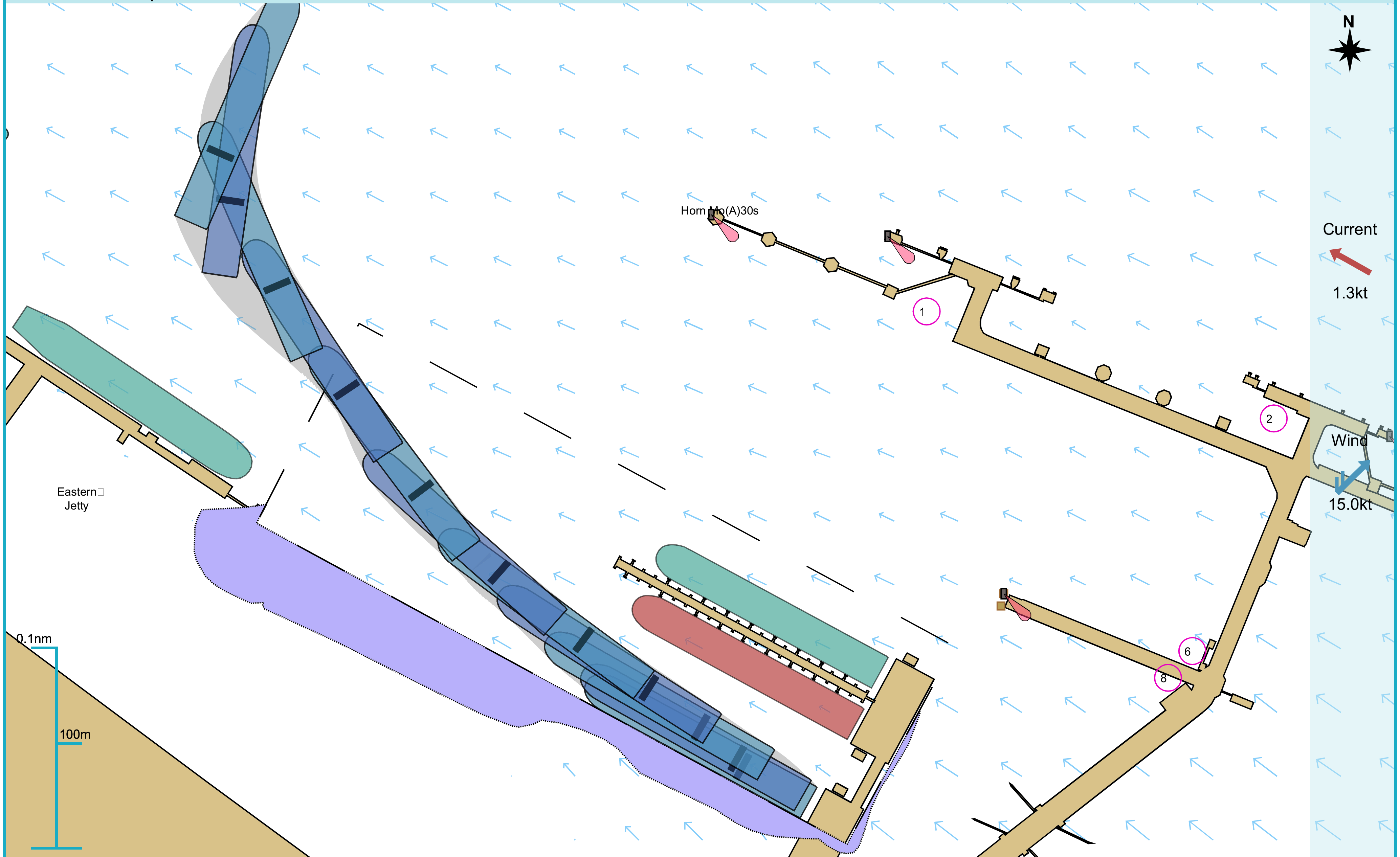
Manoeuvre track plot



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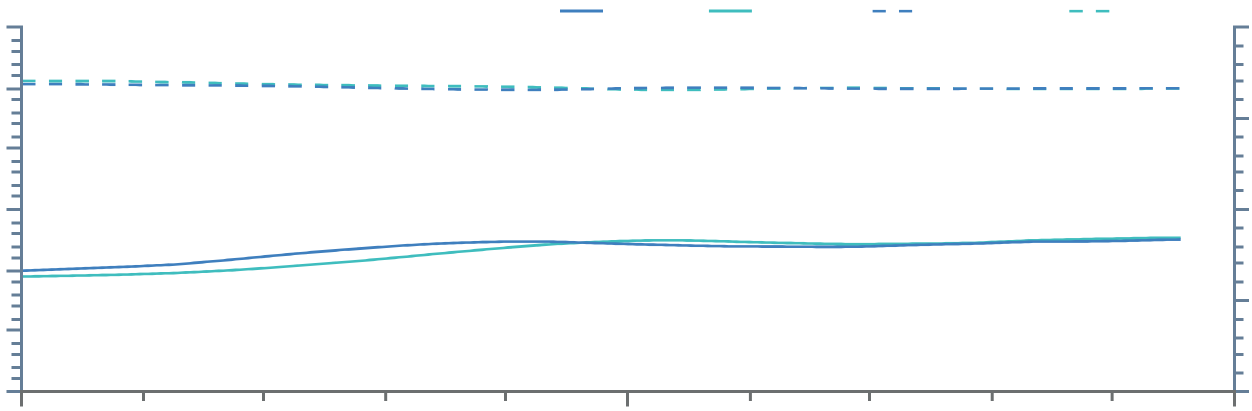
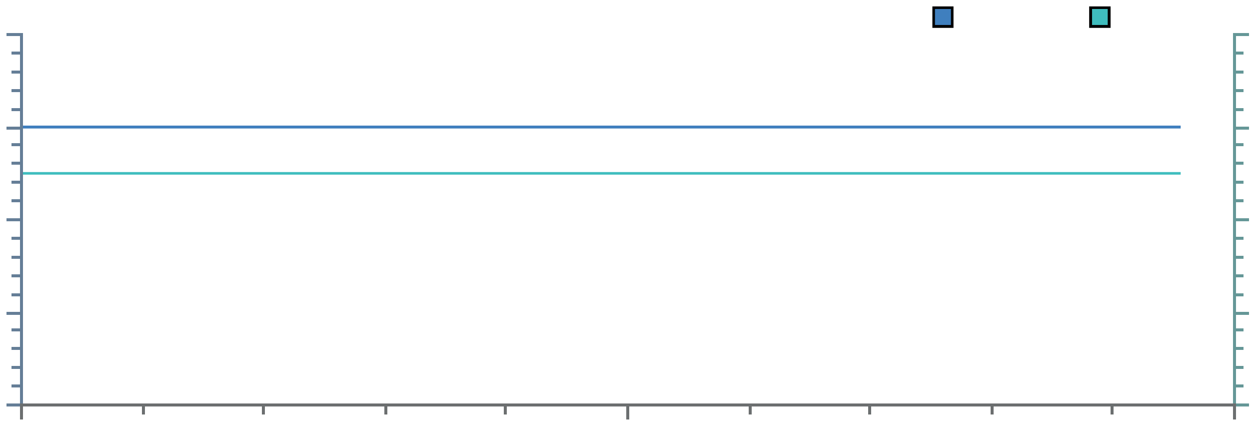
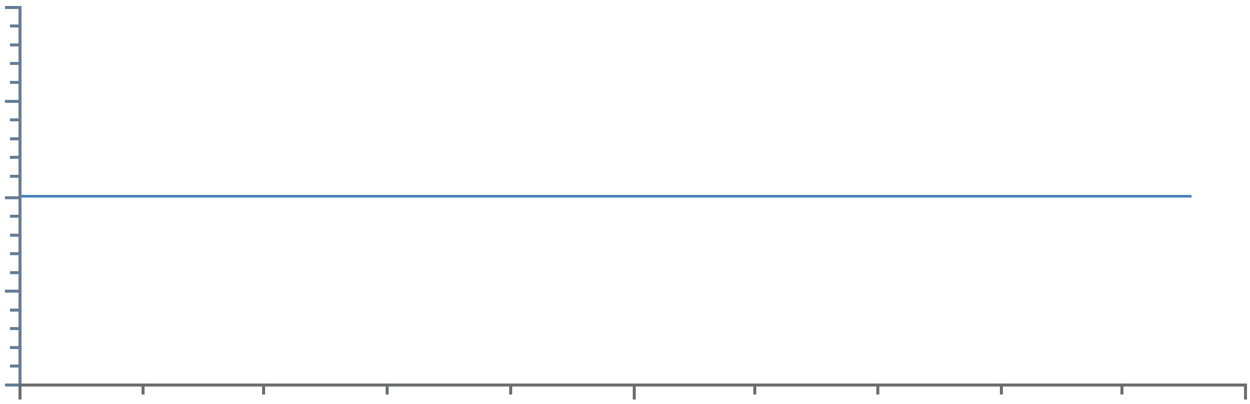
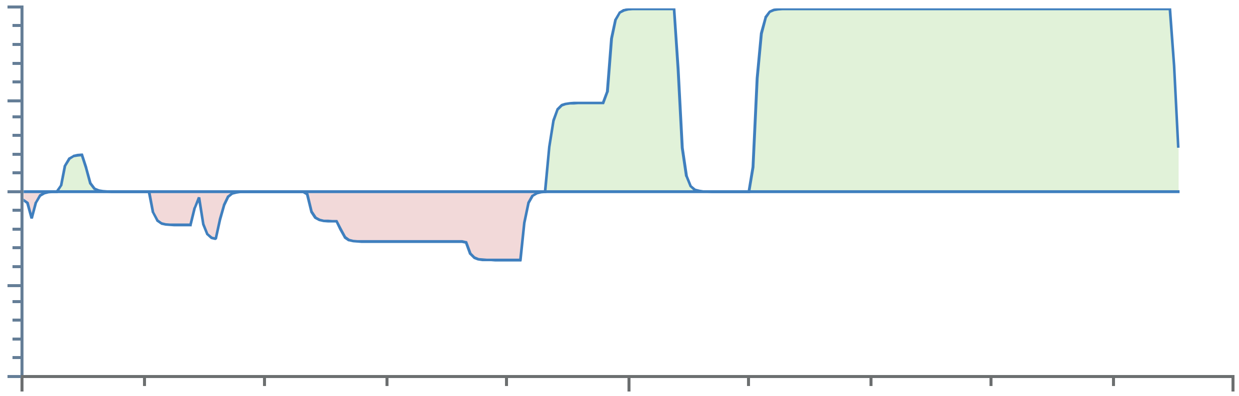
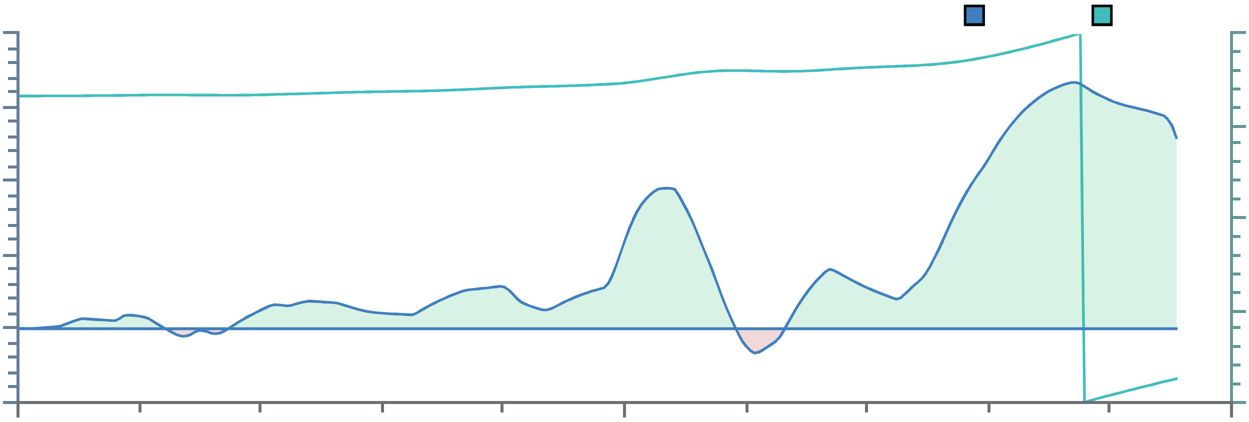
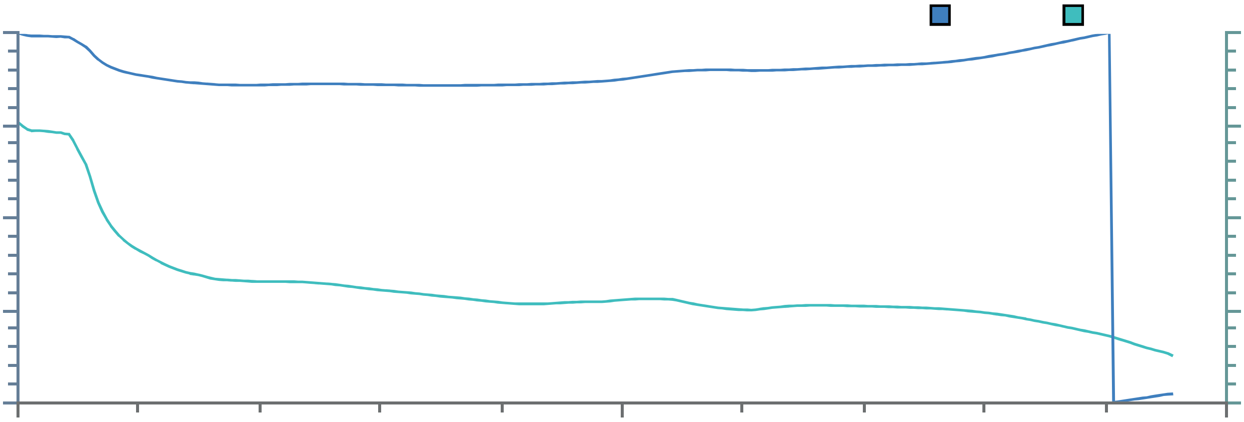


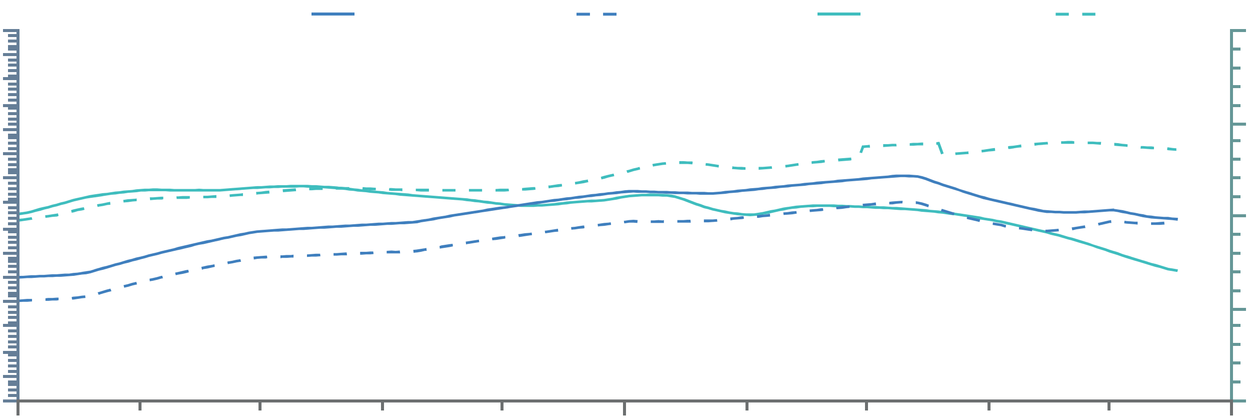


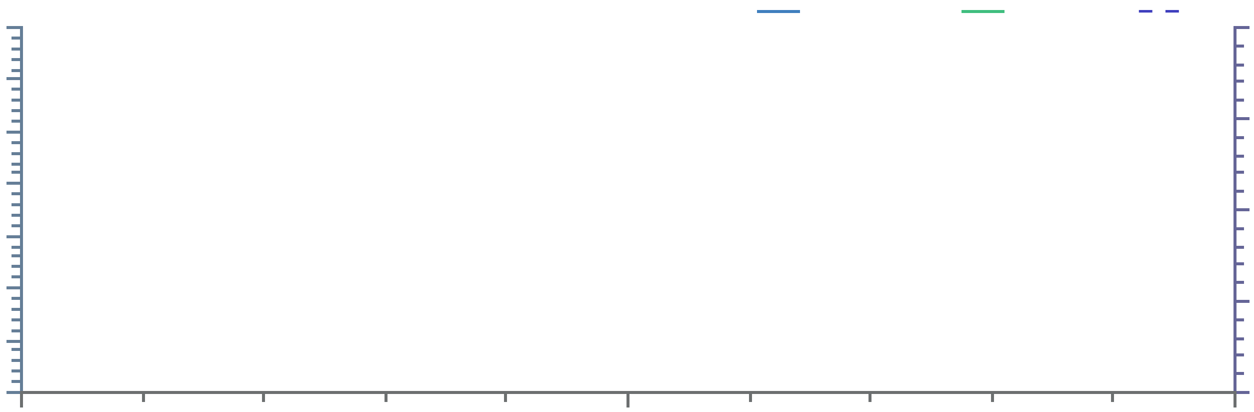


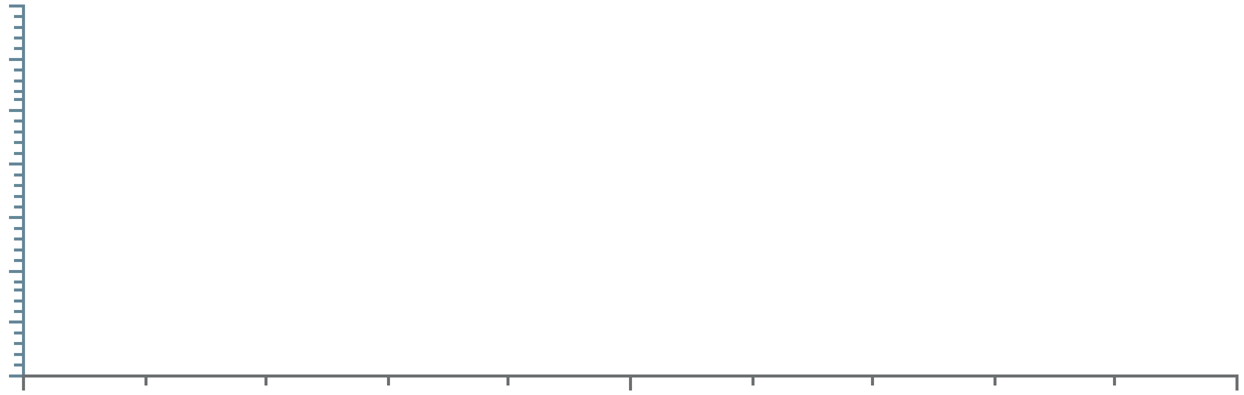




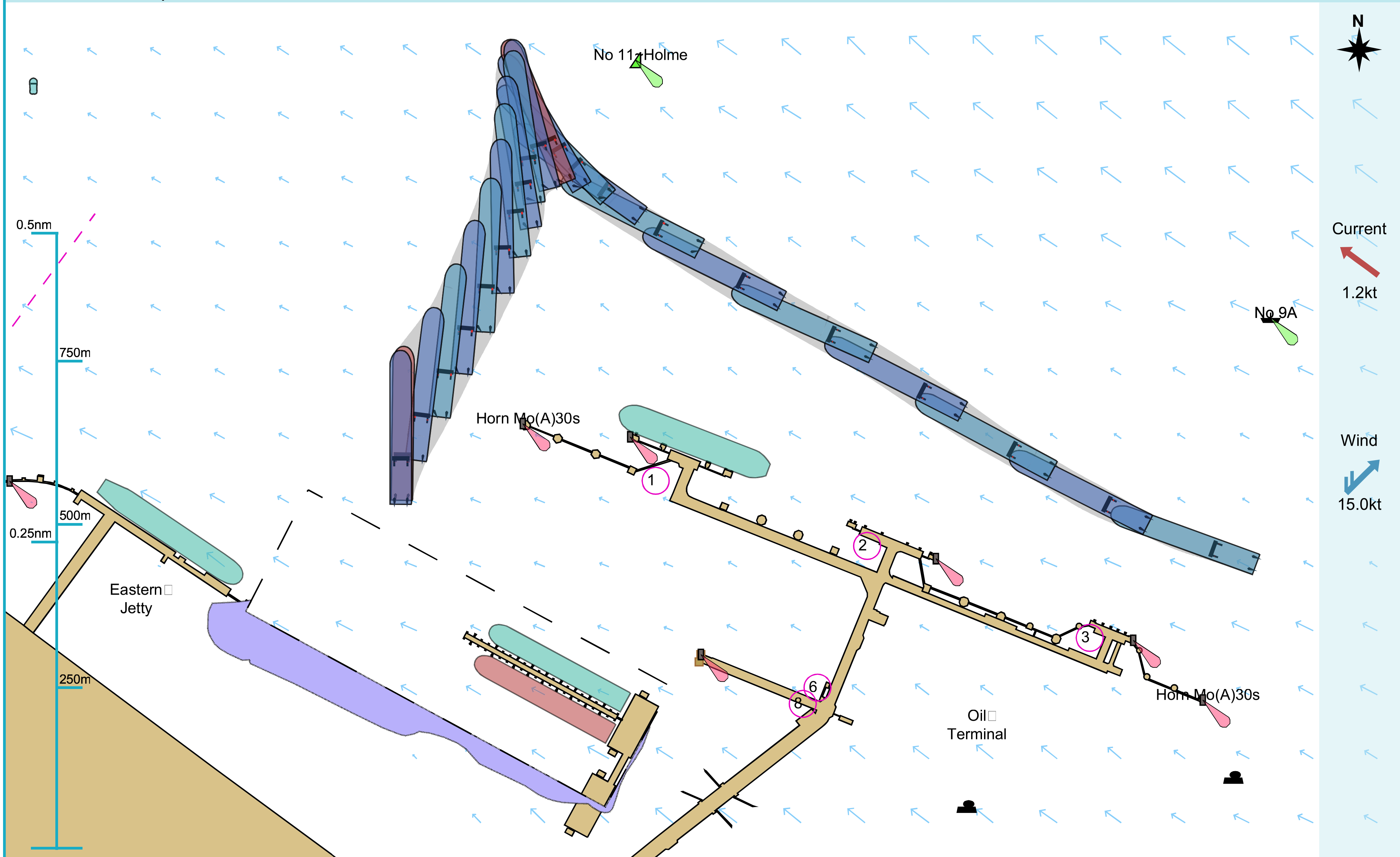








Manoeuvre track plot



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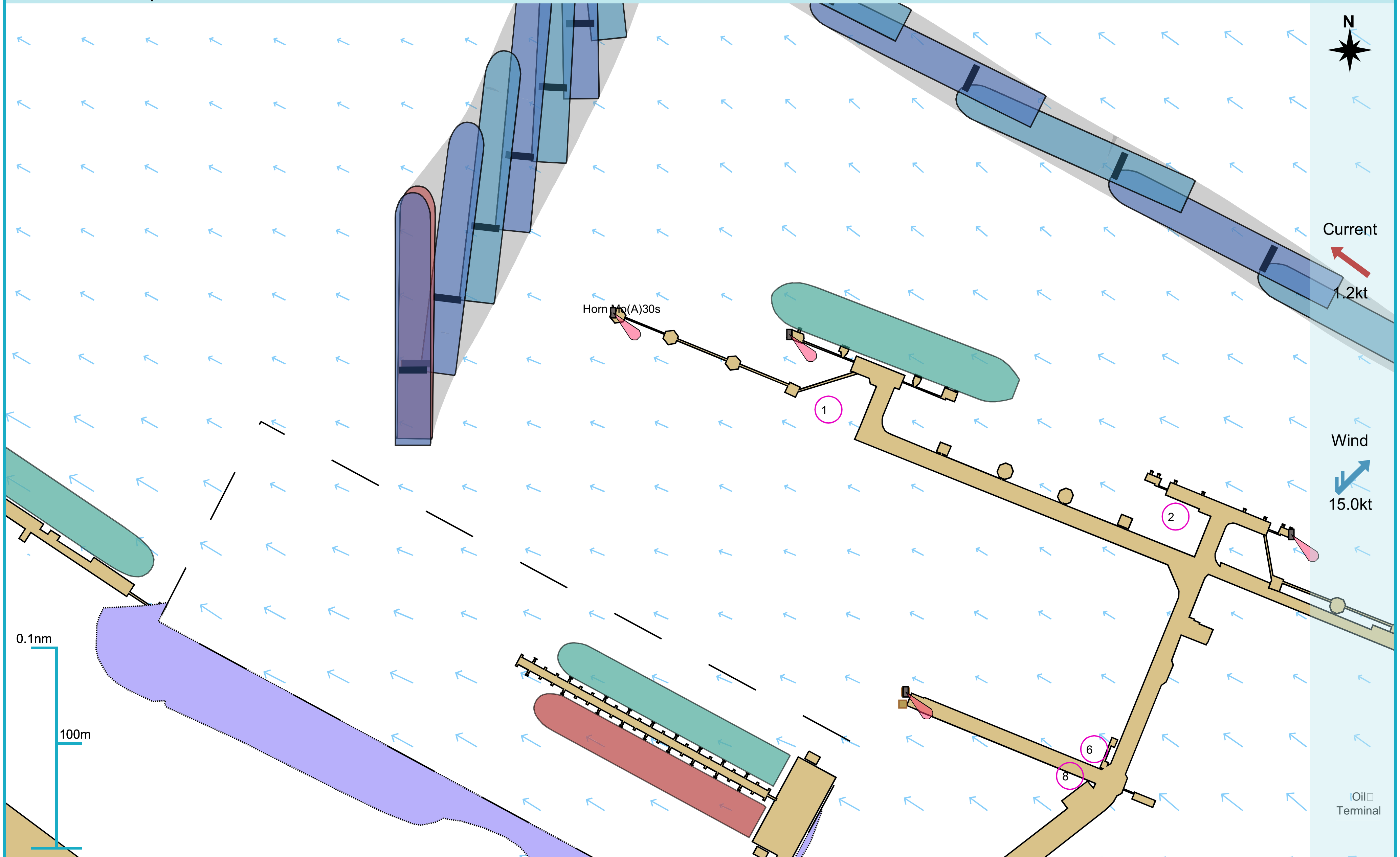

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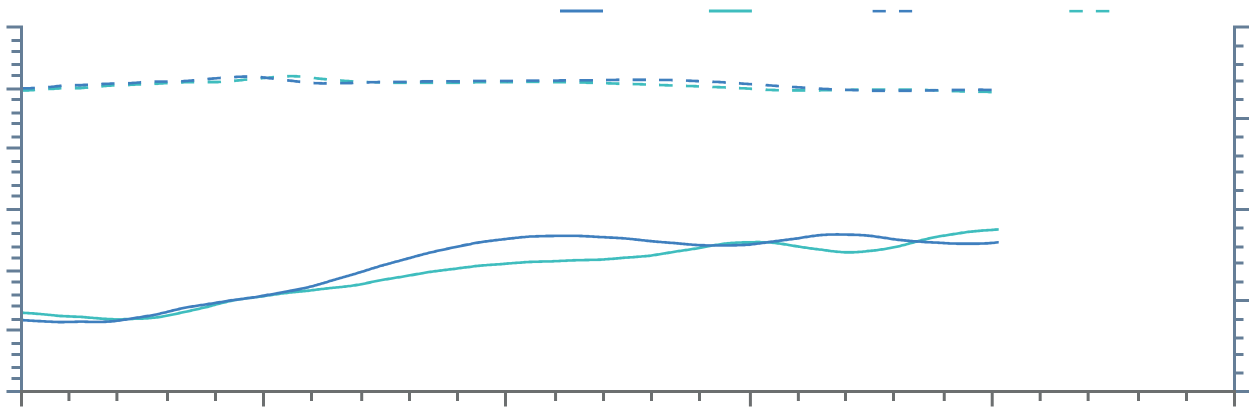

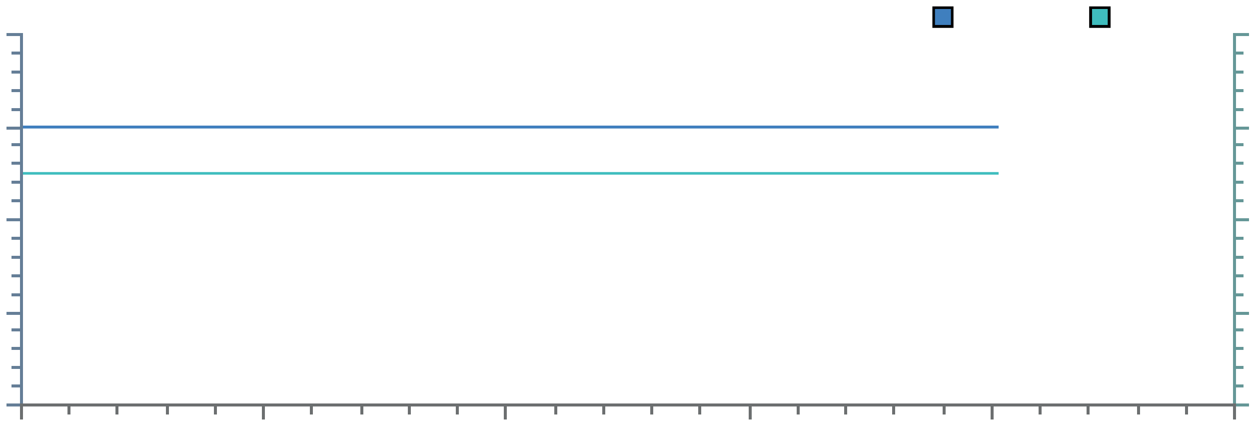

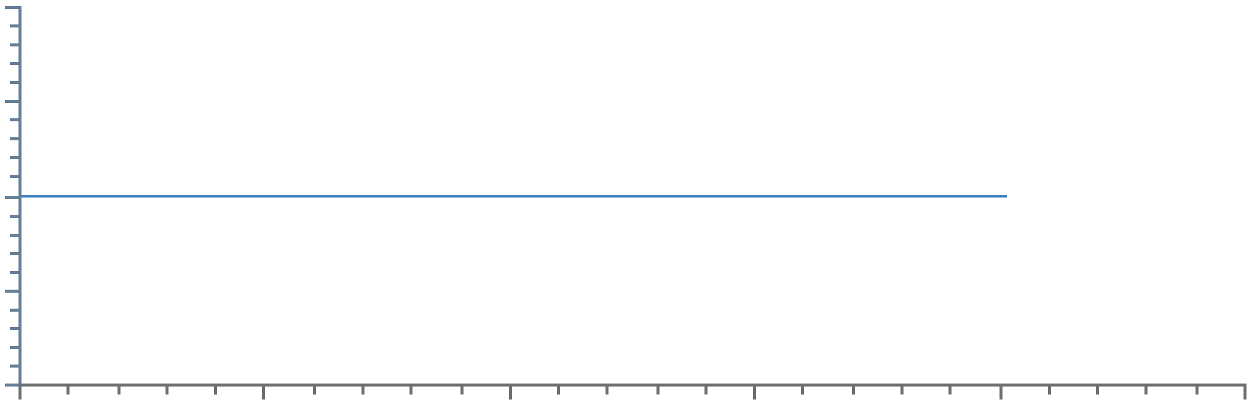

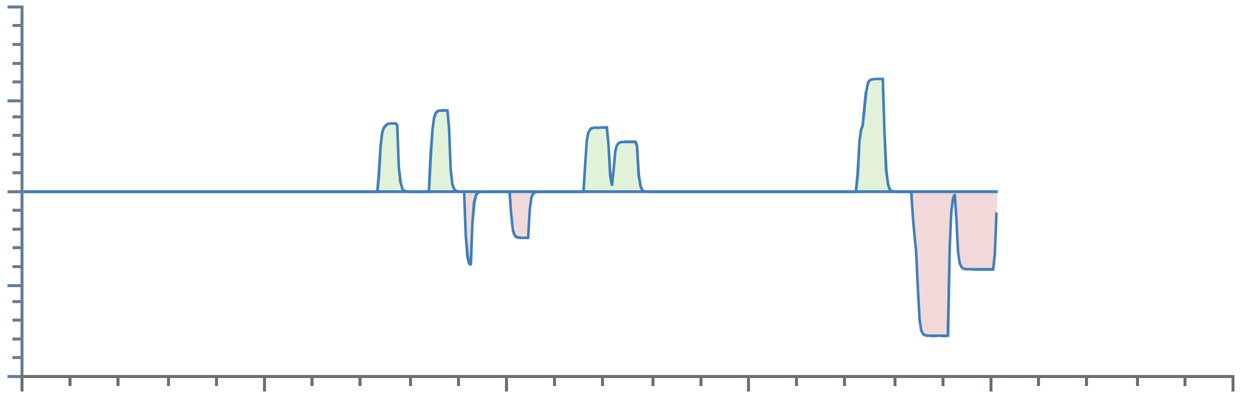

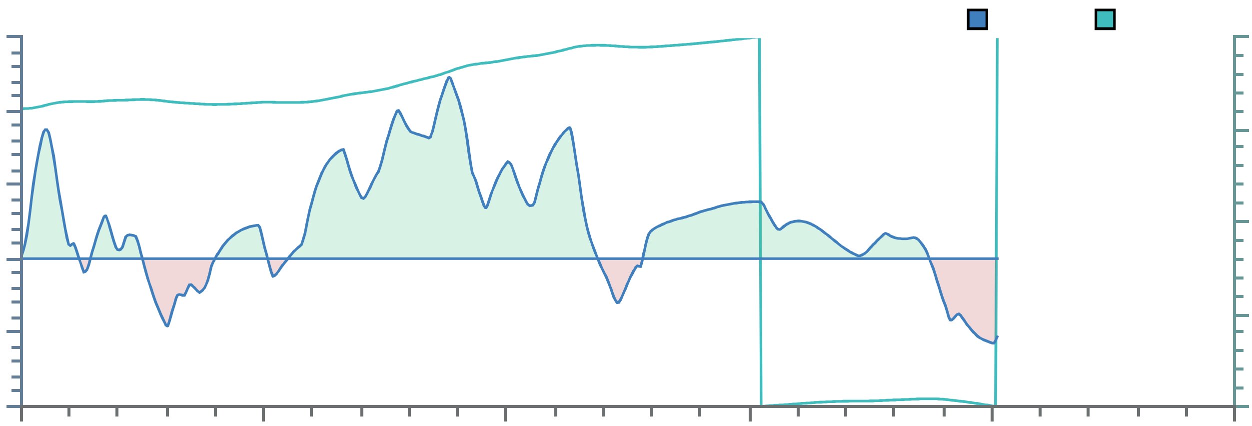

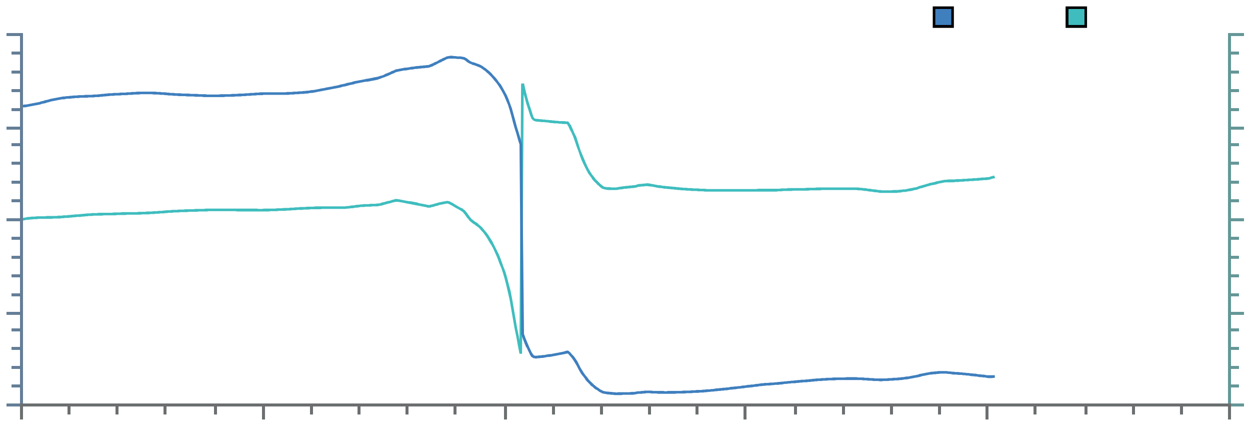

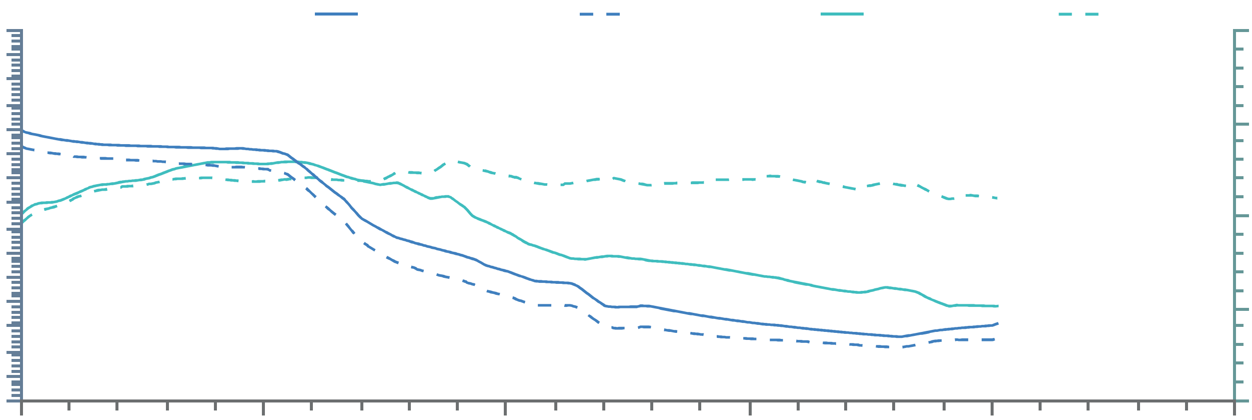

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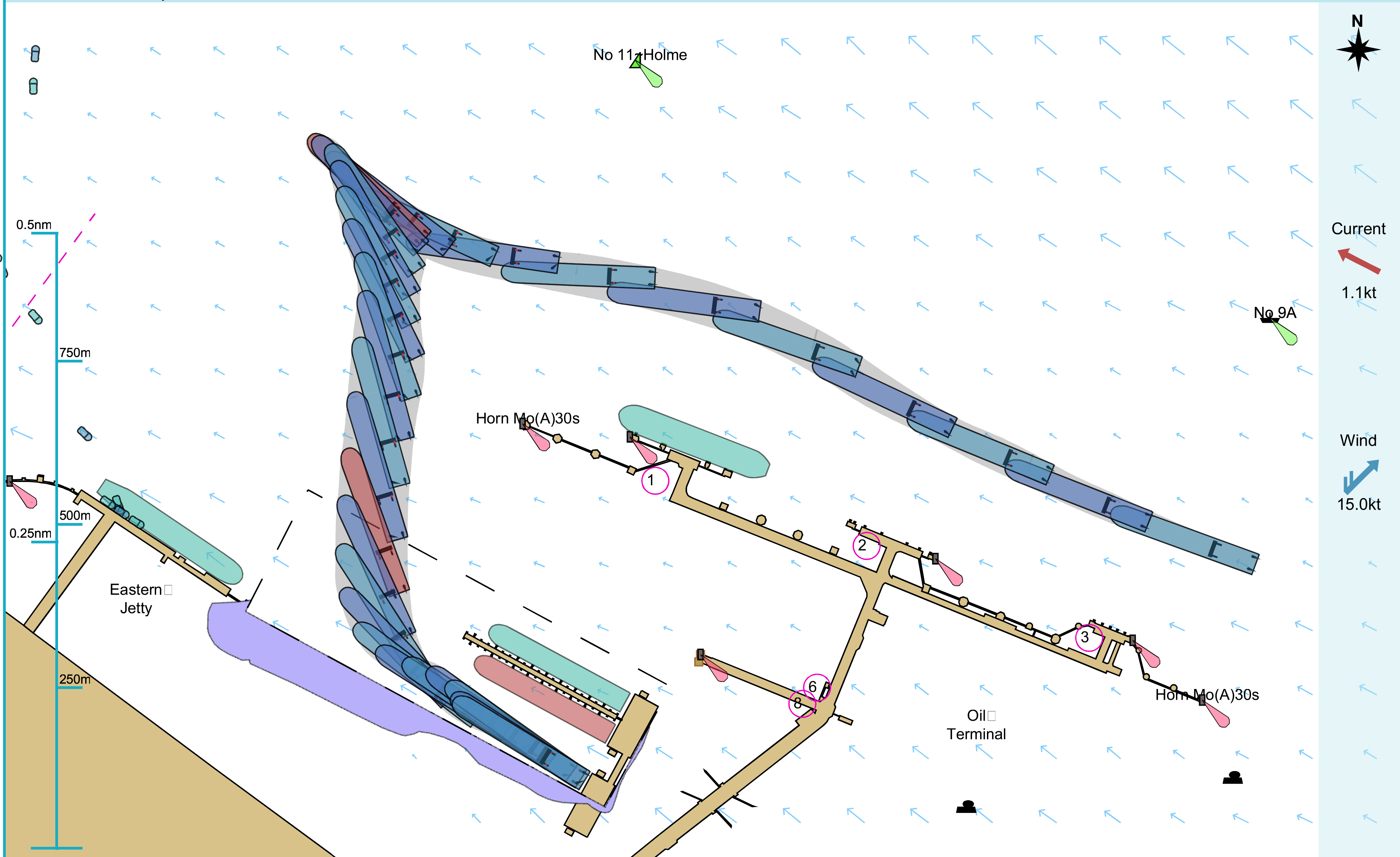

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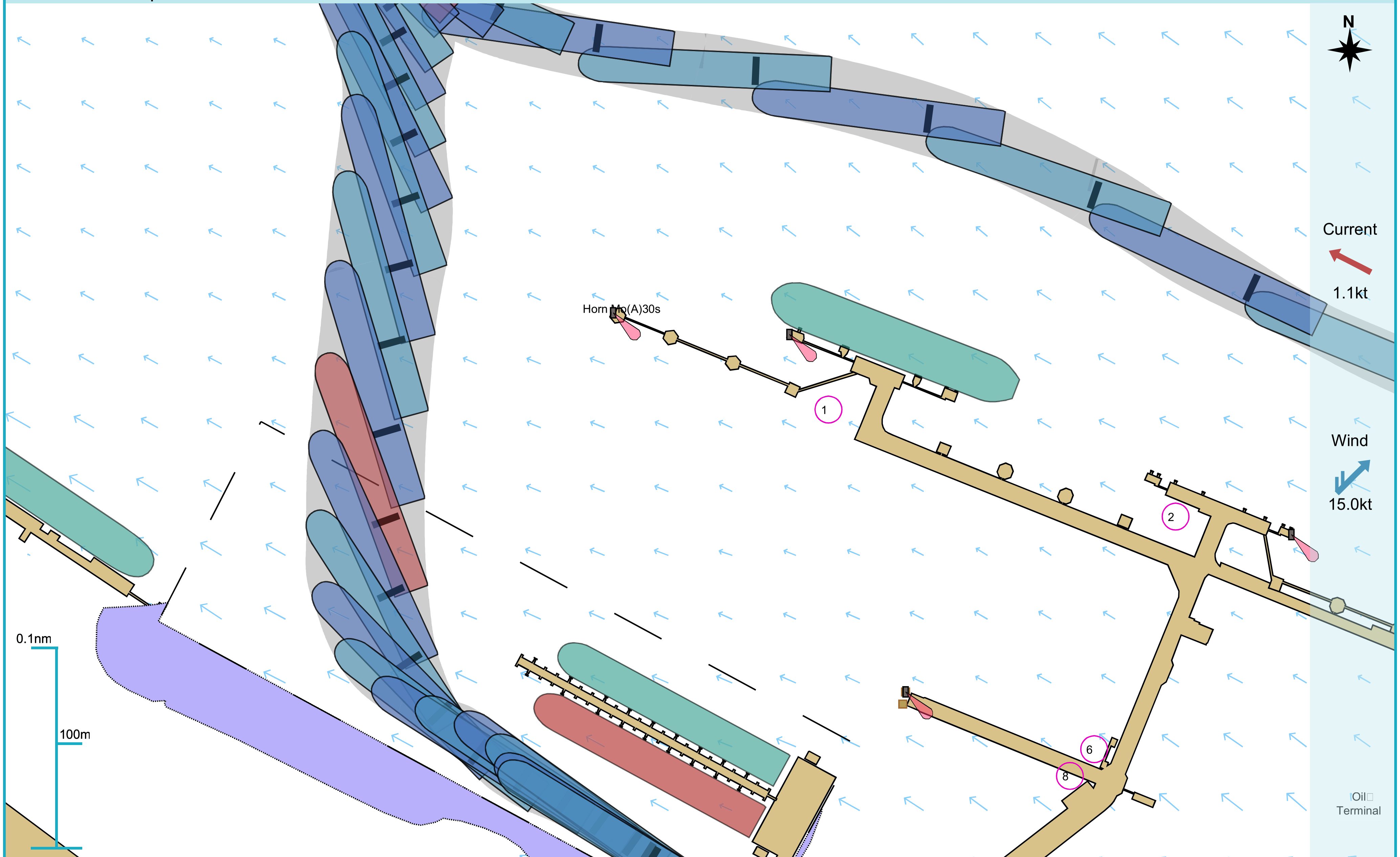

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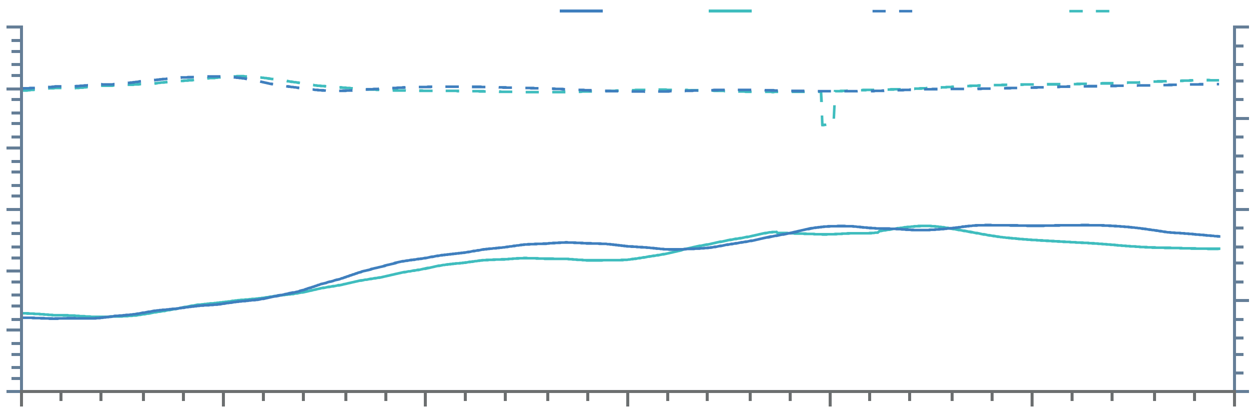
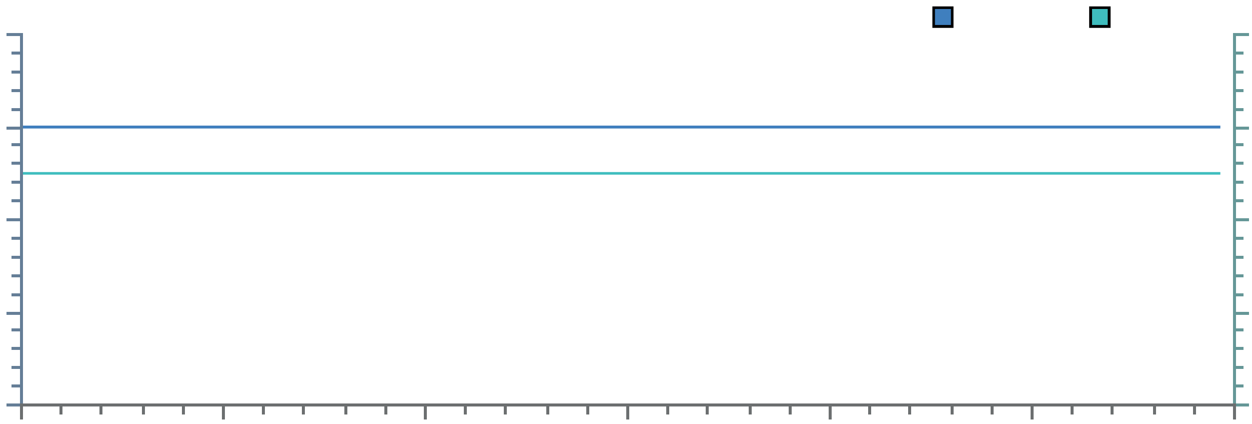
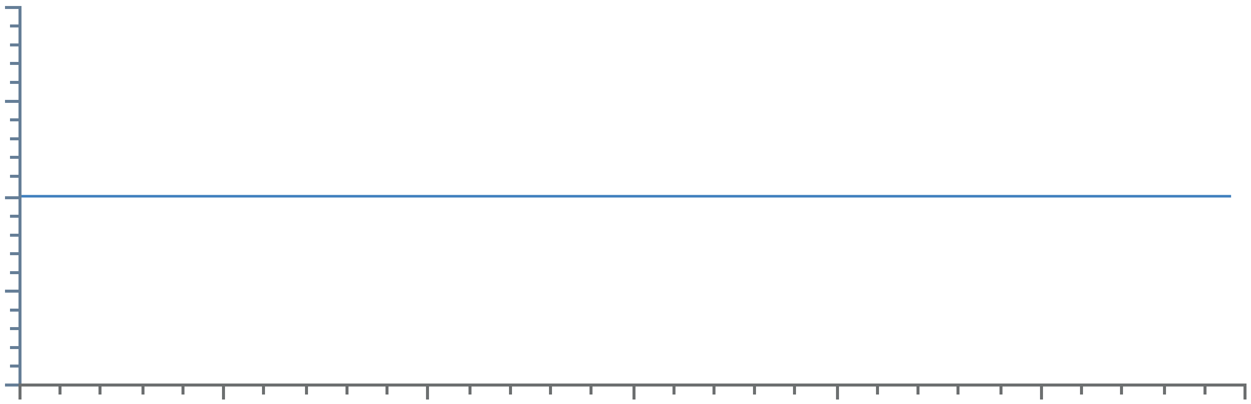
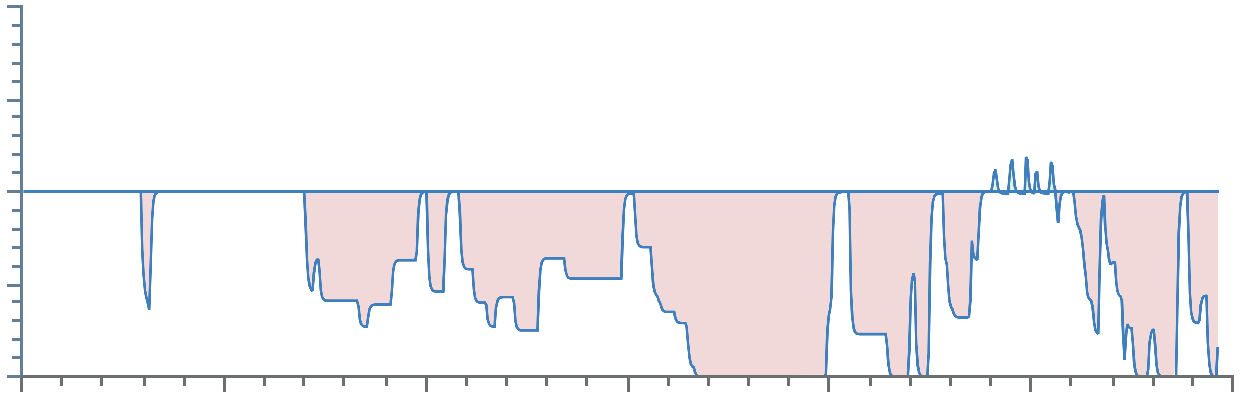
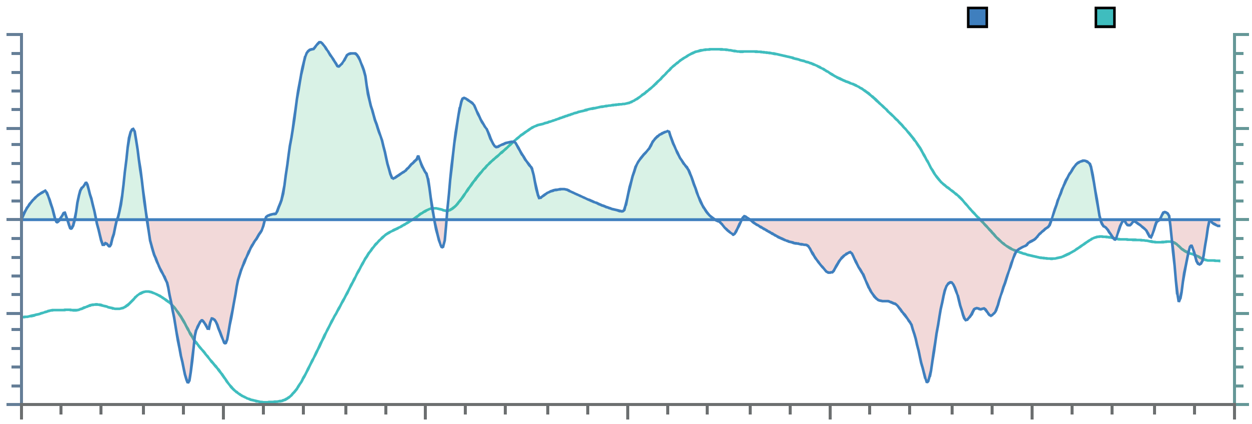
Summary | Environment | 237m RoRo unnamed

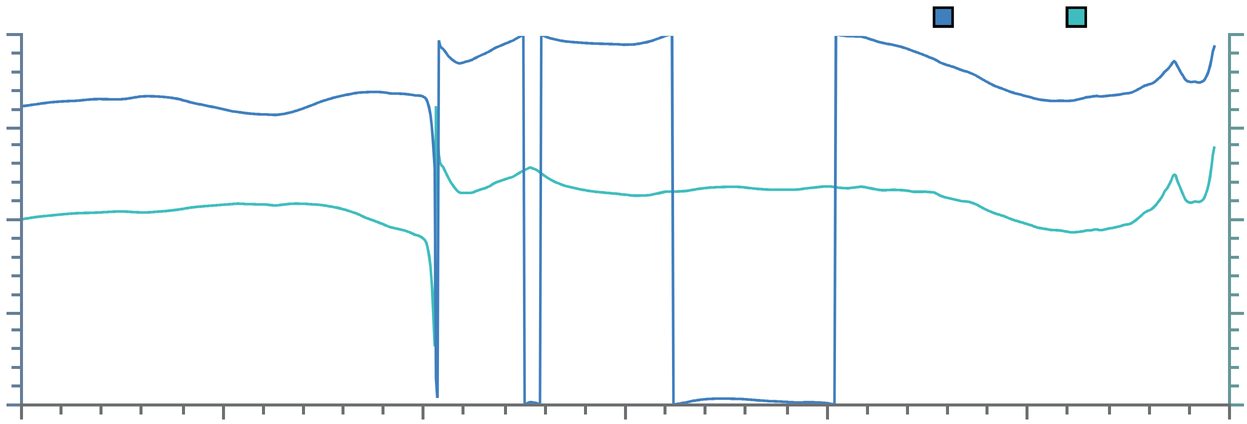


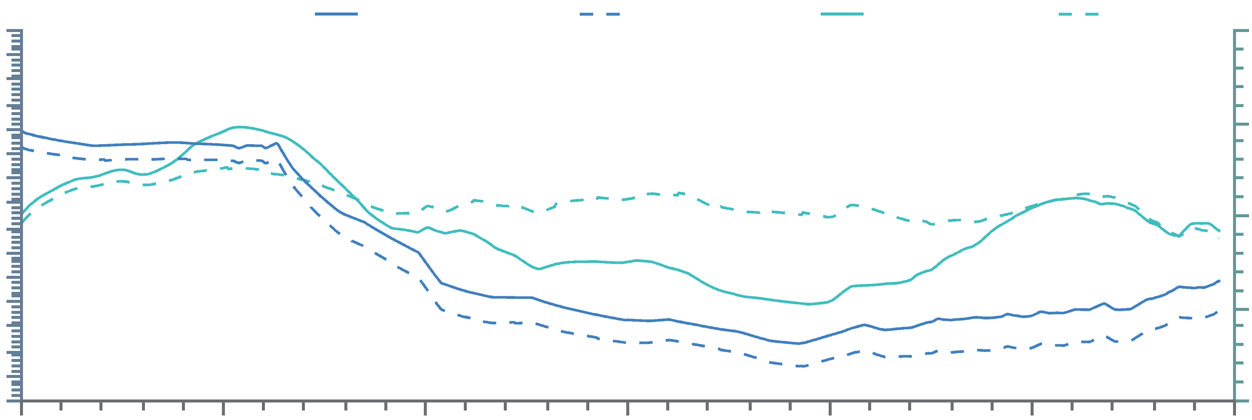




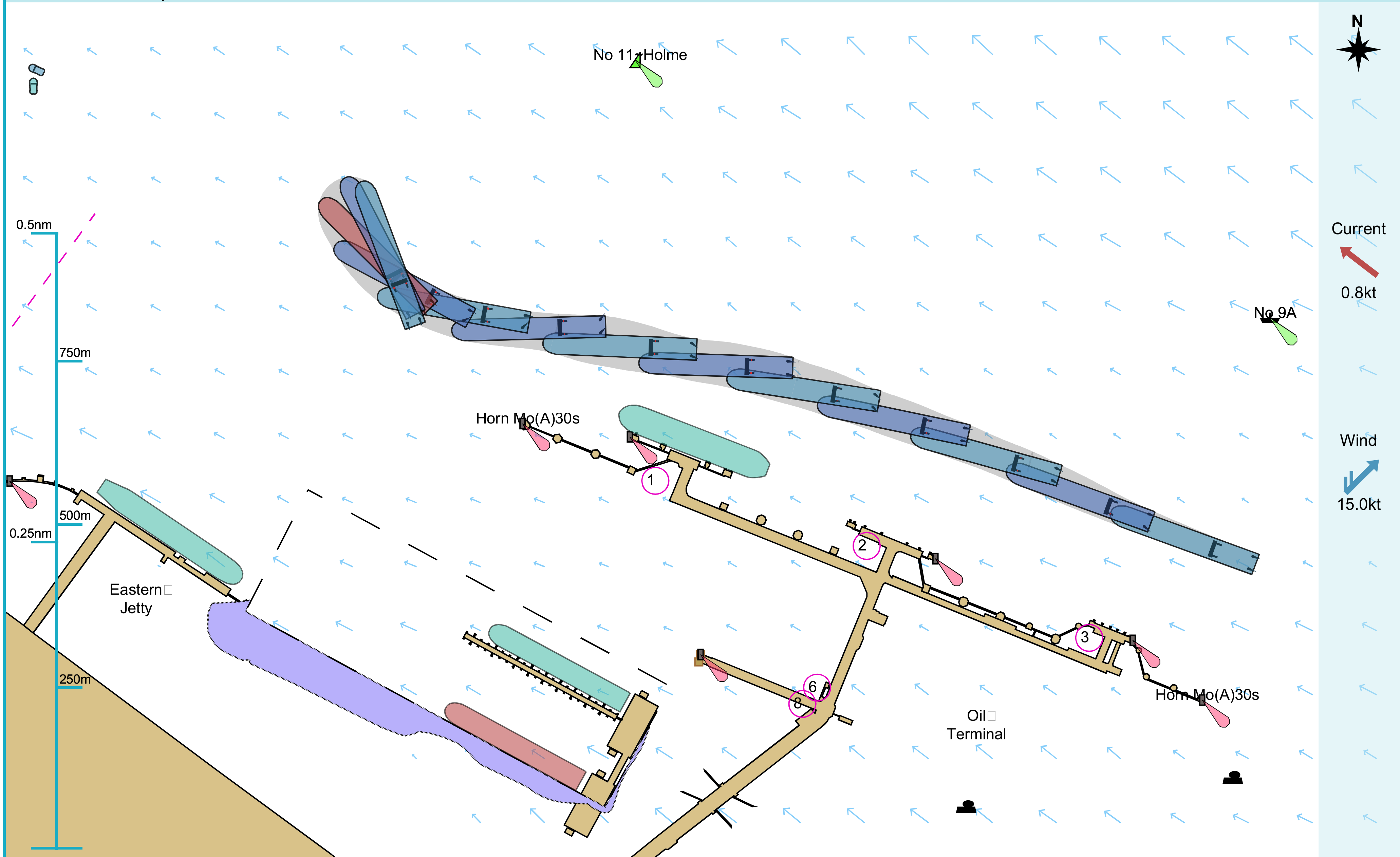








Manoeuvre track plot



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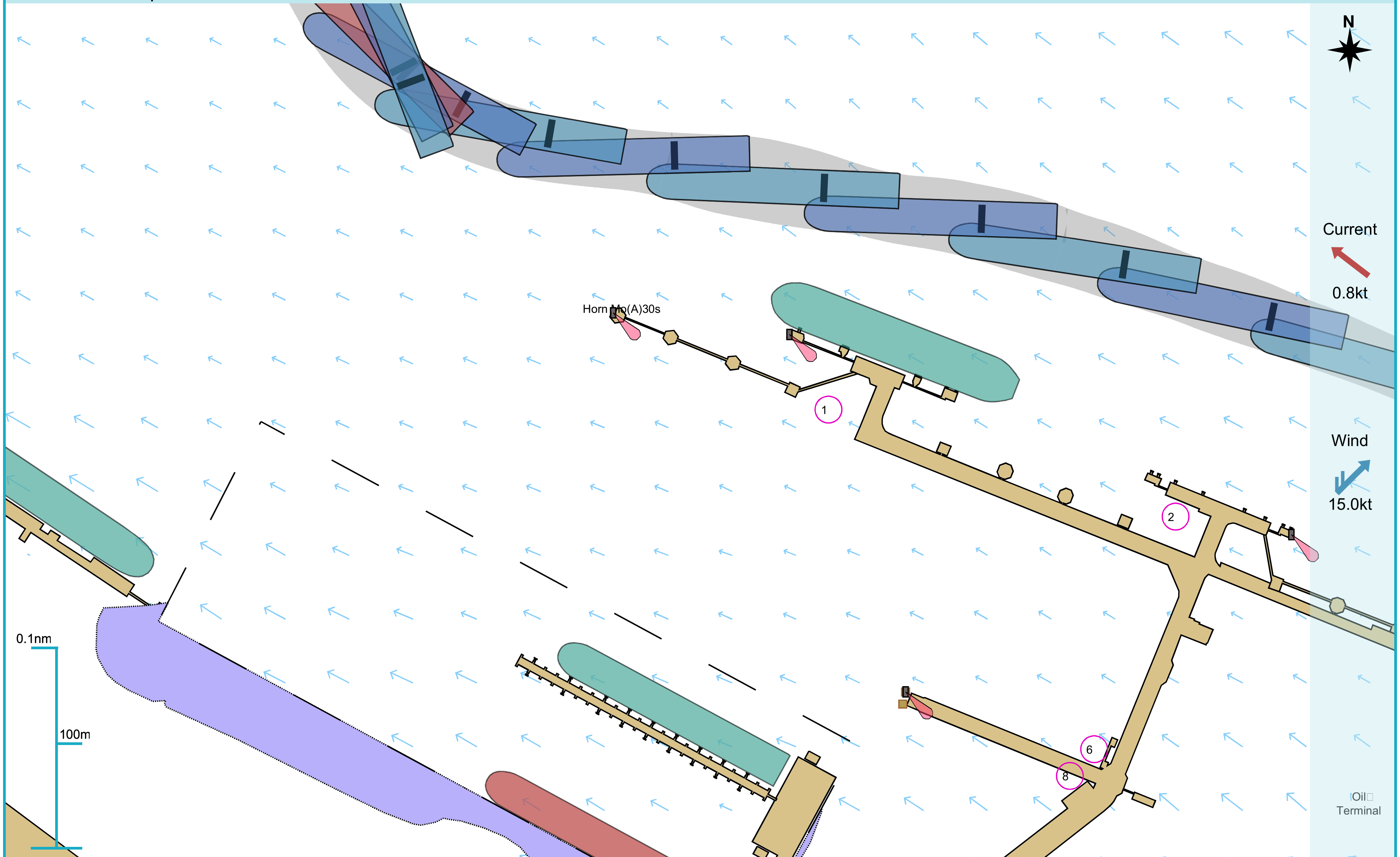
Manoeuvre track plot



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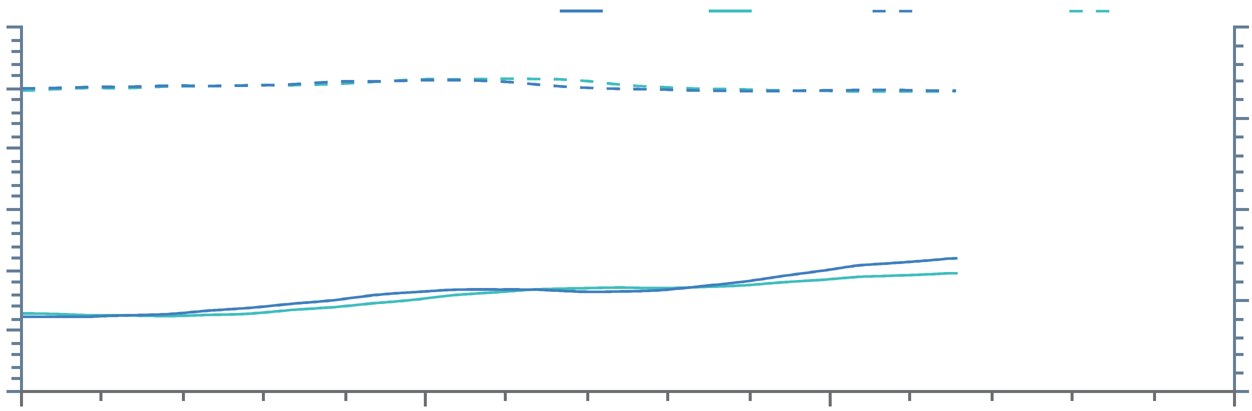
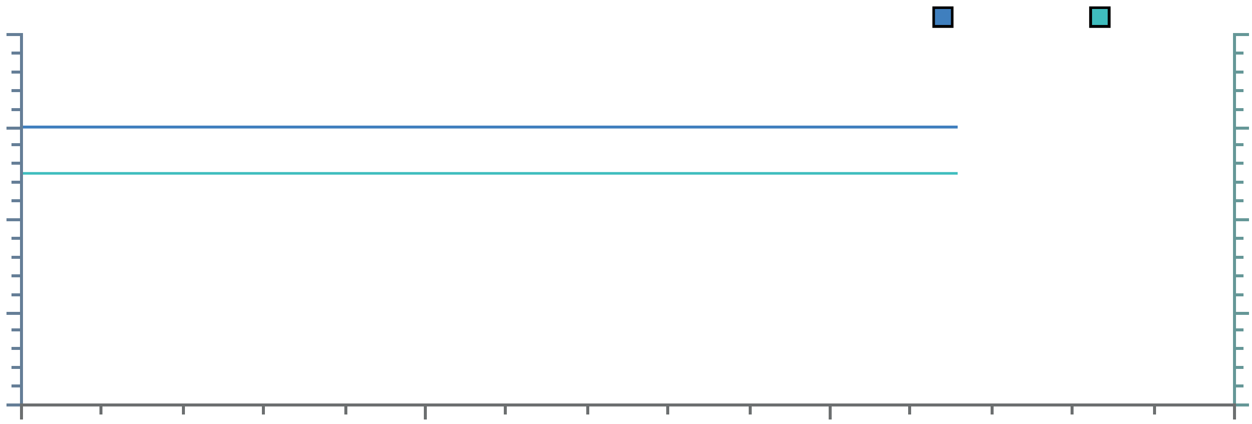
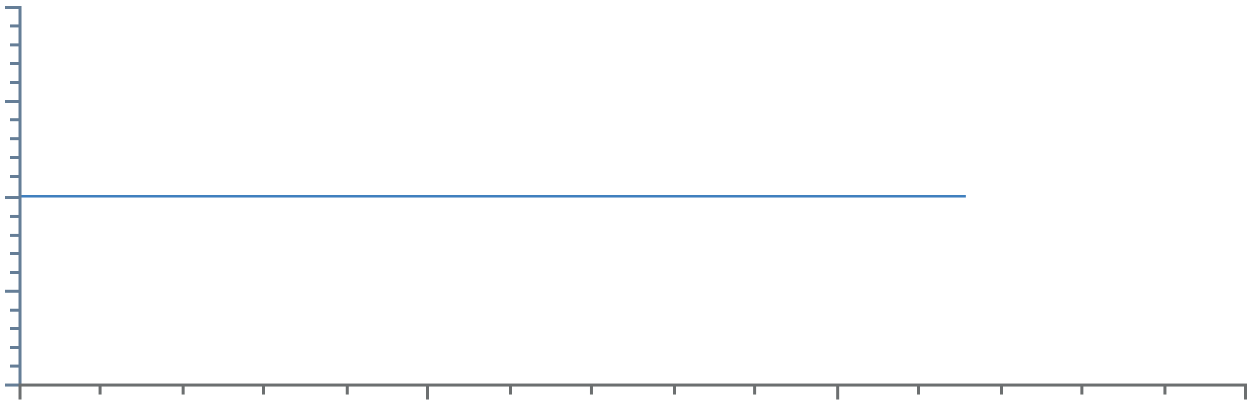
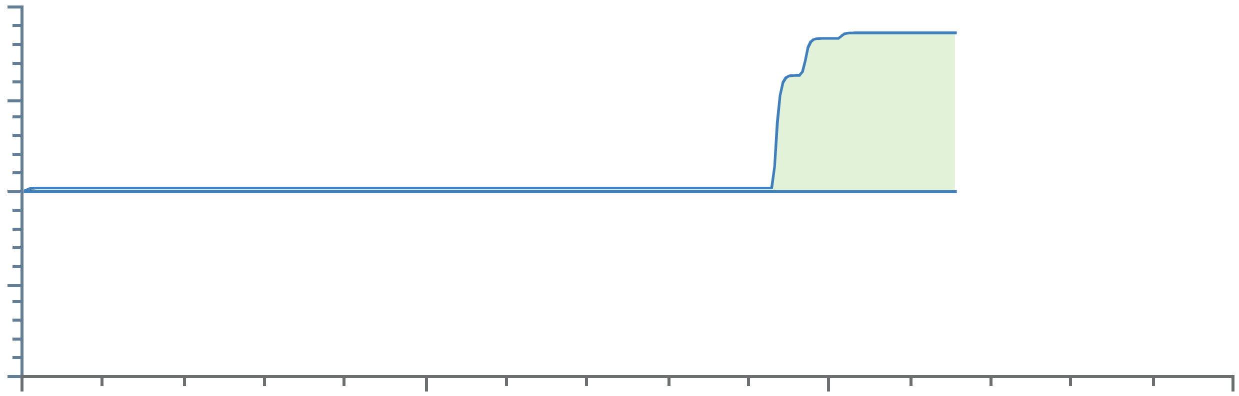
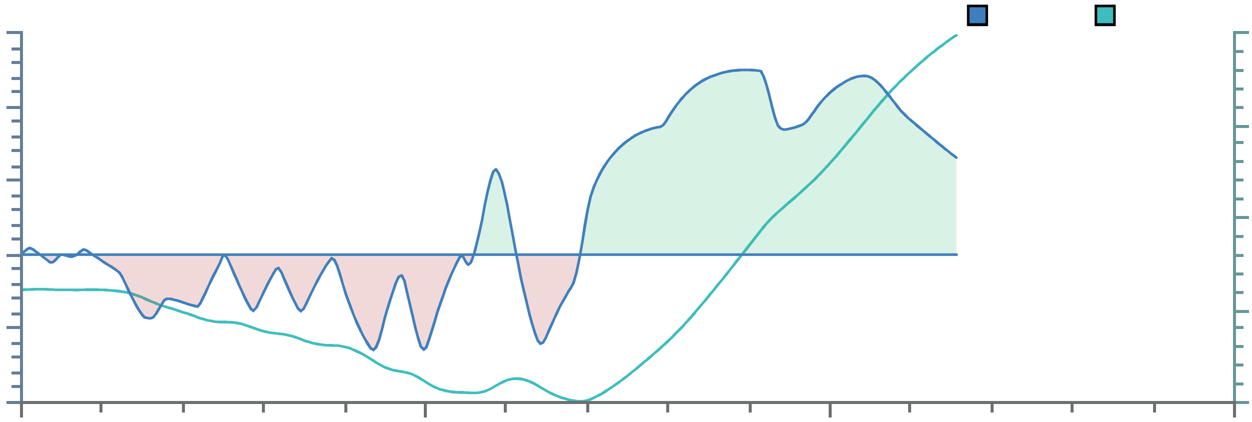
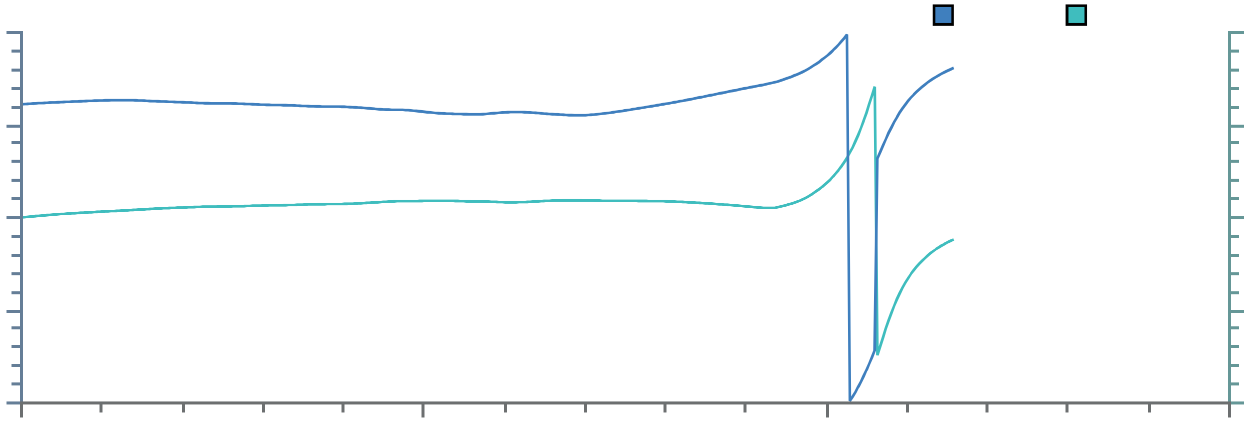


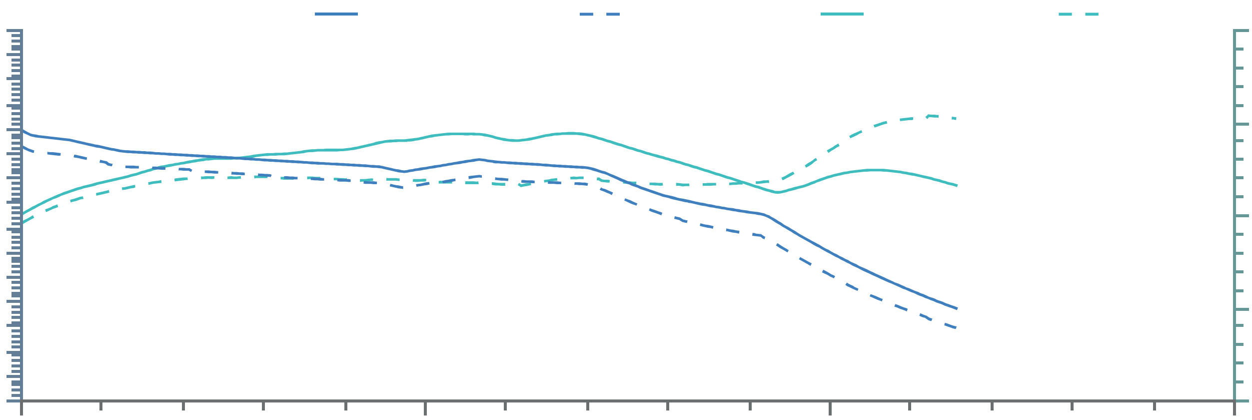




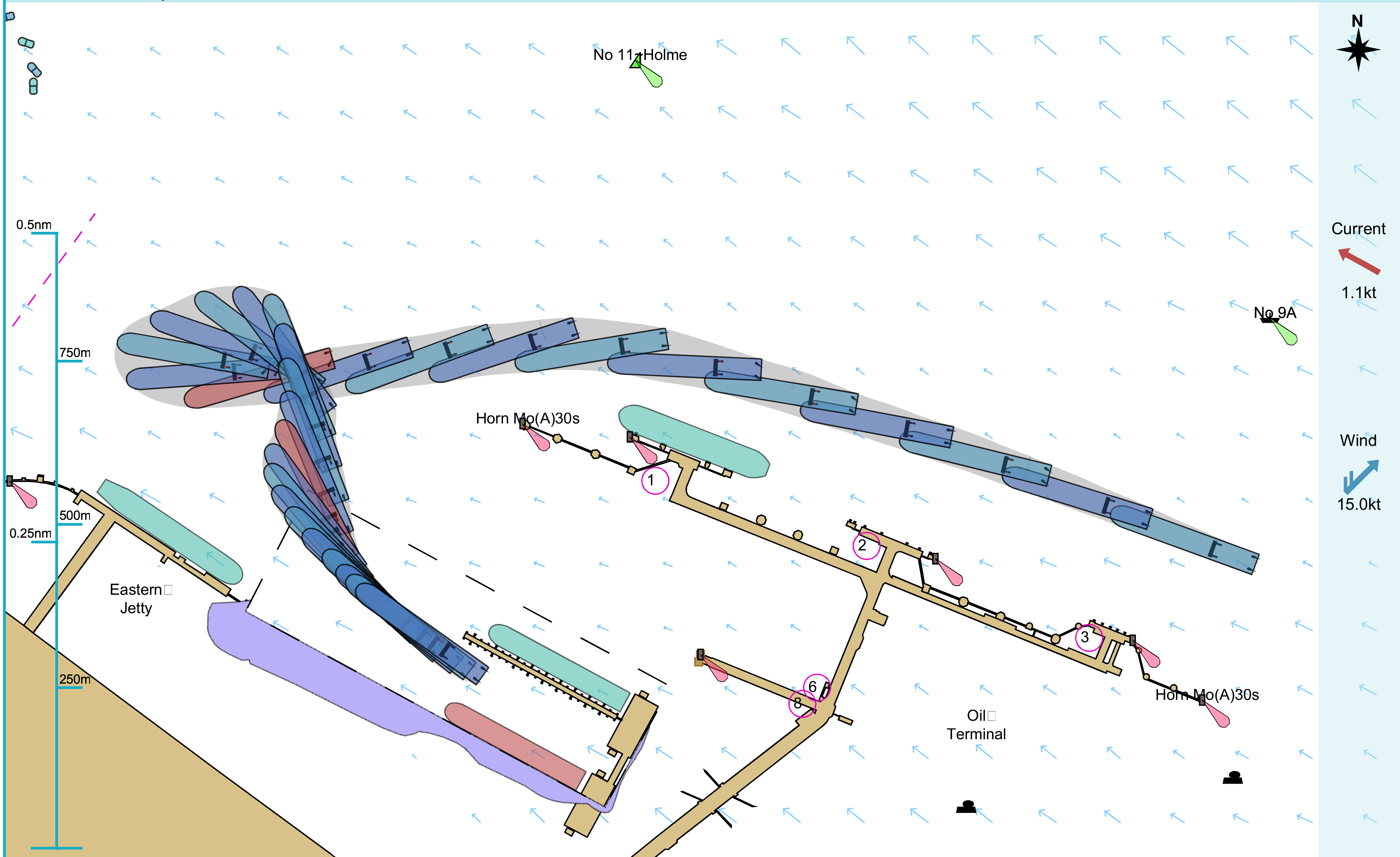








Manoeuvre track plot



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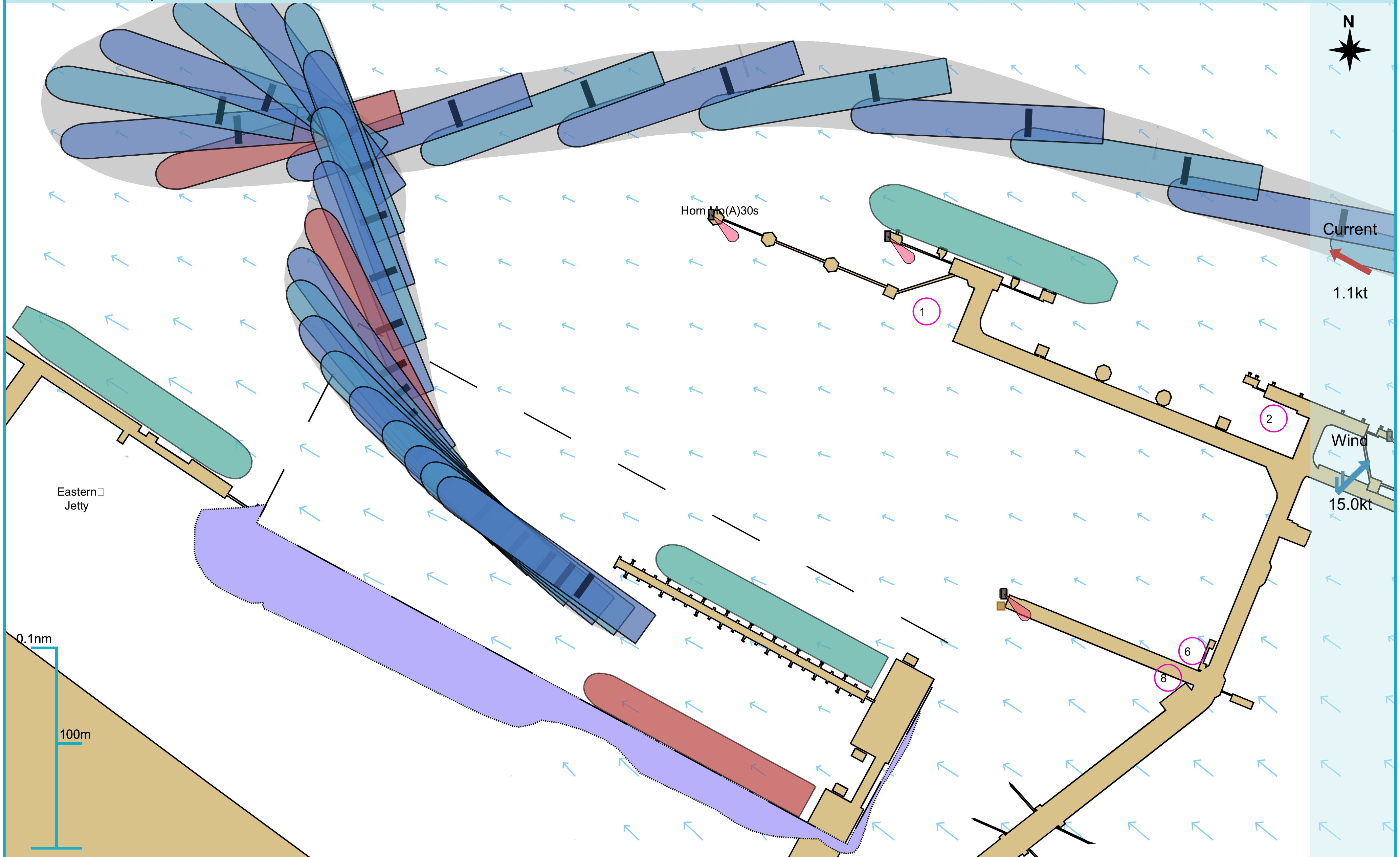
Summary | Environment | 237m RoRo unnamed

Manoeuvre track plot



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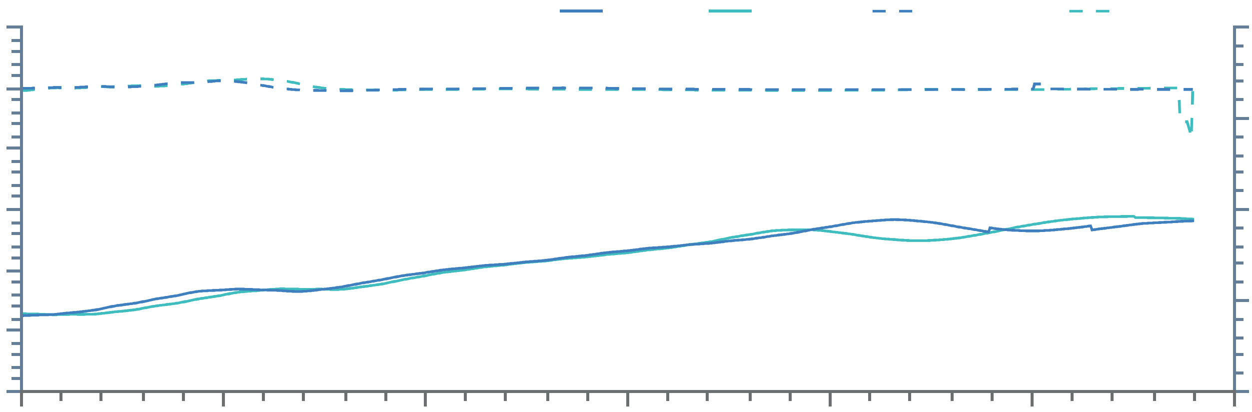

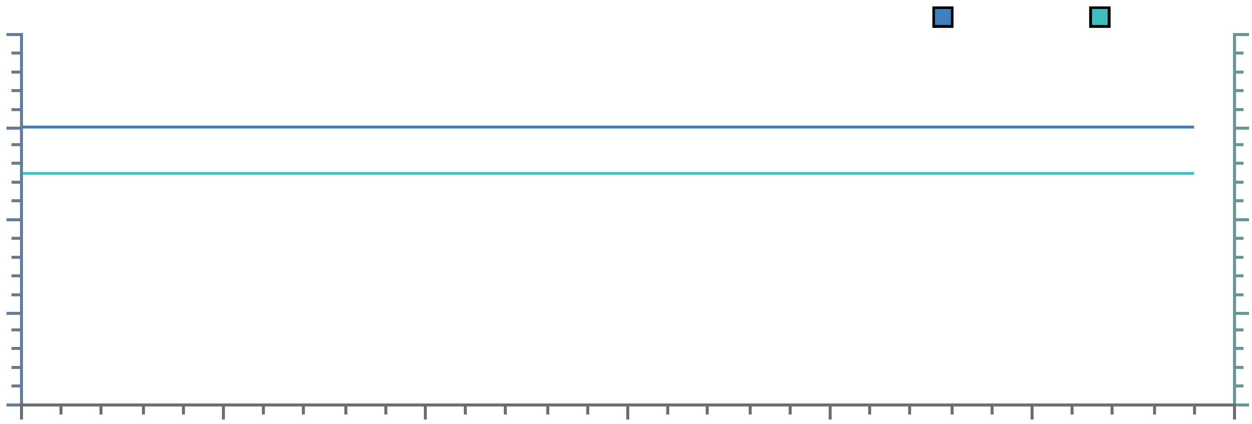

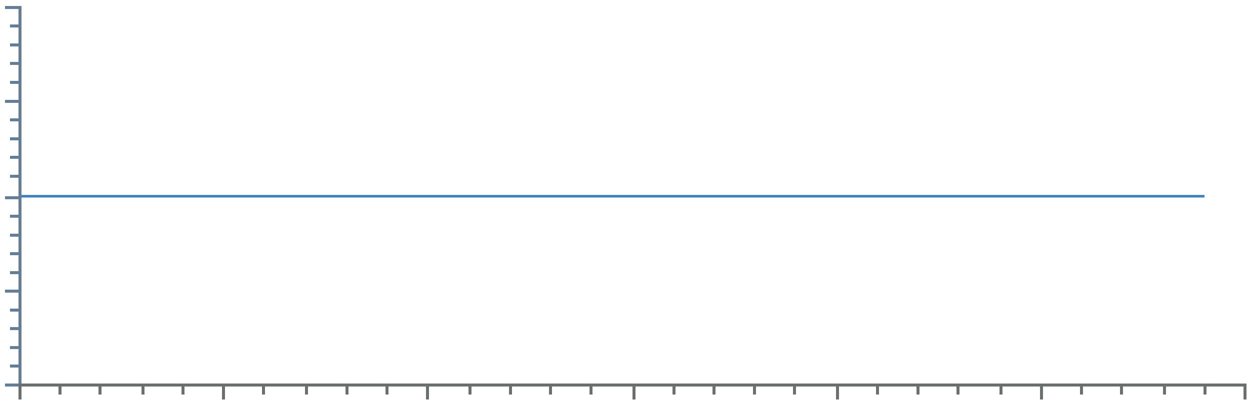

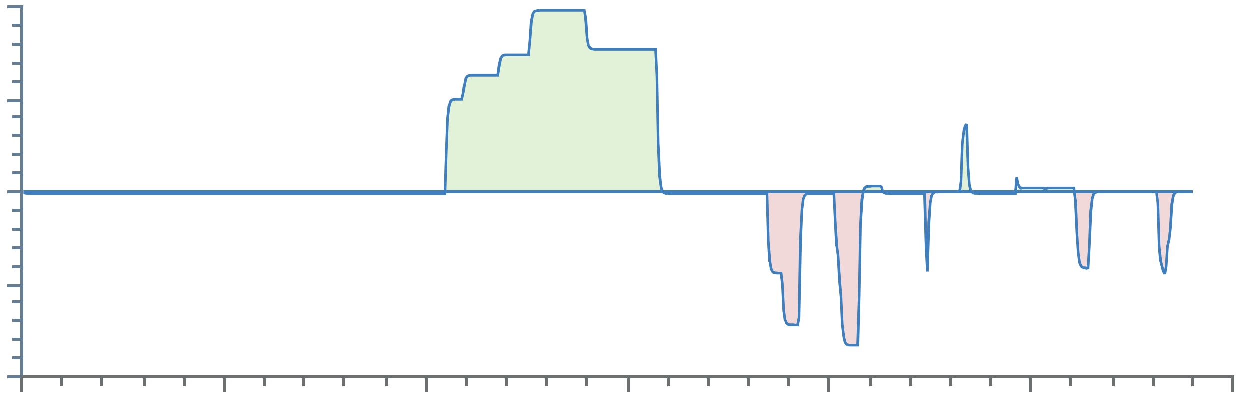

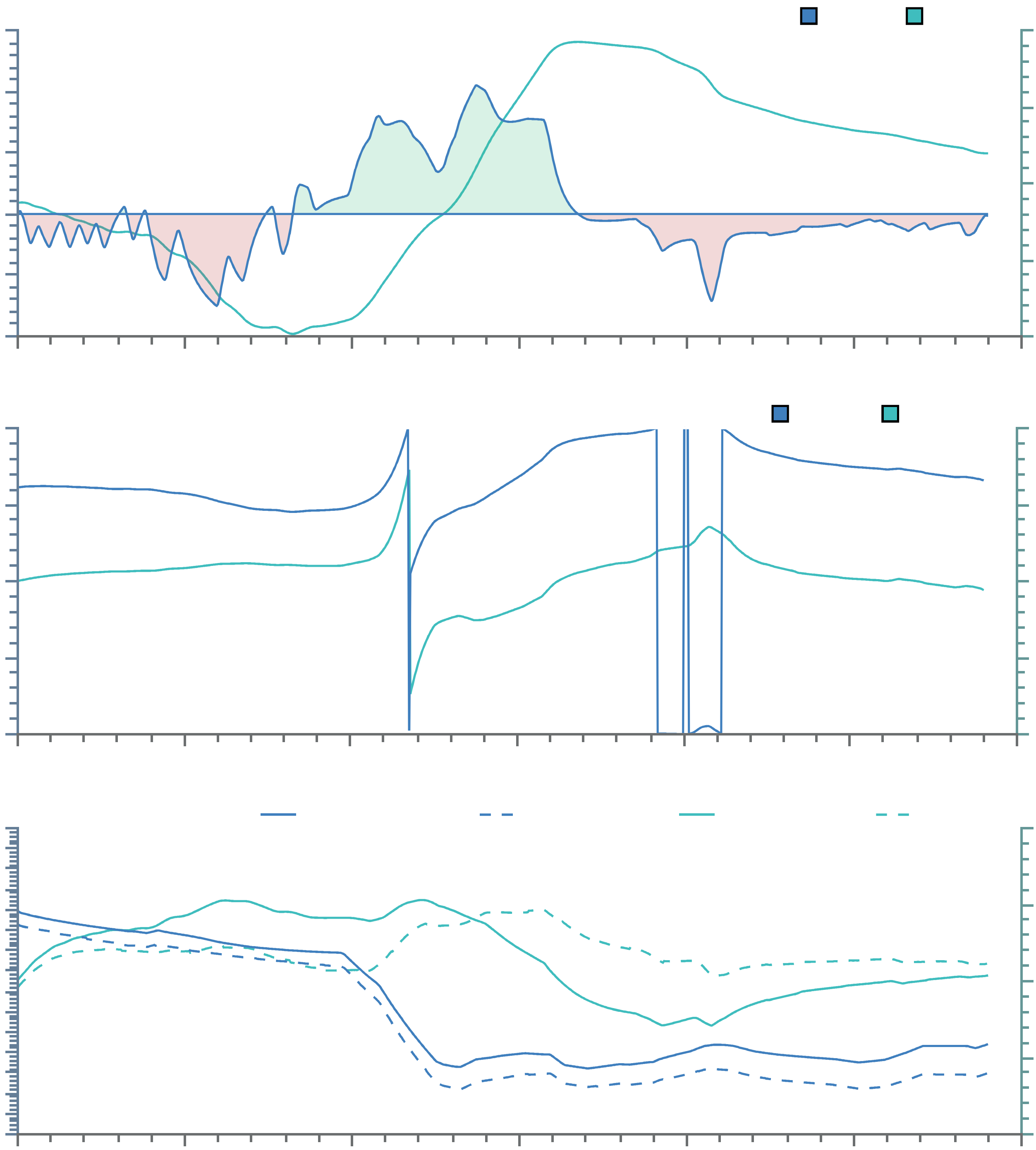

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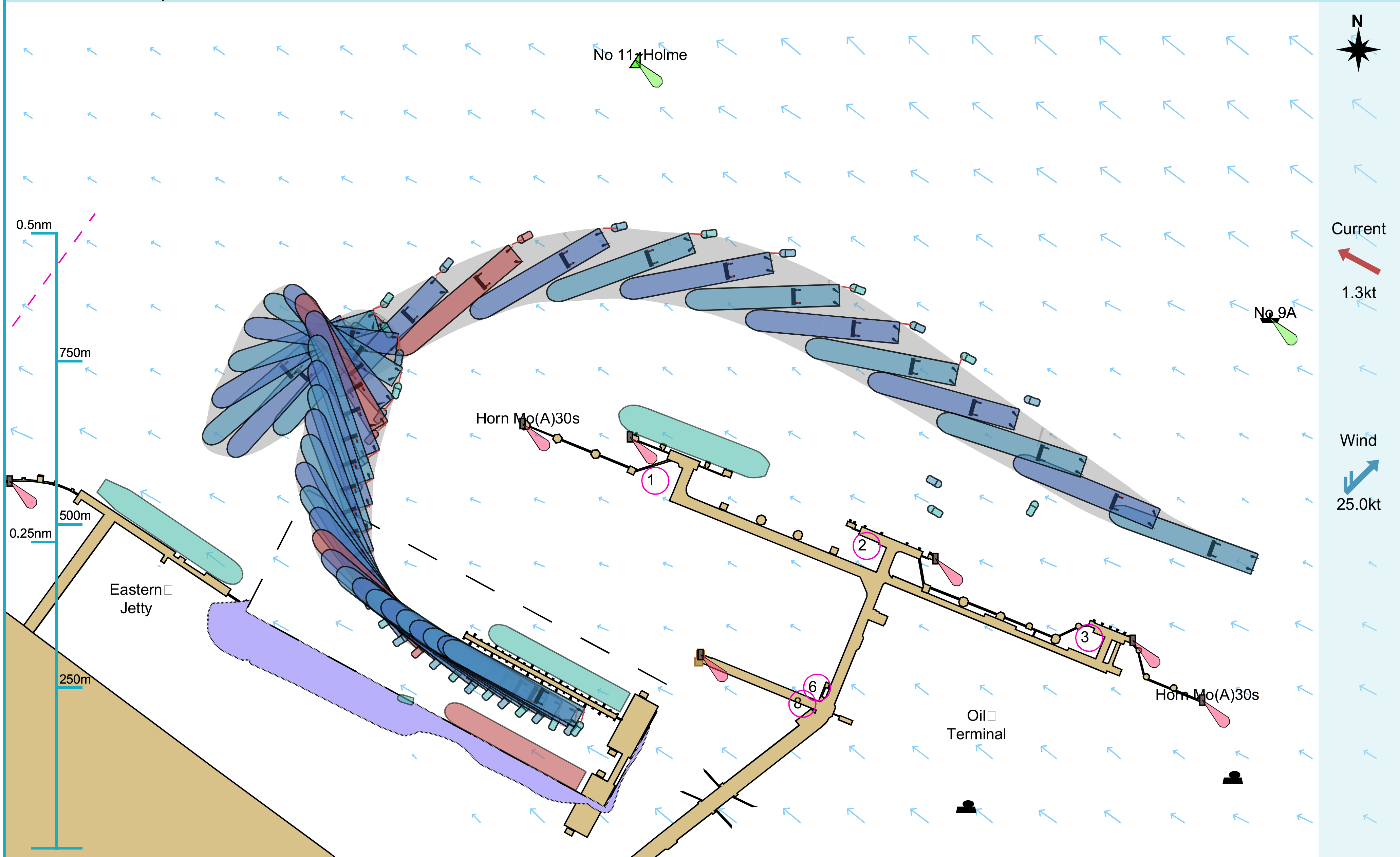

Ships plotted every 1 mins, highlight every 10 mins

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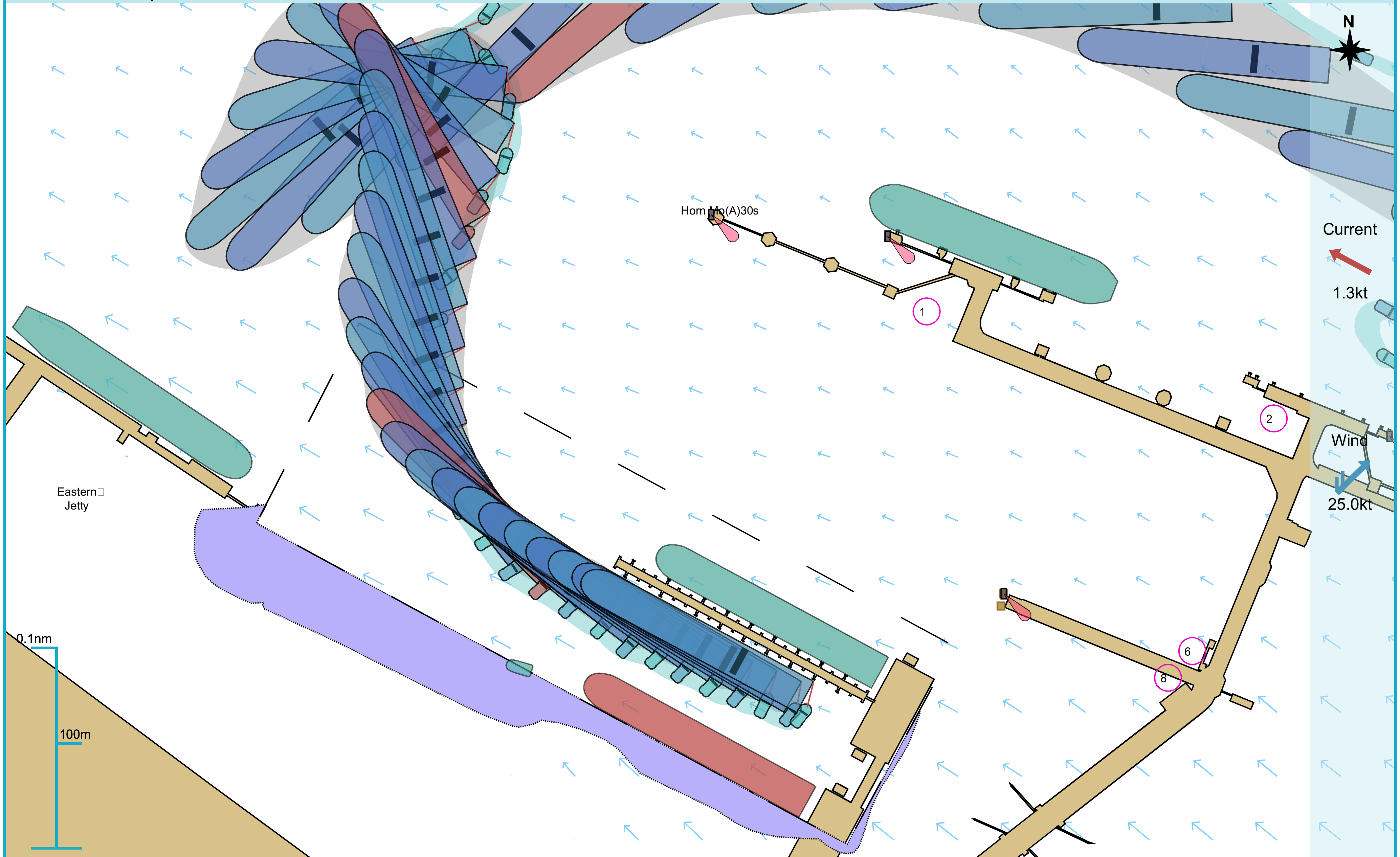

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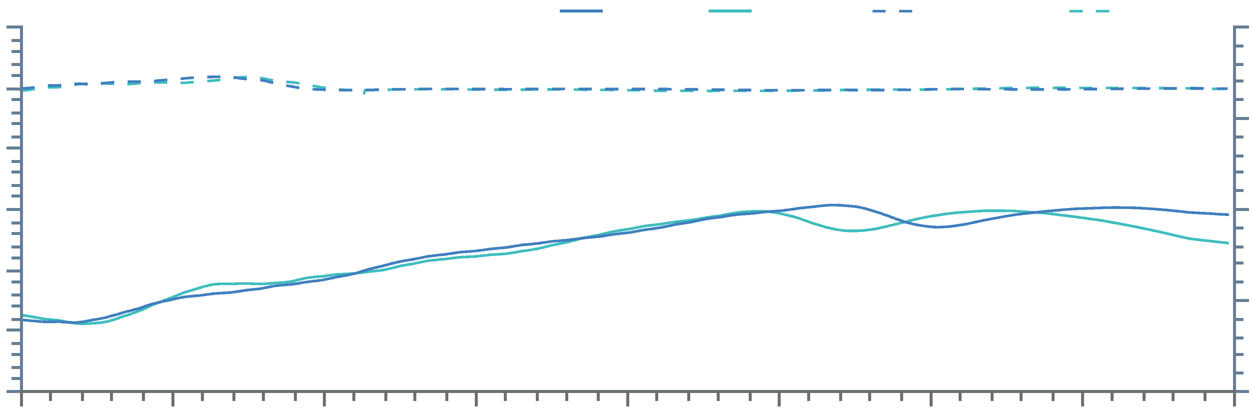
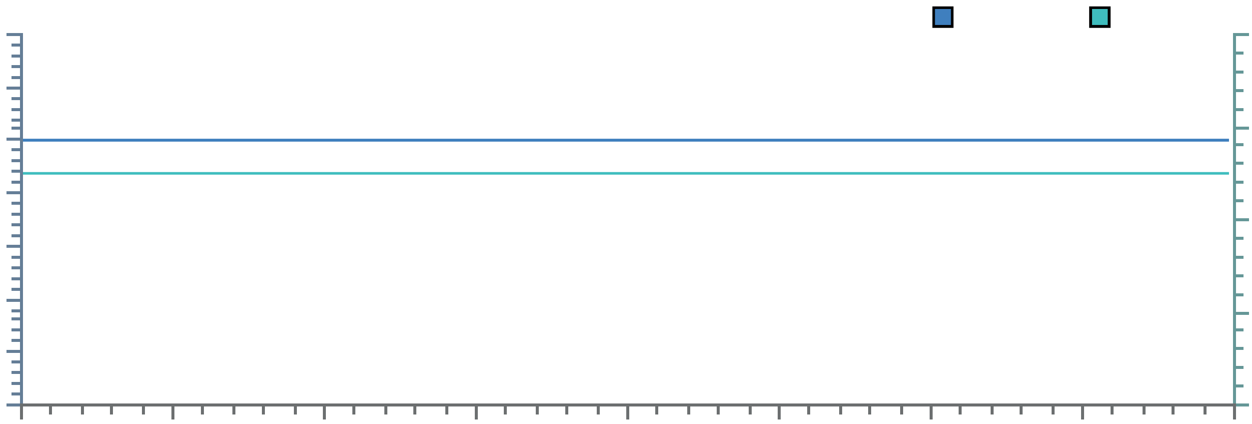
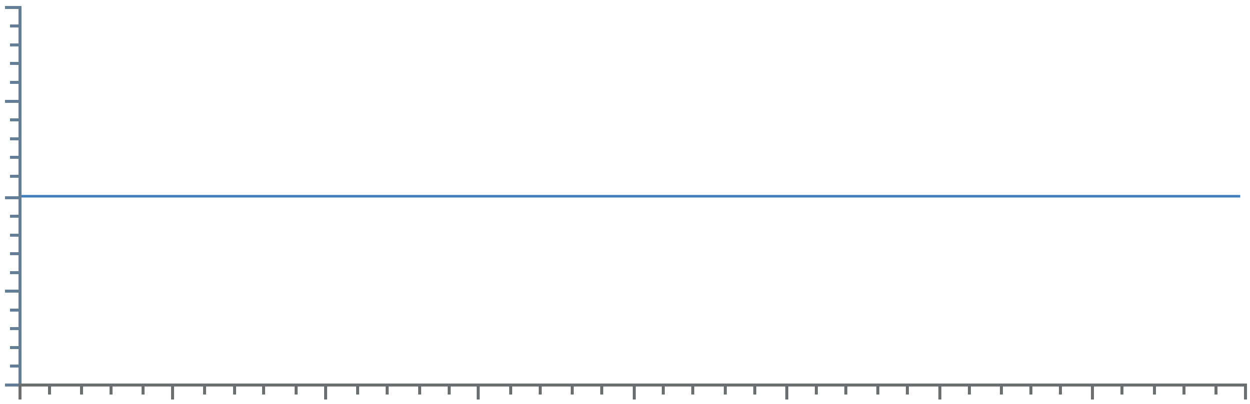
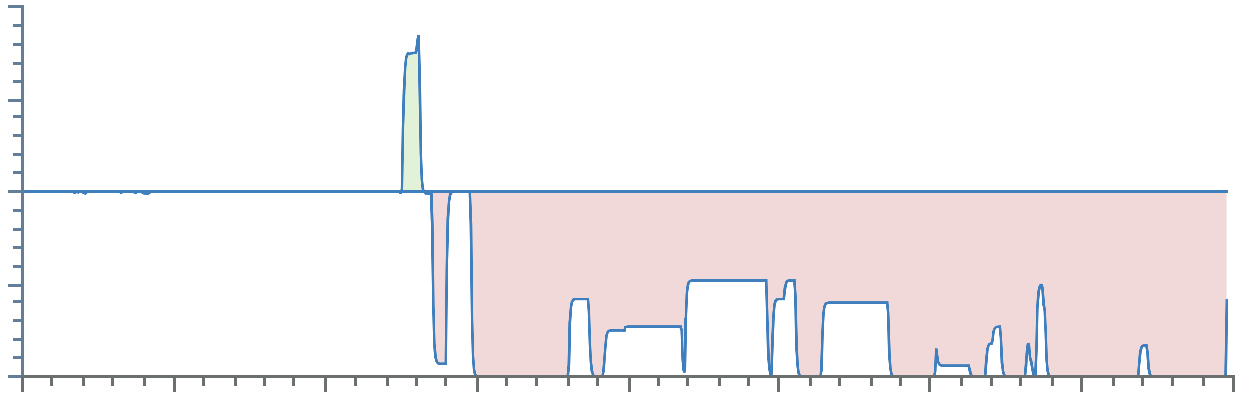
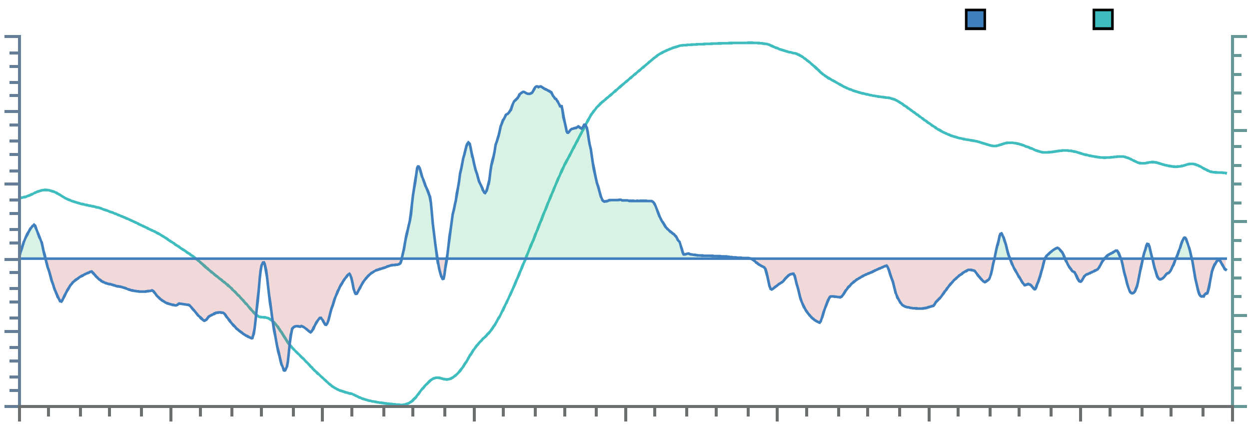
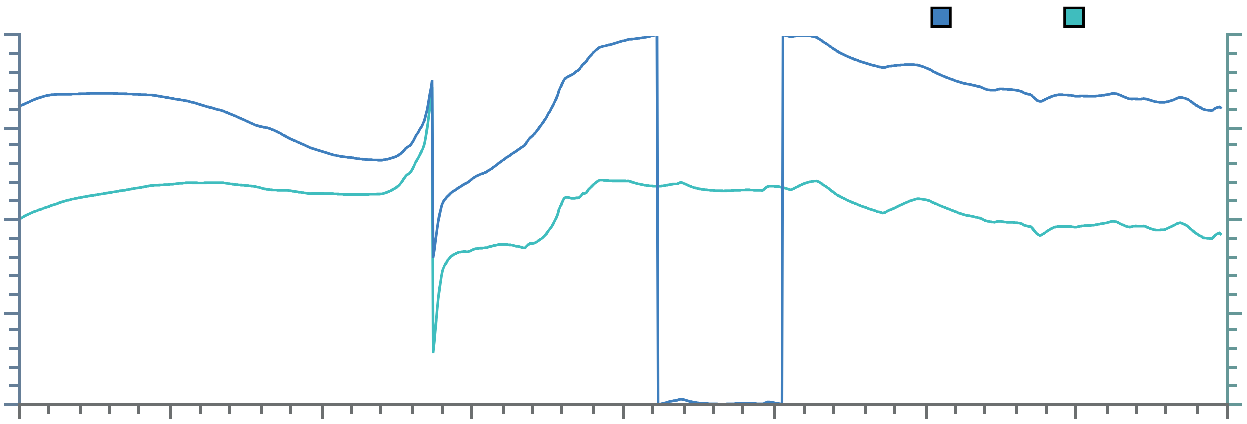


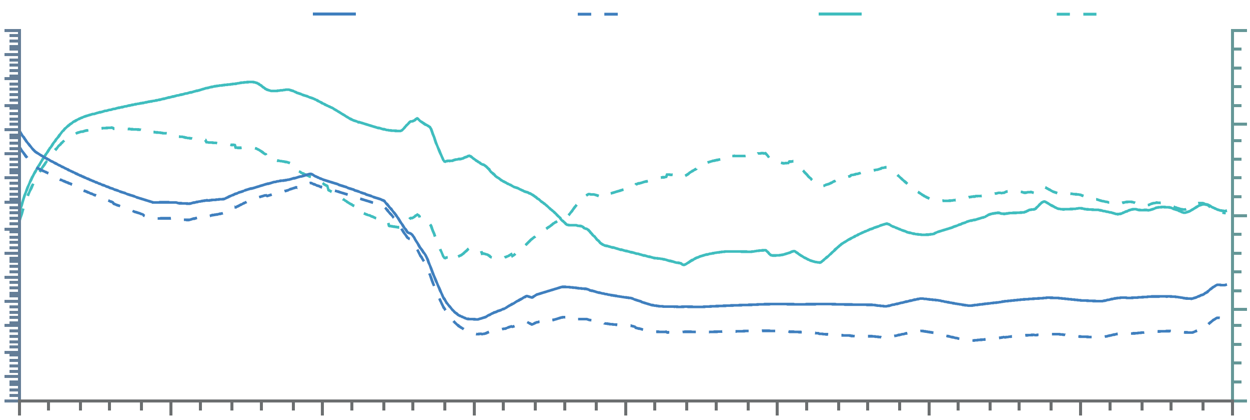


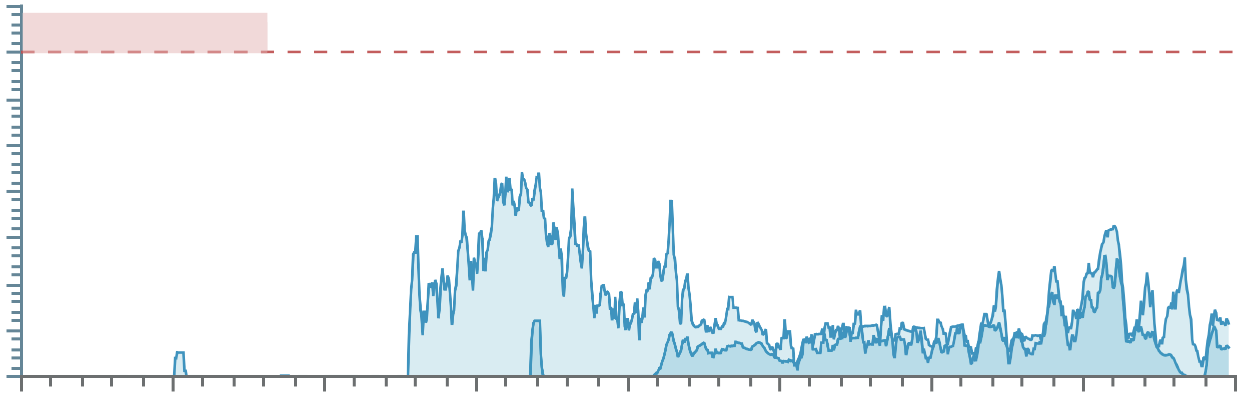




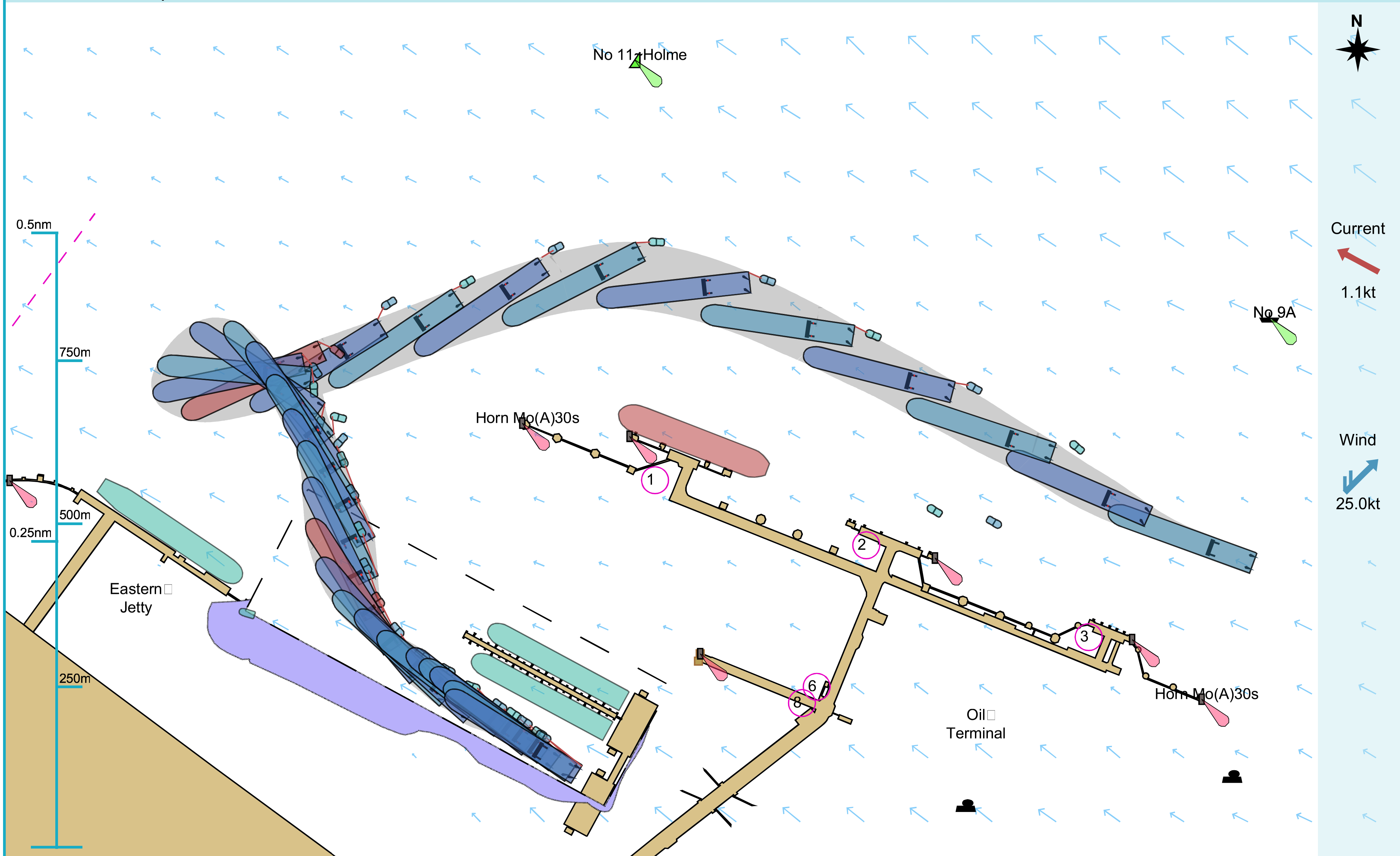








Manoeuvre track plot



Ships plotted every 1 mins, highlight every 10 mins

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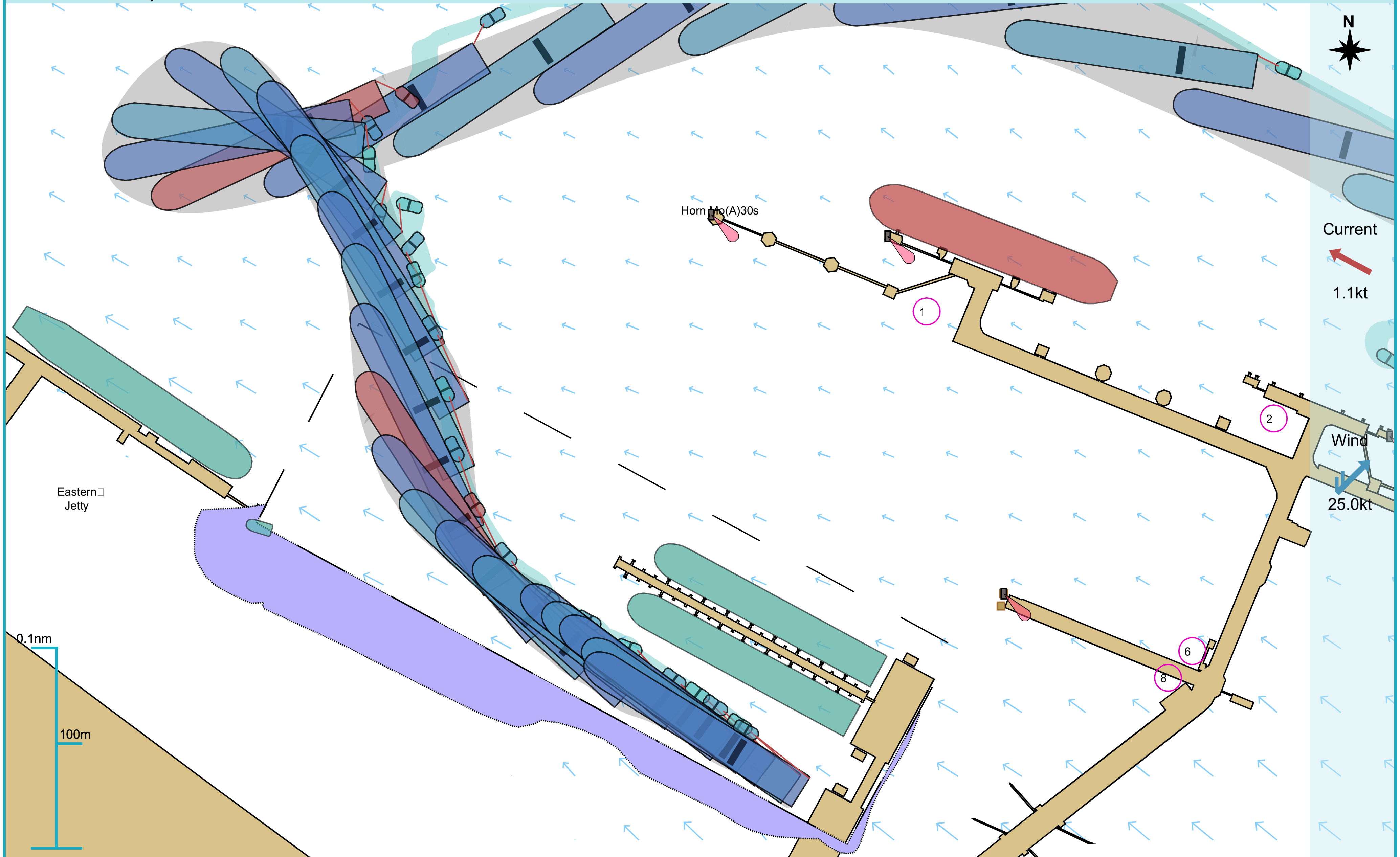

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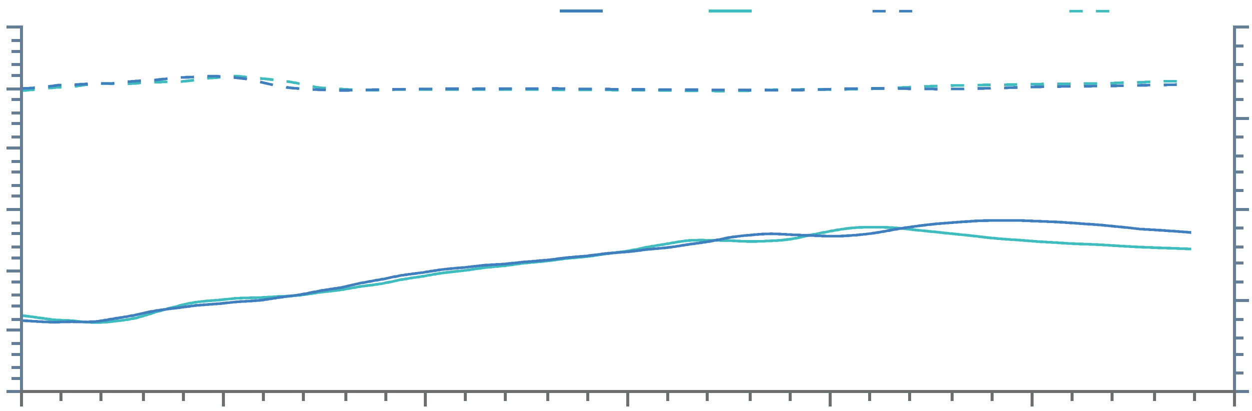

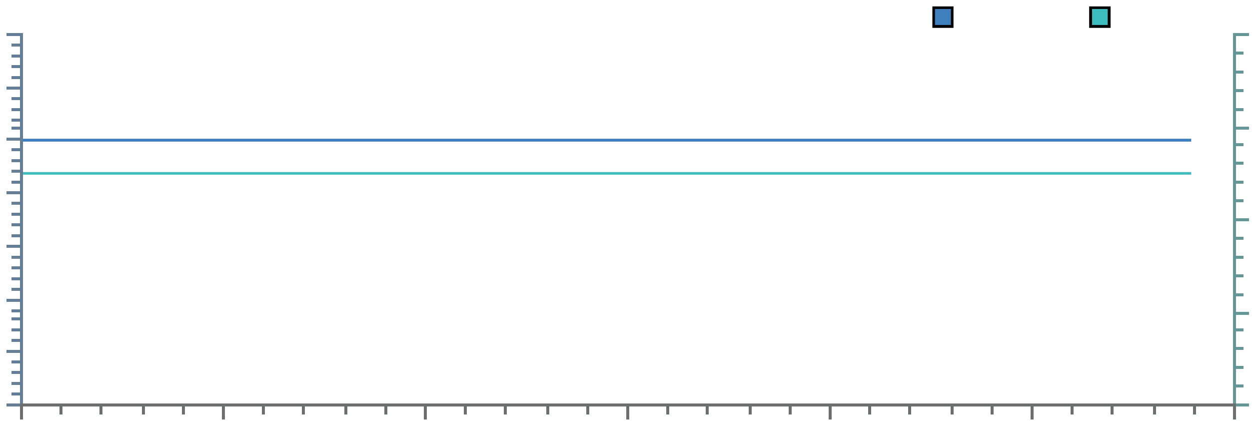

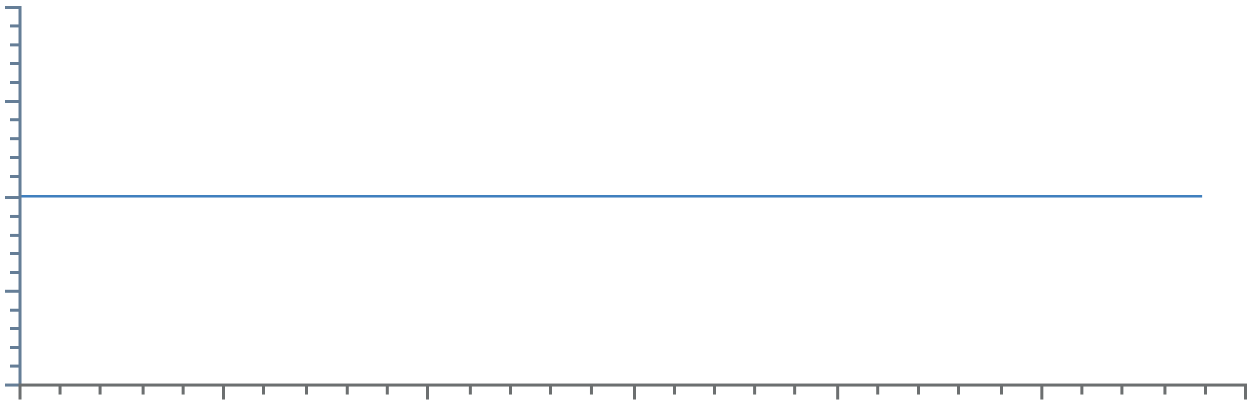

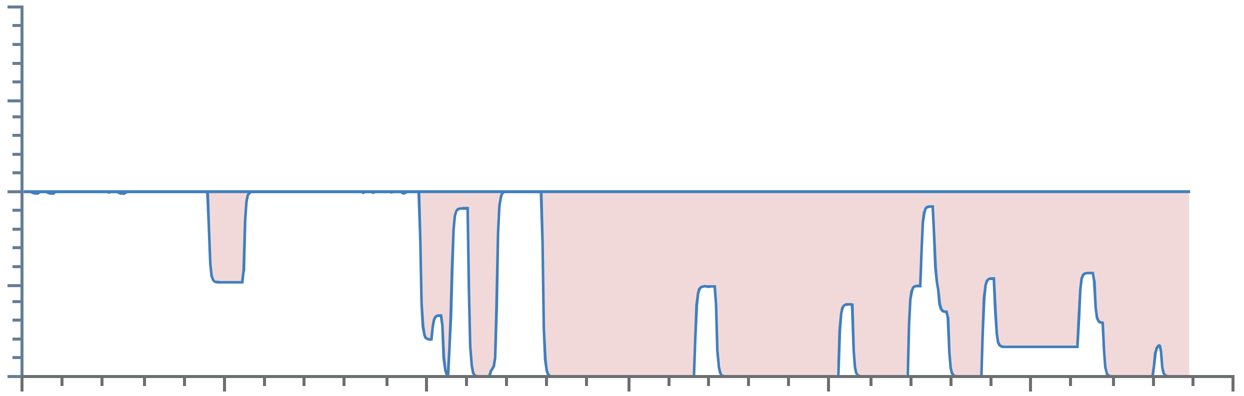

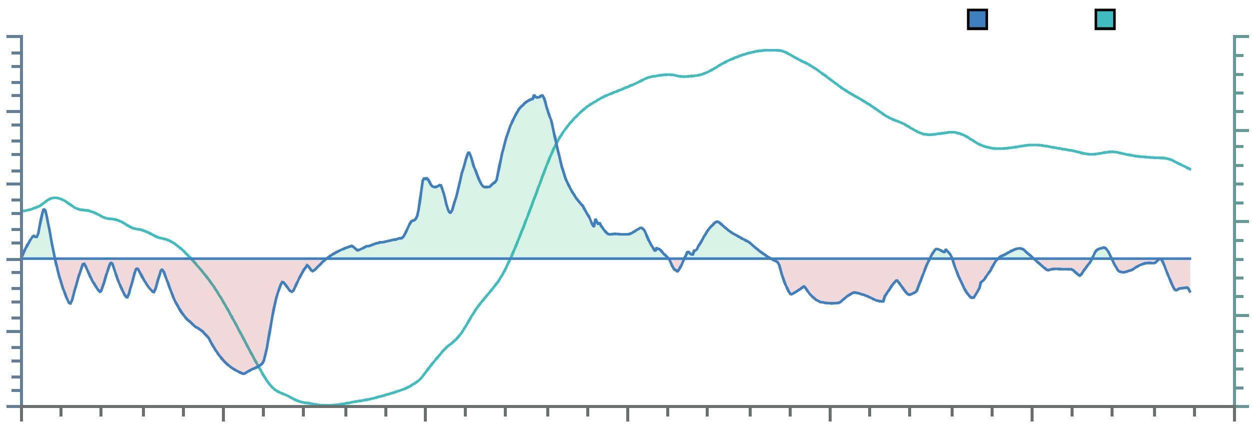

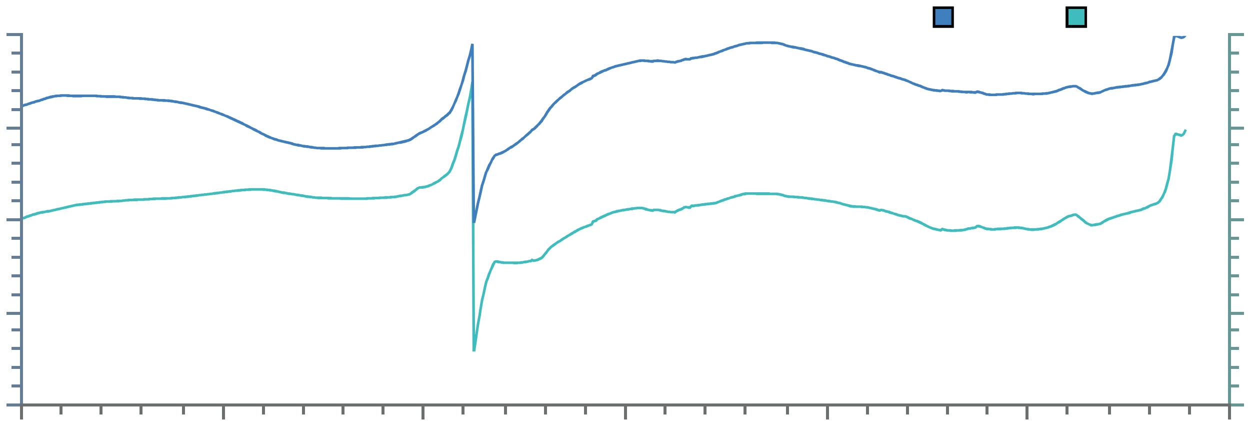

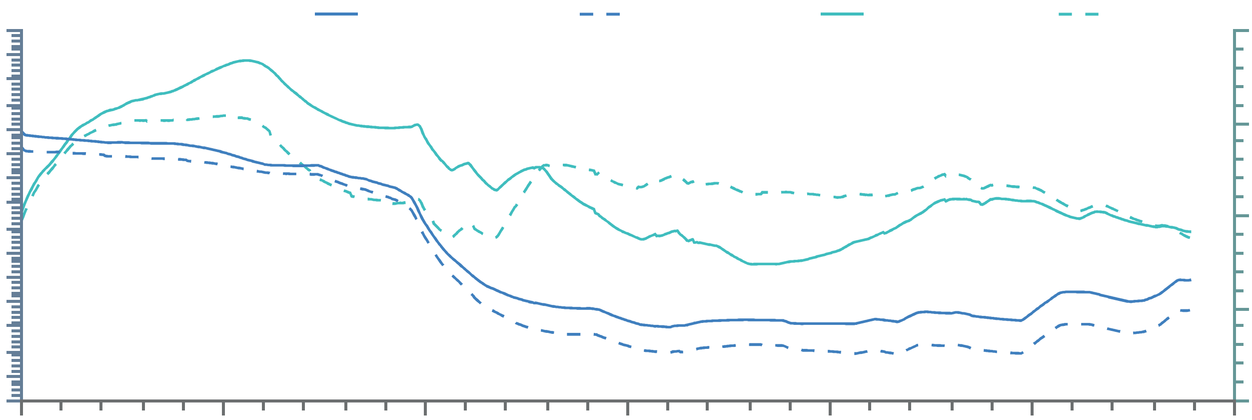

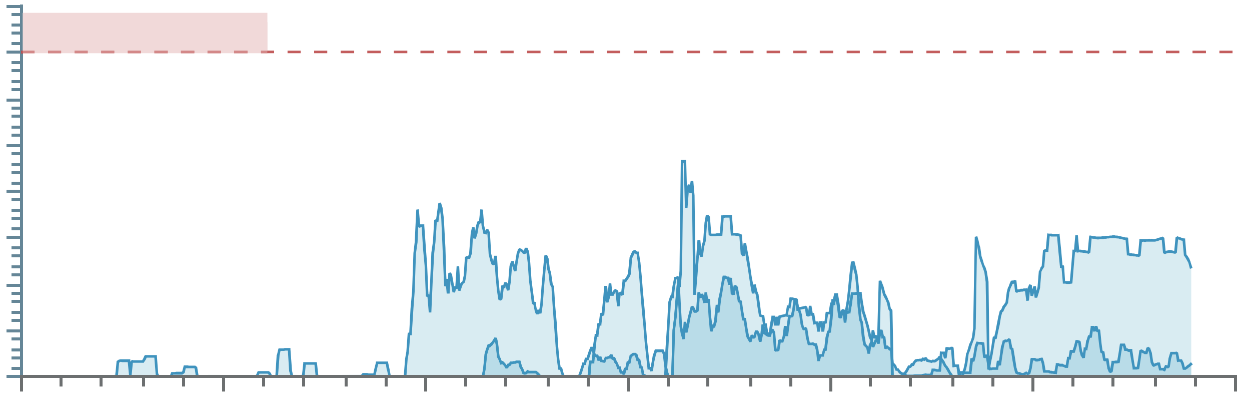

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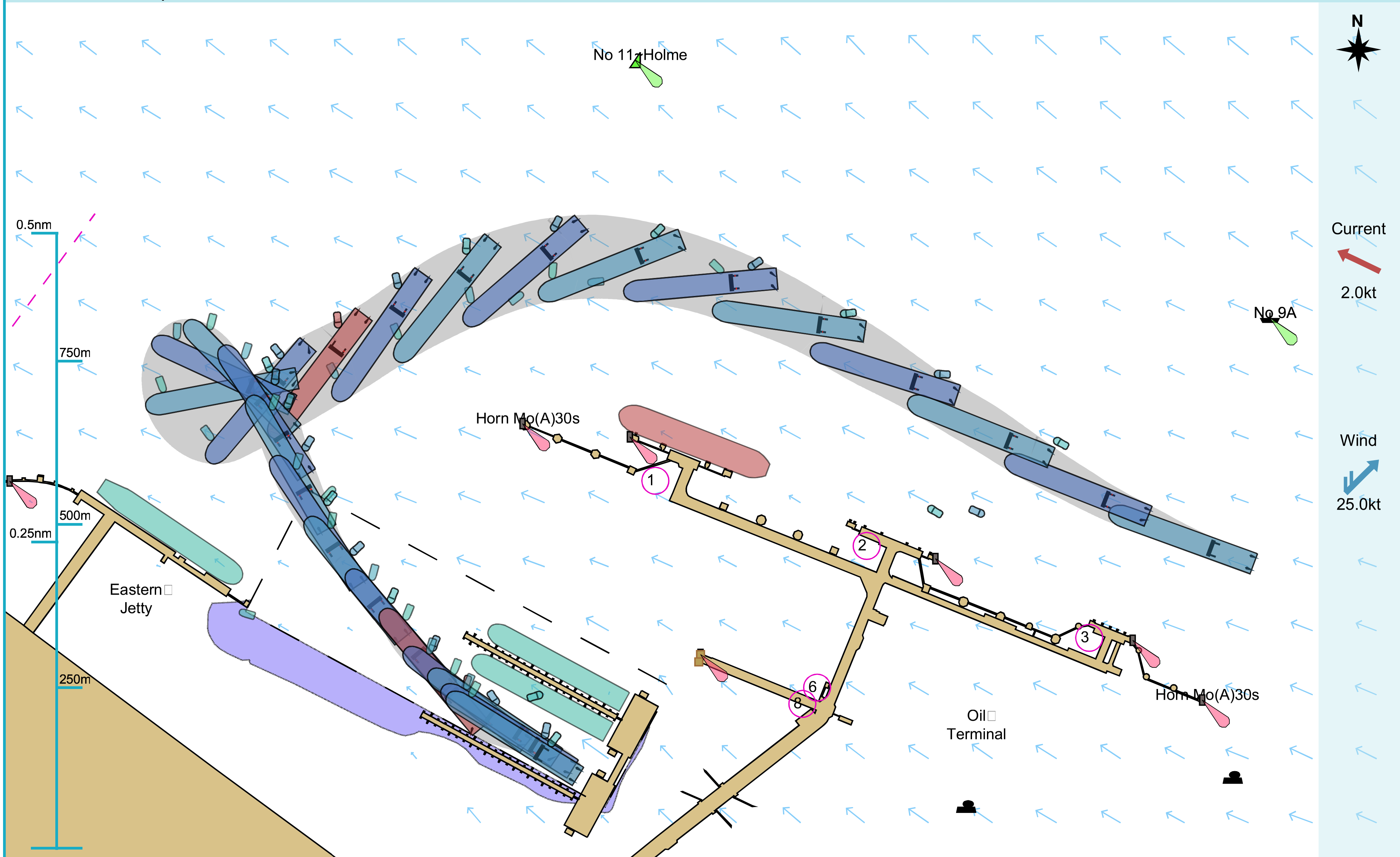

Ships plotted every 1 mins, highlight every 10 mins

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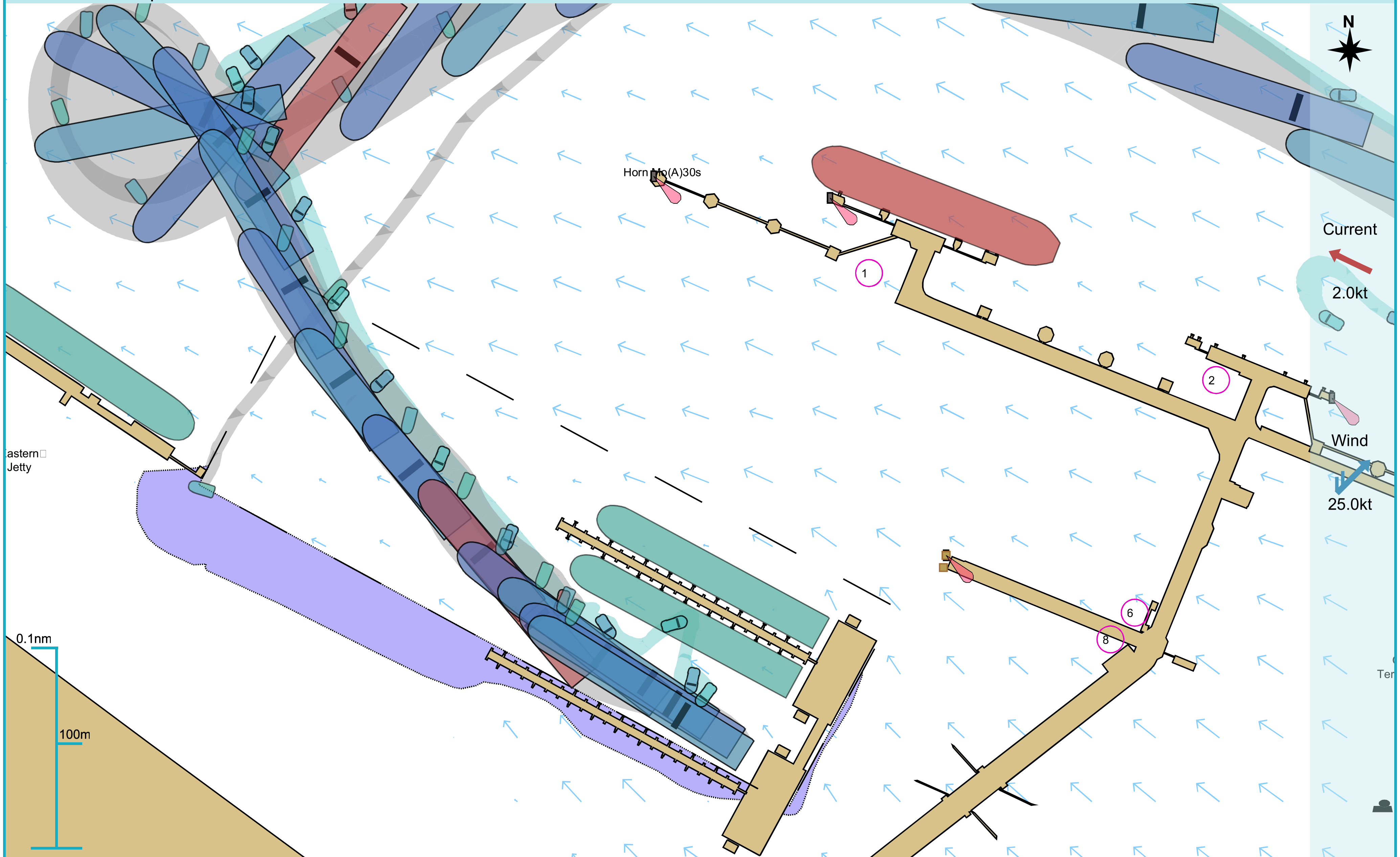

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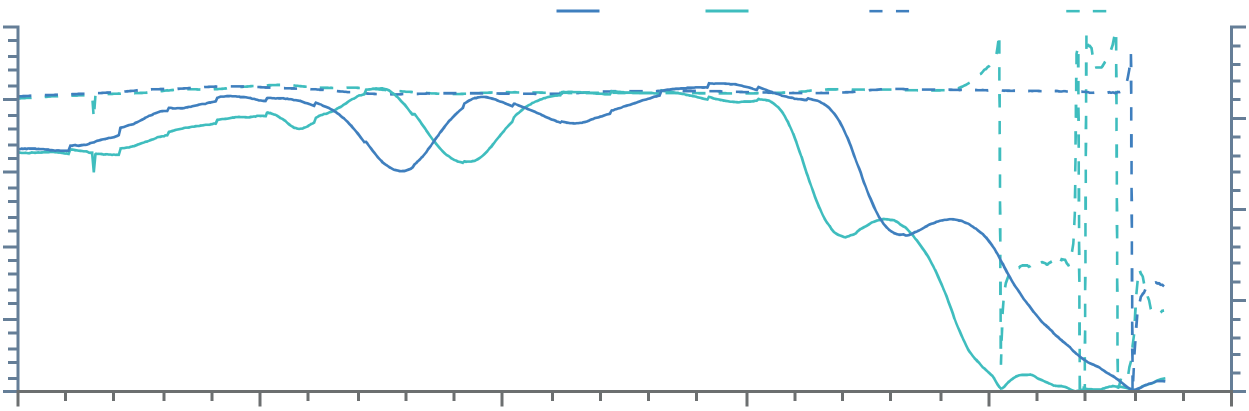
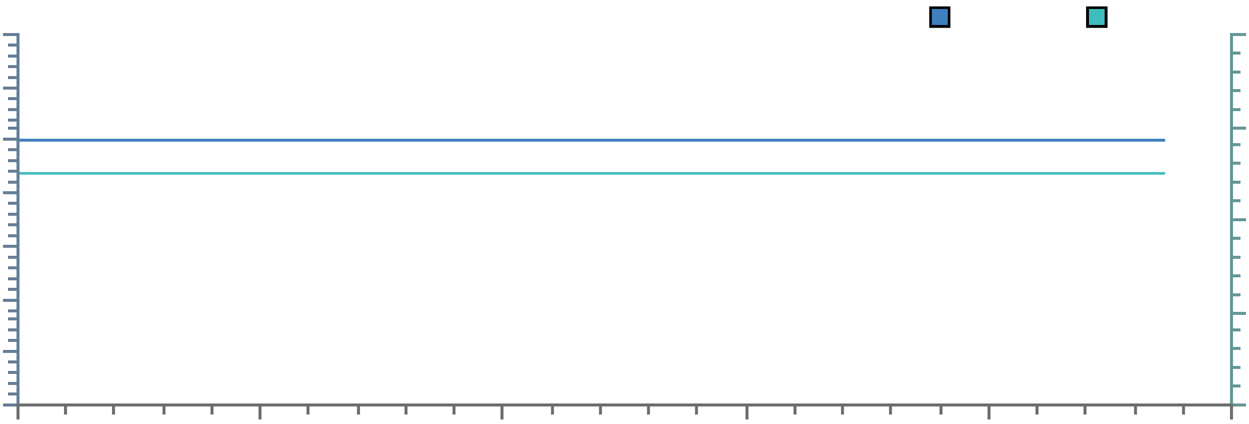
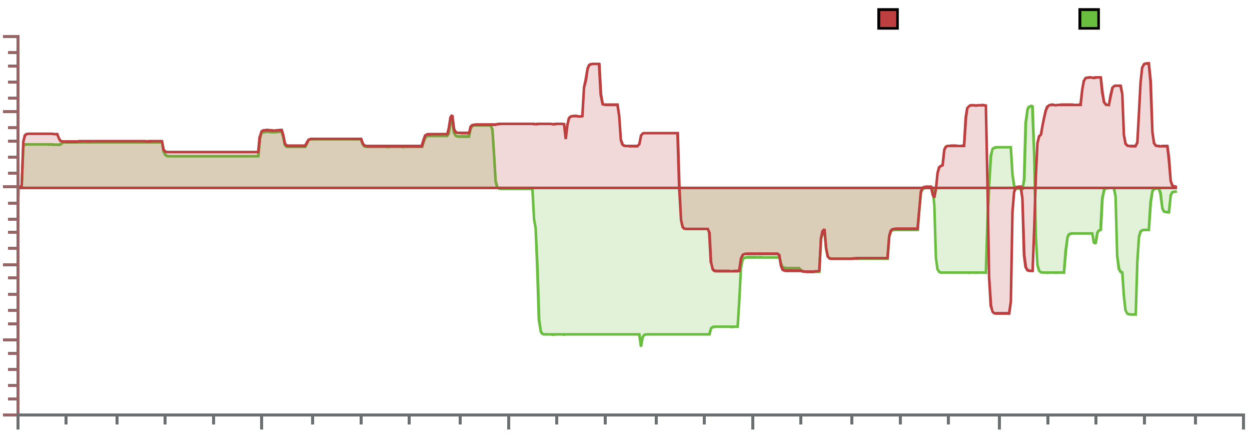
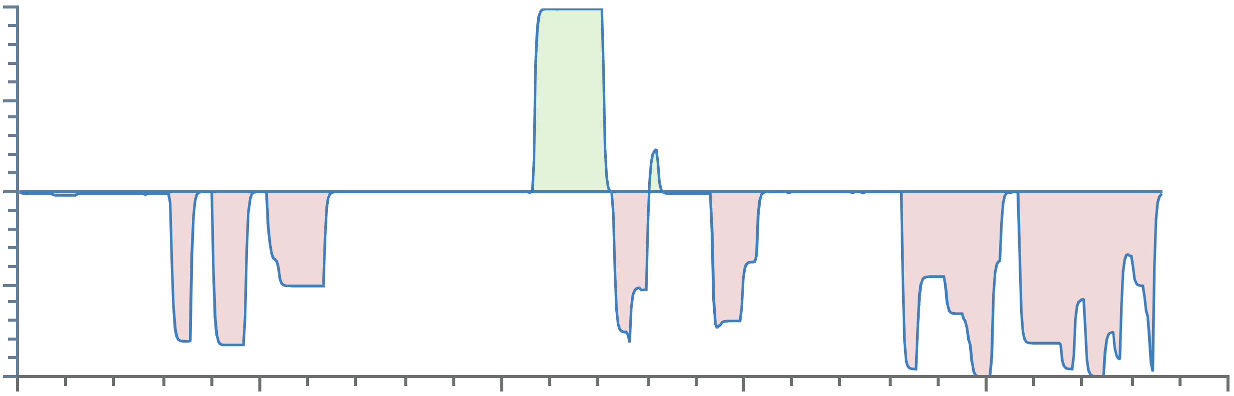
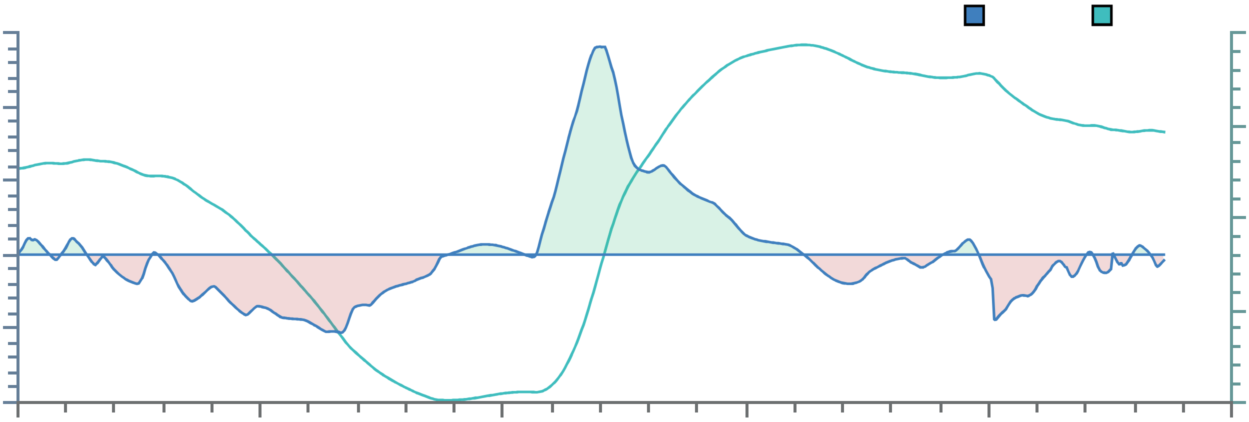
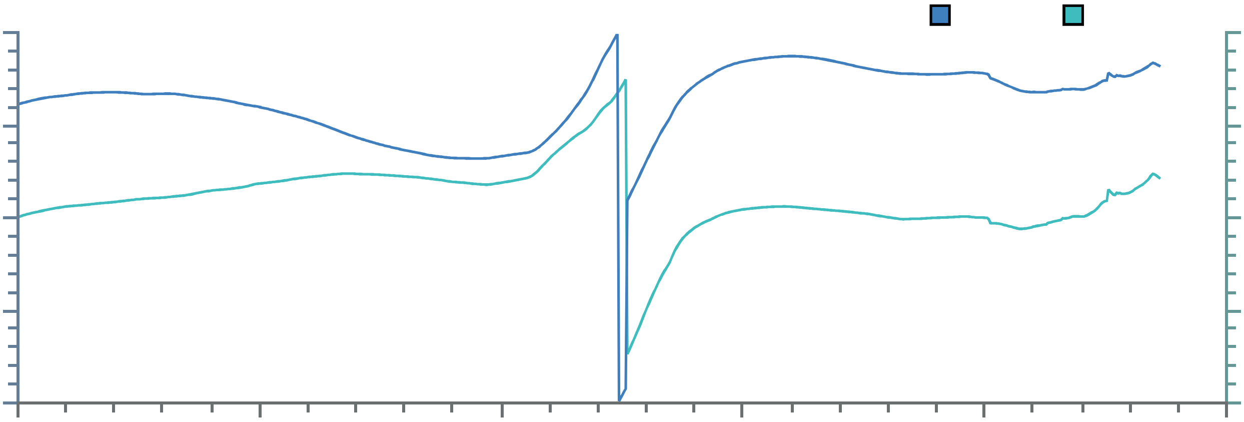


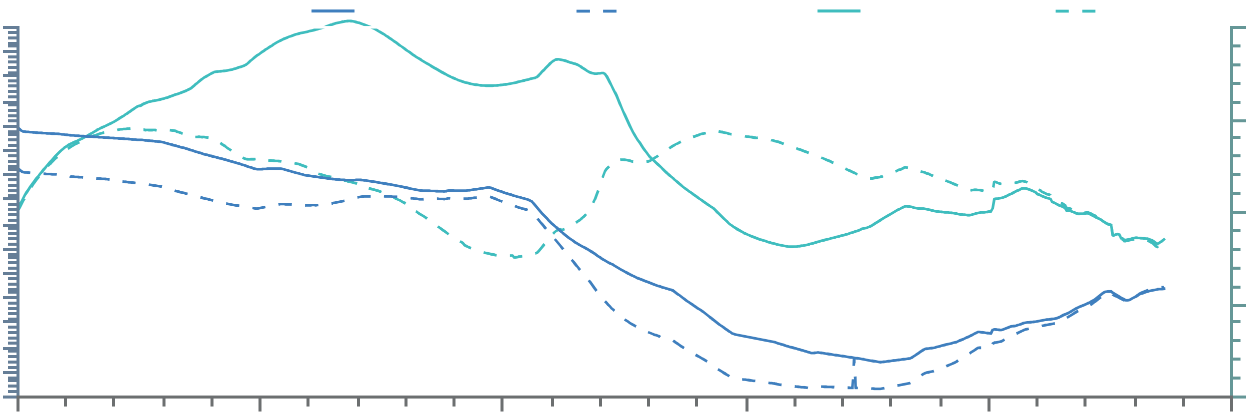


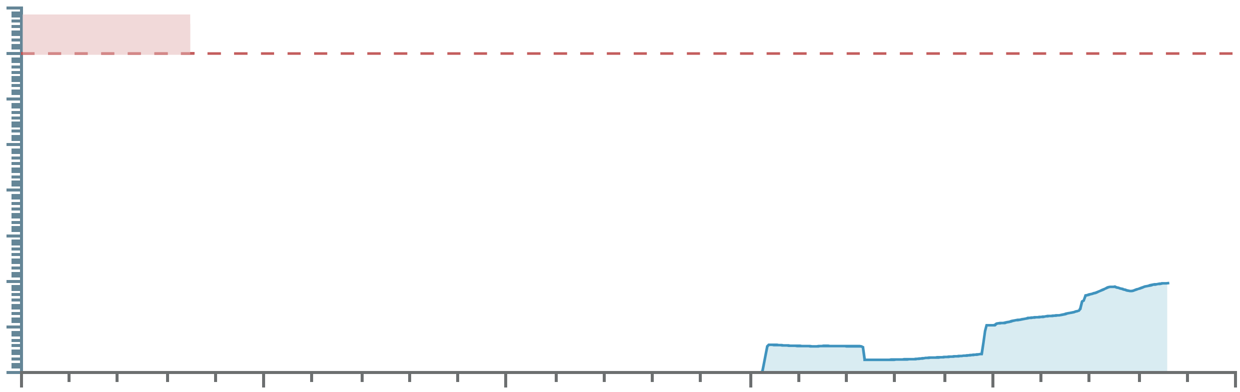


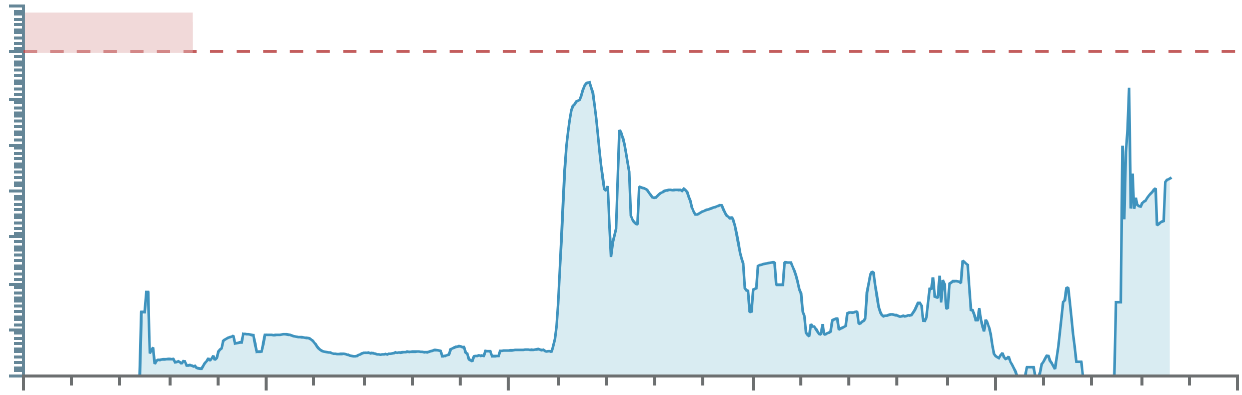




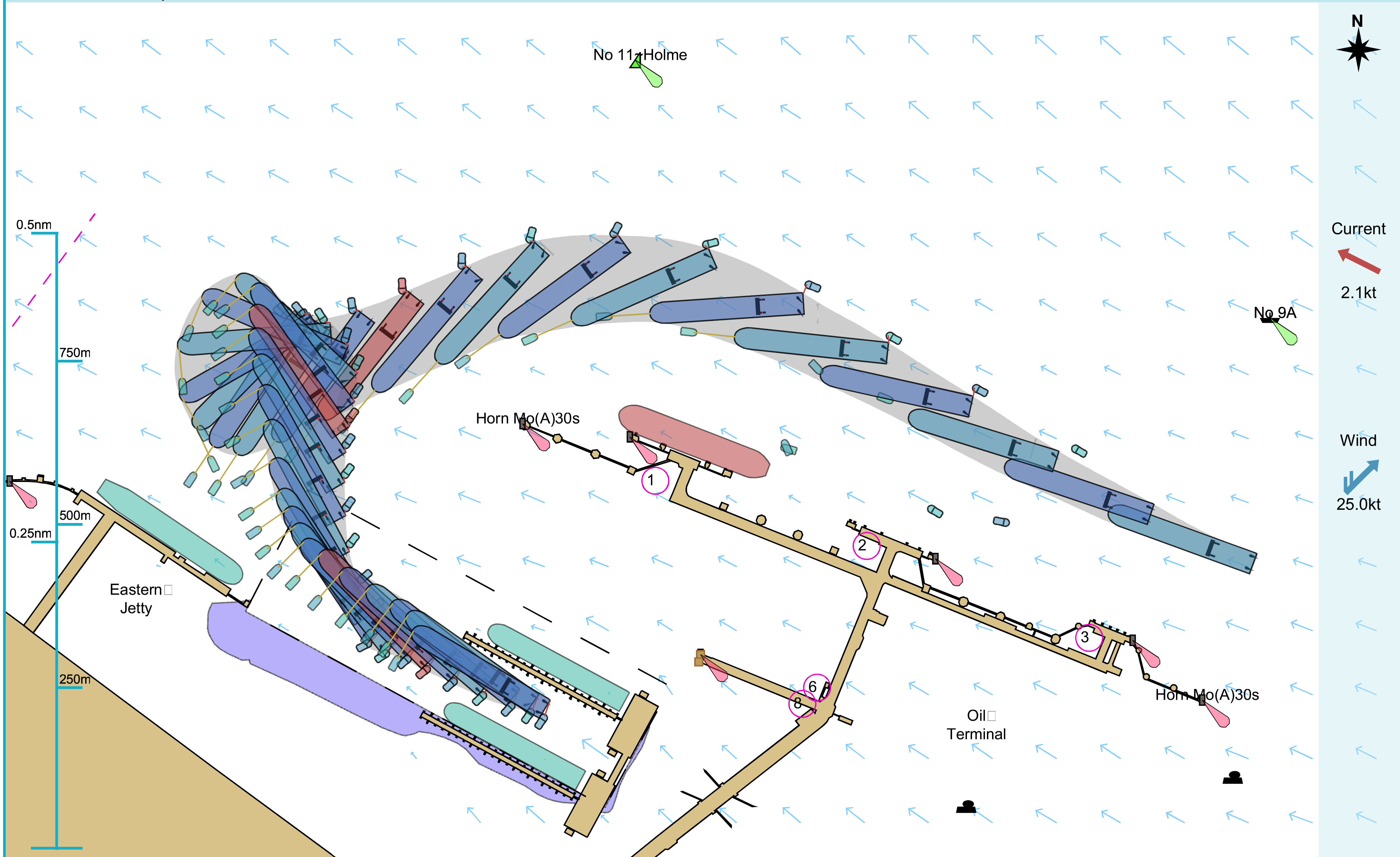






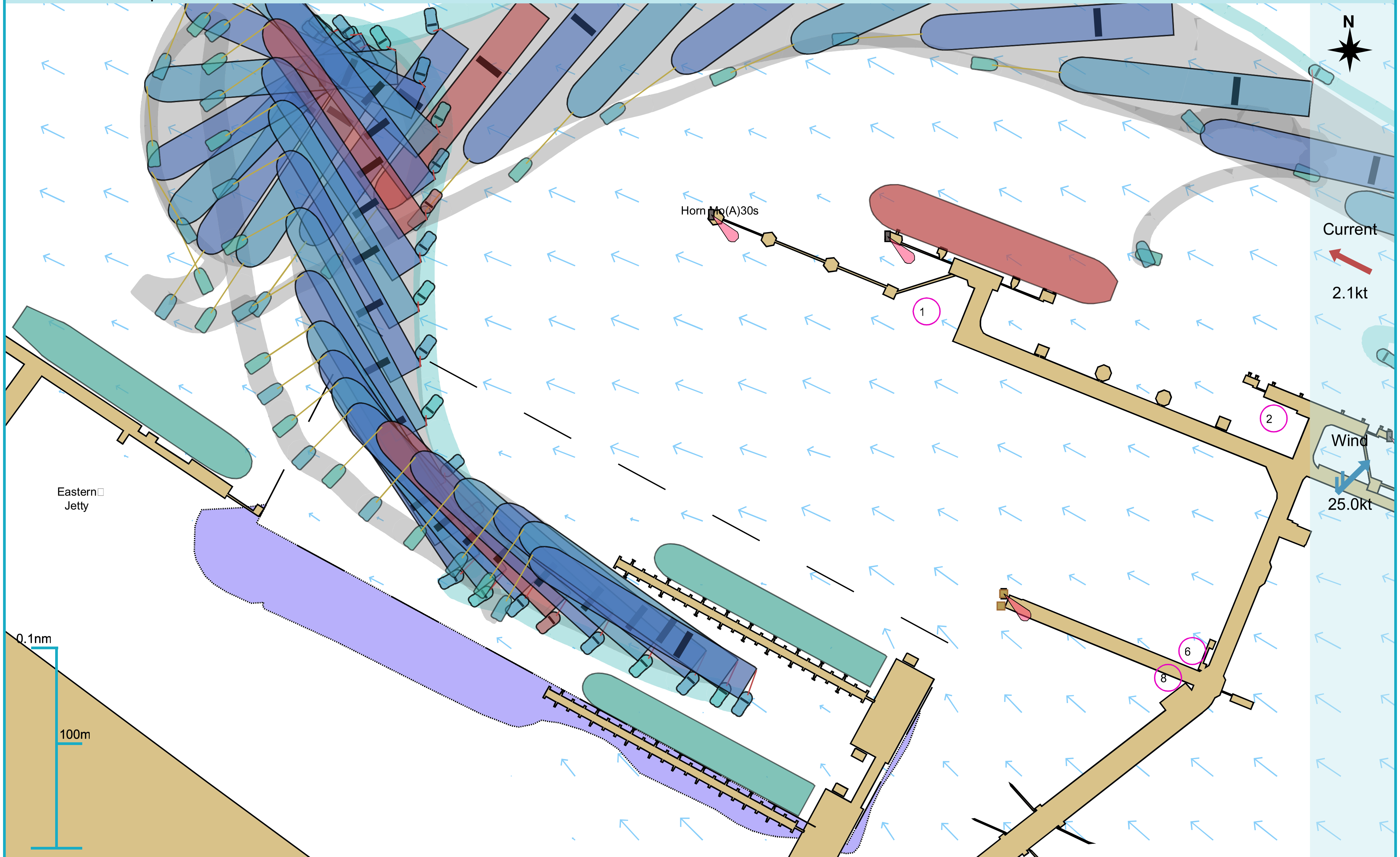


Manoeuvre track plot



Ships plotted every 1 mins, highlight every 10 mins

Manoeuvre track plot



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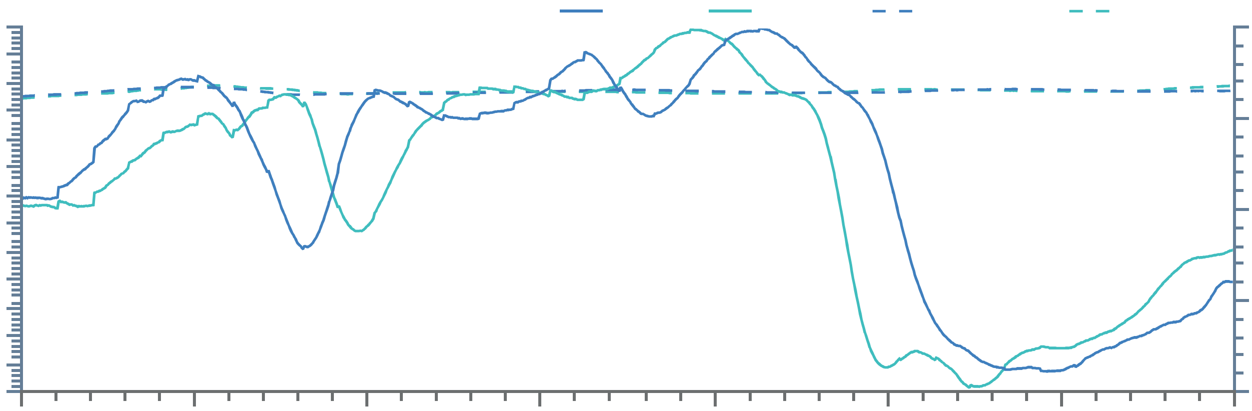
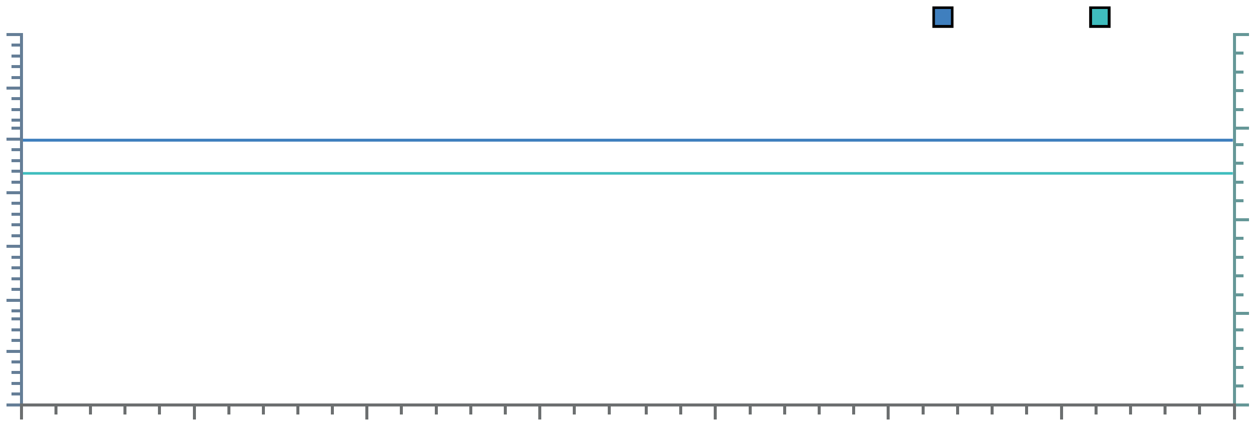
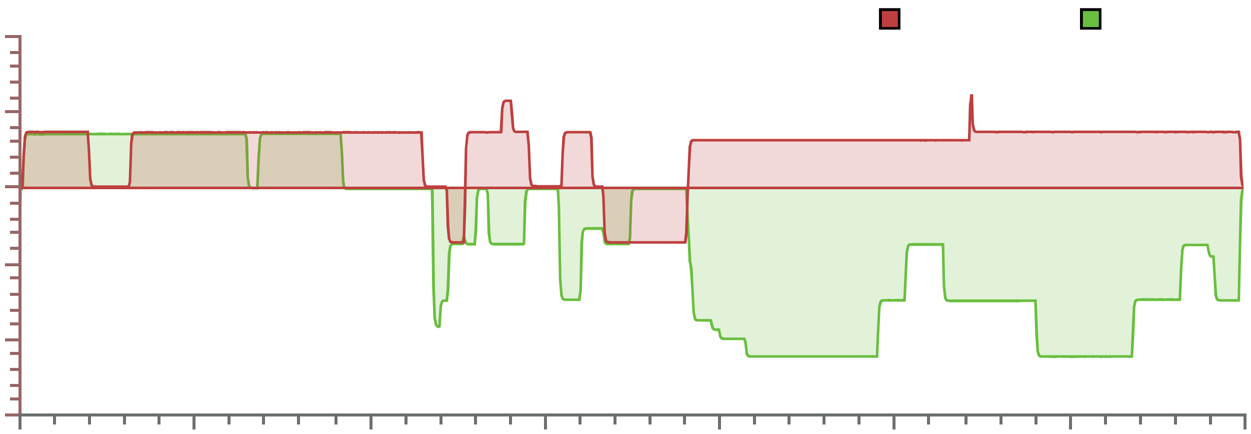
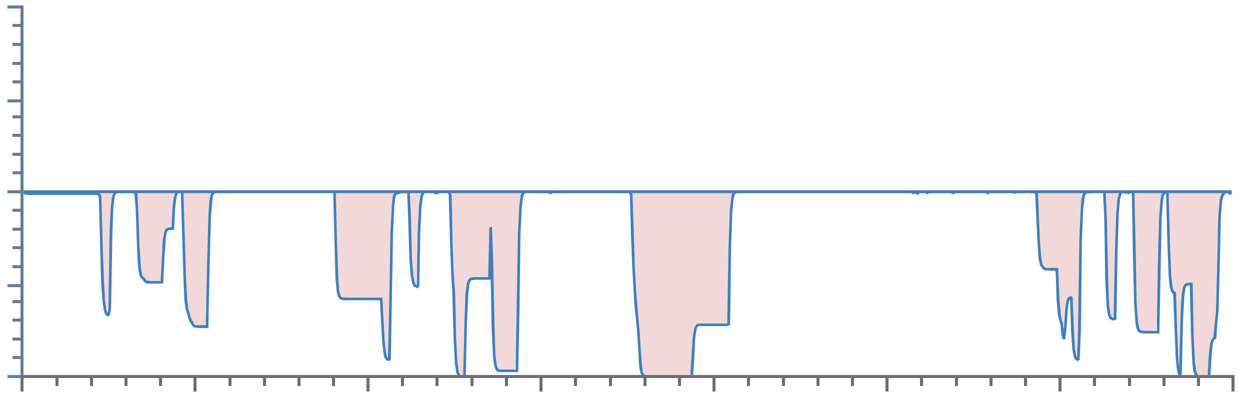
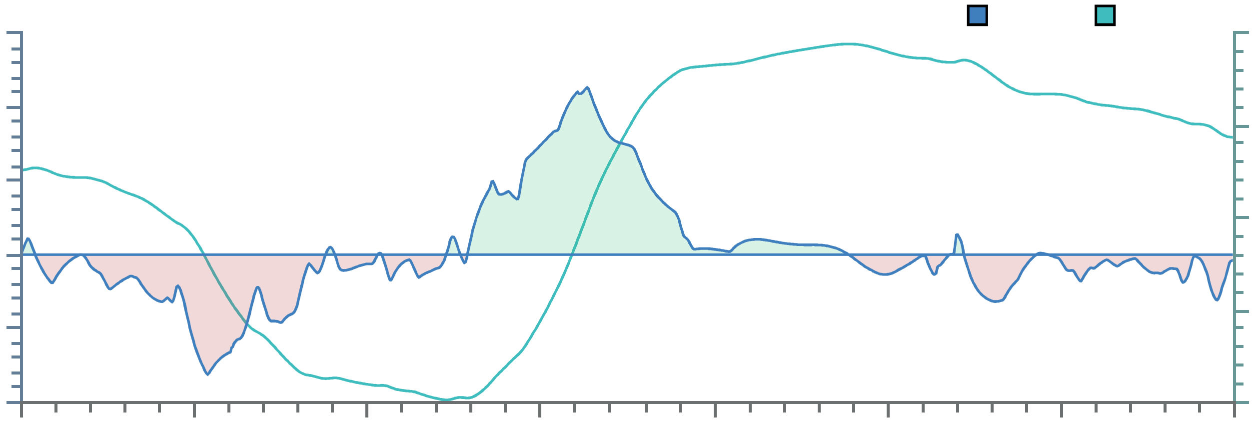
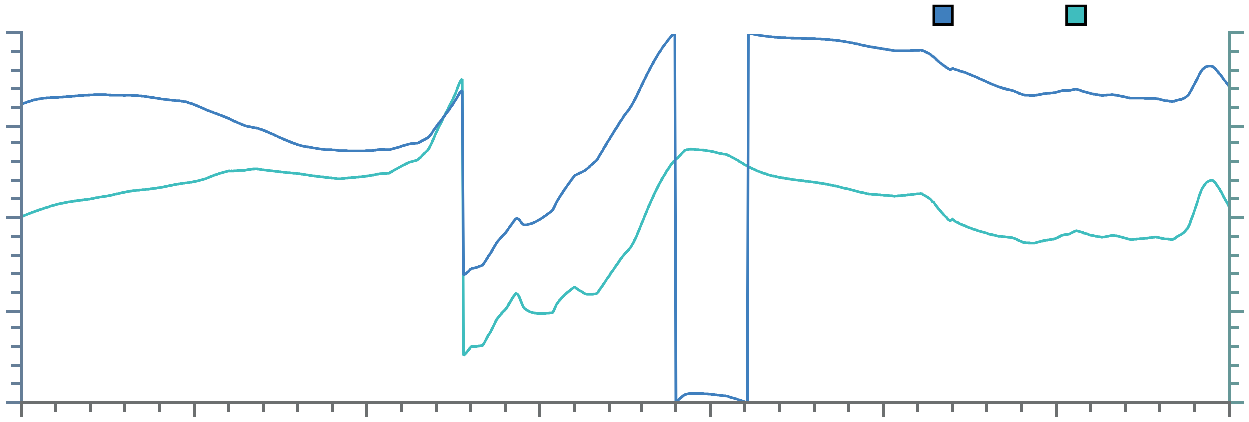


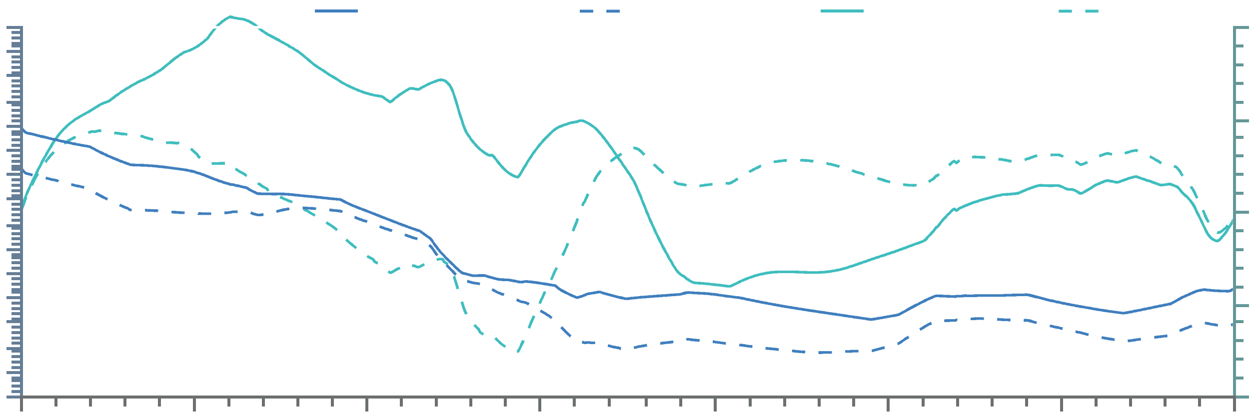


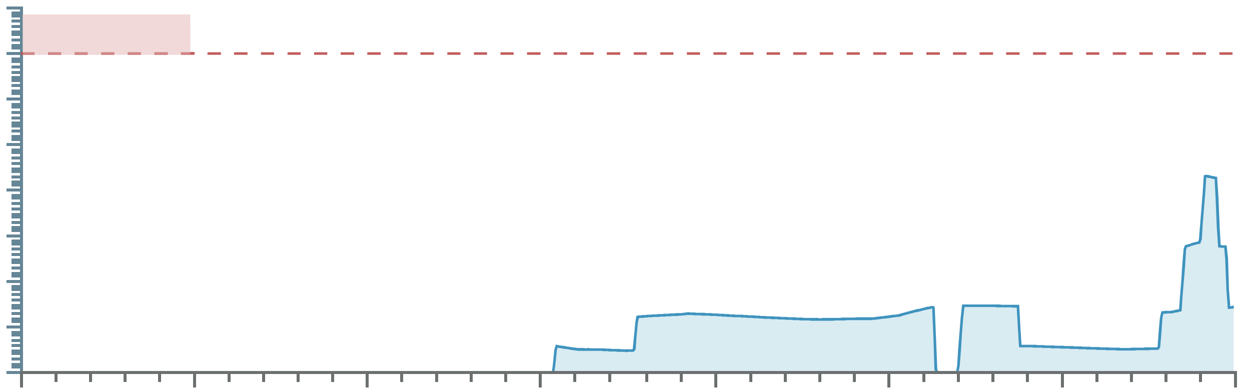


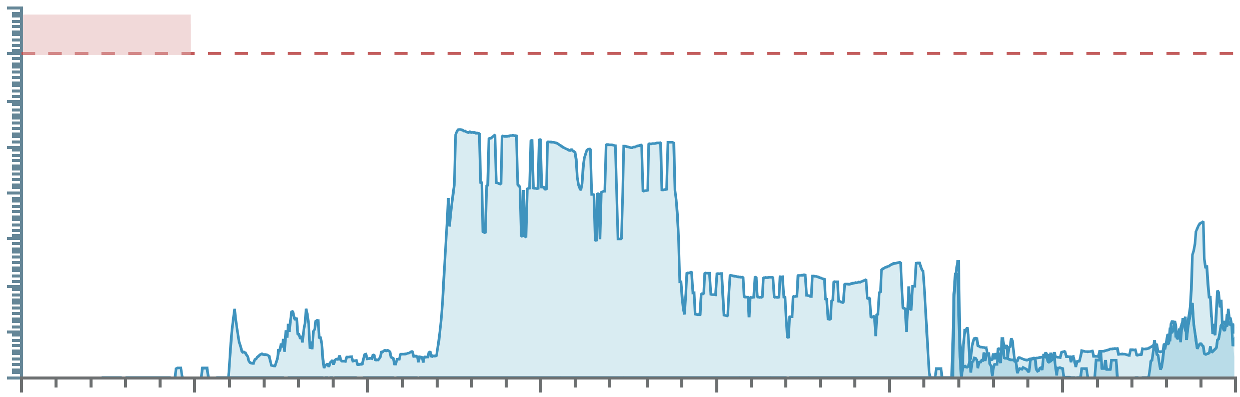




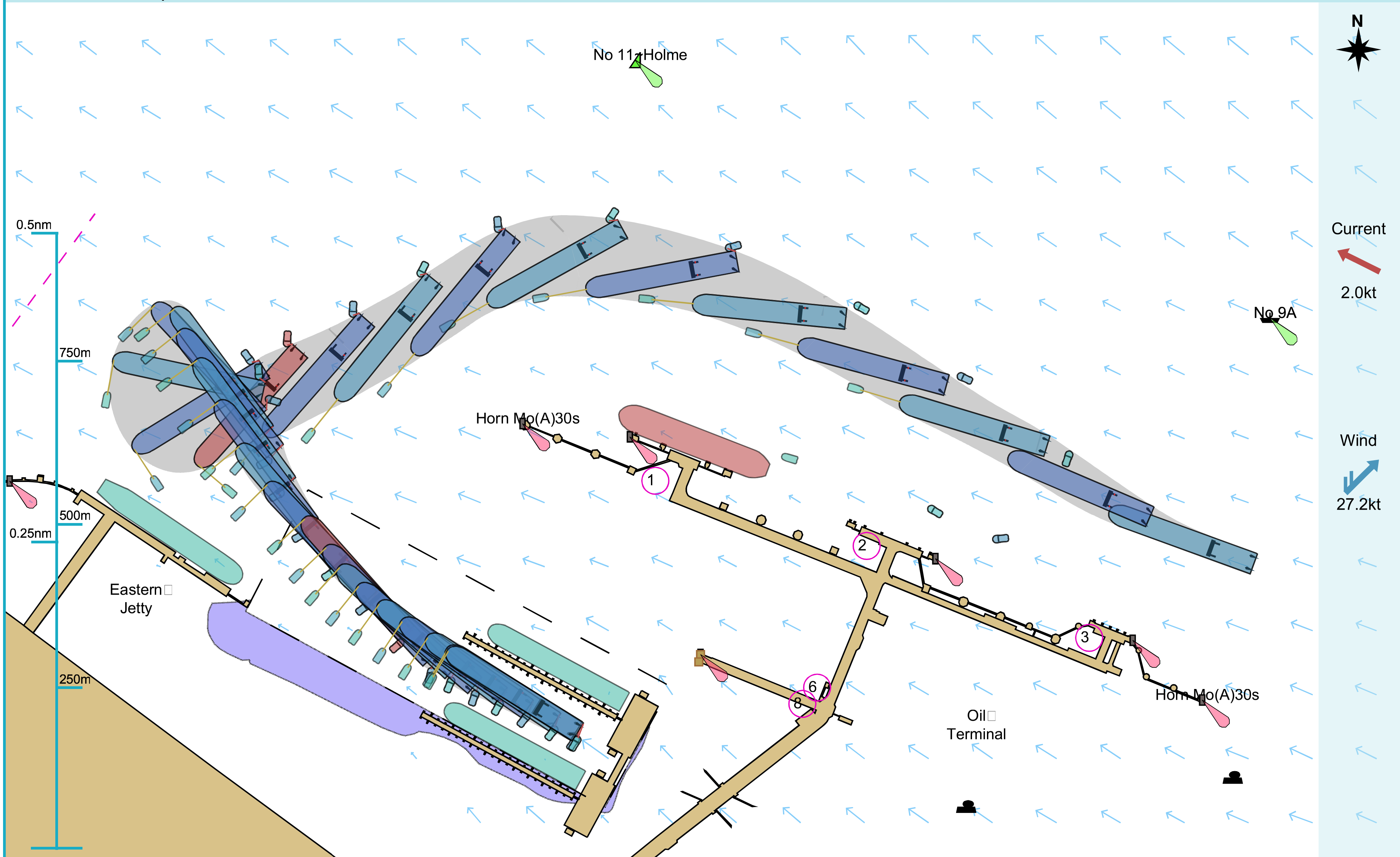








Manoeuvre track plot



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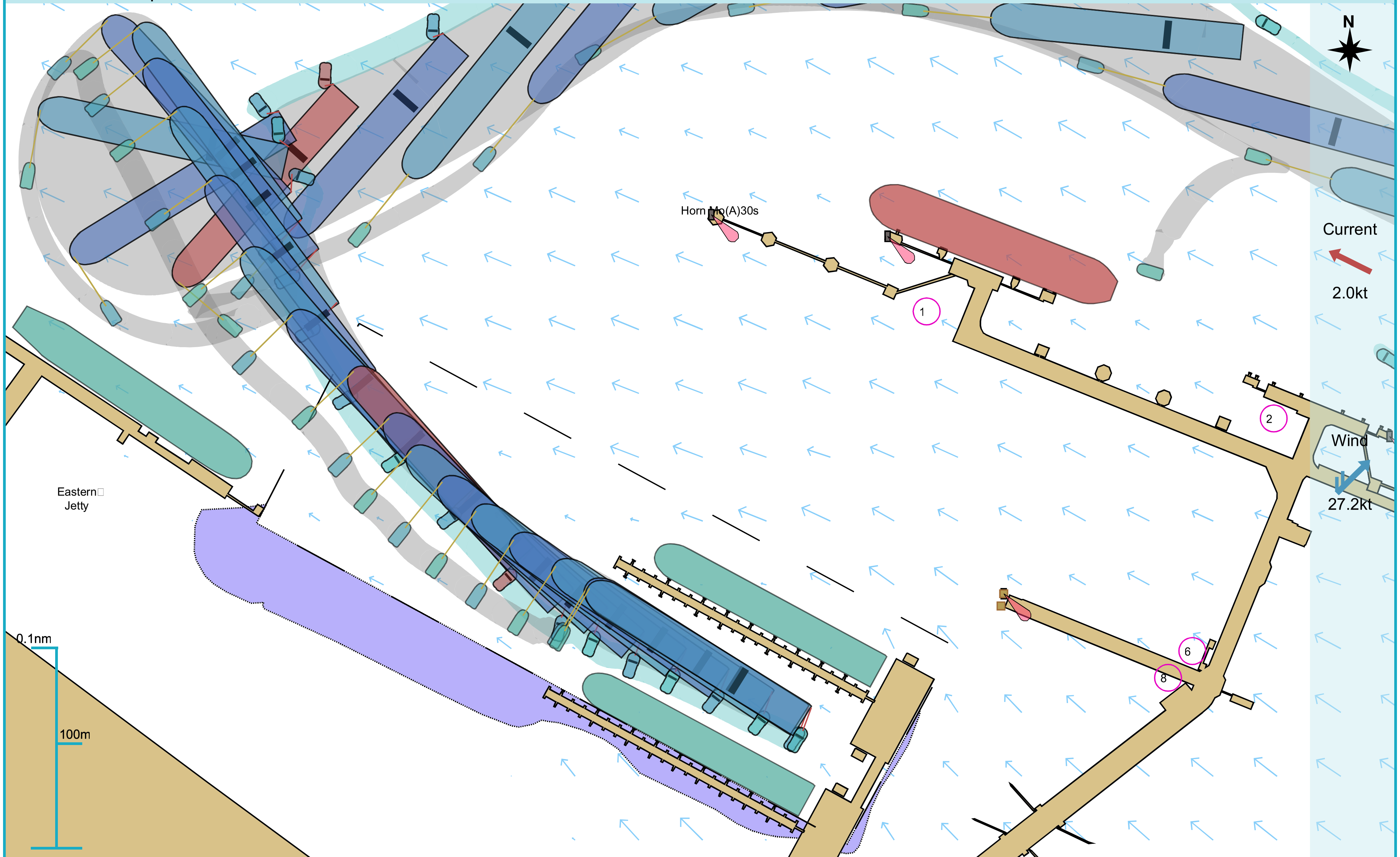

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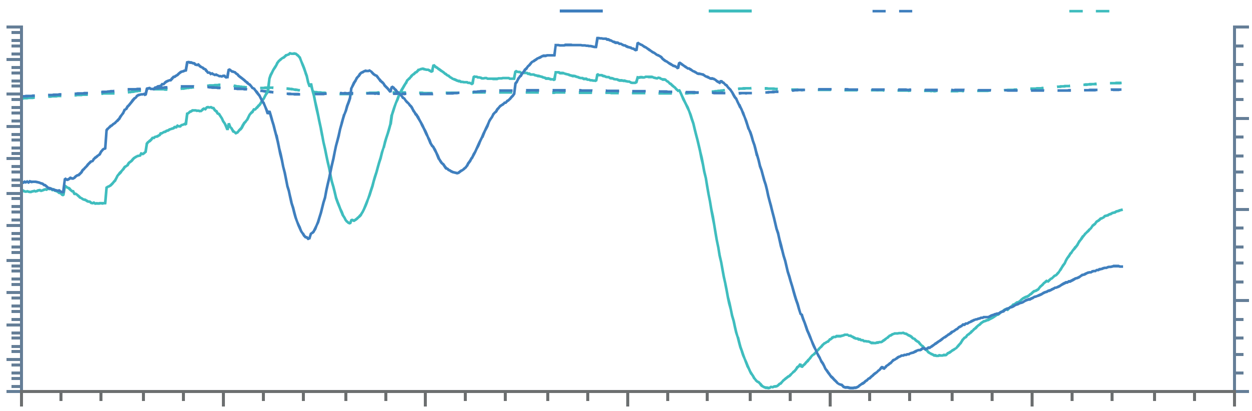
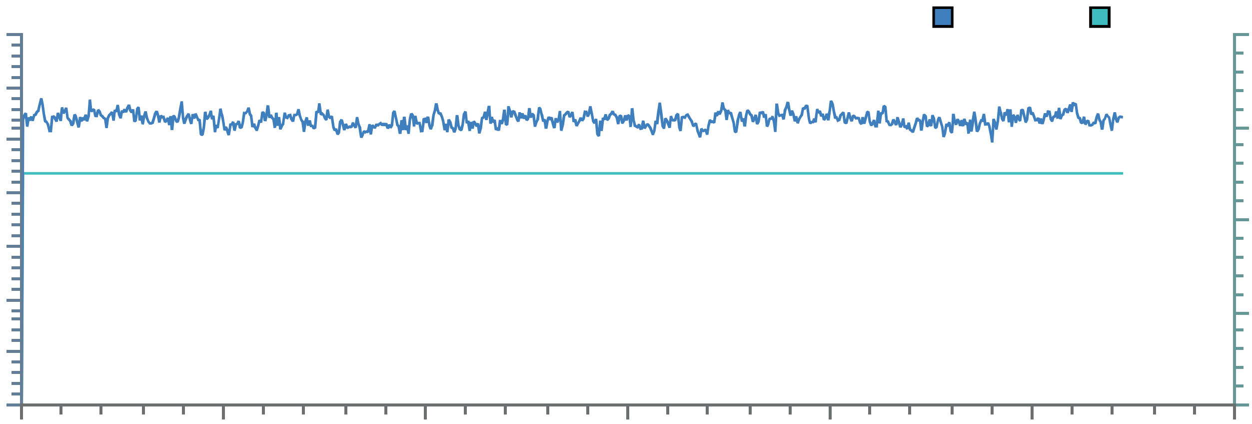
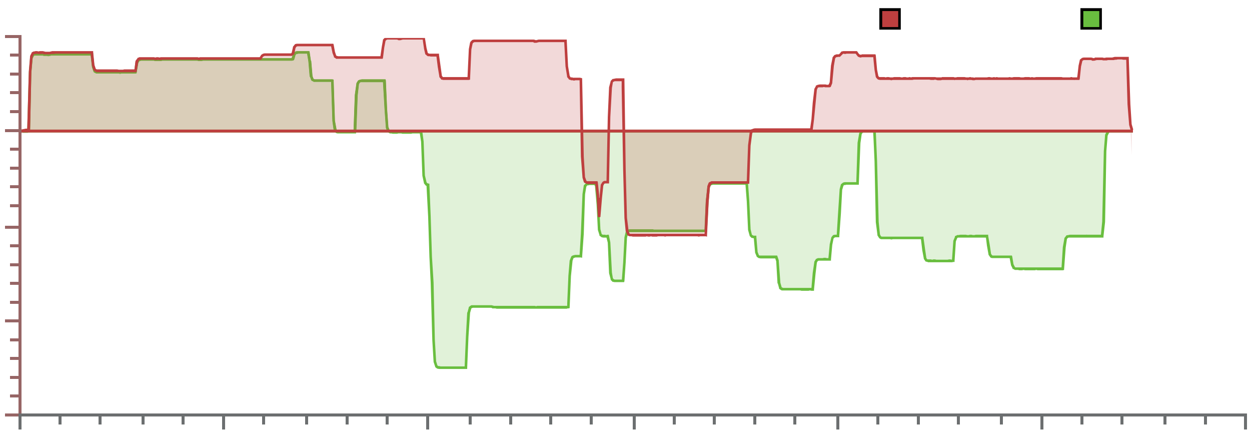
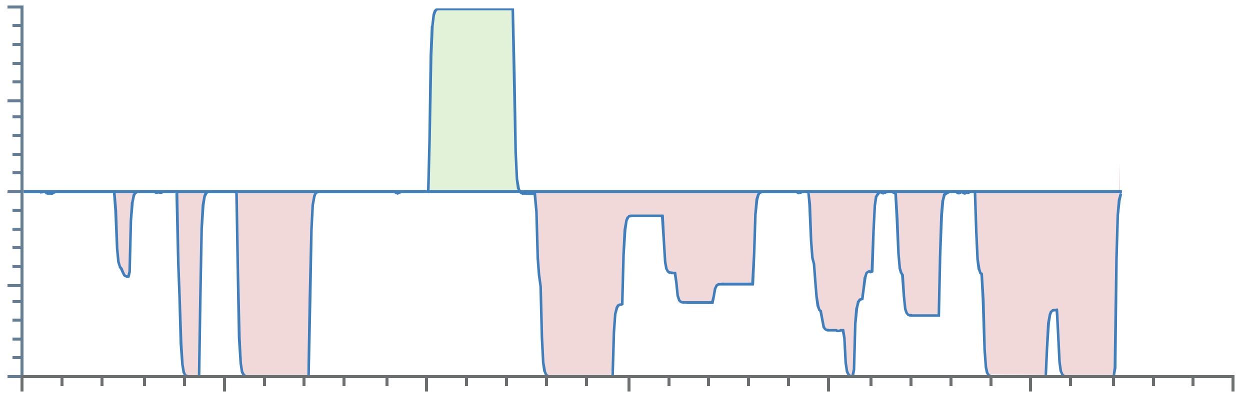
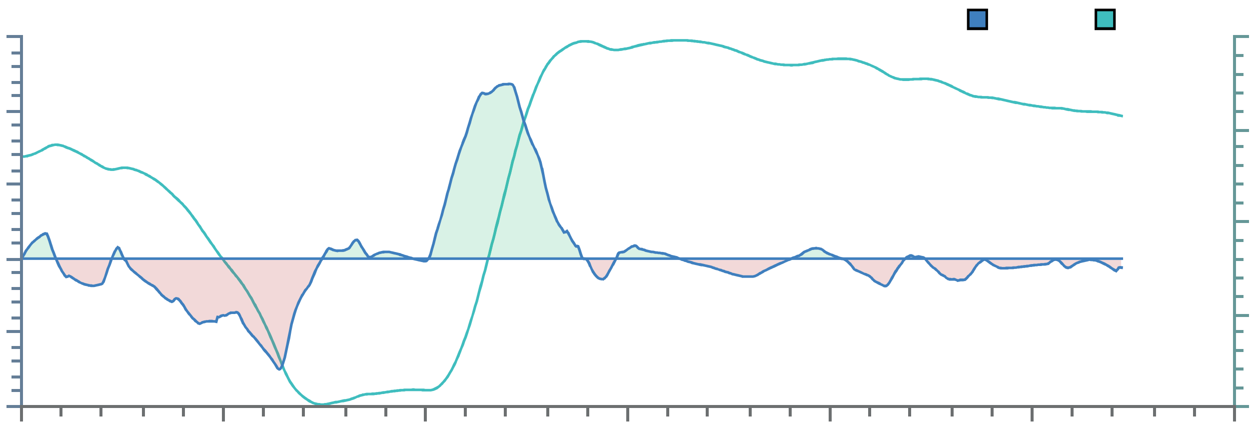
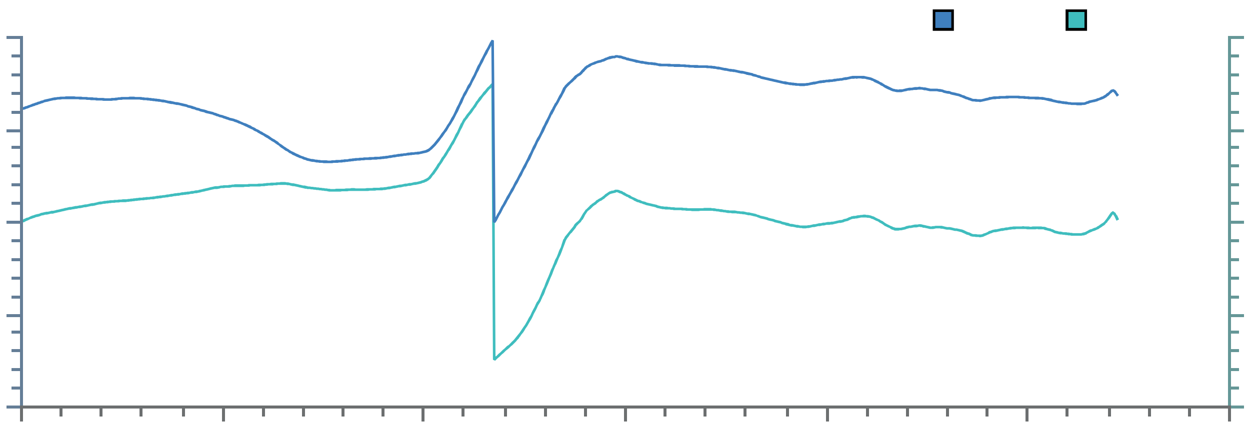


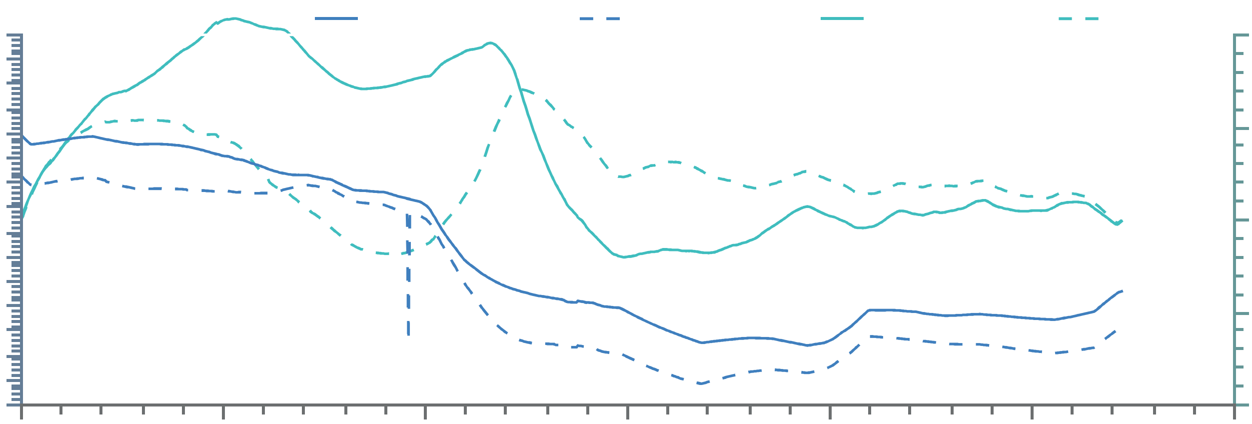


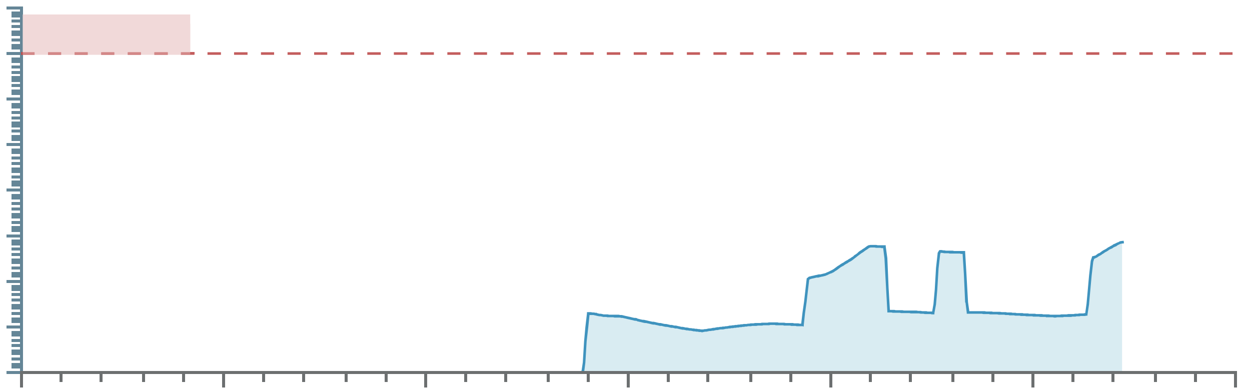


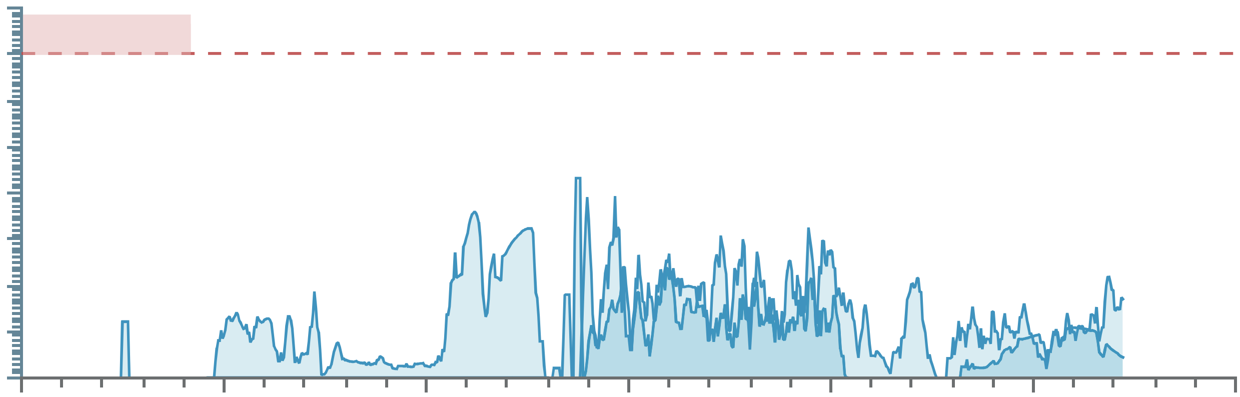




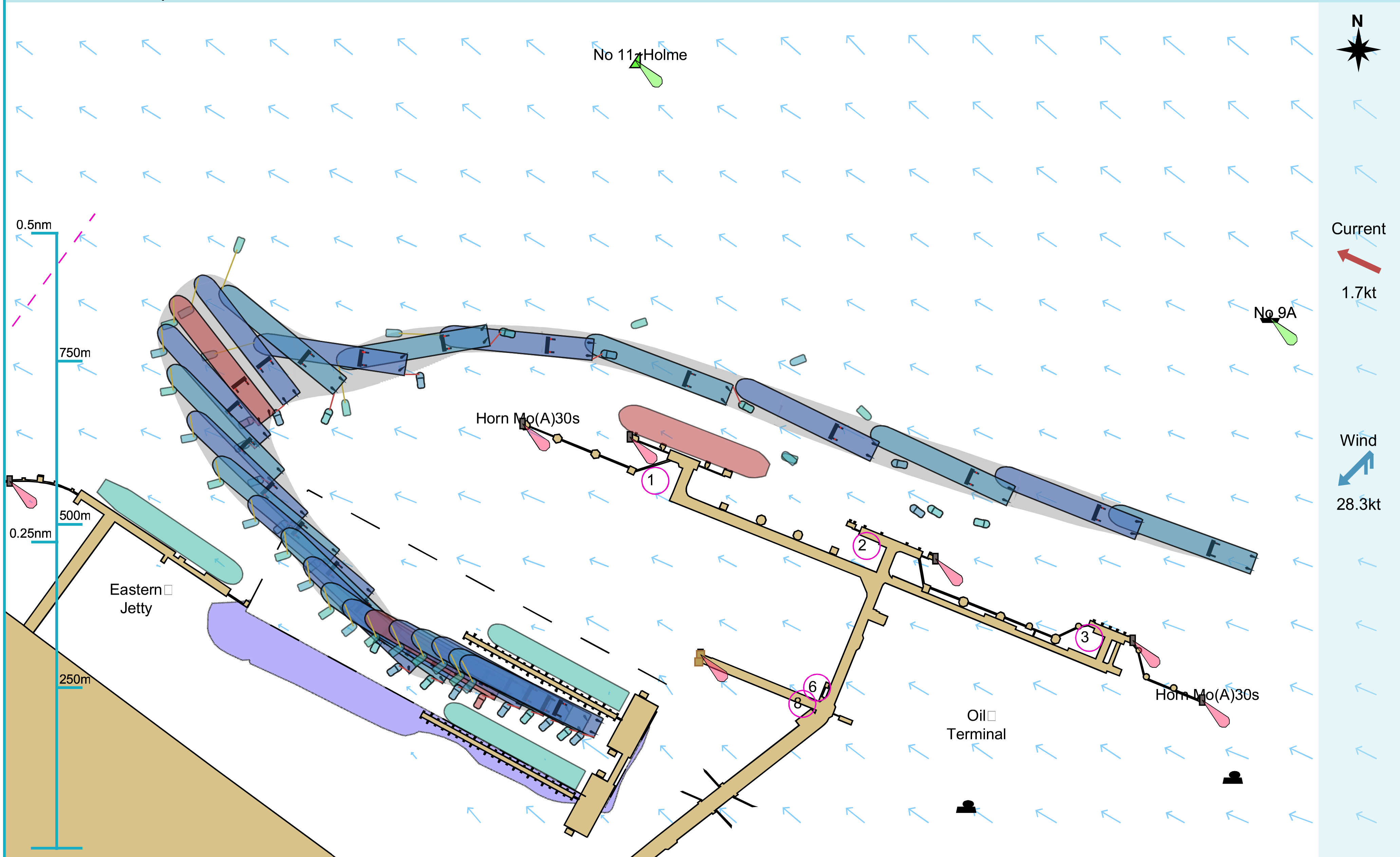








Manoeuvre track plot



Ships plotted every 1 mins, highlight every 10 mins

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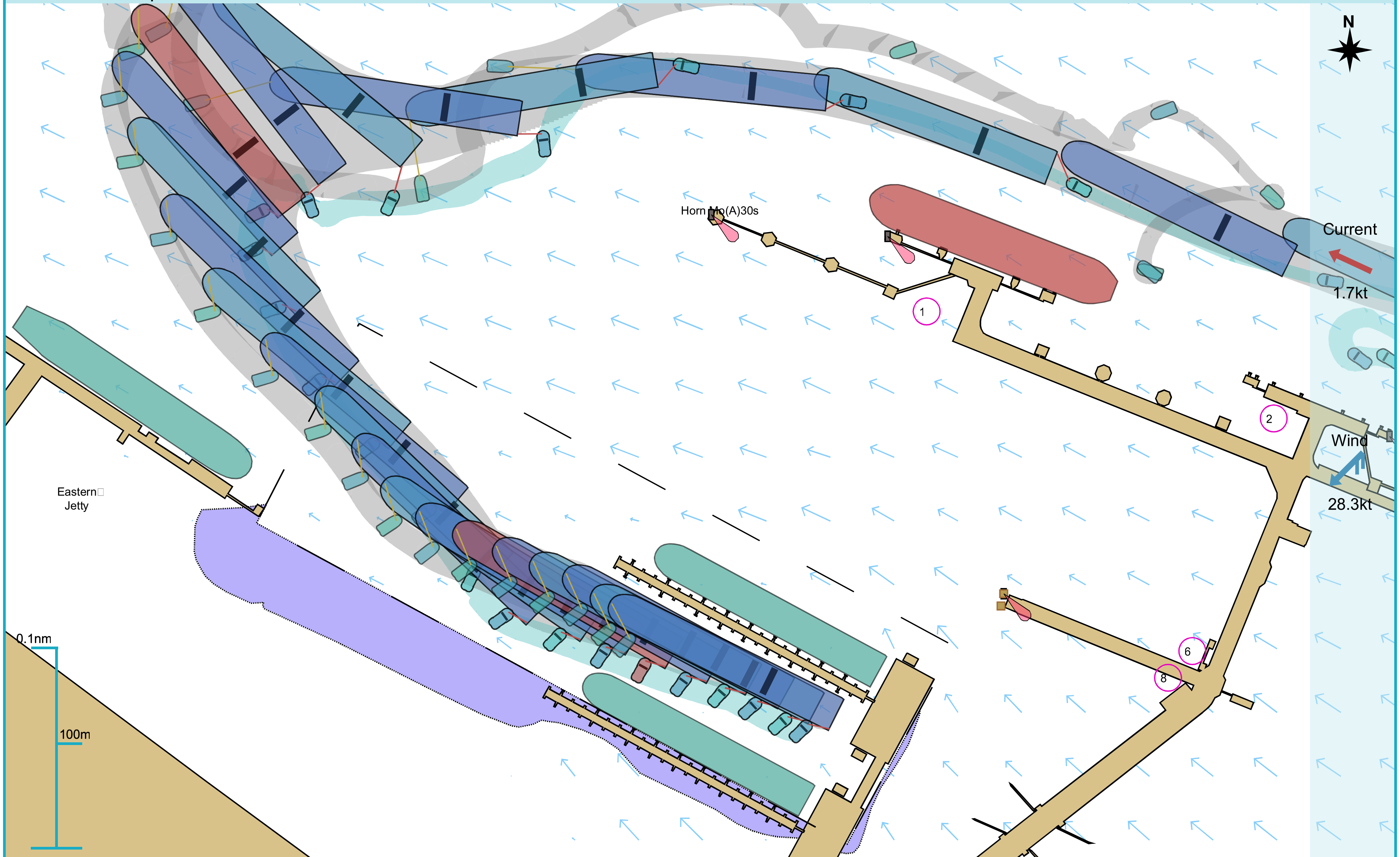

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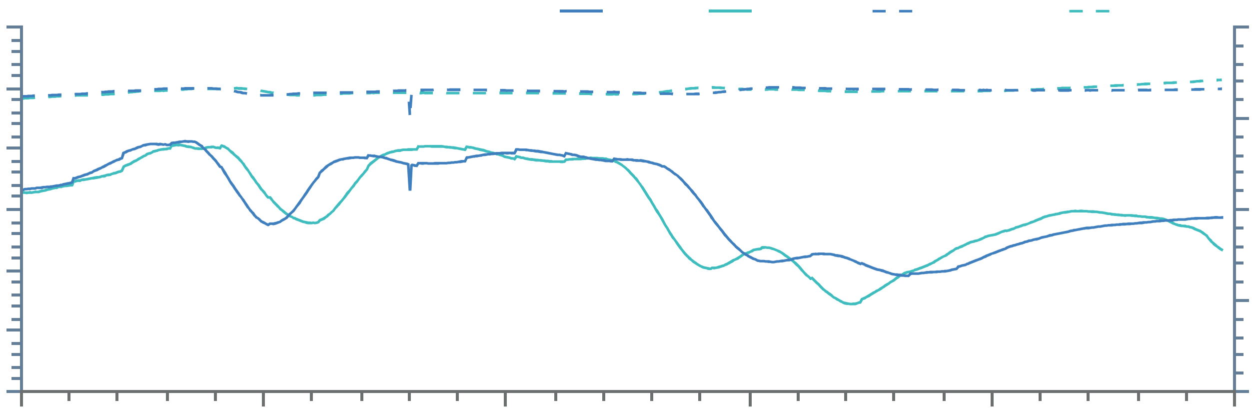

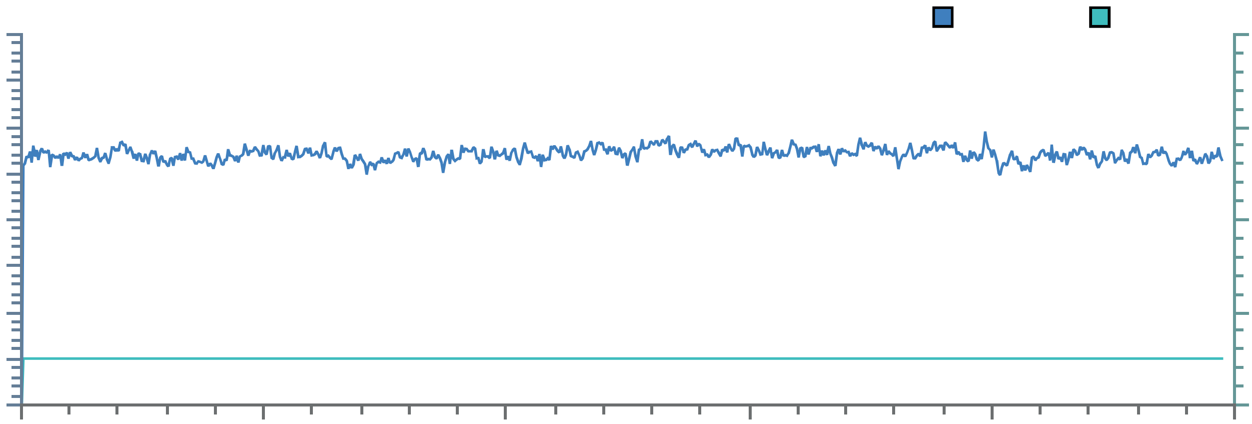

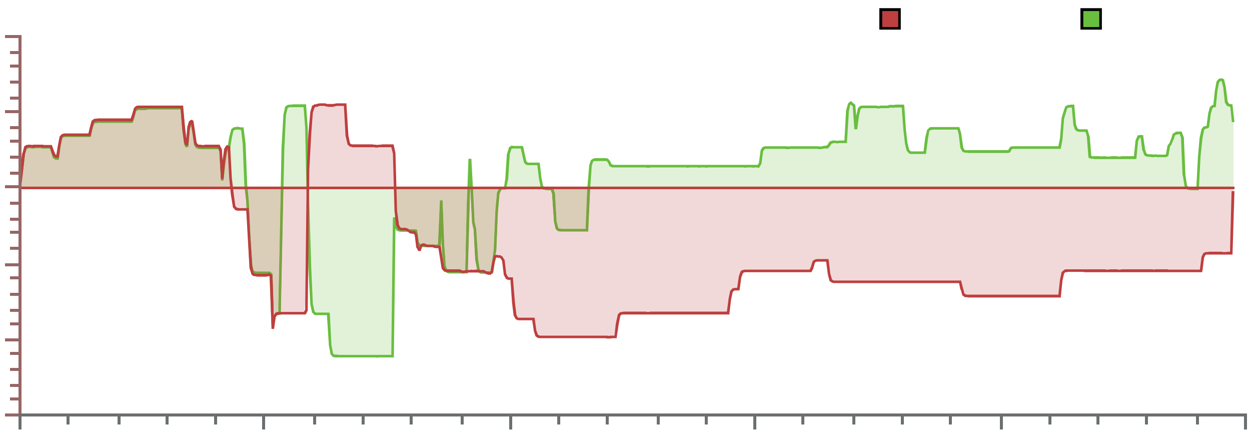

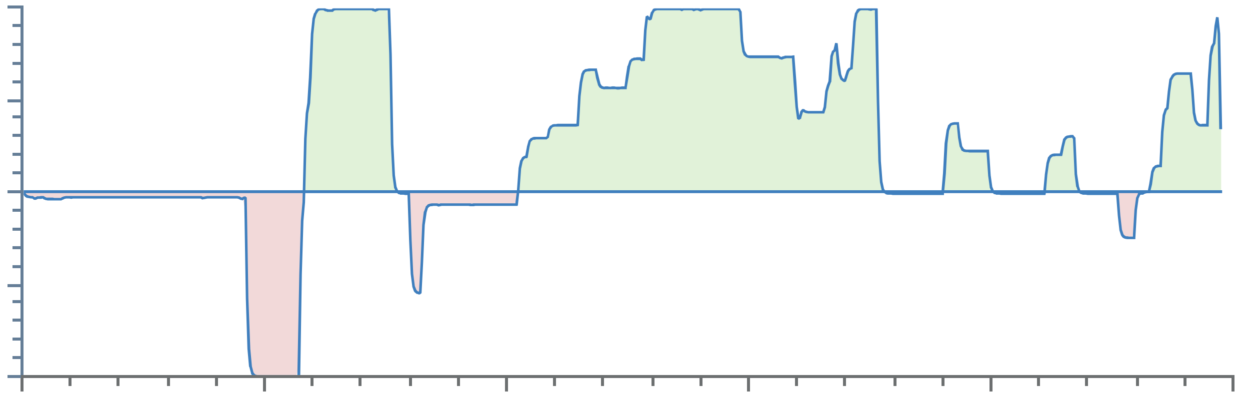

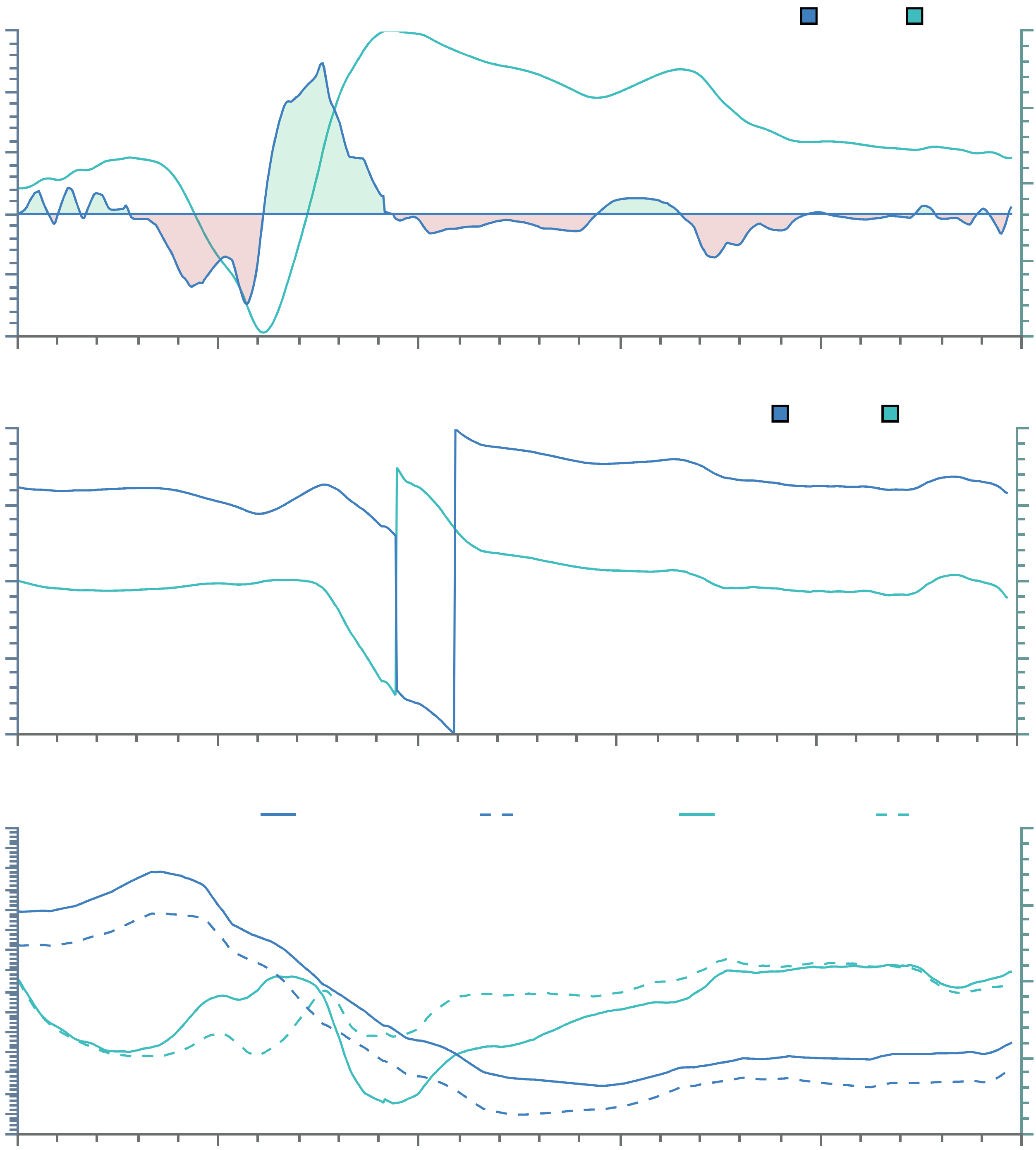

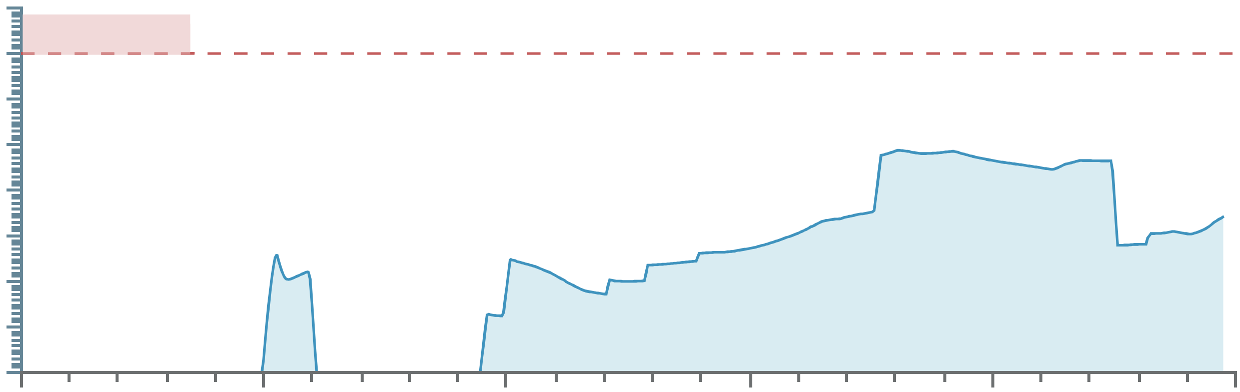

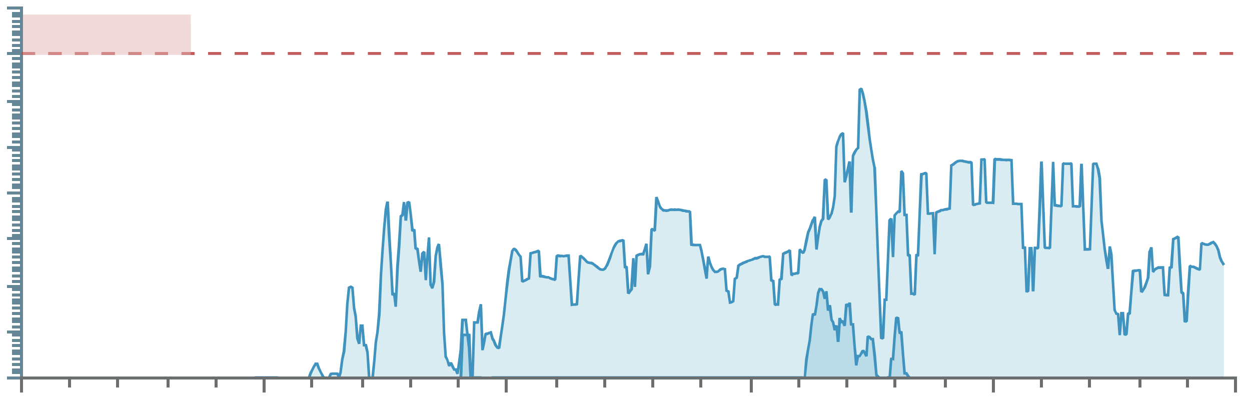

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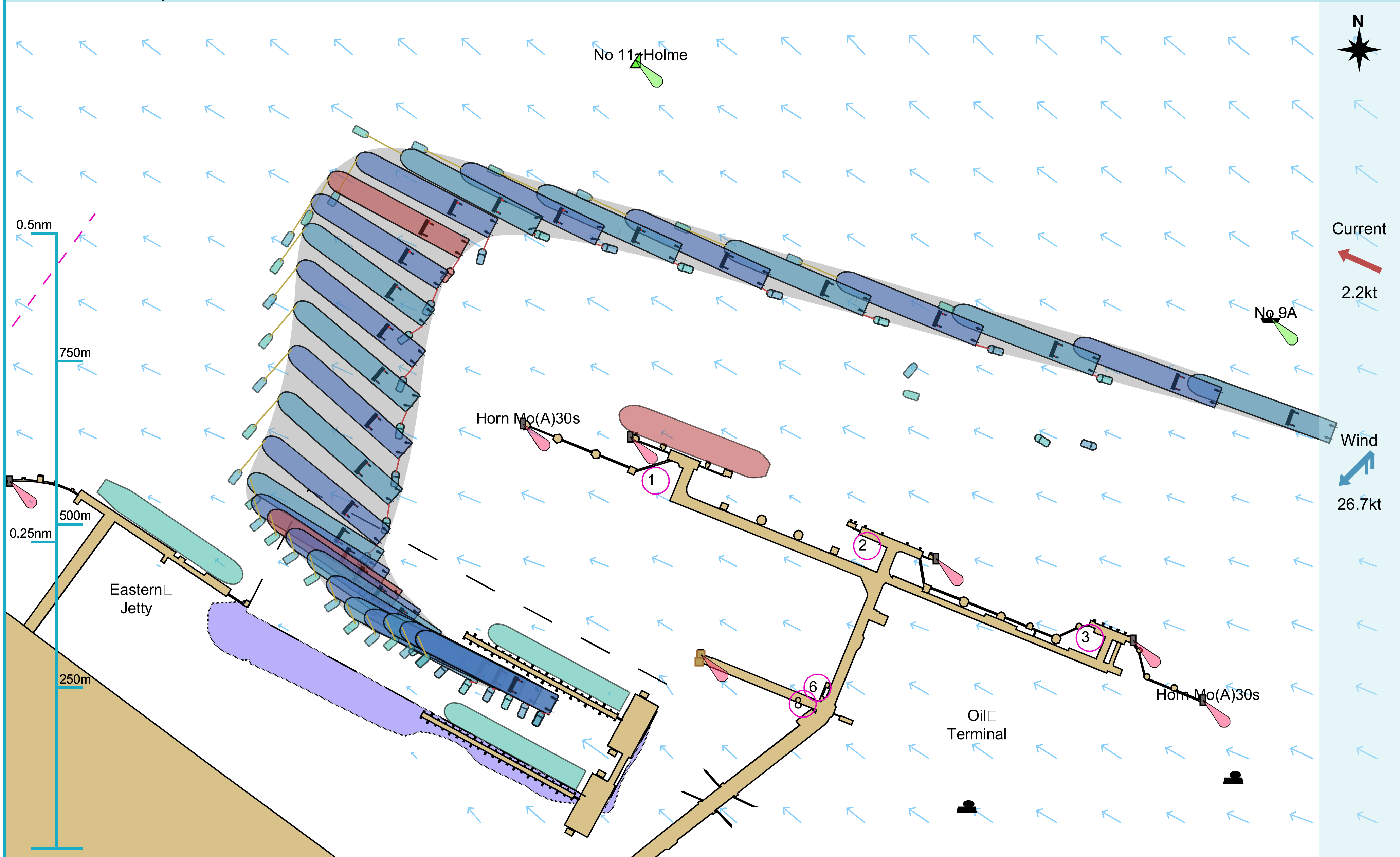

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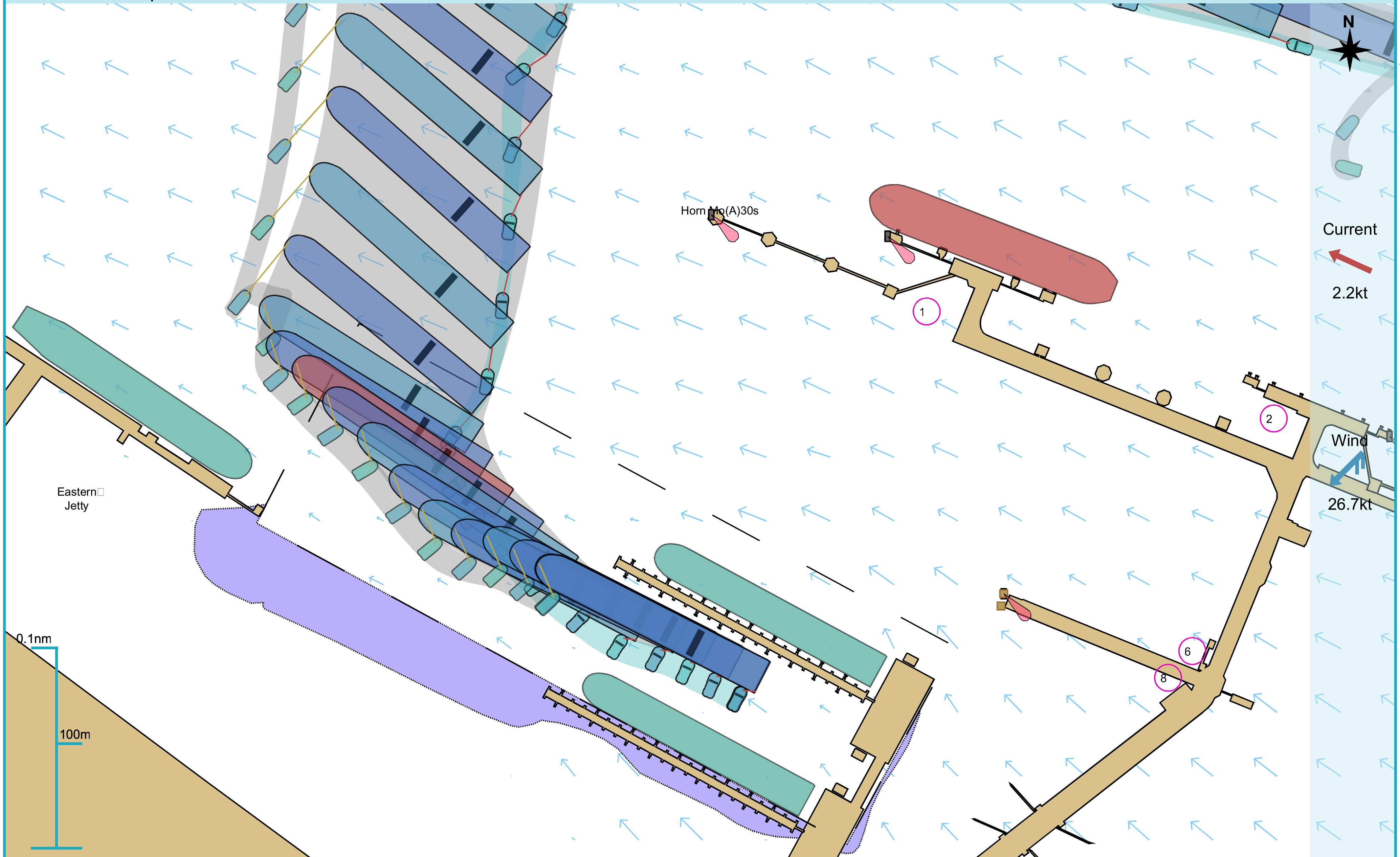

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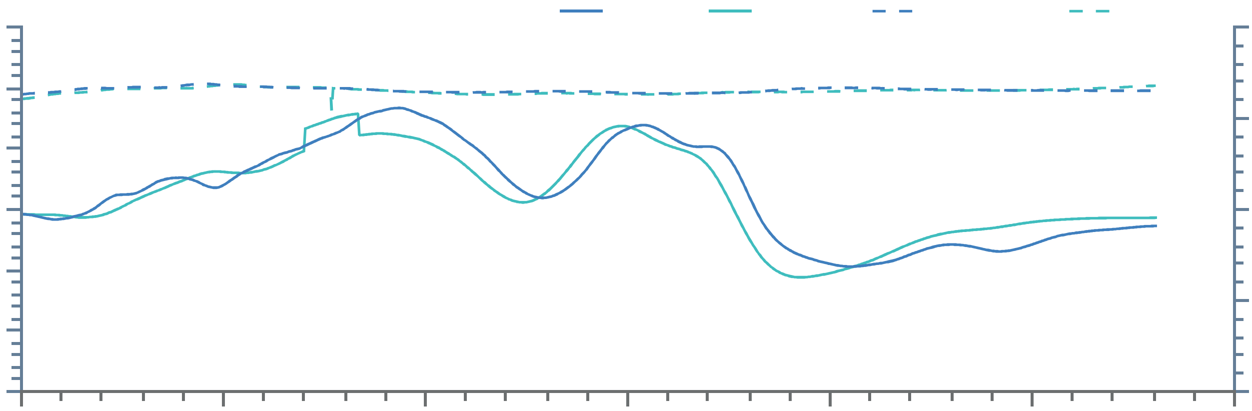
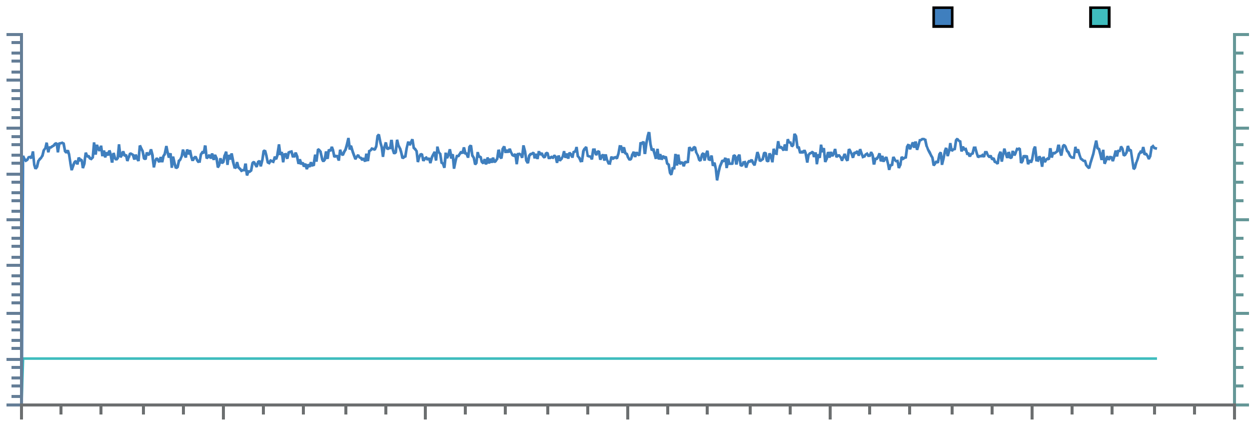
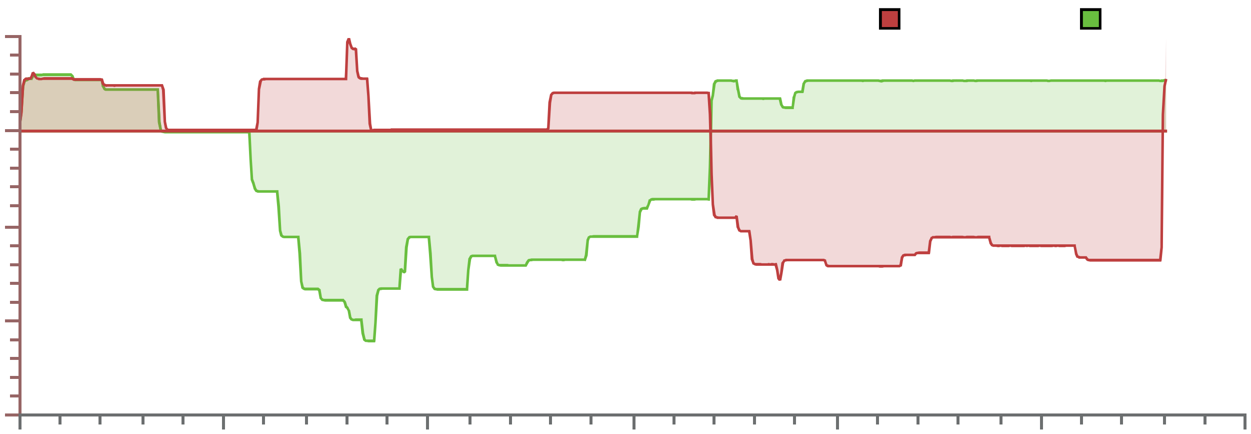
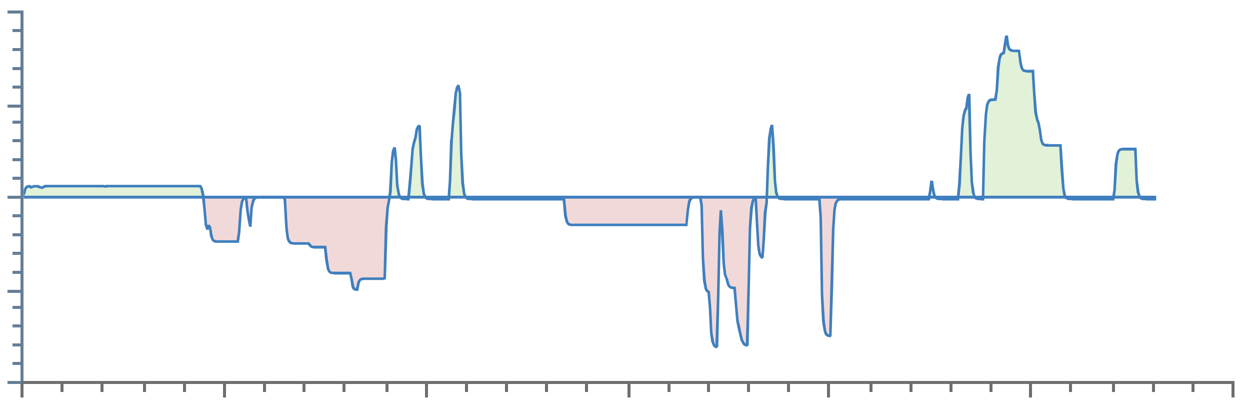
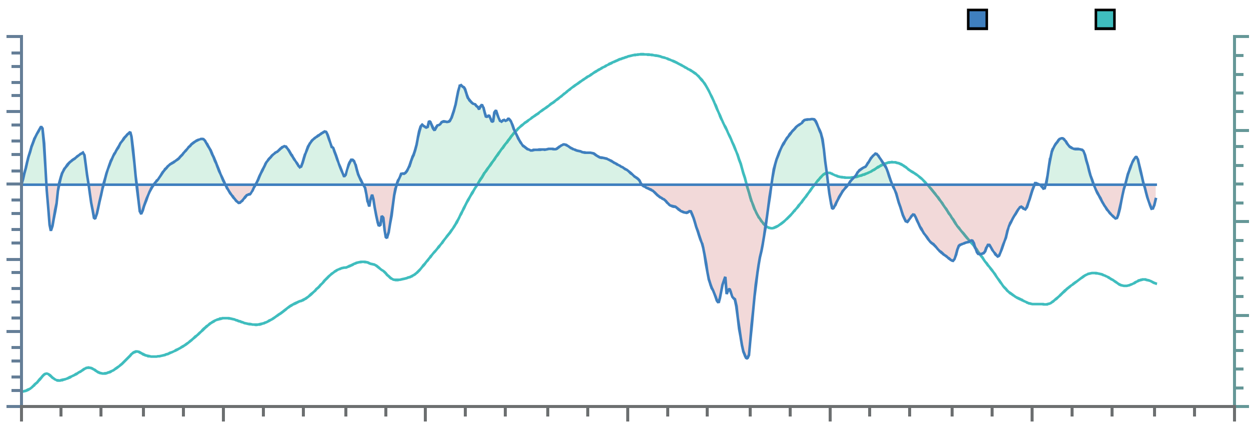
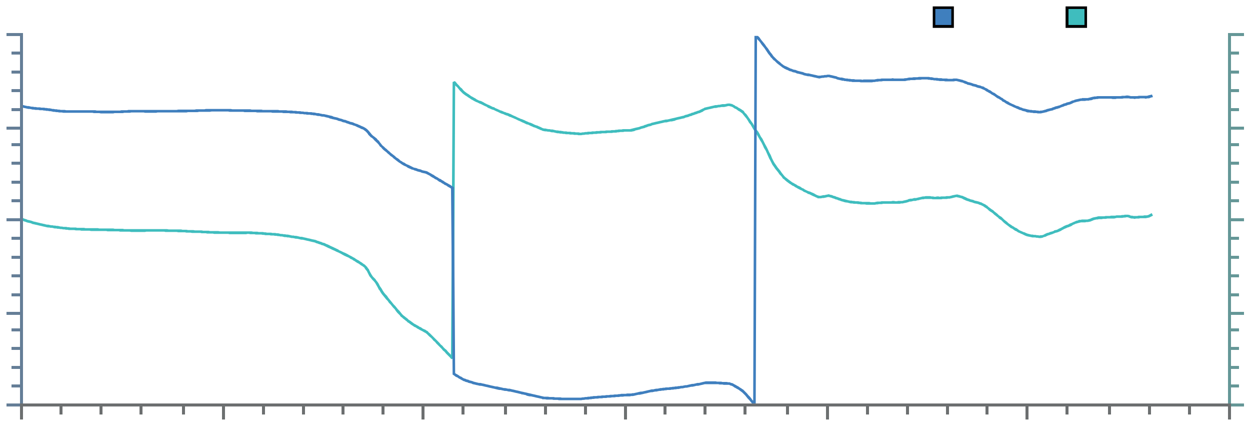


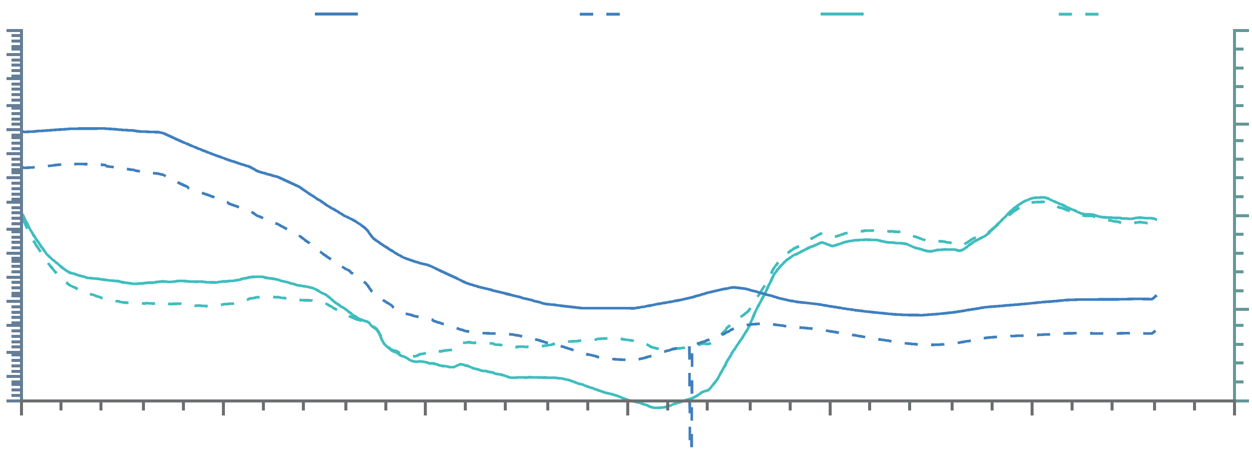


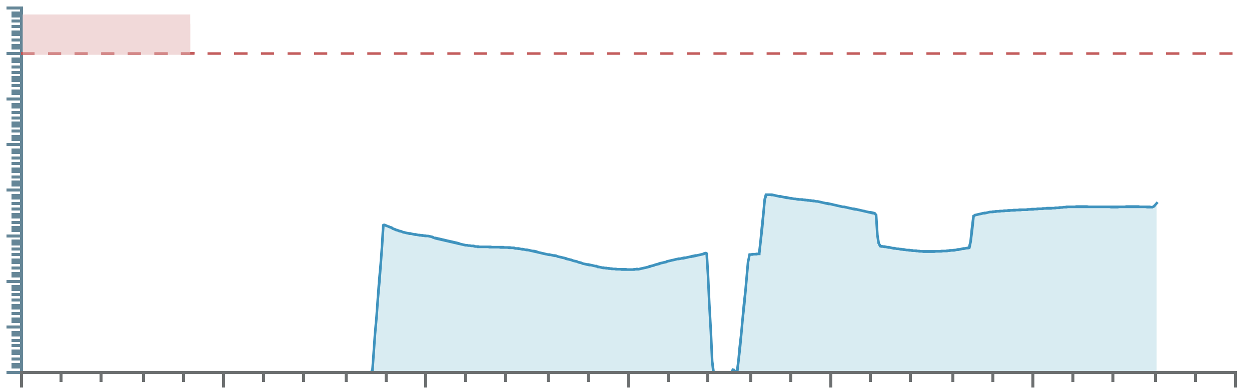


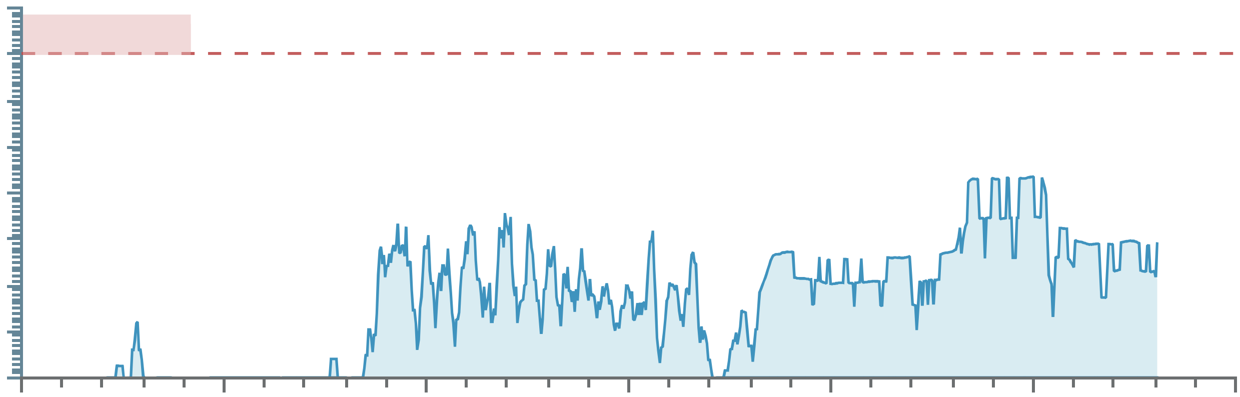




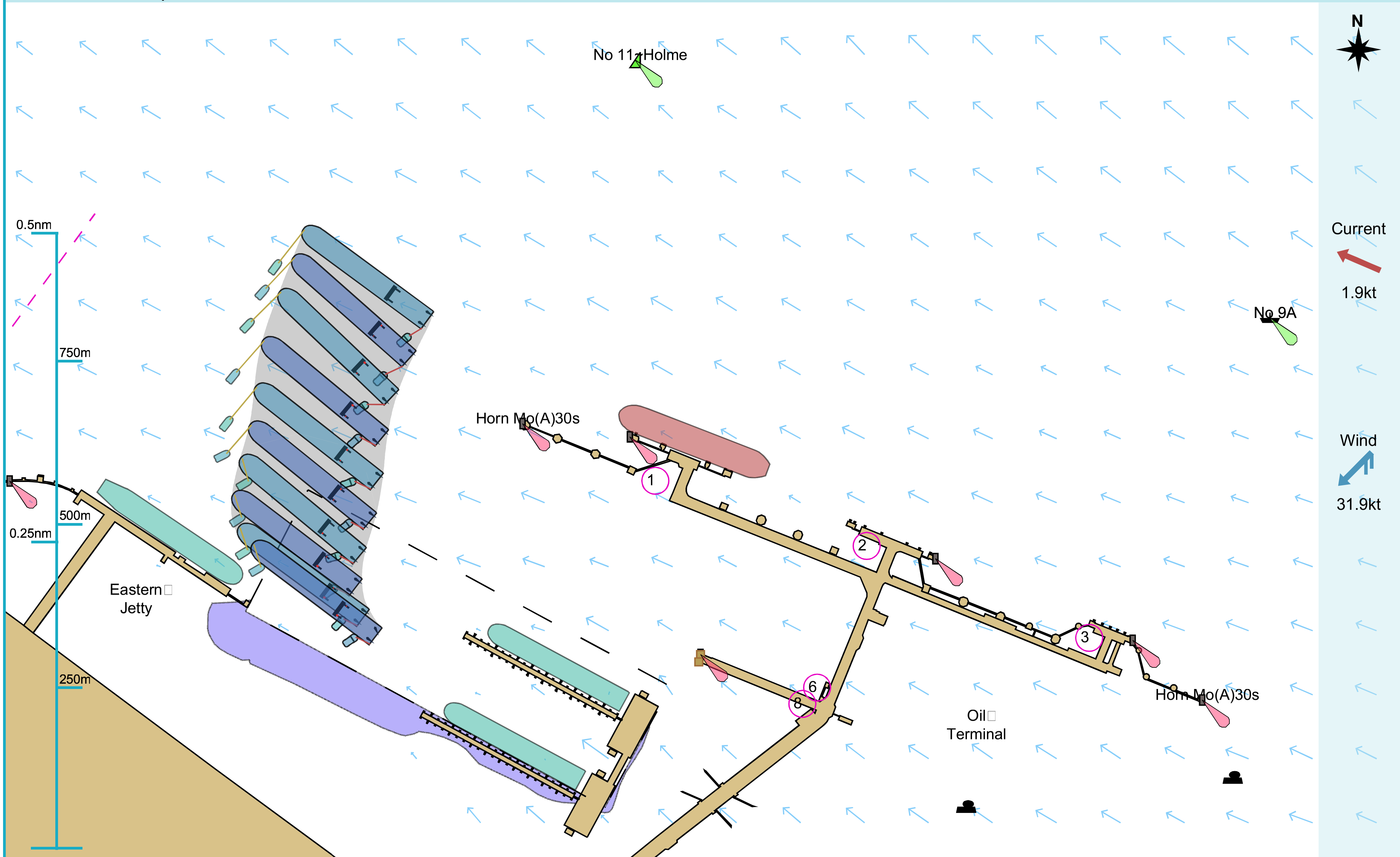






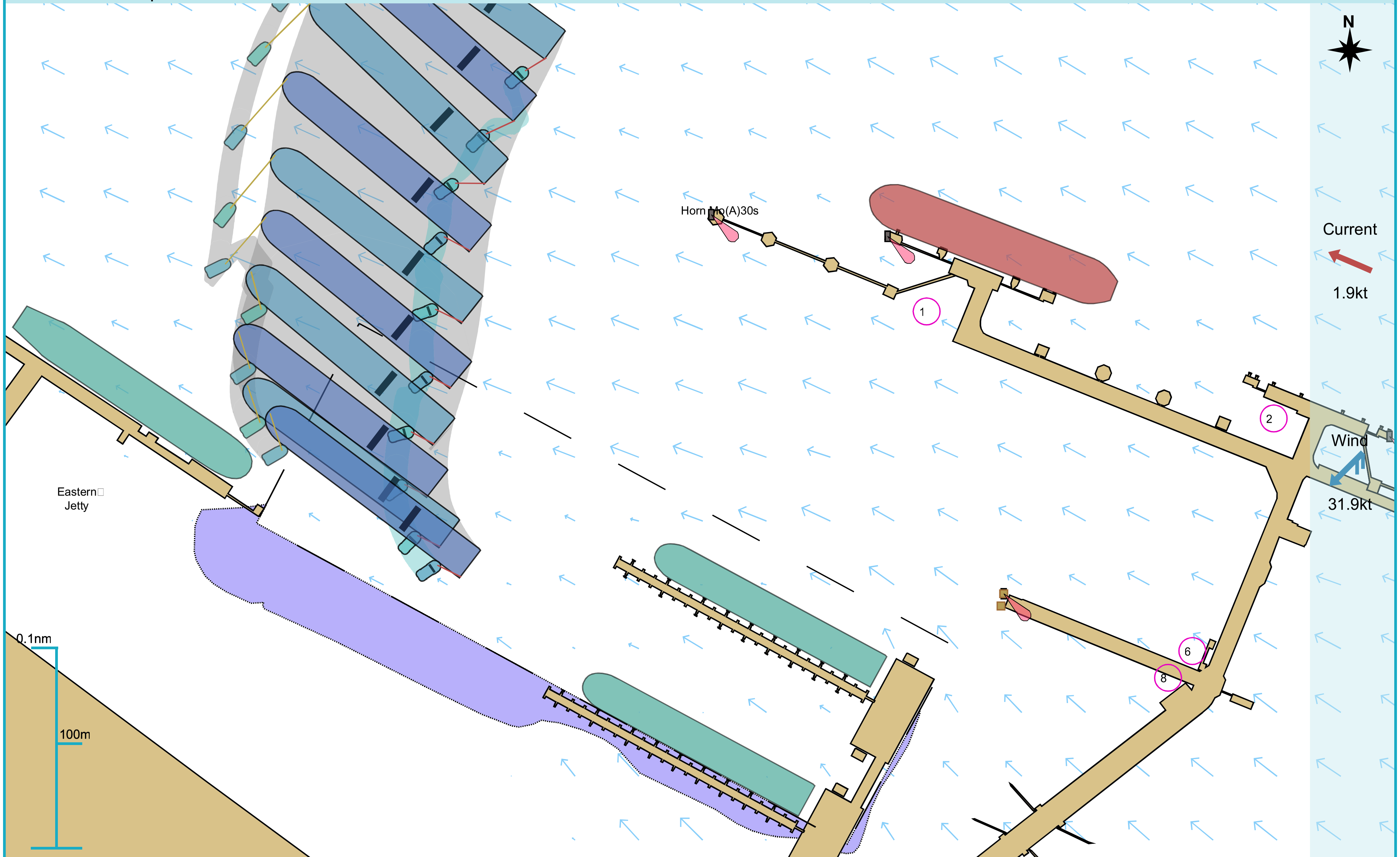


Manoeuvre track plot



Ships plotted every 1 mins, highlight every 10 mins

Manoeuvre track plot



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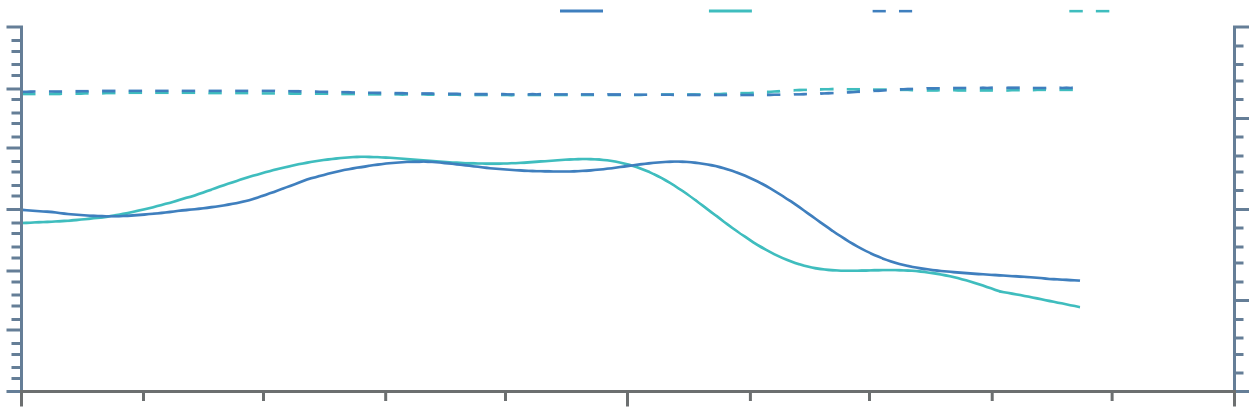

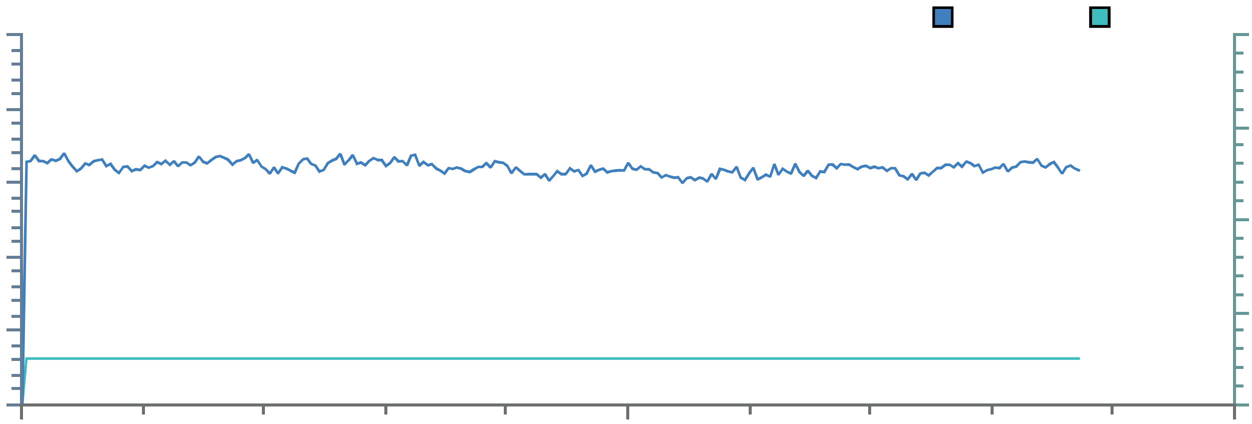

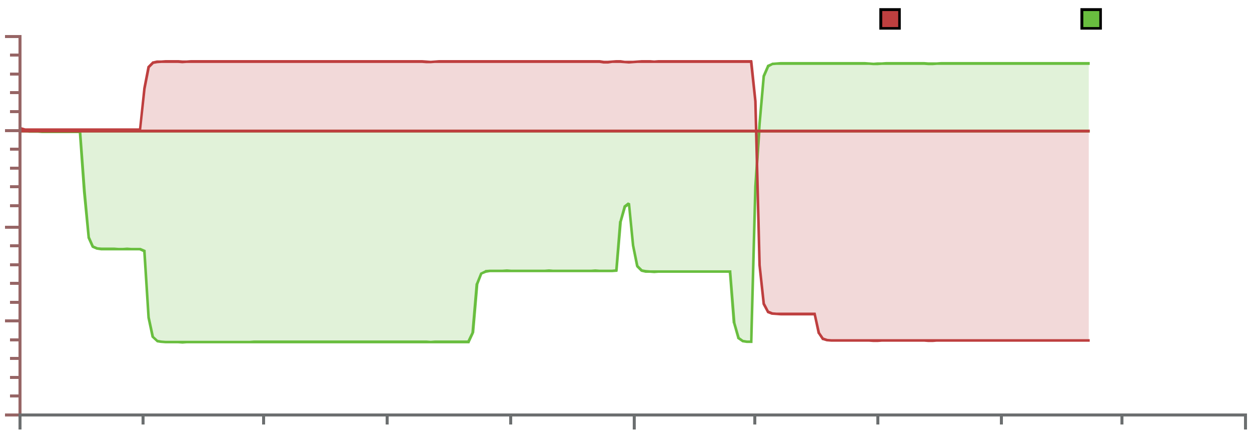

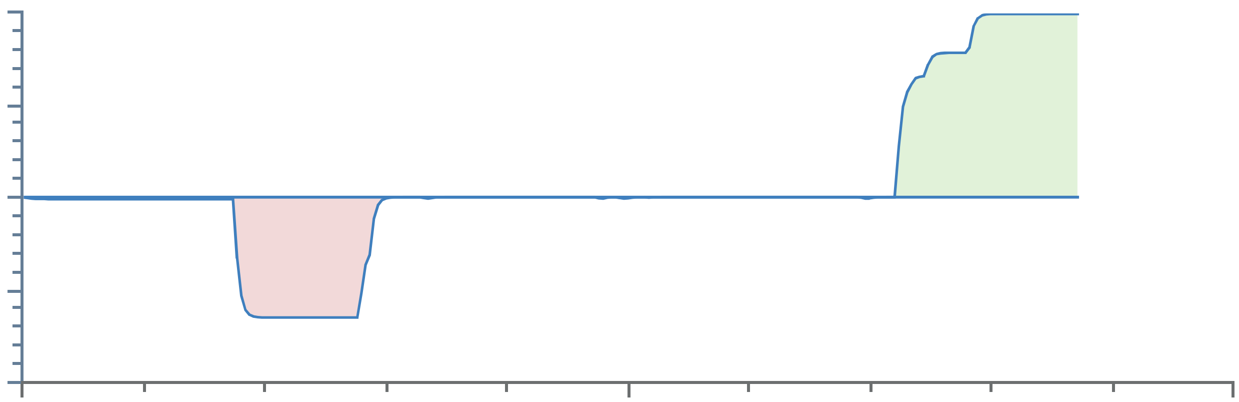

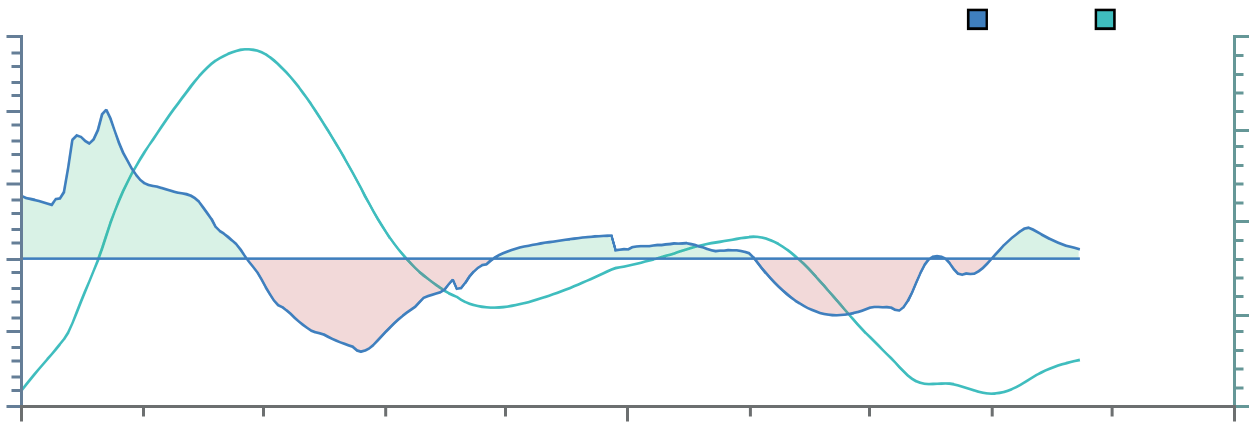

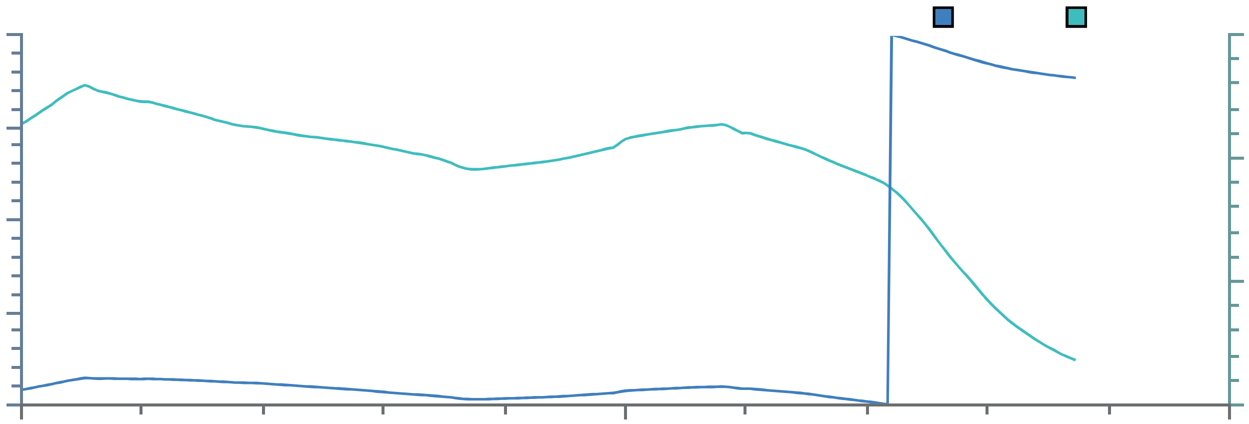

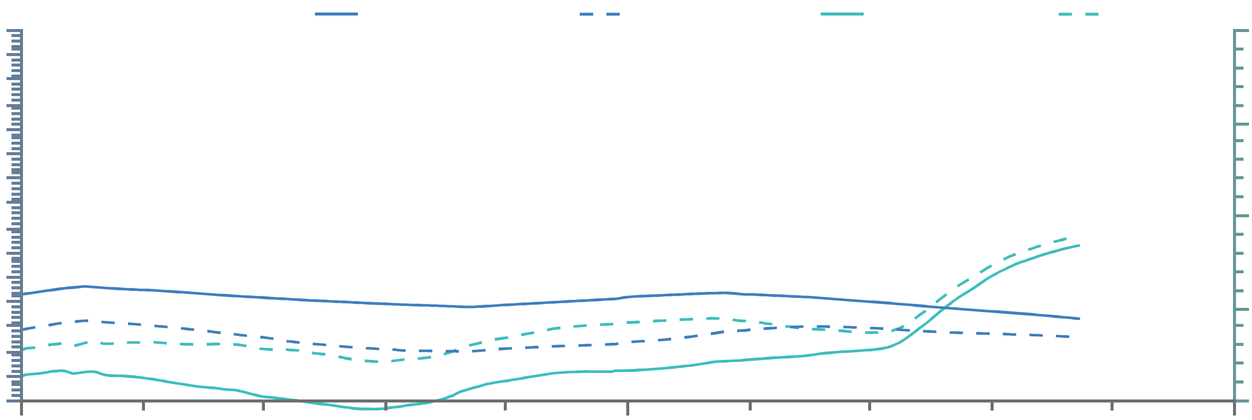

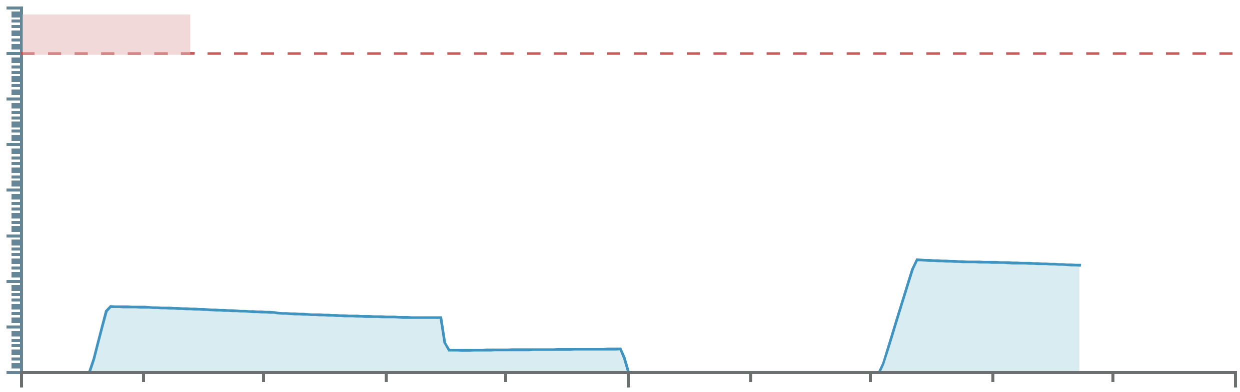

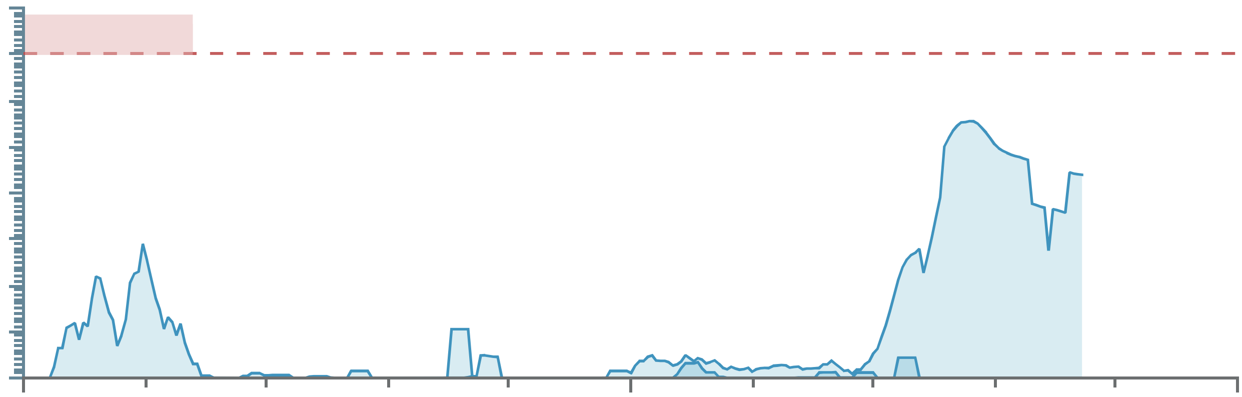

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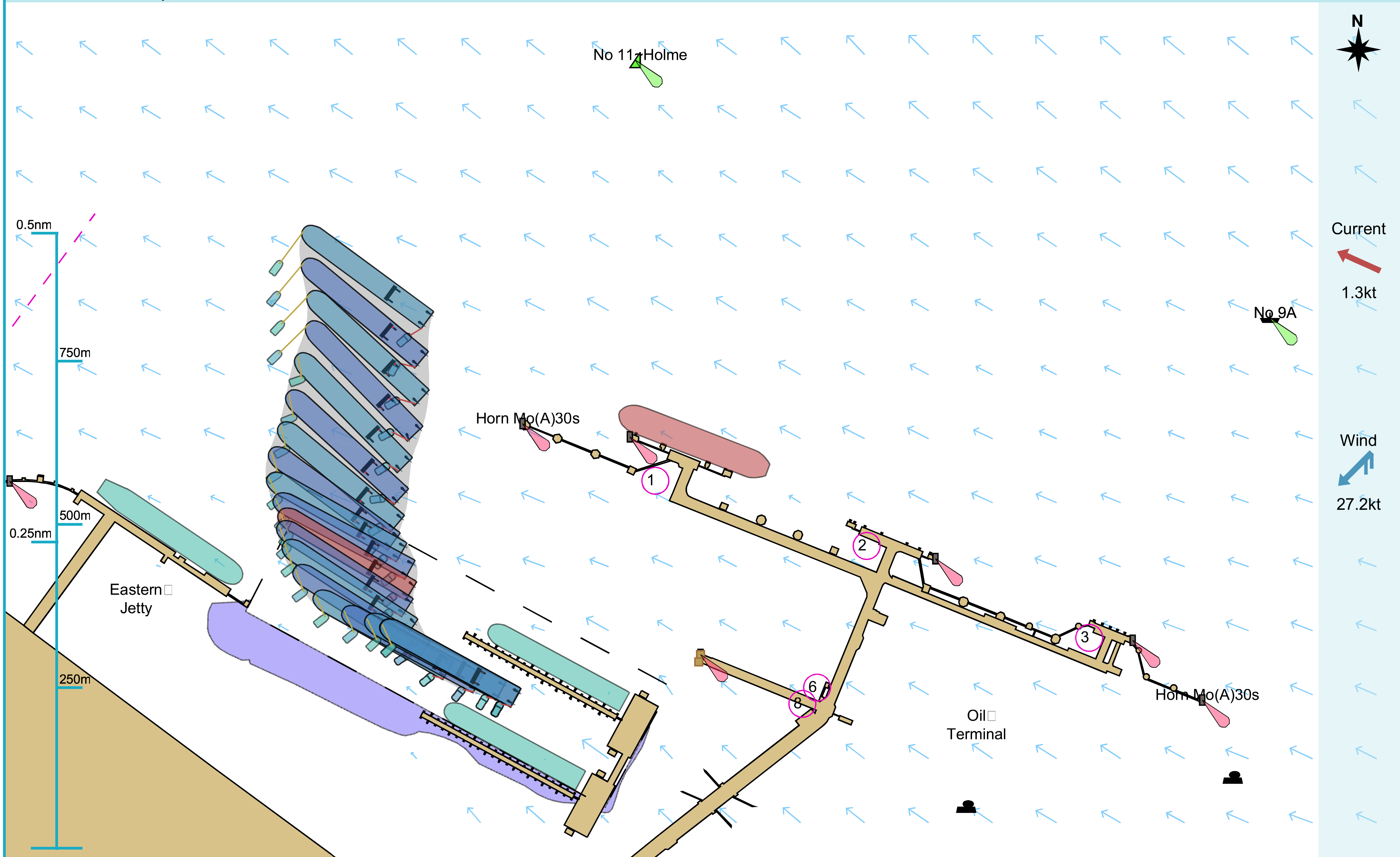
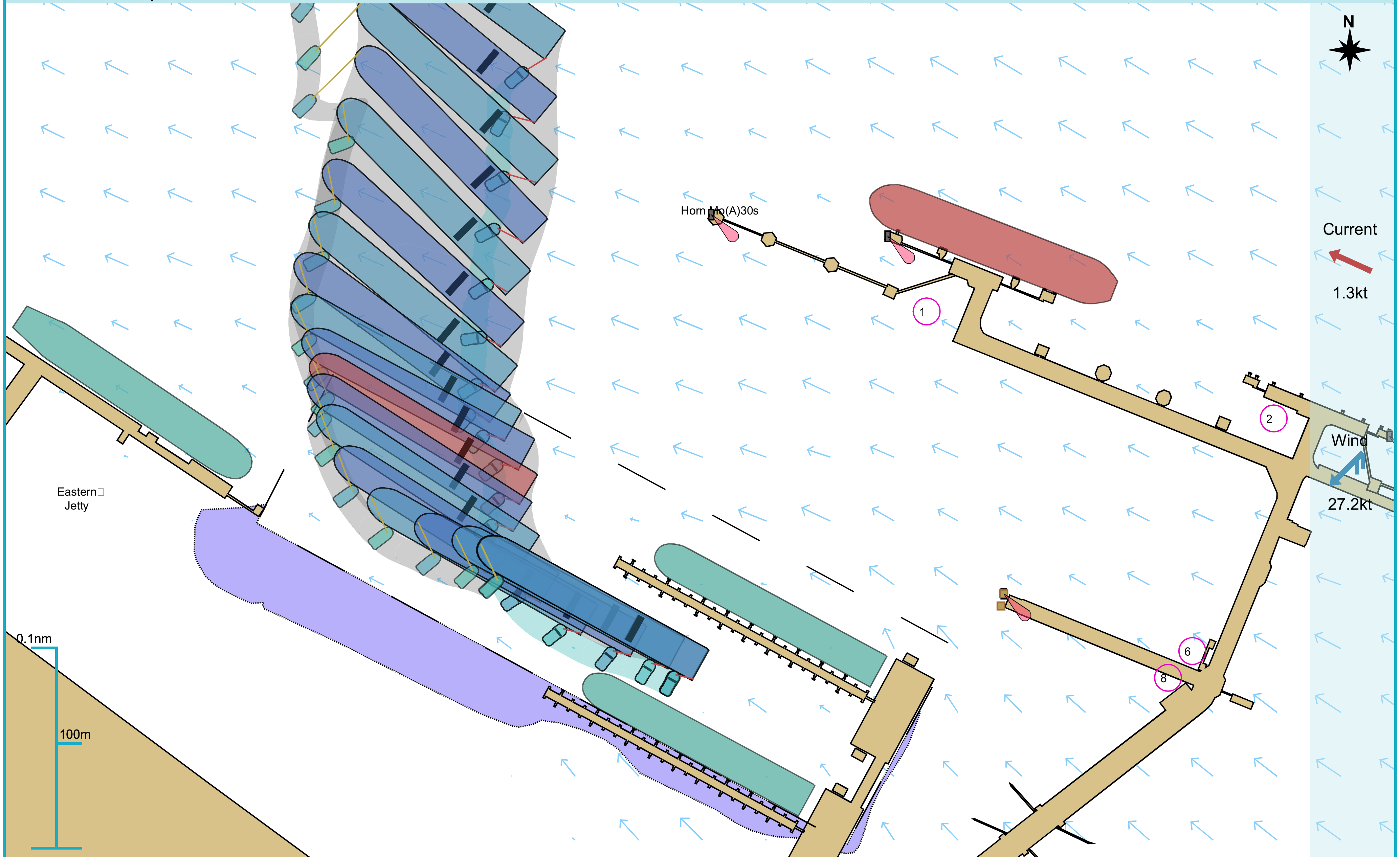


Ships plotted every 1 mins, highlight every 10 mins

Manoeuvre track plot



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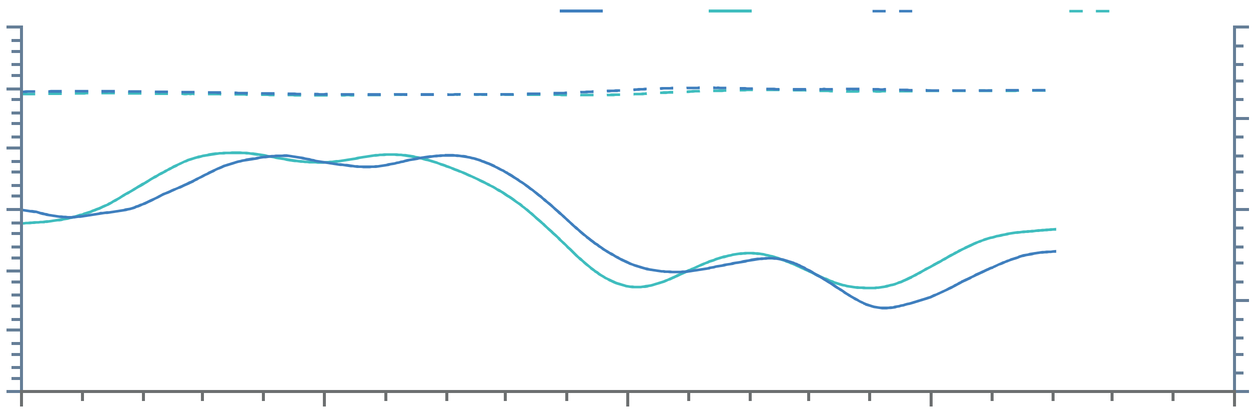

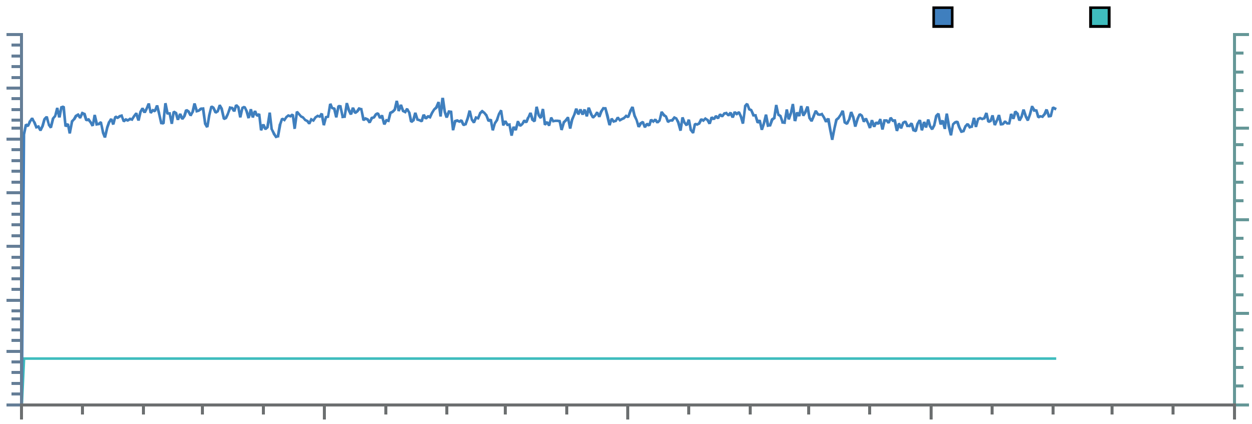

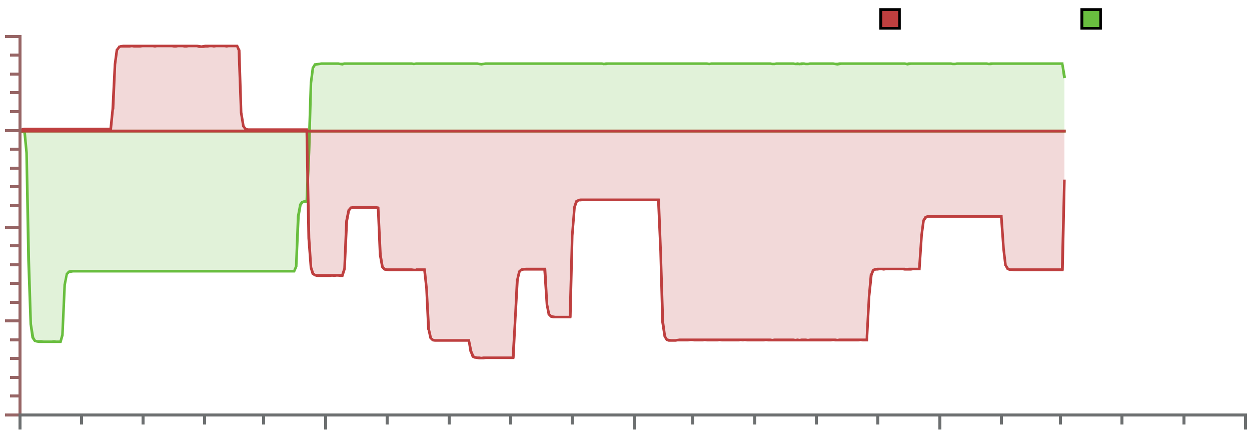

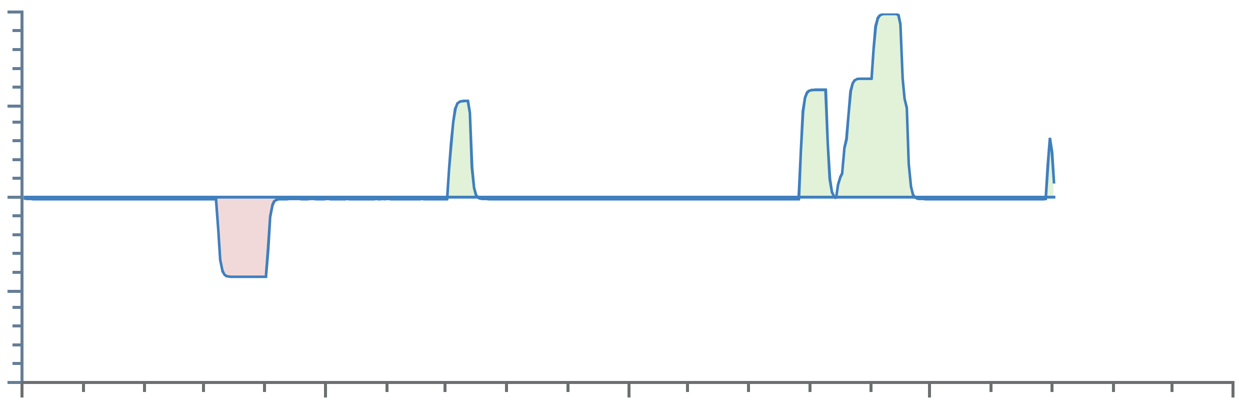

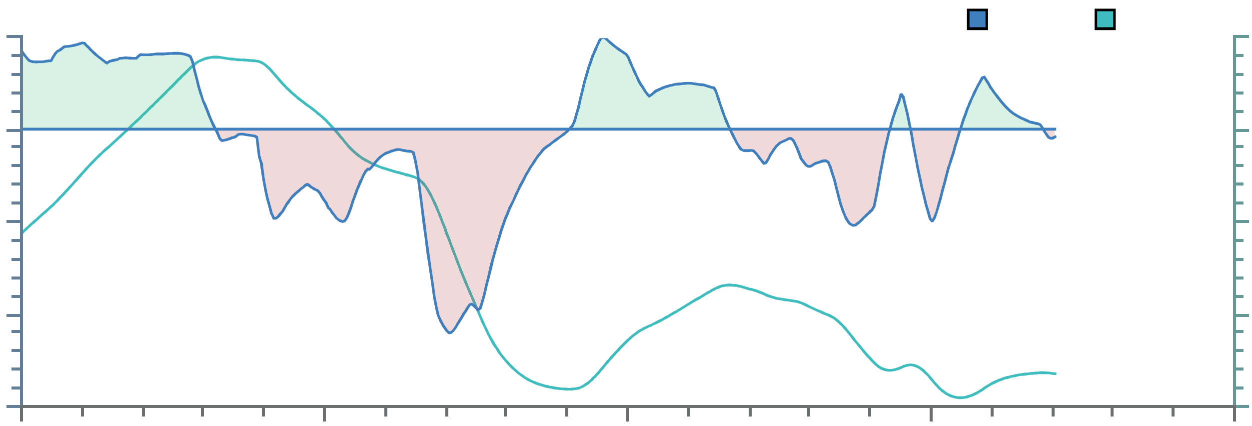

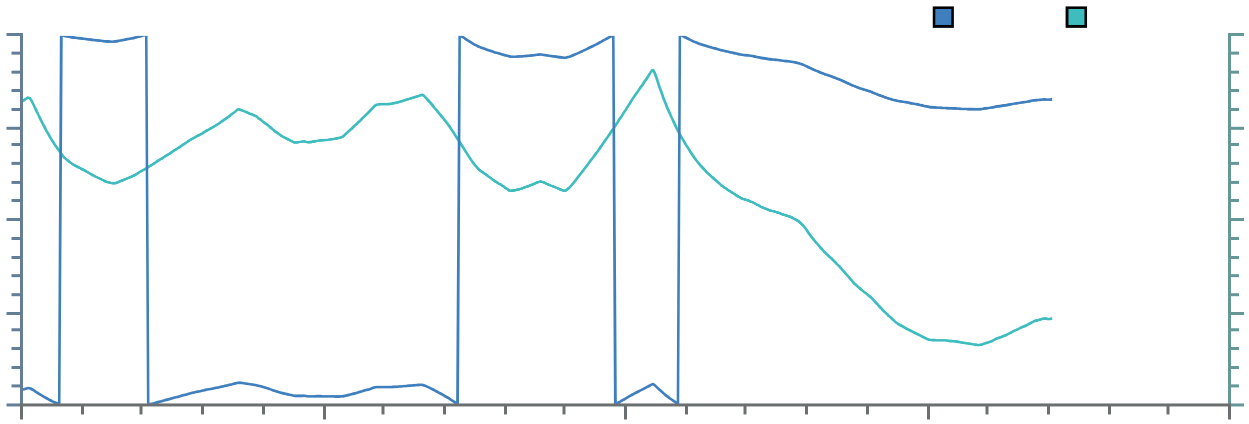

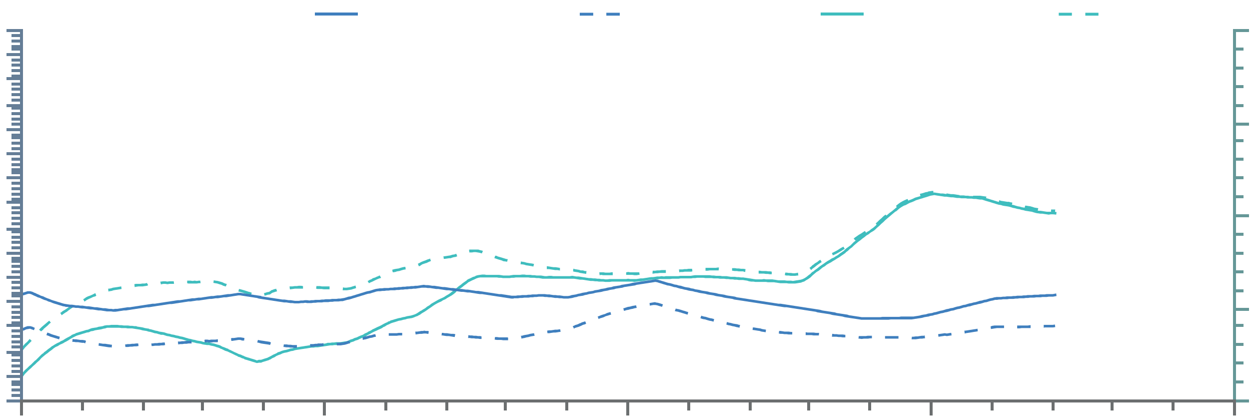

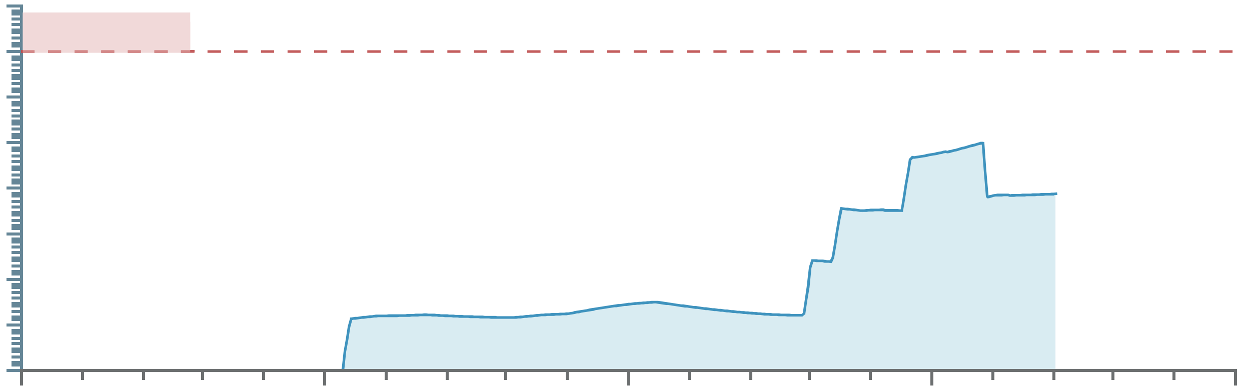

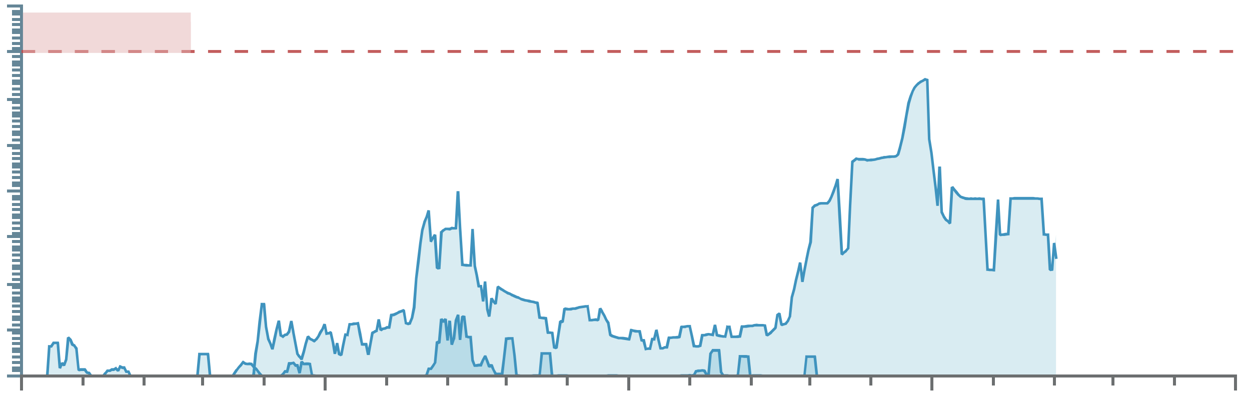

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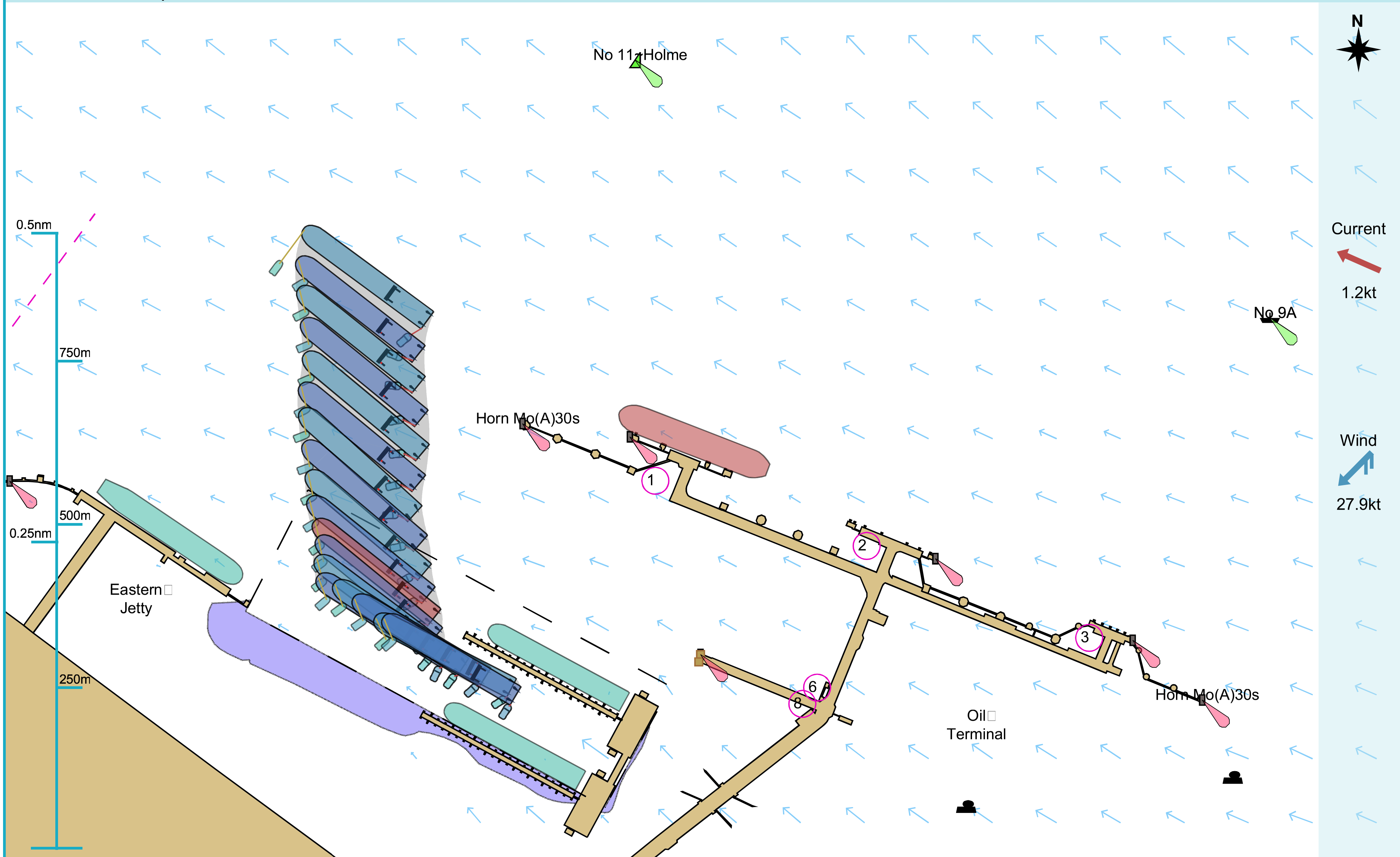
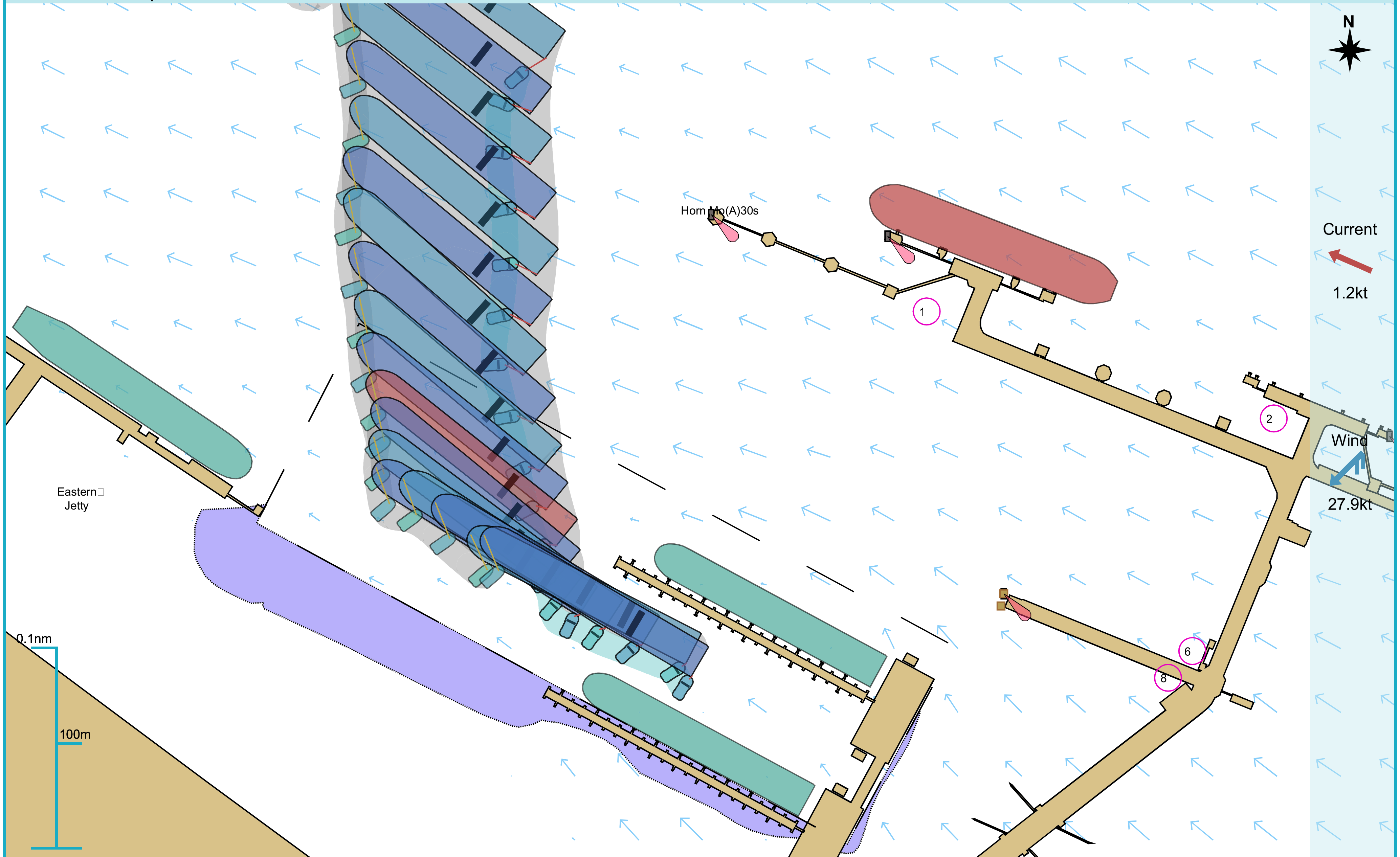


Ships plotted every 1 mins, highlight every 10 mins

Manoeuvre track plot



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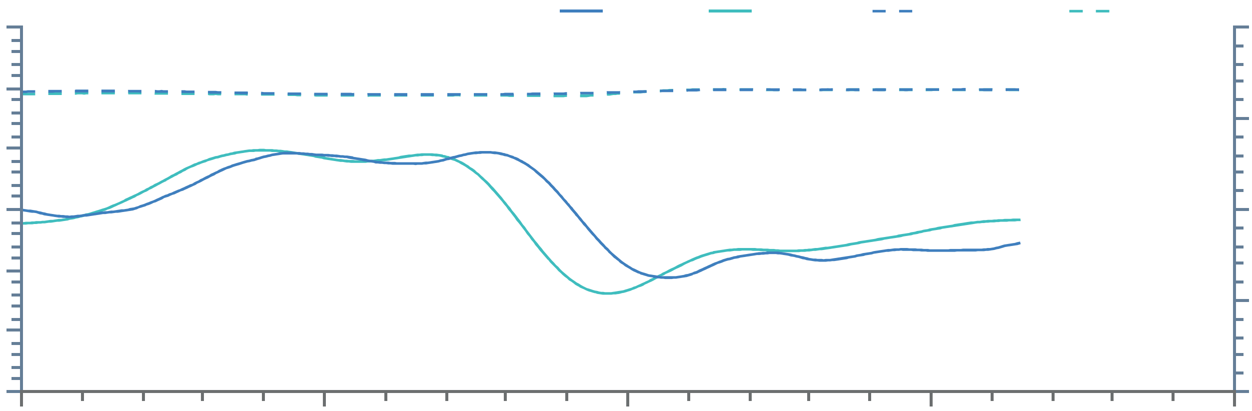

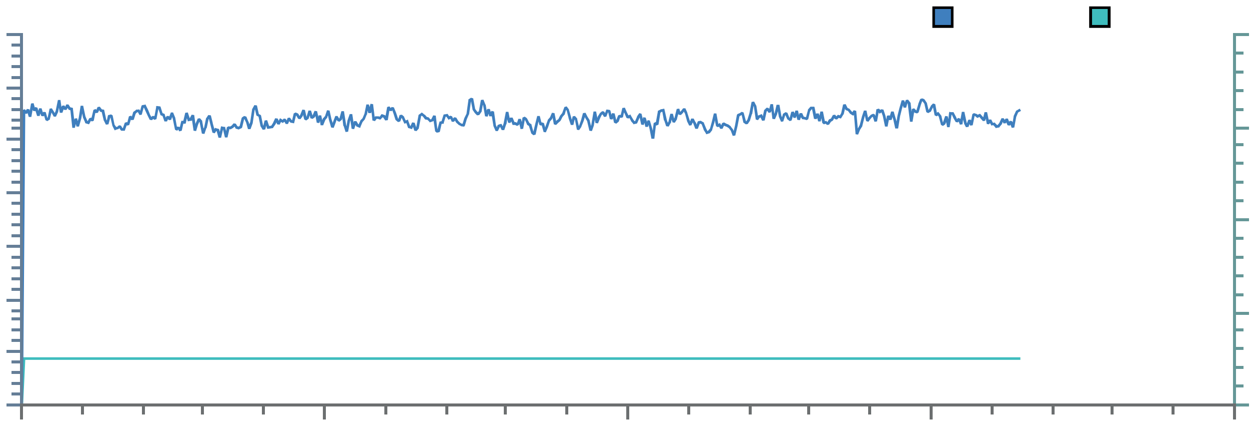

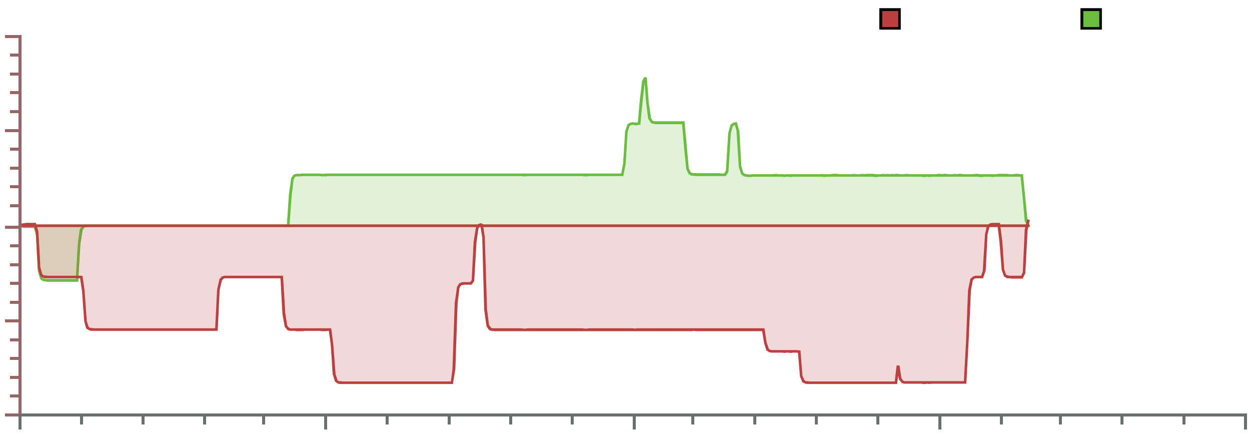

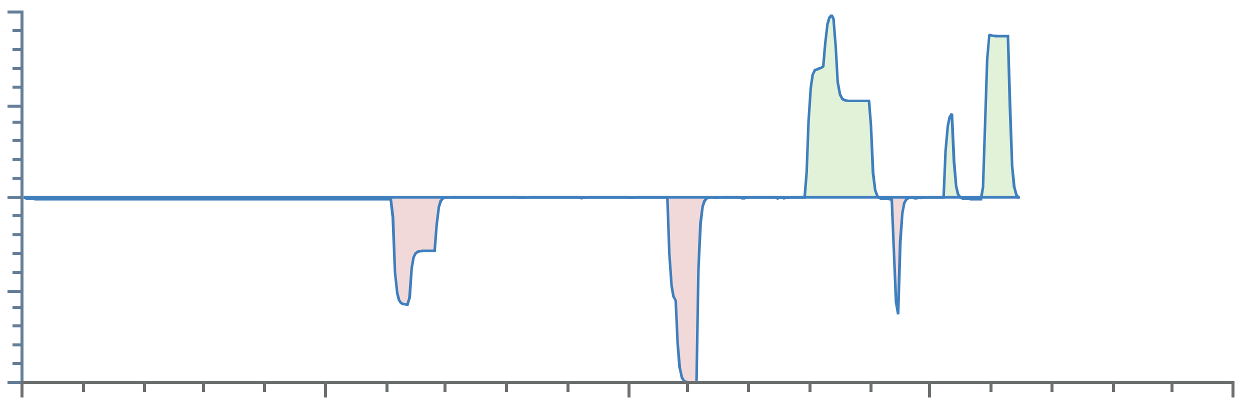

Summary | Environment | 237m RoRo unnamed | Tugs