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MALAMOCCO EXISTING CHANNEL FULL-MISSION SIMULATIONS

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1. EXECUTIVE SUMMARY

This report comprises a qualitative full-mission ship simulator study for evaluating the existing Malamocco channel in Port of Venice, Italy, in order to find the challenging parts for future development of the Malamocco channel. The channel was tested with Cruise ships, Bulk Carriers and Ro-Ro ships.

The study was carried out at FORCE Technology, Lyngby, Denmark using two coupled simulators, one for the Cruise Ship, Bulk Carrier and Ro-Ro ship and one for the manned tug with the participation of pilots from Port of Venice, tug master from Port of Venice, the Coast Guard and other participants from Italy. Two FORCE Technology captains also participated as instructors/captains.

For the simulation study a new database of Port of Venice was developed based on data from Port of Venice and DHI srl.

The conditions used for the simulations were derived based on an NCOS study and a fast-time study.

- The NCOS study was performed to give the met-ocean conditions (for a year) that were limiting with respect to safe navigation. These results were used in the fast-time study.

- The fast-time study was then used to test these conditions in order to find the conditions to be used during the real-time study, i.e. the conditions that were seen to be the most challenging.

- The outcome of the fast-time study was then used to create the scenarios used in the real-time study together with input from Port of Venice who have experience in the area.

The objectives of the full-mission simulation study were:

- Evaluate the feasibility of navigating the existing Malamocco channel with selected design ships under predefined environmental conditions (from NCOS and fast time) to point out the challenging parts and to give input for developing the new channel.

The simulations were carried out at FORCE Technology simulator bridge A and bridge H. The following participated in the simulations:

- Mr Daniele Ferrari, Venice Coast Guard
- Ms Arianna Rubino, Venice Coast Guard
- Mr Luigi Mennella, Chief Pilot Venice
- Mr Emanuele Banchieri, tugboat supervisor
- Mr Massimiliano Gambato, Tugboat Master
- Mr Luca Zaggia, National Research Council (CNR)
- Mr Paolo Menegazzo, Port of Venice
- Ms Clara Giarrusso, FORCE Technology
- Mr Jens Tommerup, FORCE Technology
- Mr Thue Rabjerg, FORCE Technology
- Mr Bugge T. Jensen, FORCE Technology
- Mr Niels Arndal, FORCE Technology

The following ships were used and accepted by the participants:

Ship No.	Name	Ship Type	Description	Load Con.	LOA m	Lpp m	Bmld m	Tf m	Ta m	Displacem	Prop.	Rudd.	Bow thrst.	Stern thrst.
3644	"Gold Sapphire"	Cruise Ship	294 m	S	294.0	261.0	32.2	8.3	8.3	50453	2F	2	3	3
3481	Roberta	Bulker	51.000 DWT	L	200.0	191.0	32.2	11.0	11.0	55690	1F	1	1	0
3601	"Atlas"	Container Ship	2.680 TEU	L	215.6	206.2	32.2	11.0	11.0	48571	1F	1	1	0
3556	Costa Luminosa	Cruise Ship	294m	S	294.0	265.4	32.25	8.1	8.1	47646	0	0	3	2AZ(fp)
3297	Tor Magnolia	RoRo	199.8m	L	199.8	190.3	26.5	7.7	7.7	21248	1C	1F	2	1
3583	"Melusina"	RoRo	215 m	L	215.0	205.0	26.5	7.7	7.7	25341	1C	1	2	2
3764	Multratug 4	Tug VSP	36m, 72 t BP	S	36.0	34.0	12.5	5.7	5.7	855	2VS	0	0	0
3852	Svitzer Maitland	Tug ASD	30m, 70 t BP	S	30.0	25.6	11.0	4.6	4.8		0	0	1	2AZ(cp)

Table 1-1 Ships used in the simulations.

The ships were maneuvered by the participating captains from Italian Coast Guard and FORCE Technology captains together with the pilot from Port of Venice. The manned tug was maneuvered by a local tug master, and the vector tugs were controlled by a FORCE Technology captain during the five days of simulations.

The results, described in the form of conclusions and recommendations, are provided in paragraphs 1.1, 1.2 and in chapter 4.

The results are based on the actual simulation runs and the tested environmental conditions as well as on the evaluations carried out by the participating captains, pilots, tug master and the FORCE Technology instructor for each run. For a detailed description of the conclusions and recommendations, please see section 4.

1.1. Conclusions

The following conclusions are based on the simulation runs conducted AFTER the simulator has been tuned to achieve a realistic behavior based on pilots experience, i.e. after fixing issues with bank effect, tug behavior and presence of a mud layer at the sea bottom.

Simulations confirmed existing issues in navigating the channel.

- Low under keel clearance for Bulk and Container ships used in the simulation
- Narrow channel for all ships used in the simulation, especially in high winds
- Bulk and Container ships used in the simulation operate on the limit, and existing limits specified in the ordinance are confirmed with respect to both wind limits and ship speed.
- Both conventional and azipod propelled cruise ships up to 300 m were able to perform safe passage in wind speeds of 10 m/s (20 knots) which is higher than specified in the ordinance of 7.5 m/s (15 knots) for that size of ships used in the simulation. Note the calculation for wind in Appendix D.

1.2. Recommendations

The following summarizes the recommendations based on discussions and brainstorming sessions carried out at the end of each simulation day between all parties involved:

- Further investigations are suggested on the most appropriate "reference wind station" to be considered for acceptance of ship passage, given that the main wind-induced issues for navigation have been found in the narrowest part of the Channel.

- Simulations confirmed the actual safety limitations for the Container ship and the Bulk Carrier used in the simulation, as stated in the Ordinanza.

- The limitations for the Cruise ships up to 300 m can be increased to 10 m/s (20 knots) for traditional ships. Azipod propelled ships showed an even larger safety margin.

2. INTRODUCTION

FORCE Technology has via the Consortium headed by DHI srl been contracted by Port of Venice (PoV) to conduct a real-time simulation study in order to assess the existing Malamocco-Marghera access channel's capacity for different selected design ships including Cruise, Container, and Bulk ships in accordance with "CEF Action n° 2019-IT-TM-0096-S CHANNELING THE GREEN DEAL FOR VENICE" and to create input for the development of the new channel.

This part of the study is to evaluate the existing channel with ships which are calling the port today in order to find the challenging parts of the channel for future development.

This report comprises a qualitative study to evaluate the approach and departure through the Malamocco Channel with Cruise ships, Bulk Carriers and Container ships.

Minor modifications were made during the simulations for bank effect and wind forces.

A Cruise ship, a Bulk Carrier and a Container ship with dimensions that call the port today were used for the simulations, see Table 2-1.

The scenarios used for the simulations were derived based on a NCOS study and a fast-time study.

- The NCOS study by DHI was performed to give the met-ocean conditions (for a year) that were limiting with respect to safe navigation. These results were used in the fast-time study.

- The fast-time study was then used to test these conditions in order to find the conditions to be used during the real-time study, i.e. the conditions that were seen to be the most challenging.

- The outcome of the fast-time study was then used to create the scenarios used in the real-time study together with input from Port of Venice.

For further information on development of scenarios, see section 5.3.

The objectives of the study were:

Evaluate the feasibility of navigating the existing Malamocco channel with selected design ships under predefined environmental conditions (from NCOS fast-time, and Port of Venice) to find the challenging parts and to give input for developing the new channel.

The simulations were carried at FORCE Technology using a full-mission bridge (bridge A) for the own ship, and a full-Mission tug bridge (bridge H) for the main assisting tug.

The following personnel took part in the simulations:

- Mr Daniele Ferrari, Venice Coast Guard
- Ms Arianna Rubino, Venice Coast Guard
- Mr Luigi Mennella, Chief Pilot Venice
- Mr Emanuele Banchieri, Tugboat supervisor
- Mr Massimiliano Gambato, Tugboat Master
- Mr Luca Zaggia, National Research Council (CNR)
- Mr Paolo Menegazzo, Port of Venice
- Ms Clara Giarrusso, FORCE Technology
- Mr Jens Tommerup, FORCE Technology
- Mr Thue Rabjerg, FORCE Technology
- Mr Bugge T. Jensen, FORCE Technology
- Mr Niels Arndal, FORCE Technology

The following ships were used during the simulations (3852 only as vector tug):

Ship No.	Name	Ship Type	Description	Load Con.	LOA m	Lpp m	Bmld m	Tf m	Ta m	Displac em	Prop.	Rudd.	Bow thrst.	Stern thrst.
3644	"Gold Sapphire"	Cruise Ship	294 m	S	294.0	261.0	32.2	8.3	8.3	50453	2F	2	3	3
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3852	Svitzer Maitland	Tug ASD	30m, 70 t BP	S	30.0	25.6	11.0	4.6	4.8		0	0	1	2AZ(cp)

Table 2-1 Ships used in the simulations.

The ships were maneuvered by the participating captains from Italian Coast Guard, FORCE Technology captains and pilots from Port of Venice. The VSP 72t BP tug at bridge H was maneuvered by the tug master from Port of Venice. A FORCE Technology captain/instructor controlled the other vector tugs and conducted the simulations.

The results, described in the form of conclusions and recommendations, are provided in paragraphs 0.1, 0.2 and in chapter 4.

The results are based on the simulation runs and the tested environmental conditions as well as on the run evaluations carried out by participating captains, pilots, tug master and the FORCE Technology instructor. For a detailed description of the conclusions and recommendations, please see section 4.

All environmental data and drawings were provided by Port of Venice and DHI srl.

The following hardware and software equipment were utilized during the study:

- Two of FORCE Technology's full-mission bridge simulators, bridge A (own ship) and bridge H (main assisting tug 72 t BP).
- Vector tugs of 70 t BP.
- One database of Port of Venice.

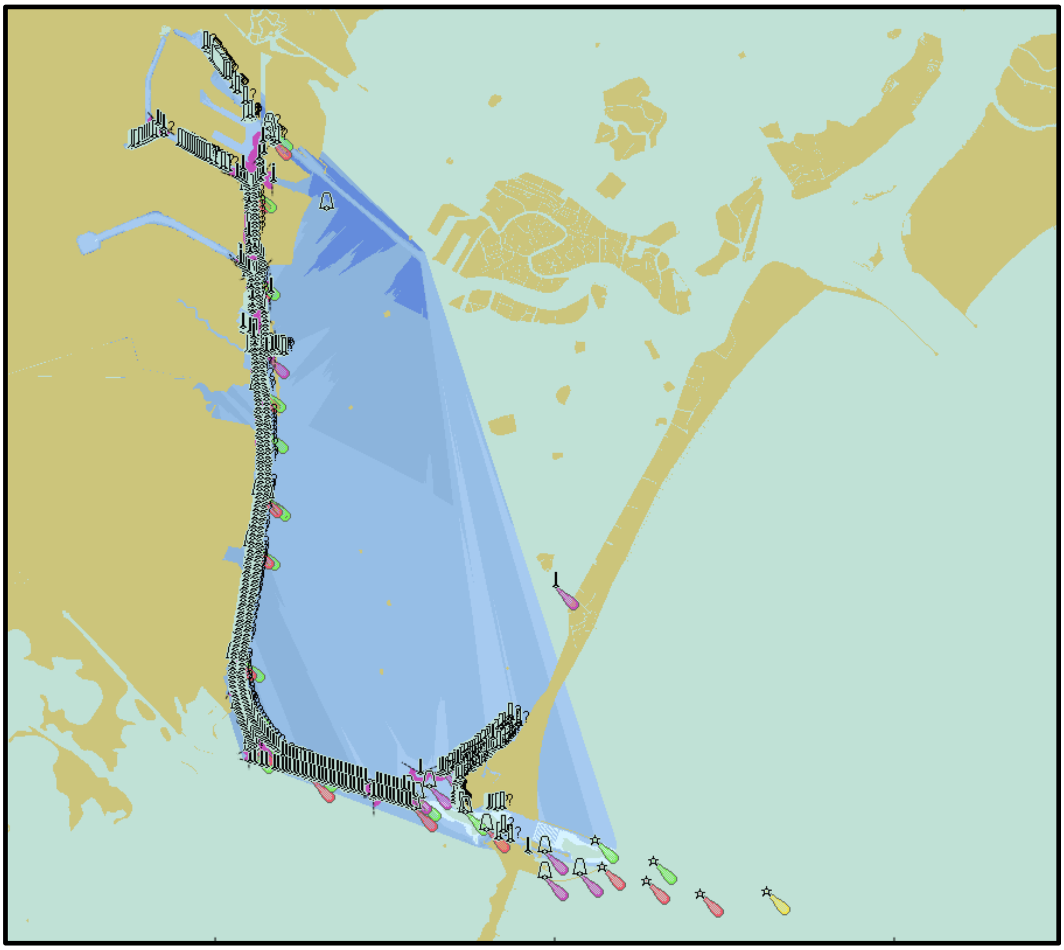


Figure 1 Layout of Port of Venice.

The layout of the database is described in Appendix C.

3. SUMMARY AND OBSERVATIONS

3.1. Summary

Prior to the simulations, a FORCE Technology captain validated the ship, the tugs and the database.

A 2D and 3D database of the port was produced. It contained all necessary visual and bathymetric information based on the data provided by Port of Venice and DHI srl. Current, tide and wave maps were extracted from DHI met-ocean data

During the first day of simulations, the wind forces for the Cruise ship were adjusted to give the anticipated drift angle in wind of 10 m/s (20 knots).

The VSP tug was changed to a model corresponding in behavior to the tugs used in Port of Venice.

During the second day, the bank forces were adjusted by request of the pilot who has experience with the Malamocco channel, and the ships were tested to replicate the effect felt by the pilot in real-life sailing.

Further, the presence of the existing mud layer in the channel of approximately 50 cm was accounted for in the simulations.

The wind speed varied between 7.5 m/s (15 knots), 10 m/s (20 knots), 12.5 m/s (25 knots) and 15 m/s (30 knots), and the directions tested were from NE and ENE.

During five days of simulations, 35 runs were completed as follows.

- 7 runs with the conventional rudder-propeller driven cruise ship
- 2 runs with the Azipod Cruise ship
- 9 runs with the Container ship
- 10 runs with the Bulk Carrier
- 7 runs with the Ro-Ro ship

The simulations included a manned ASD tug of 72 t BP and two ASD vector tugs of 70 t BP each which were assisting the own ship.

After each run, the captain, the pilot, the tug master, and the FORCE Technology instructor completed an electronic evaluation form with all relevant observations and remarks dealing with the corresponding run. These comments together with the replays formed the basis for the conclusions and recommendations.

3.2. Observations

General

Groundings were found to occur in areas where the pilots can usually handle the ships. The pilot said that in real life they were sailing over muddy bottom which allowed the ships to pass even if they brushed the bottom; in the simulator the ships will ground in such areas. To achieve more realistic conditions of navigation a layer of approximately 50 cm was accounted for in the simulations.

Day one

On the first day, four (4) runs were completed with the 294m conventional driven cruise ship. The pilot from Venice felt that the drift angle of the cruise ship was too small. The cruise ship was therefore updated with a new wind coefficient which the pilot felt worked right.

The runs went well, and it was observed that wind of 12.5 m/s (25 knots) was too much for safe maneuvering whereas as 10 m/s (20 knots) was safe. For a 294 m conventional driven cruise ship.

In run 104, the pilot had difficulties with controlling the ship when the speed of the ship was slowed down, to fulfill Ordinanza requirement. The ship grounded at the end of the simulation.

Day two

On the second day, three (3) runs were completed with the Cruise ship and four (4) were completed with the Bulk carrier

The pilot kept a speed of approximately 7 knots in the channel as he is used to be able to handle this speed with these kinds of ships.

For the 294 m rudder propeller driven cruise ship, it was possible to make an outbound run in 12.5 m/s (25 knots) wind without experiencing any problems, likewise with 10 m/s (20 knots). The rudder propeller driven cruise ship is even more challenging to control than Azipod driven cruise ships hence the result indicate that cruise ships can depart in 12.5 m/s (25 knots) in emergency situations.

The Bulk Carrier was able to handle 10 m/s (20 knots) wind without experiencing any problems.

Visibility did not influence the maneuvering significantly.

Day three

On the third day, six (6) runs were completed with the Bulk Carrier.

The ship grounded in run 301. The ship grounded just after Fusina. The reason is that the bathymetry was not updated with the latest data from DHI srl/the port of Venice (cell 34).

On departure in run 305, the ship grounded just south of Fusina due to a combination of the 12.5 m/s NE wind and bank effect Vessel drifted towards the bank to the west, this resulted in banking effect and vessel started swinging to port and, with a speed of 7,7 knots, the rudder moment was not enough to stop the swing and vessel grounded.

Day four

On the fourth day, nine (9) runs were completed: the Container ship (3 runs), the Bulk Carrier (1 run) the Azipod Cruise ship (2 runs) and the Ro-Ro ship (3 runs).

Sailing with “Costa Luminosa”, Azipod Cruise ship could be done in wind of 7.5 m/s (15 kts).

The “Costa Luminosa”, Azipod Cruise ship, grounded when slowing down in 10.0 m/s (20 knots) in run 408.

It was seen that the Container ship could be handled in wind of 12.5 m/s (25 knots) whereas it was seen that 15 m/s (30 knots) is acceptable in emergency cases.

Day five plus FORCE-conducted runs

On the fifth day plus FORCE Technology runs, eight (8) runs were completed with the Container ship and the Ro-Ro ships.

Outbound in run 502, the Container ship touches the ground after 14 minutes of simulation. The ship came too close to the west side of the channel after passing an open area. The ship had difficulties to steer at low speed, and combined with bank effect, it made the ship shortly touch the western bank.

The Container ship grounded in run 504 outbound due to poor steering at low speed combined with strong wind from ENE. On departure wind of 15 m/s from ENE is limit conditions.

The Ro-Ro ship (3297) did not perform as the pilot expected. Later, the maneuver was repeated with a lager Ro-Ro ship (3435) in run 602, and the simulation showed that this maneuver can be carried out safely in 12.5 m/s wind from NE.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

The following conclusions are based on the simulation runs conducted AFTER the simulator has been tuned to achieve a realistic behavior based on pilot's experience, i.e. after fixing issues with bank effect, tug behavior and presence of a mud layer at the sea bottom.

The ships (Cruise ship, Bulk Carrier and Container and main VSP tug, see Table 2-1) were navigated by captains from Italian Coast Guard, FORCE Technology and pilots from Port of Venice.

The following summarizes the conclusions agreed between all parties involved based on the brainstorming sessions carried out during the daily debriefings and the summary on the last day.

General table 2-1

The outcome of the NCOS and fast-time simulations showed that to be able to navigate the channel it was necessary to arrive/depart at water level as stated in the actual Ordinanza.

The existing wind limits for the Port of Venice were confirmed during the simulations as the ships in the simulator experienced the same limitations:

- Low under keel clearance for Bulk and Container ships used in the simulation.
- Narrow channel for all ships used in the simulation, especially in high winds.
- Bulk and Container ships operate on the limit, and existing limits specified in the ordinance are confirmed with respect to both wind limits and speed for ships used in the simulation.
- Both conventional and Azipod propelled cruise ships up to 300 m were able to were able to perform safe passage in wind speeds of 10 m/s (20 knots) which is higher than specified in the ordinance of 7.5 m/s (15 knots) for that size of ships.

4.2. Recommendations

The following recommendations are based on discussions and brainstorming sessions conducted daily at the end of the simulation day between all parties involved.

- Further investigations are suggested on the most appropriate "reference wind station" to be considered for acceptance of ship passage, given that the main wind-induced issues for navigation have been found in the narrowest part of the Channel

- Simulations confirmed the actual safety limitations for the Container ship and the Bulk Carrier used in the simulation, as stated in the Ordinanza.

- The limitation for the Cruise vessels up to 300 m can be increased to 10 m/s (20 knots) for traditional ships. Azipod propelled ships showed an even larger safety margin.

5. METHOD

5.1. General

The background for the present study is that FORCE Technology has via the Consortium headed by DHI srl been contracted by Port of Venice (PoV) to conduct a real-time simulation study in order to assess the existing Malamocco-Marghera access channel's capacity for different selected design ships including Cruise, Container, and Bulk ships in accordance with "CEF Action n° 2019-IT-TM-0096-S CHANNELING THE GREEN DEAL FOR VENICE".

The method consists of the following:

- Develop the database of Port of Venice and Malamocco channel
- Use ships from the FORCE Technology database of ships
- Develop list of runs
- Environment settings
- Scenario development
- Simulations
- Debriefing
- Evaluation of runs

5.2. List of runs

A list of runs was created by Port of Venice and FORCE Technology in cooperation for the evaluation. The list of runs was indicative as it could be changed during the simulations due to findings. The run list was based on the findings in the fast-time and the NCOS study. See list of conducted runs in Table 9-1.

5.3. Scenario development

General

The scenarios were selected by Port of Venice, DHI srl and FORCE Technology based on results found during a NCOS study performed by DHI srl and the fast-time study performed by FORCE Technology.

The initial positioning of the ship, whether on arrival or departure, was chosen in order for the captains to control the ship initially, assuring that they had full control before beginning the maneuver.

The following were considered when developing the simulation scenarios:

- Own ships
- Environmental conditions (wind, current, tide and waves)
- Tugs of 70 t BP available

NCOS study

The NCOS study (by DHI) was performed to pinpoint the met-ocean conditions that were the limiting conditions for safe navigation. The NCOS study was based on one year of observations.
NCOS indicated that both Container and Bulk Carrier should be able to navigate the channel at water level lower than mean sea level, and number successful passings were selected for further analysis with the fast-time simulations.

It should be noted that NCOS assumes the ship follows the track perfectly (center of channel) like a train. Bank effects are not included.

The fast-time simulator includes the dynamics of the ship and is essentially the same simulator kernel as used in the full-mission simulator. The only difference is that a track controller with human behavior is used to control the ship.

Twenty (20) different met-ocean conditions were selected for investigations with the fast-time simulator.

Details of the NCOS study can be found in Appendix F

Fast-time study

The fast-time study was used to test the conditions found in the NCOS study in order to help find the conditions to be used during the real-time study, i.e. the conditions that were seen to be the most challenging.

The fast-time study was performed using the FORCE Technology developed software SimFlex Navigator.

From the NCOS simulations, a number of environmental conditions were found that were candidates for further investigation. These were further cut down to have the 20 most challenging conditions which were used in the fast-time study.

A route for each chosen ship was then developed with respect to wind, current, wind and waves by experienced captains. These routes were implemented in the fast-time simulator along with the chosen scenario found from NCOS. Each scenario was then sailed in fast time and repeated 5 times. The track pilot used in SimFlex includes some human behavior so each repetition will have a slightly different output from each run.

The outcome of the fast-time study was swept area plots for each scenario from which the challenging parts could be derived.

The main conclusion from the fast-time simulation was not to try to pass the channel on slack water with either Bulk Carrier or Container ships with the tested design draft.

The Cruise ships were able to sail to the Fusina basins, and further investigations were needed with a full-mission simulator

Based on the obtained fast-time results, it was decided to use a spring flood tide and an ebb flood tide to create worst case current flow in the channel. Simulations were timed to operate in the port area at or near high tide to maximize under keel clearance.

DHI calculated wave maps for the lagune based on 5, 10 and 15 m/s wind speed from NE, and these maps were used corresponding to the tested case.

A run list of performed runs can be seen in section 9.1.

5.4. Simulations

The simulations conducted were carried out at two of FORCE Technology's bridges, bridge A from where the captains maneuvered the own ship and bridge H where the tug master maneuvered the tug.

Figure 2 Picture from the own ship bridge A.

Figure 3 Picture from the tug bridge H.

5.5. Debriefing

After each simulation day, a short debriefing session was conducted to sum up the findings of the runs. The participants could elaborate on the runs and give their comments on what they had experienced, thereby giving their observations and conclusions to what they had seen.

5.6. Evaluation of runs

The evaluation of the feasibility to arrive/depart through the Malamocco channel with the tested ships is based on the participants' perceptions of the runs as seen during the simulations.

After each run, the participating captains, pilot from Port of Venice, tug master and the FORCE Technology instructor each filled out an evaluation form with their experience of the newly finished run.

The questions for the participants were within the areas of:

- Basic info (run number, name, bridge)
- Realism
- Safety
- Navigation
- Communication
- Free text

Further, the in-house developed evaluation program "Analyser" was used to replay each run, thereby being able to show tracks of the runs.

5.7. Assessment of model accuracy

The applied model can be considered a state-of-the-art simulation model in the time domain. There are, however, some modelling uncertainties and assumptions that need to be addressed in order to be able to evaluate the conclusions and recommendations.

The ship model is an accurate maneuvering model with accurate mass and moments of inertia. The effect of shallow water on the hydrodynamic forces has been estimated using empirical methods from the literature. The motion of the ship is dominated by inertia effects which are accurately modelled, meaning that any uncertainties in hydrodynamic forces have small influence on the obtained motion.

When doing a ship simulation study, one should always bear in mind that a simulator is only a model of real life and not real life itself. By using a ship maneuvering simulator, a large number of assumptions are made that in smaller or larger scale reduce the accuracy, or in other words how close the simulated scenarios are to real life. There will always be a discrepancy between the simulated/modelled world and real life. Hence, the goal is to always stay conservative when carrying out simulations and to know to what level a given assumption will impact the outcome and the conclusions. In other words, the purpose of the use of a ship maneuvering simulator has to match a sufficient accuracy and detail level with the data provided.

Within ship maneuvering simulators, it is a mandatory requirement that all calculations should be done in real time. If this requirement is not respected, the behavior of the navigator controlling the ship will become unrealistic. The real-time requirement is at the same time a constraint in terms of the modelling accuracy. For example, the physics of waves propagating from deep water to shallow water can be modelled quite accurately by use of wave modelling tools. However, despite plenty of computer power, such tools take days to calculate just an hour of real-time wave action which clearly conflicts with the real-time requirement.

As a consequence of the above, the waves in the simulator are calculated in a more “real-time” manner, meaning that a wave spectrum is used to simulate the waves with input Hs, Tp, direction and ship speed. To change the wave conditions during the simulation, a new input is needed which is done either by applying a wave map or using event lines.

Wave forces and motions are in SimFlex modelled in real time based on output from the FORCE Technology OMEGA program. OMEGA uses a panel description of the hull form and potential theory to calculate wave coefficients. Given a spectrum, the wave height, period, direction, and ship speed, the wave forces and hence the motions can be calculated in real time.

Another source of lack of accuracy is data. A ship maneuvering simulator can never be better than the input data provided. Using the waves again as an example, only if the local wave conditions in an area, for example the area close to the port entrance, is well defined either by physical measurements or by use of other more accurate wave modelling tools, a satisfactory level of accuracy can be obtained.

Another example is the ship model. The generation of a ship model can be based on data from other similar ships (type and size), physical model tests in a towing tank and sea trials. A model based on all three types of data will give the most accurate ship model obtainable. But still well-known sources of errors are known. There are scaling effects when doing model tests. Sea trials are rarely done in shallow water and always under influence of wind, current and waves although typically attempted to be completed in calm weather.

All assumptions made, whether being a result of the accuracy of data or being a consequence of the level of mathematical modelling, will in the end limit the accuracy of the obtainable results. Hence, a ship maneuvering simulator can provide conclusions and recommendations only to a certain level where each assumption made should be considered carefully. As an example, if groundings are experienced during a simulation, the ship maneuvering simulator can only indicate that there is a problem, bearing in mind that the results must be expected to be conservative. We call this qualitative evaluation; hence, the simulator cannot quantify how often it will happen.
In the grounding situation more accurate data and tools will be necessary to evaluate the risk and thereby also to address the means to avoid such groundings

6. DESCRIPTION OF AREA LAYOUT

The Venice database is developed based on data from Port of Venice and DHI srl. as no ENC (Electronic Nautical Charts) were available.

The following is included in the database:

- Land contours from shape files
- Sentiero luminoso are the metal light poles along the channel
- Briccole are the wooden constructions along the channel
- Boa-Meda is the green_lights and red_lights along the channel
- Faro fanale simbolo and Mede are Pier lighthouses
- Palo di ancoraggio is the wooden poles for anchoring
- Bathymetry
- Waves
- Current
- Tide
- Visual database

6.1. Environment

The Port of Venice is located at the eastern coast of northern Italy with access to the Adriatic Sea. The channel (Malamocco channel) leading up to the industrial area and Fusina basin from the Malamocco entrance is influenced by wind, waves and current.

The following periods of current and tide were used during the real-time full-mission study:

- 24-01-2020 at 20:00 hours and twelve hours forward
- 09-01-2020 at 15:20 hours and twelve hours forward

The time in the simulator was set in order for the ship to approach the channel at high tide.

6.2. Bathymetry

The bathymetry of the existing channel was by delivered by DHI srl.

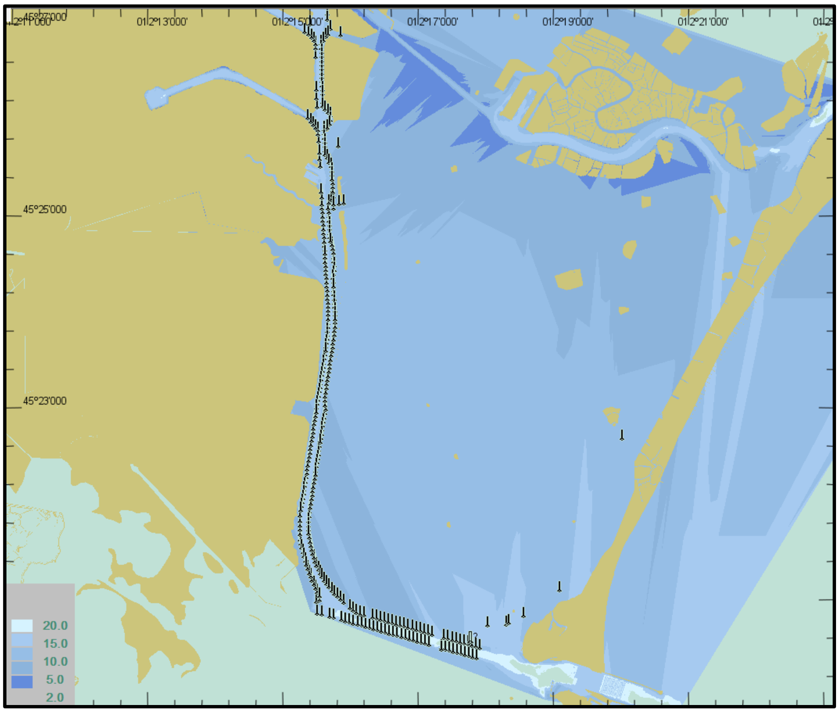


Figure 4 Bathymetry.

6.3. Wind

The magnitude of the wind was chosen based on information from DHI srl conducted NCOS simulations as statistic data.

Please note that the definition of wind speeds in the simulator is based on wind tunnel tests and are converted to a uniform wind speed in 10 meters height which is the normal meteorological definition. This wind speed may be different from the captain's observation of the ship's wind indicator. See Appendix D.

6.4. Current

For the simulations both ebb and flood currents for a whole year were delivered by DHI srl as dfsu files. From the dfsu files, different periods of 2 hours were extracted for the fast-time study. An example of the grid and the current is shown in below Figure 5 and Figure 6.

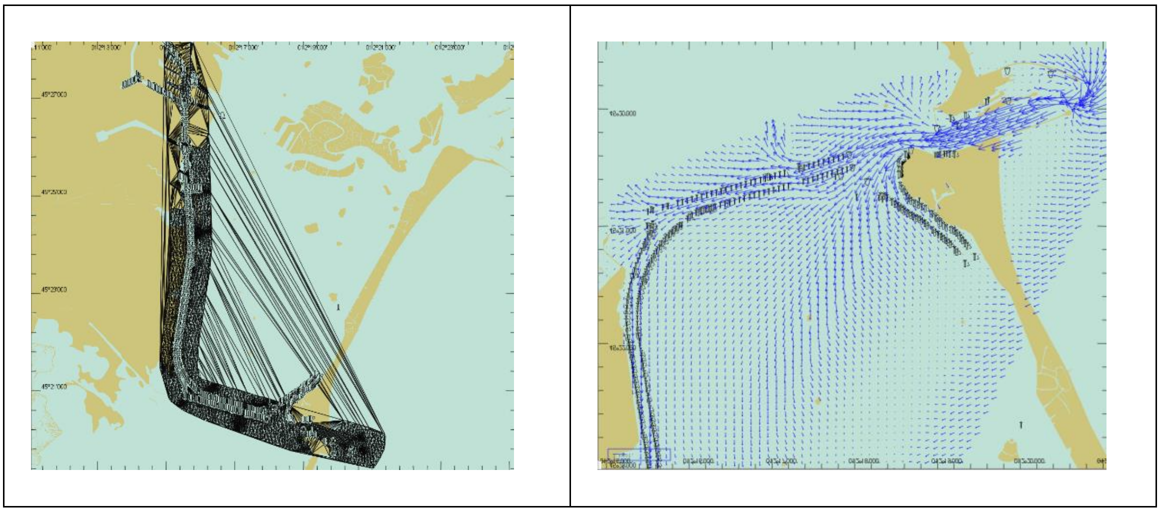


Figure 5 Example of current grid and arrow plot.

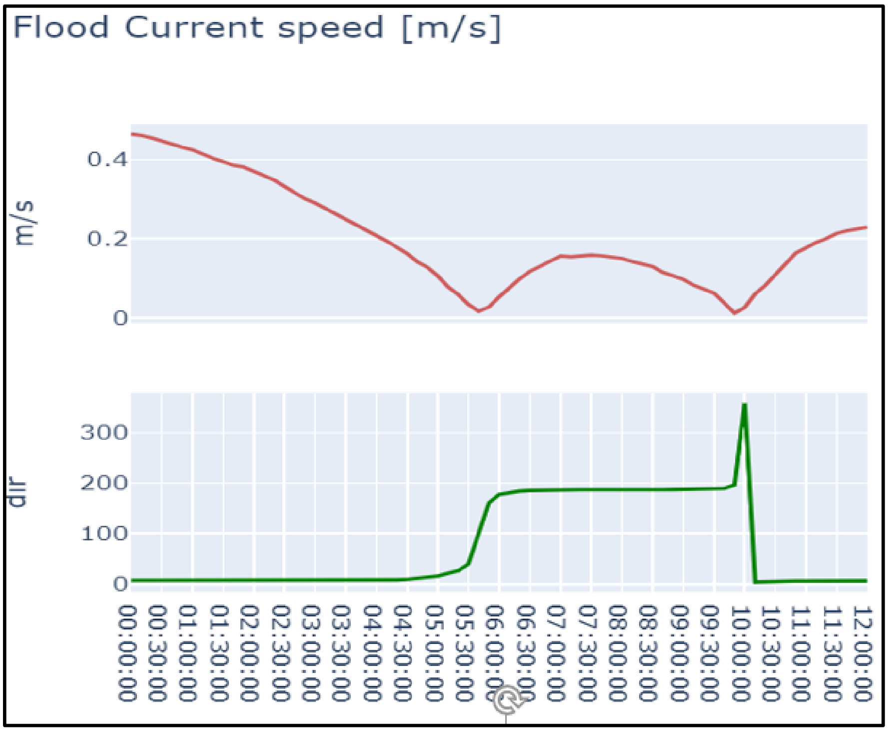
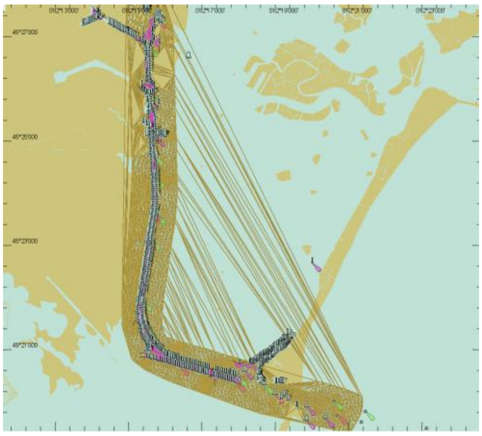


Figure 6 Current curve and direction for a 12-hour period.

6.5. Tide

For the simulations tide was delivered by DHI srl as dfsu files. The grid for the tide files is shown in the below Figure 7 and Figure 8.



```
NODE-POINTS
 45 21 142.768 N  12 15 622.401 E
TIME-TABLE
0  -0.617414  -0.617414
600  -0.63902  -0.63902
1200  -0.656465  -0.656465
1800  -0.670878  -0.670878
2400  -0.682991  -0.682991
3000  -0.69131  -0.69131
3600  -0.695462  -0.695462
4200  -0.696255  -0.696255
4800  -0.692022  -0.692022
5400  -0.683084  -0.683084
6000  -0.671192  -0.671192
6600  -0.656689  -0.656689
7200  -0.637117  -0.637117
7800  -0.614244  -0.614244
8400  -0.587283  -0.587283
9000  -0.558239  -0.558239
```

Figure 7 Tide grid and a part of a point showing time (col 1) and elevation (col 2)

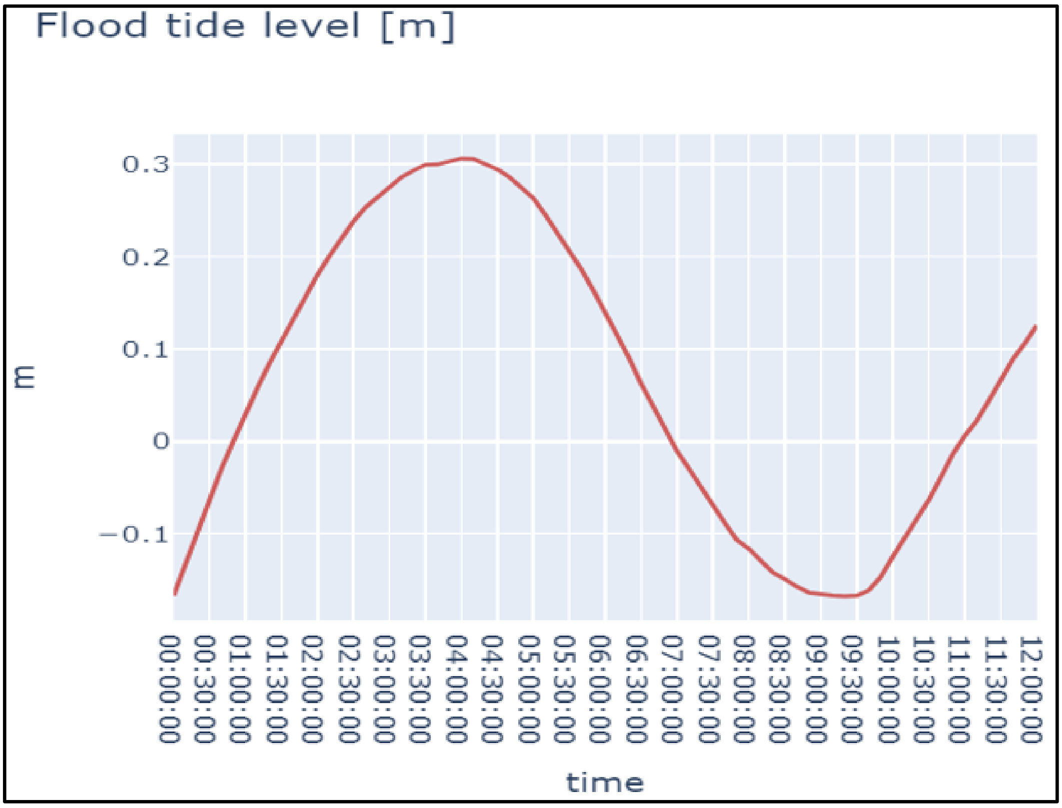


Figure 8 Tide curve for a 12-hour period

6.6. Waves

The channel is exposed to waves, but the waves are not significant as they are very low, For the simulations, waves was delivered by DHI srl as dfsu files.

The waves delivered were wind-driven waves for wind coming from NE at speeds of 5 m/s, 10 m/s and 15 m/s. See Figure 9 below for an example of a wave map (15 m/s wind).

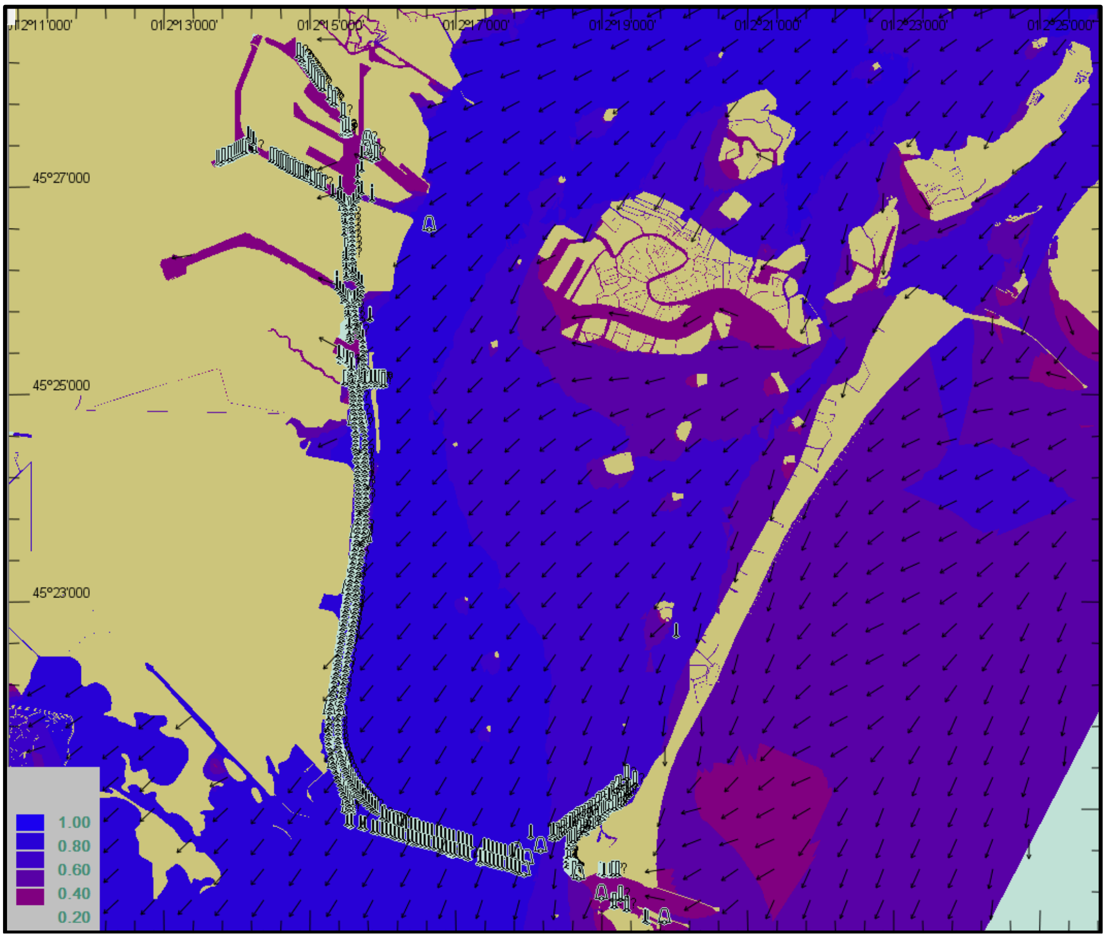


Figure 9 Example of a wave map (15 m/s wind).

The significant wave height is defined as the average height of the highest one-third in a wave spectrum, i.e. it is possible to encounter a wave that is much higher than the significant wave height. So statistically the maximum wave height might be up to or more than 2 times the significant height.

6.7. Visual

The visual part of the database is based on google and photos received. See example in Figure 10 below.

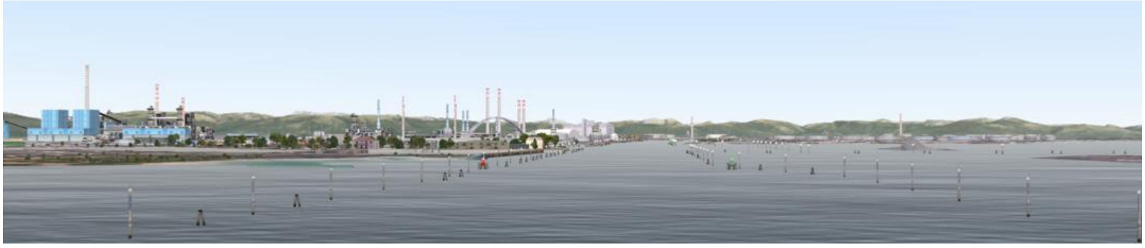


Figure 10 Example of visual database.

7. SHIPS

7.1. General

The ships used in the simulations were six degree-of-freedom mathematical ship models of real ships. A full description of the ship mathematical models is found in Appendix B.

The below table shows the main dimensions. See Table 7-1.

Ship No.	Name	Ship Type	Description	Load Con.	LOA m	Lpp m	Bmld m	Tf m	Ta m	Displacem	Prop.	Rudd.	Bow thrst.	Stern thrst.
3644	"Gold Sapphire"	Cruise Ship	294 m	S	294.0	261.0	32.2	8.3	8.3	50453	2F	2	3	3
3481	Roberta	Bulker	51.000 DWT	L	200.0	191.0	32.2	11.0	11.0	55690	1F	1	1	0
3601	"Atlas"	Container Ship	2.680 TEU	L	215.6	206.2	32.2	11.0	11.0	48571	1F	1	1	0
3556	Costa Luminosa	Cruise Ship	294m	S	294.0	265.4	32.25	8.1	8.1	47646	0	0	3	2AZ(fp)
3297	Tor Magnolia	RoRo	199.8m	L	199.8	190.3	26.5	7.7	7.7	21248	1C	1F	2	1
3583	"Melusina"	RoRo	215 m	L	215.0	205.0	26.5	7.7	7.7	25341	1C	1	2	2
3764	Multratug 4	Tug VSP	36m, 72 t BP	S	36.0	34.0	12.5	5.7	5.7	855	2VS	0	0	0
3852	Svitzer Maitland	Tug ASD	30m, 70 t BP	S	30.0	25.6	11.0	4.6	4.8		0	0	1	2AZ(cp)

Table 7-1 Ship used in the simulations.

Note that tug 3852 was only used as a vector tug (not manned).

Further, tugs used were one manned tug and one vector tug which are tugs controlled by the operator. The tugs can be connected on a line or as push/pull at the request of the pilots. The force and direction are controlled by the operator at the pilot/captain's request for the vector tugs. The manned tug was maneuvered by a local Venice Tug Master

Tugs available for these simulations were:

- Manned tug of 72 t bollard pull
- Vector tugs of 70 t bollard pull

8. SIMULATION DESCRIPTION

During the full-mission simulations, the FORCE Technology bridge A (360 degrees outlook) was used for the own ship. The main set-up for the bridge is that the simulator is controlled by a navigator, the “Captain”, standing inside a “mock-up” of a standard navigation bridge in front of a screen covering 360 degrees’ outlook through the bridge windows.

The tug bridge H is smaller than bridge A, but also provides 360 degrees outlook. The main set-up for the bridge is that the simulator is controlled by a navigator, the tug master, sitting inside a “mock-up” of a standard tug bridge in front of a screen covering 360 degrees outlook through the bridge windows.

The simulator bridge is equipped with instruments similar to those found on a real bridge, including radar and electronic chart.

Based on the information thus displayed, the navigator can activate his engines, rudders and thrusters by means of the analogue control handles.

All simulation runs are logged electronically (“black box”) in order to be able to replay second by second what happened during the runs. This includes time series of a number of parameters, e.g. speed over ground and through water, rudder angle, propeller revolutions etc. This provides an opportunity to investigate all runs in detail at a later stage.

The replay system has been used to generate the track plots in Appendix A.

Figure 11 Simulator bridge A set-up, Cruise ship bridge.

Figure 12 Simulator bridge H set-up, tug bridge.

9. DOCUMENTATION OF SIMULATIONS

9.1. List of simulation runs

Run no	Ship	Type	Cond	Wind speed (m/s)	Wind dir (deg)	Current File	Wave file	Wave height	Wave direction	Wave period	Remarks
101	3644	Cruise	294 m	5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	
102	3644	Cruise	294 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
103	3644	Cruise	294 m	10	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
104	3644	Cruise	294 m	10	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	grounded. Lossing control when slowing dov
201	3644	Cruise	294 m	10	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
202	3644	Cruise	294 m	12.5	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
203	3644	Cruise	294 m	10	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
204	3481	Bulker	200 m	7.5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	grounded in the first turn
205	3481	Bulker	200 m	7.5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	grounded due to bank effect
206	3481	Bulker	200 m	7.5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	
207	3481	Bulker	200 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
301	3481	Bulker	200 m	12.5	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	grounded east side of the channel
302	3481	Bulker	200 m	10	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
303	3481	Bulker	200 m	7.5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	
304	3481	Bulker	200 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
305	3481	Bulker	200 m	12.5	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	grounded. Departure. Wind and bank effect.
306	3481	Bulker	200 m	12.5	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
401	3601	Container	294 m	7.5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	
402	3601	Container	294 m	10	45	Venice_2021_24-1-2020-2000hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
403	3481	Bulker	200 m	12.5	67	Venice_2021_24-1-2020-2000hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
404	3601	Container	294 m	15	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
405	3297	RoRo	200 m	12.5	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
406	3297	RoRo	200 m	12.5	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
407	3297	RoRo	200 m	12.5	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
408	3556	Cruise	295 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	Stopping and drifting out of channel
409	3556	Cruise	295 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
501	3297	RoRo	200 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
502	3601	Container	294 m	7.5	23	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_5ms_NE_wind.wmp	1	ENE	1	Grounded. Difficult to steer at low speed
503	3601	Container	294 m	10	45	Venice_2021_24-1-2020-2000hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	
504	3297	RoRo	200 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	Ship behavior not realistisc
504	3601	Container	294 m	15	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
505	3556	Cruise	295 m	15	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
601	3297	RoRo	200 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
602	3435	RoRo	220 m	10	45	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_15ms_NE_wind.wmp	1	ENE	1	
603	3601	Container	294 m	12.5	67	Venice_2021_9-1-2020-1520hrs.cur	Venice_2021_wave_10ms_NE_wind.wmp	1	ENE	1	Grounded. Difficult to steer at low speed

Table 9-1 List of executed runs.

9.2. Geographical plots of maneuvers

The simulated maneuvers are shown as sweep plots in Appendix A. Each plot contains land contours, leading lines and marks.

10. NOMENCLATURE

LOA	=	Length over all	[m]
Lpp	=	Length between perpendiculars	[m]
B	=	Breadth	[m]
Ta	=	Draft aft	[m]
Tf	=	Draft forward	[m]
UKC	=	Under Keel Clearance	[m]

11. REFERENCES

[1] IALA Guidelines

APPENDICES

APPENDIX A

TRACK PLOTS

These plots illustrate the tracks followed by the vessels during the full-time simulation, conducted during week 20. For each track there are various pictures which follow a short table showing the parameters (wind speed, WS in m/s, wind direction in deg, wave height, WH in m, wave direction and wave period in s) considered during the simulation, characterizing each scenario. This tables also include the number of the run, and the ship number, type and length.

Run	Ship	Type	Cond	WS (m/s)	Wind dir (deg)	WH (m)	Wave dir	Wave period
101	3644	Cruise	294 m	5	23	1	ENE	1

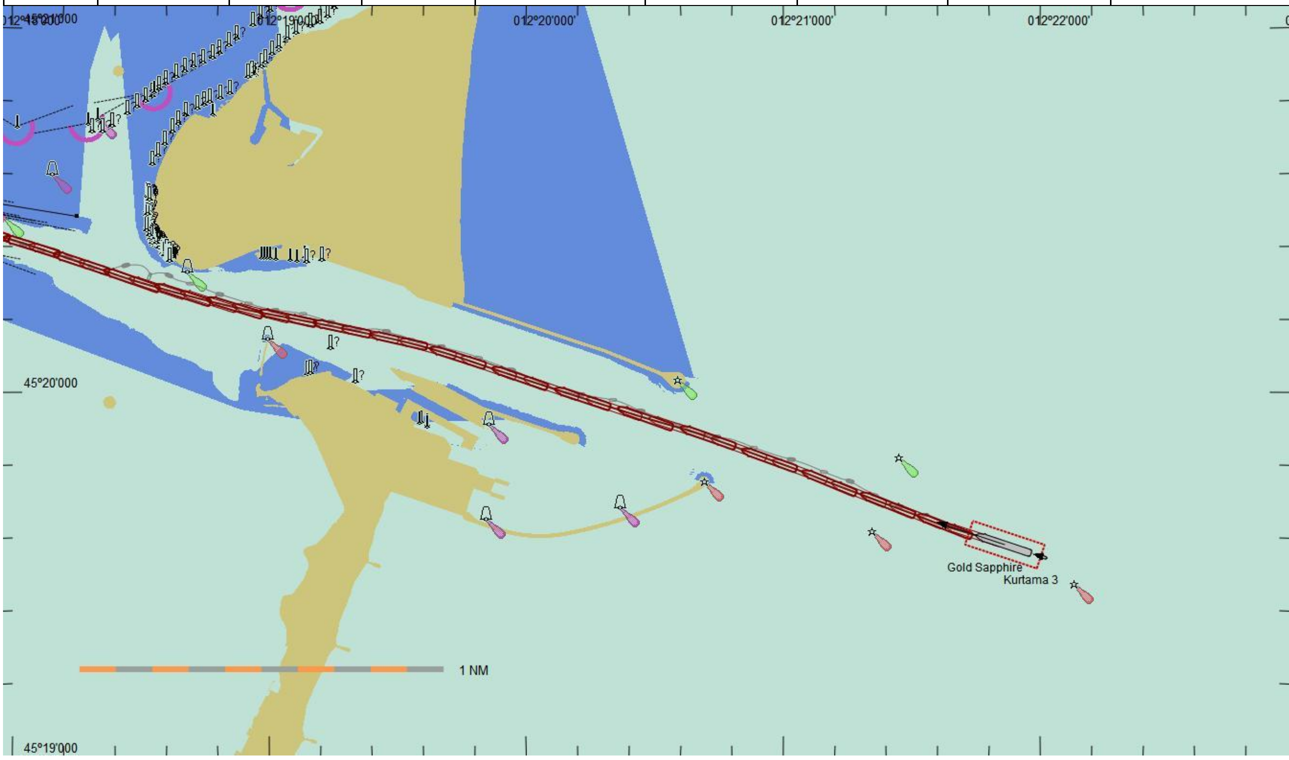


Figure 13 Run 101, Arrival at the entrance of the channel.

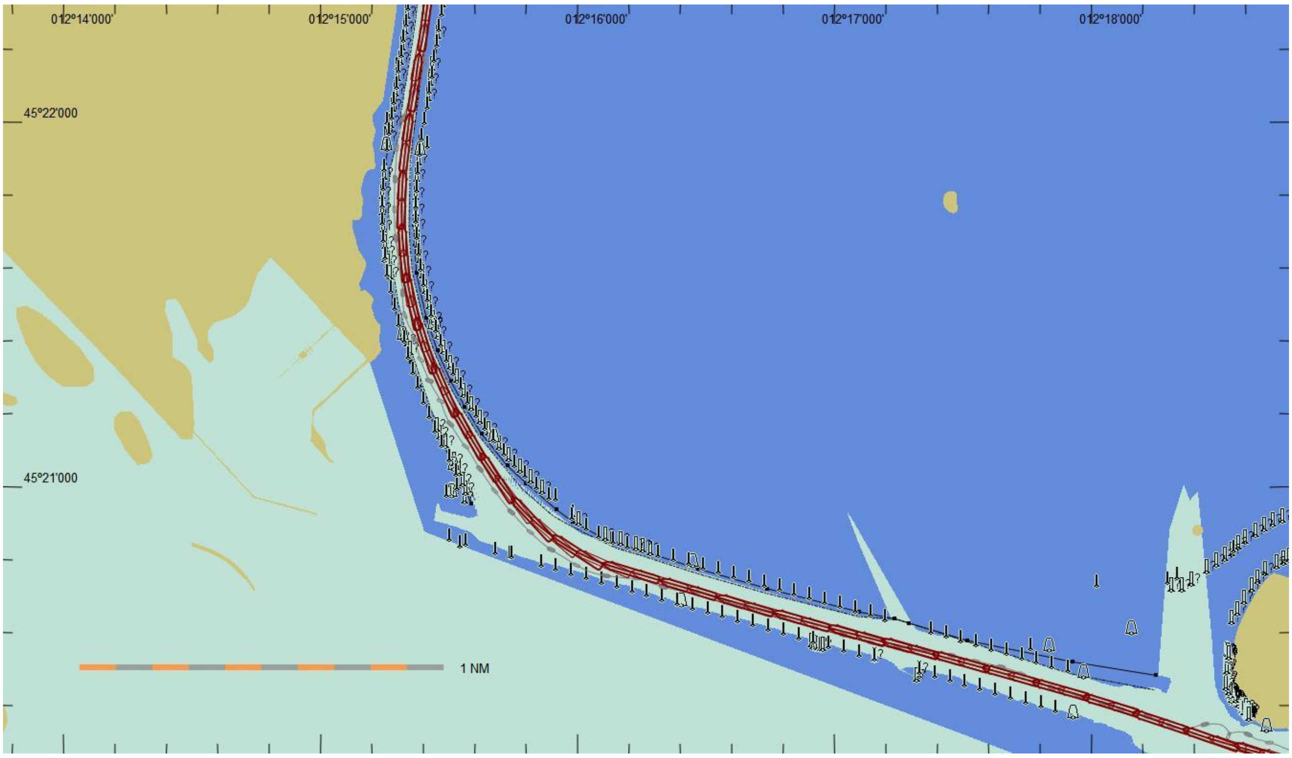


Figure 14 Run 101, curve on the south part of the channel

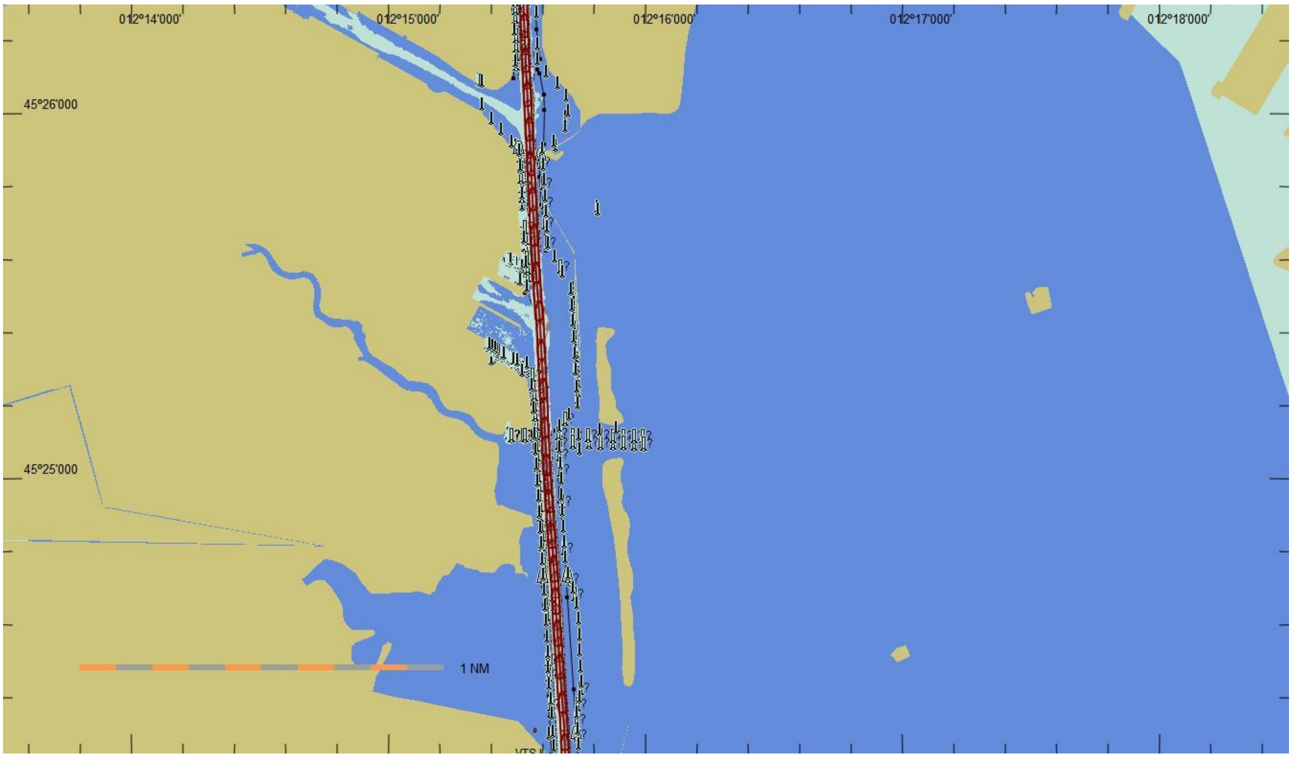


Figure 15 Run 101, center of the channel

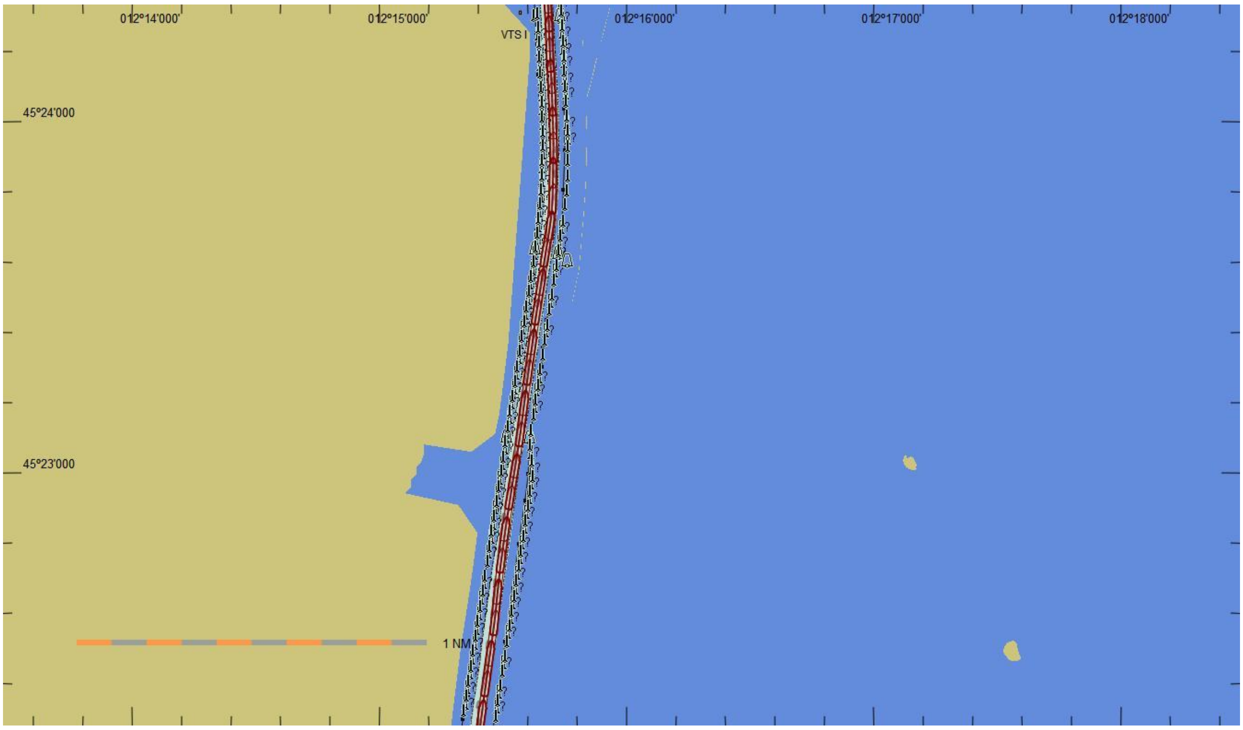


Figure 16 Run 101, detail of the center part of the channel

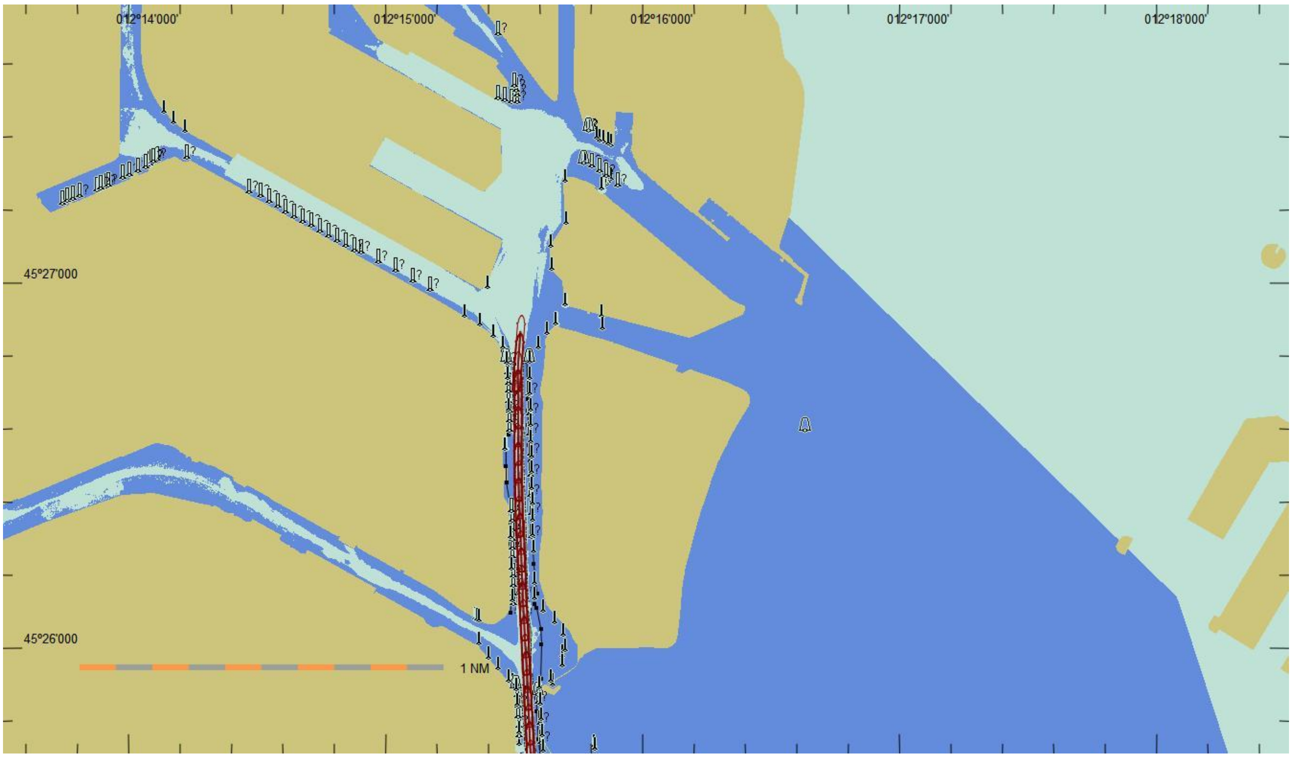


Figure 17 Run 101, grounding area at the end of the channel

102	3644	Cruise	294 m	10	45	1	ENE	1

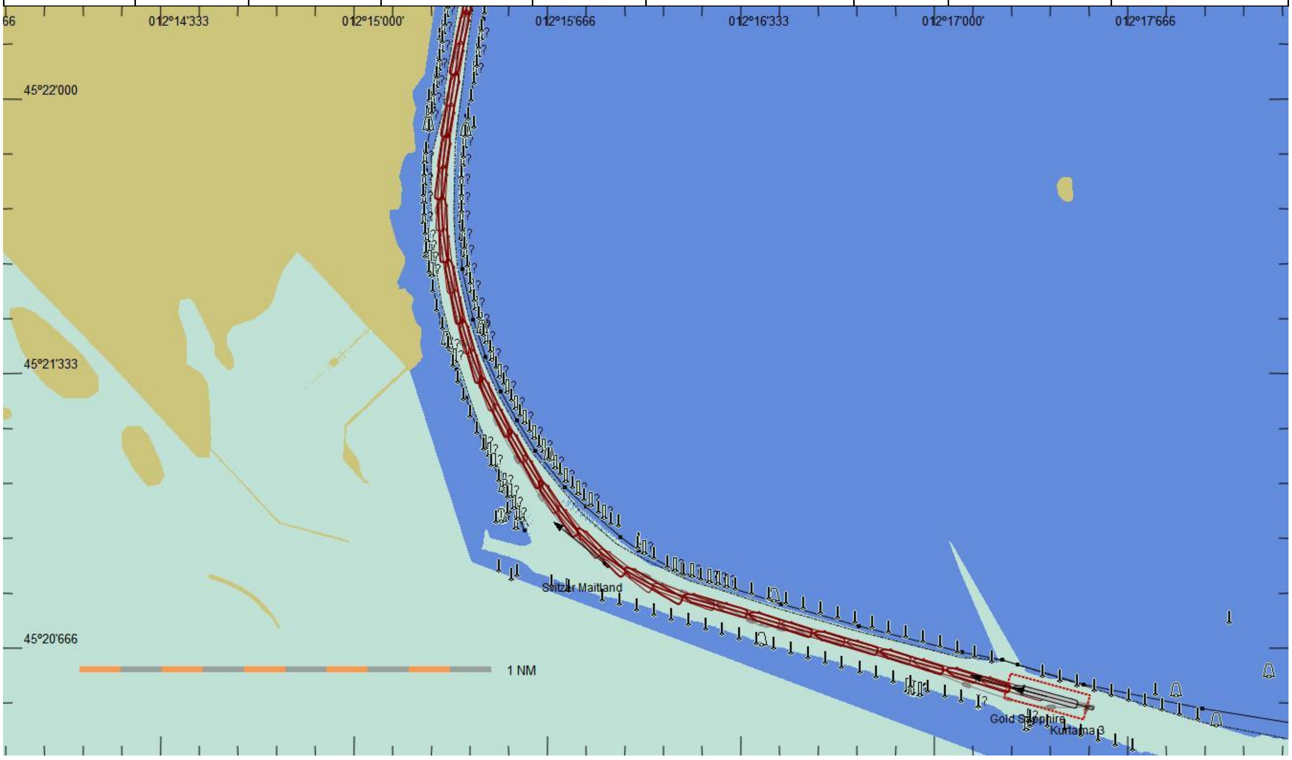


Figure 18 Run 102, arrival, ship approaching the curve on the south part of the channel

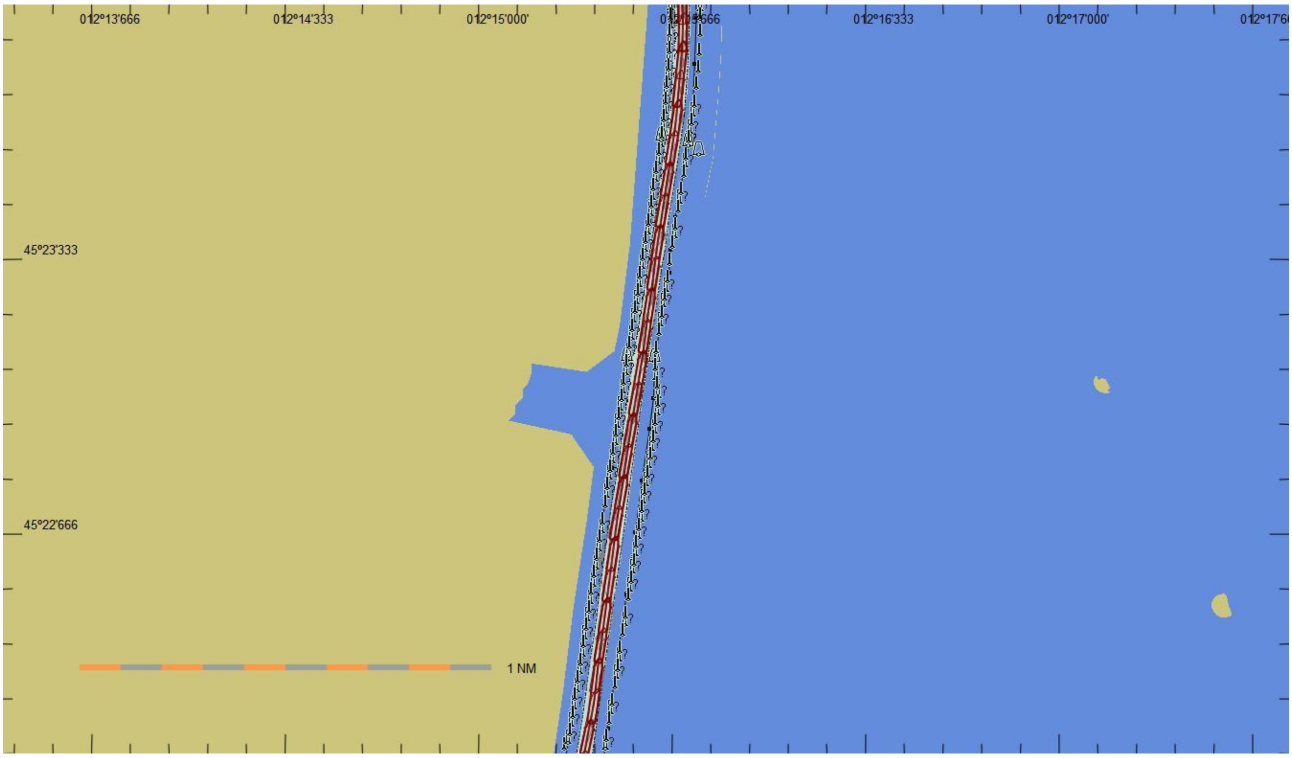


Figure 19 Run 102, detail of the center of the channel

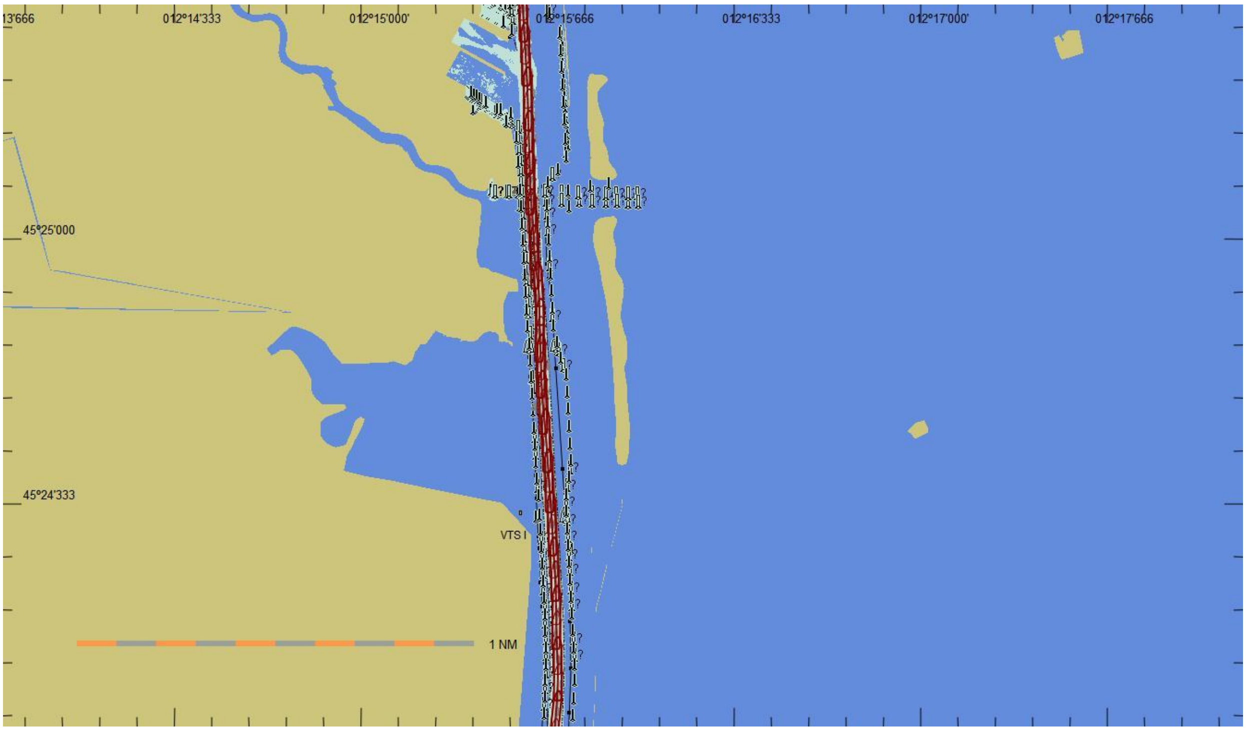


Figure 20 Run 102, center of the channel

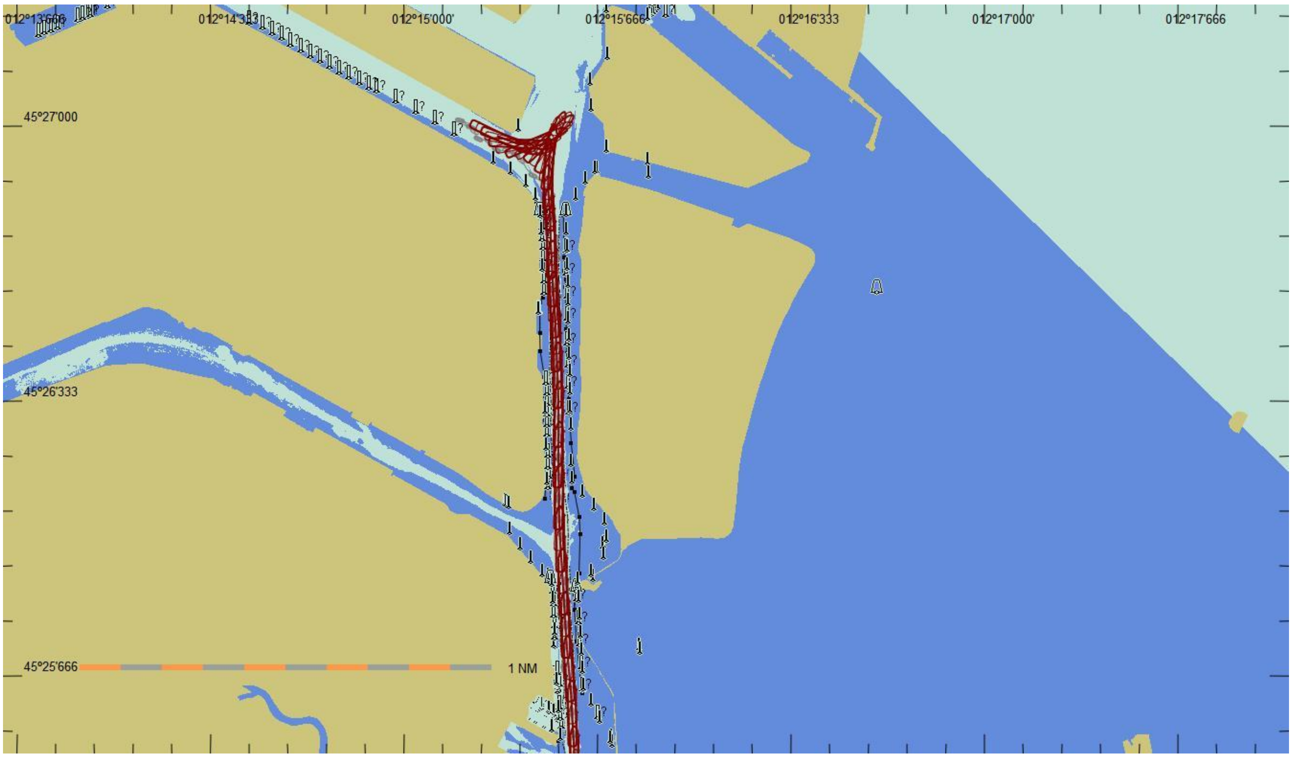


Figure 21 Run 102, end of the track in proximity of the basin, north of the channel

103	3644	Cruise	294 m	10	67	1	ENE	1

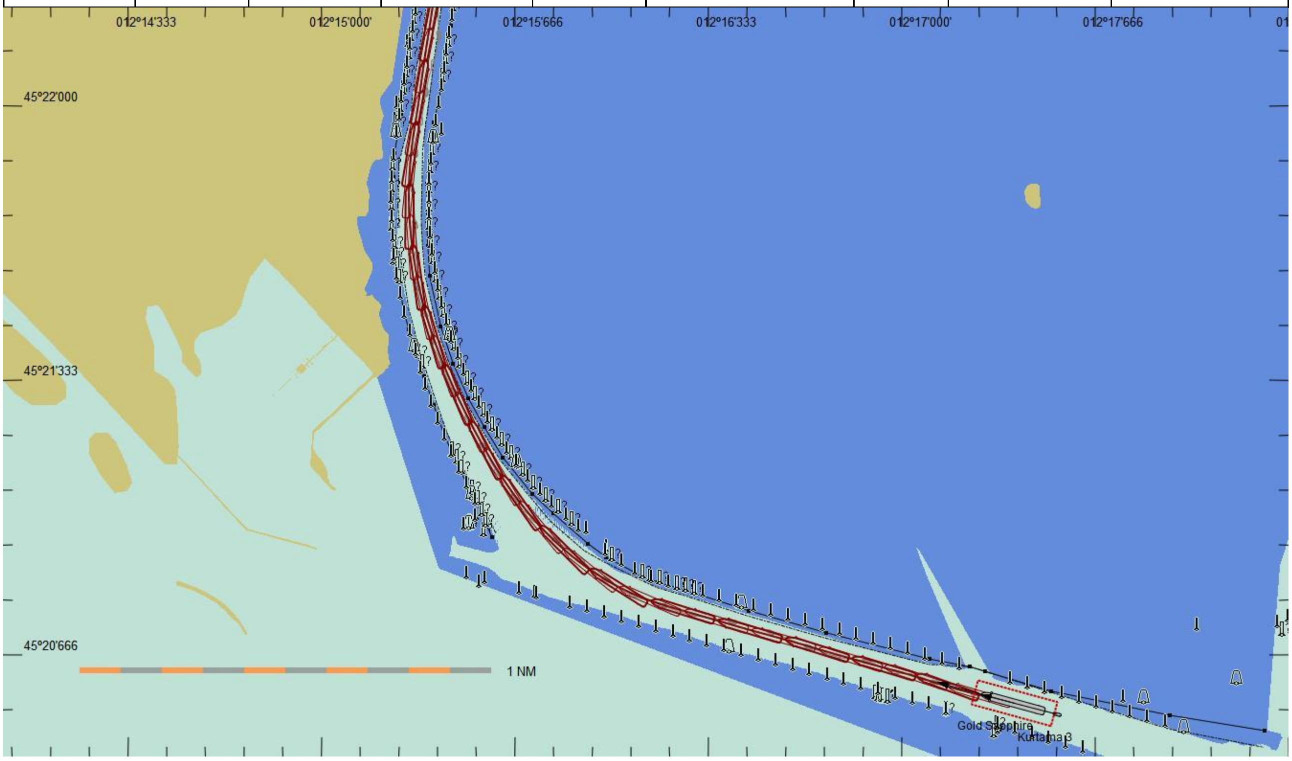


Figure 22 Run 103, arrival, ship approaching the curve on the south of the channel

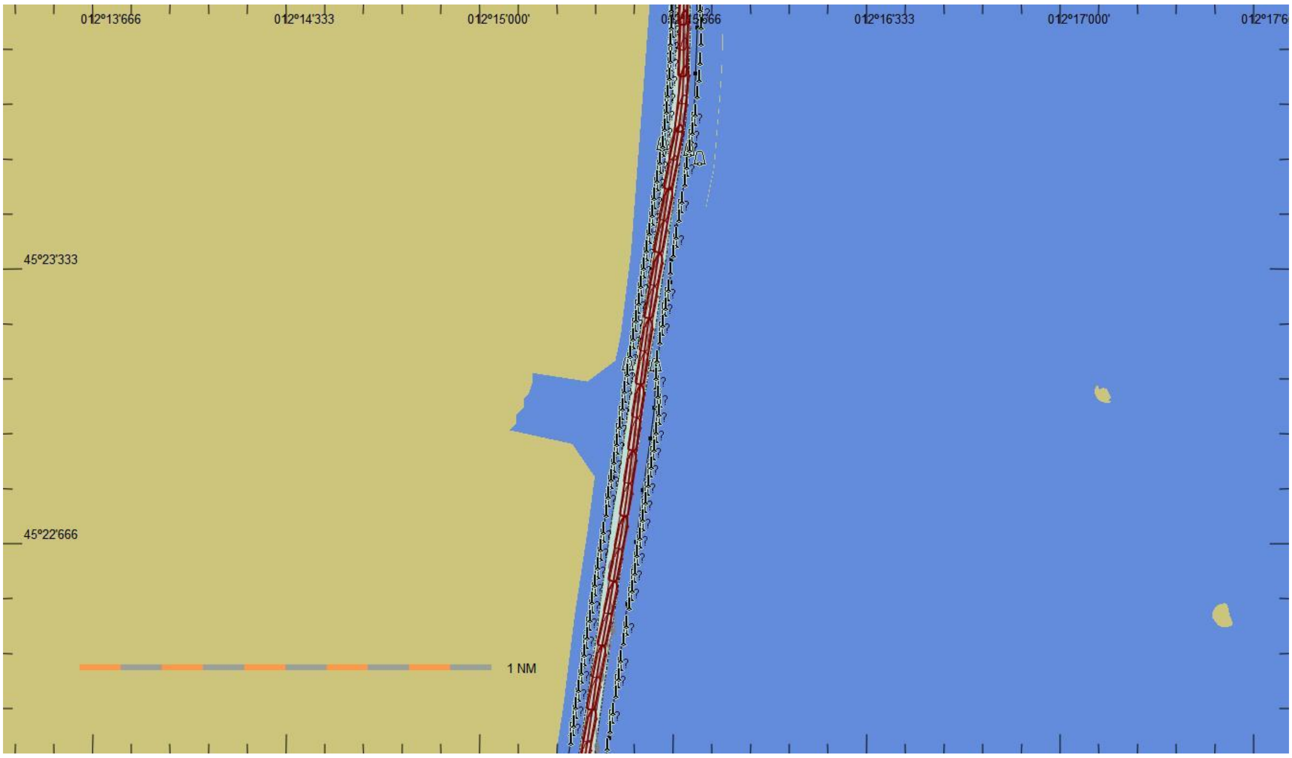


Figure 23 Run 103, detail of the central part of the channel, just after the curve.

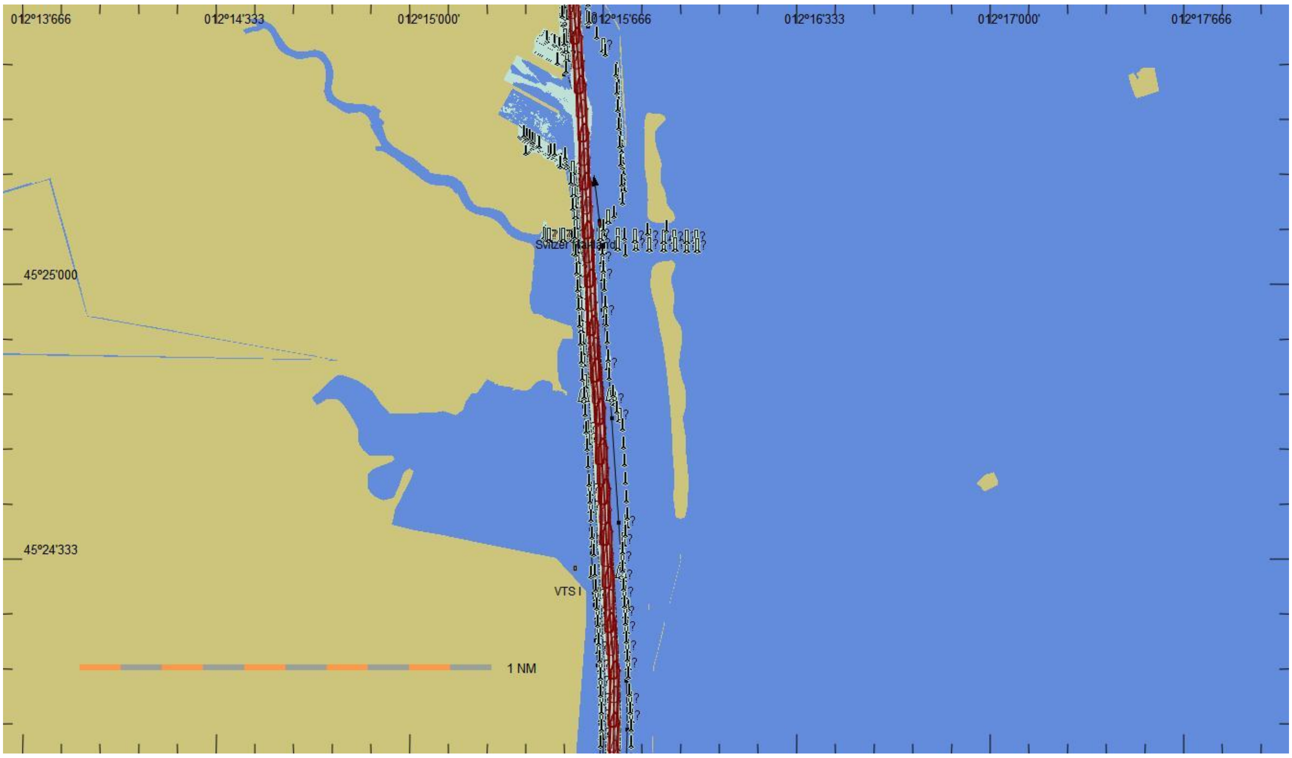


Figure 24 Run 103, track in the center of the channel

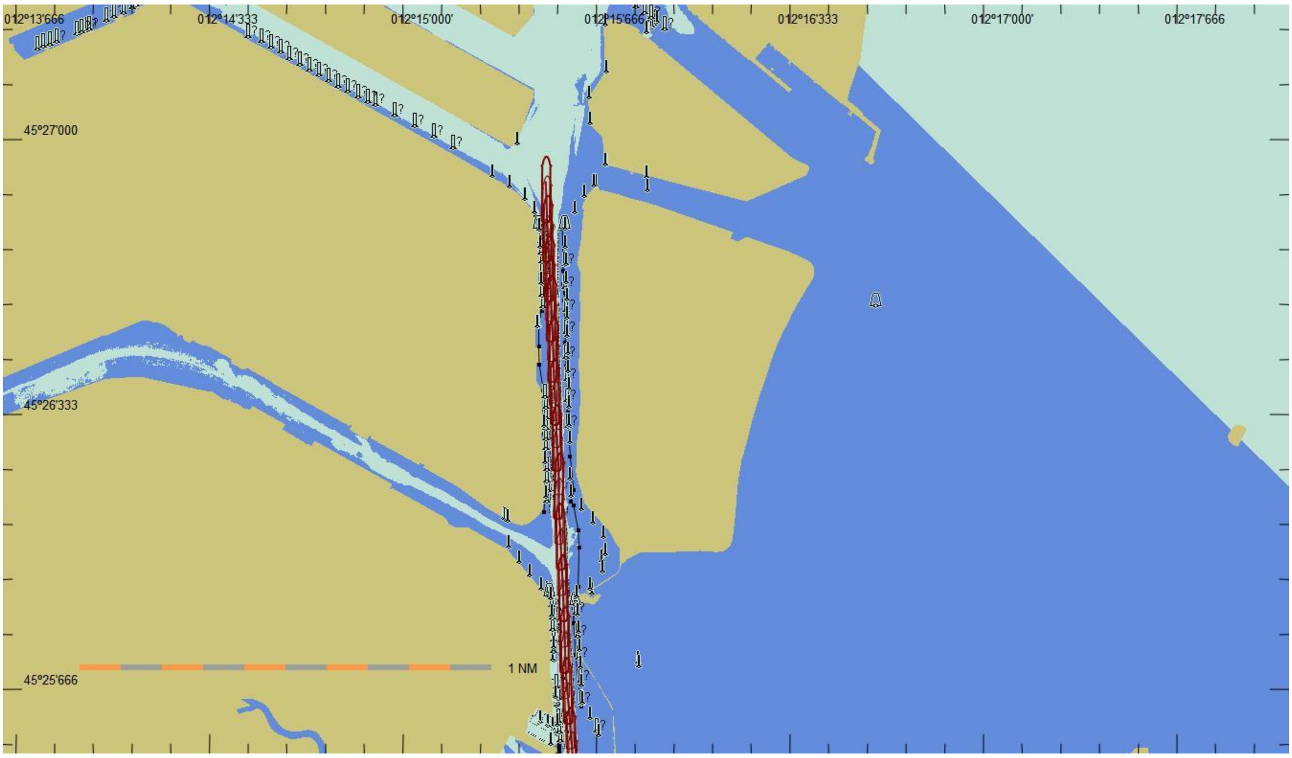


Figure 25 Run 103, end of the track, north part of the channel

104	3644	Cruise	294 m	10	67	1	ENE	1

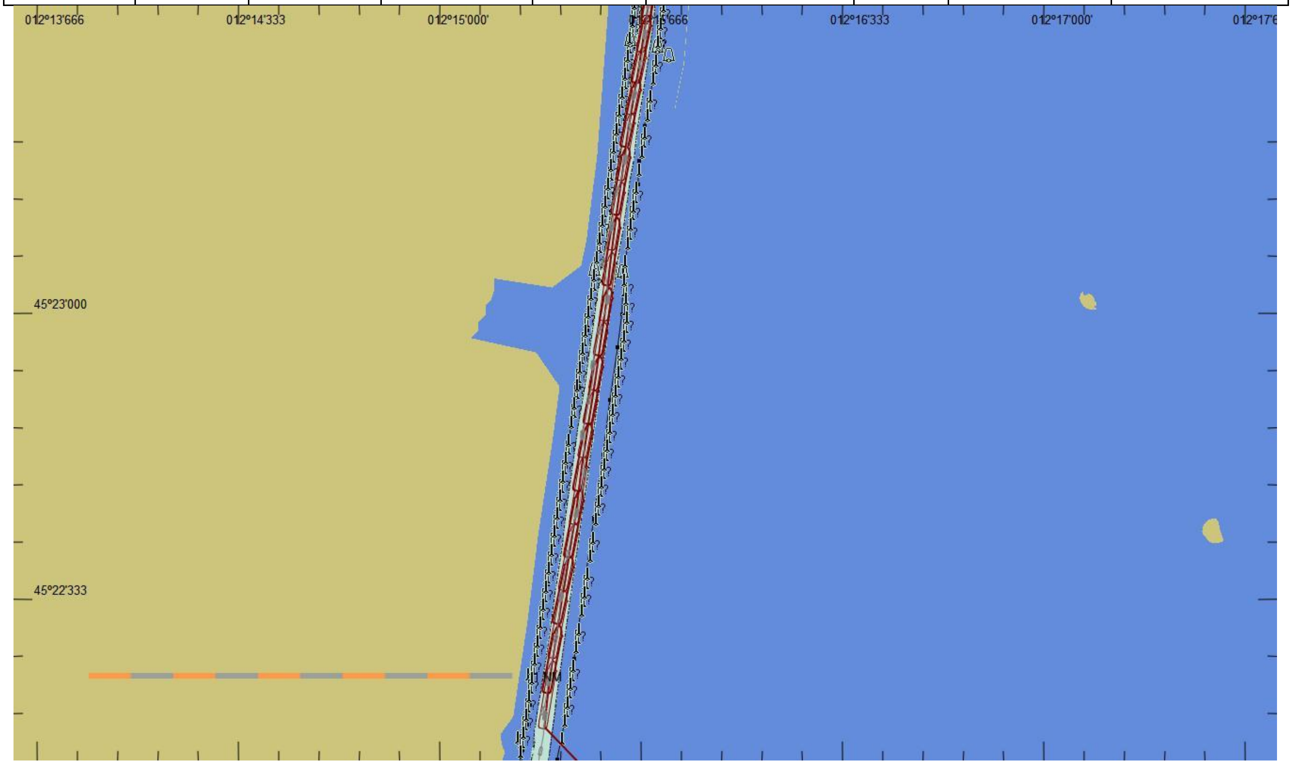


Figure 26 Run 104, arrival, ship approaching the central part of the channel, just after the curve

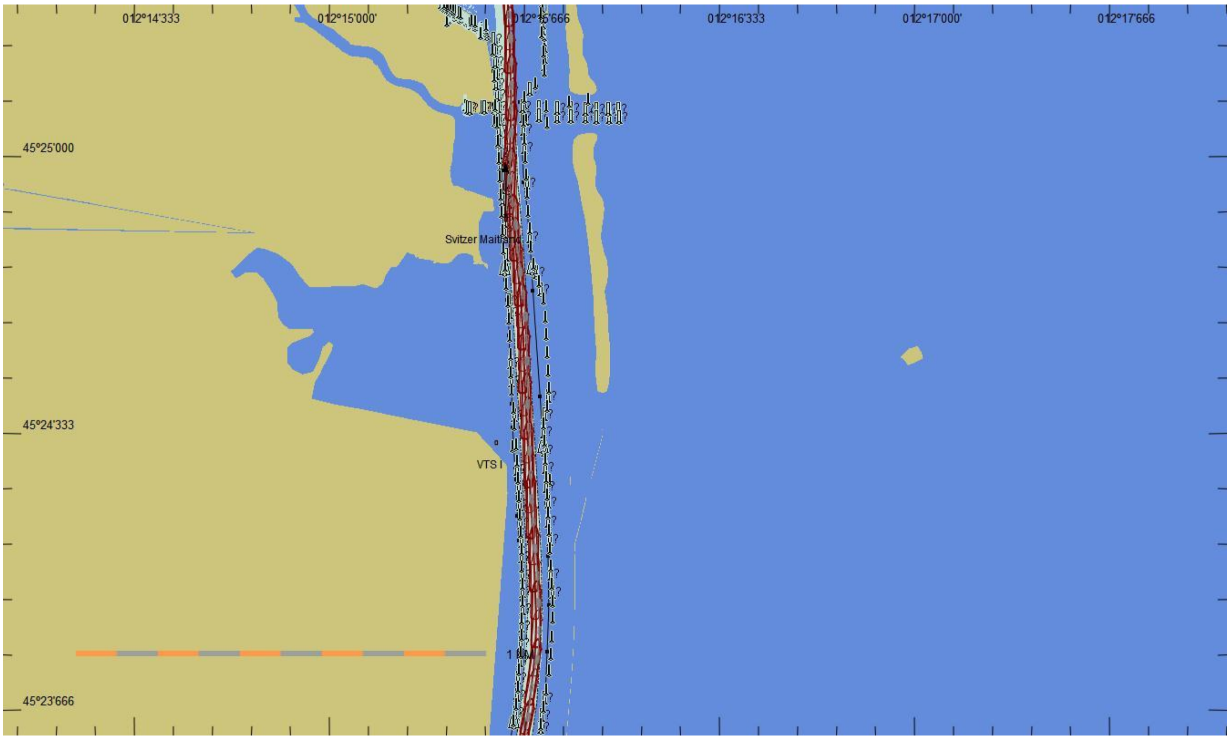


Figure 27 Run 104, track of the ship at the center of the channel

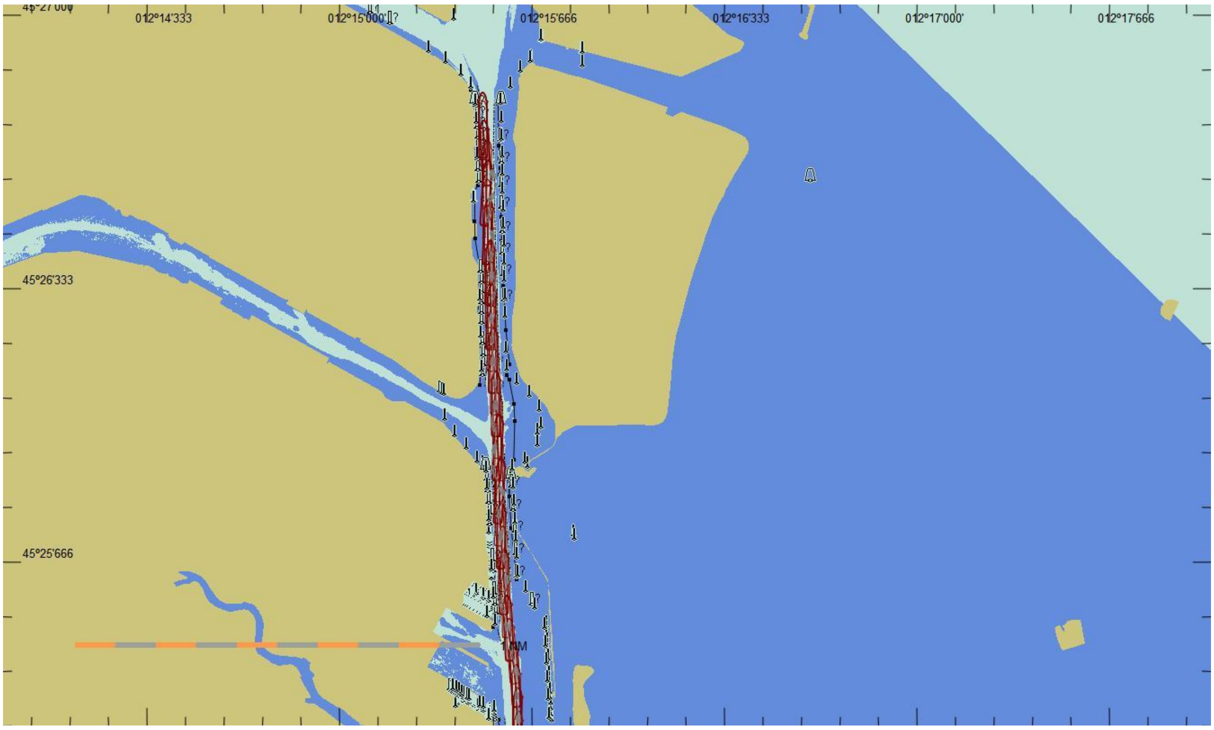


Figure 28 Run 104, the end of the track, northen part of the channel.

201	3644	Cruise	294 m	10	23	1	ENE	1

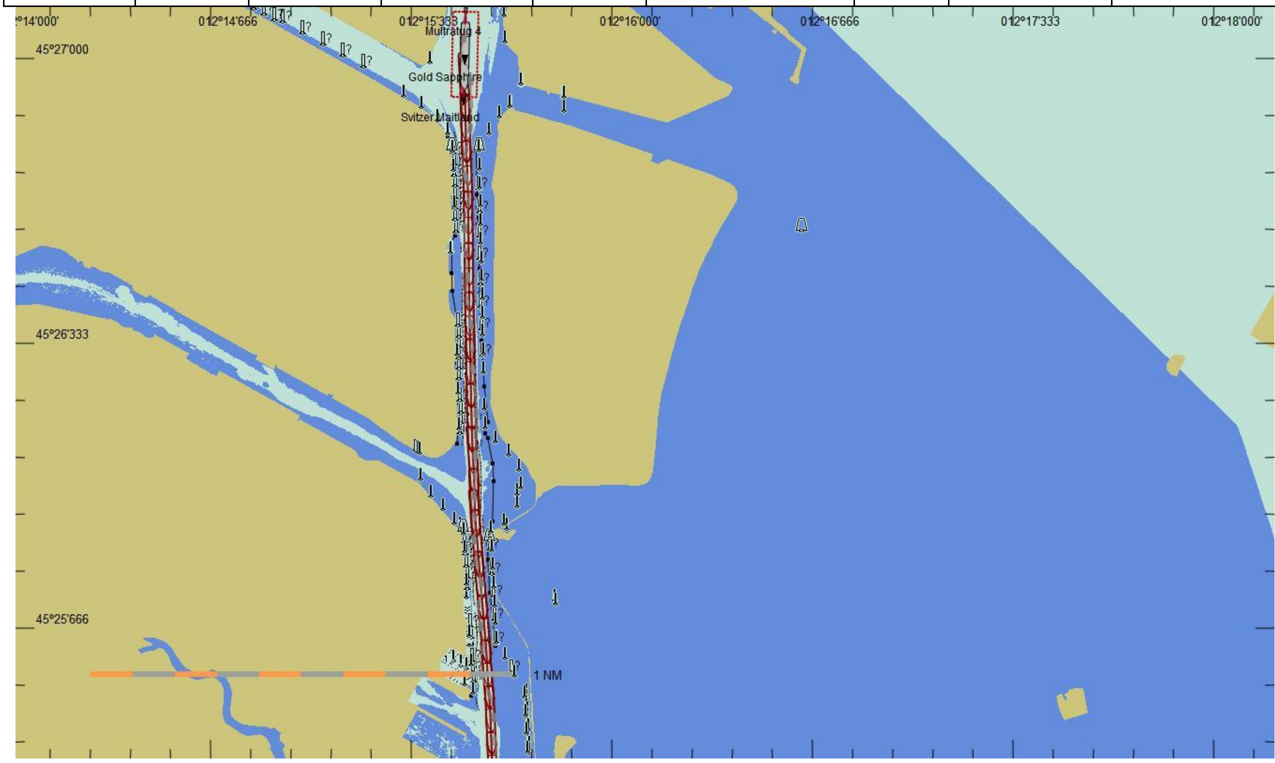


Figure 29 Run 201, departure from the basin in the northen part of the channel

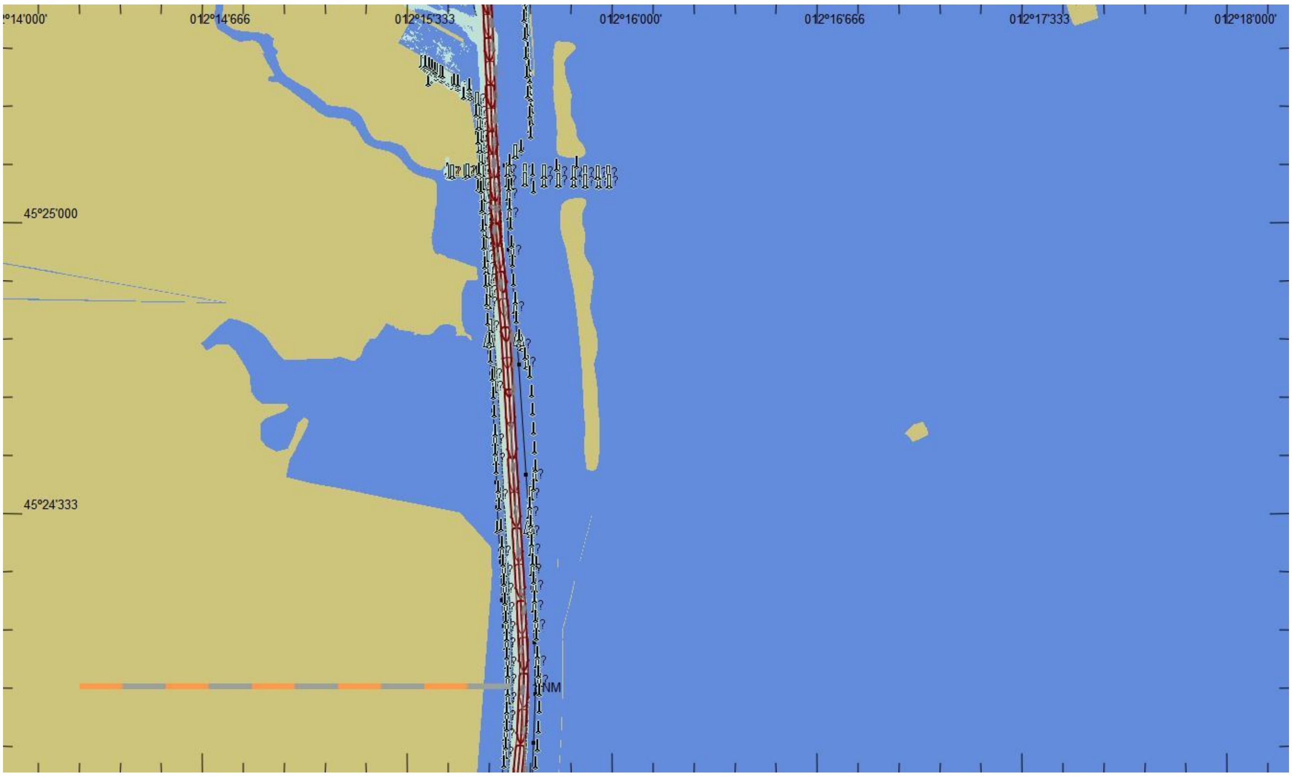


Figure 30 Run 201, view of the track in the center part of the channel.

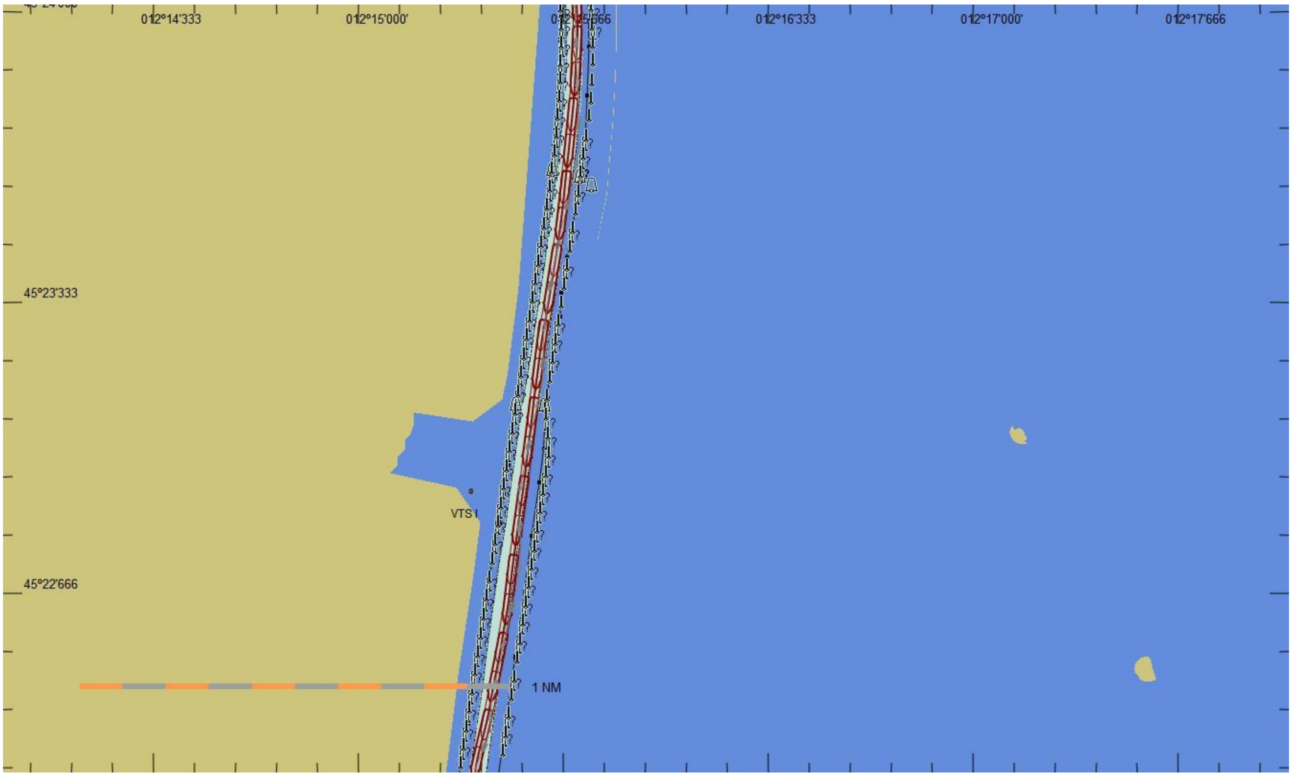


Figure 31 Run 201, track in the center part of the channel.

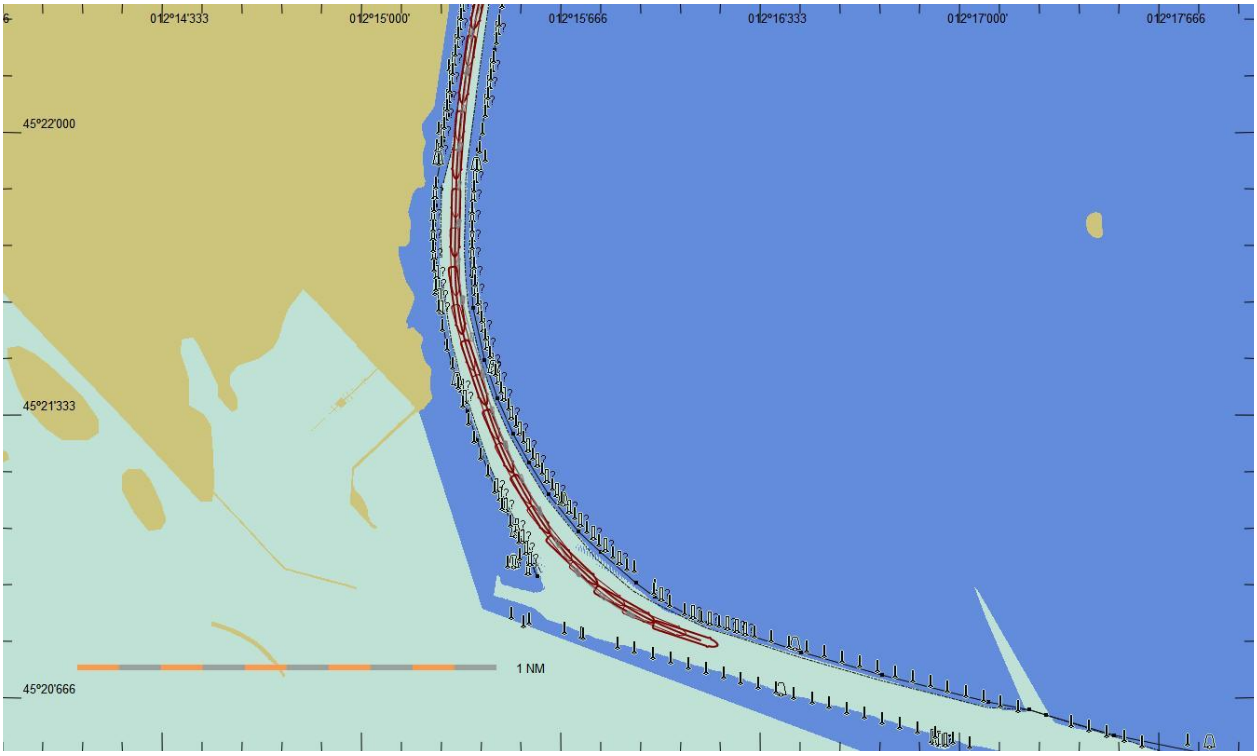


Figure 32 Run 201, ending of the track in the south curve of the channel, probably grounding.

202	3644	Cruise	294 m	12.5	67	1	ENE	1

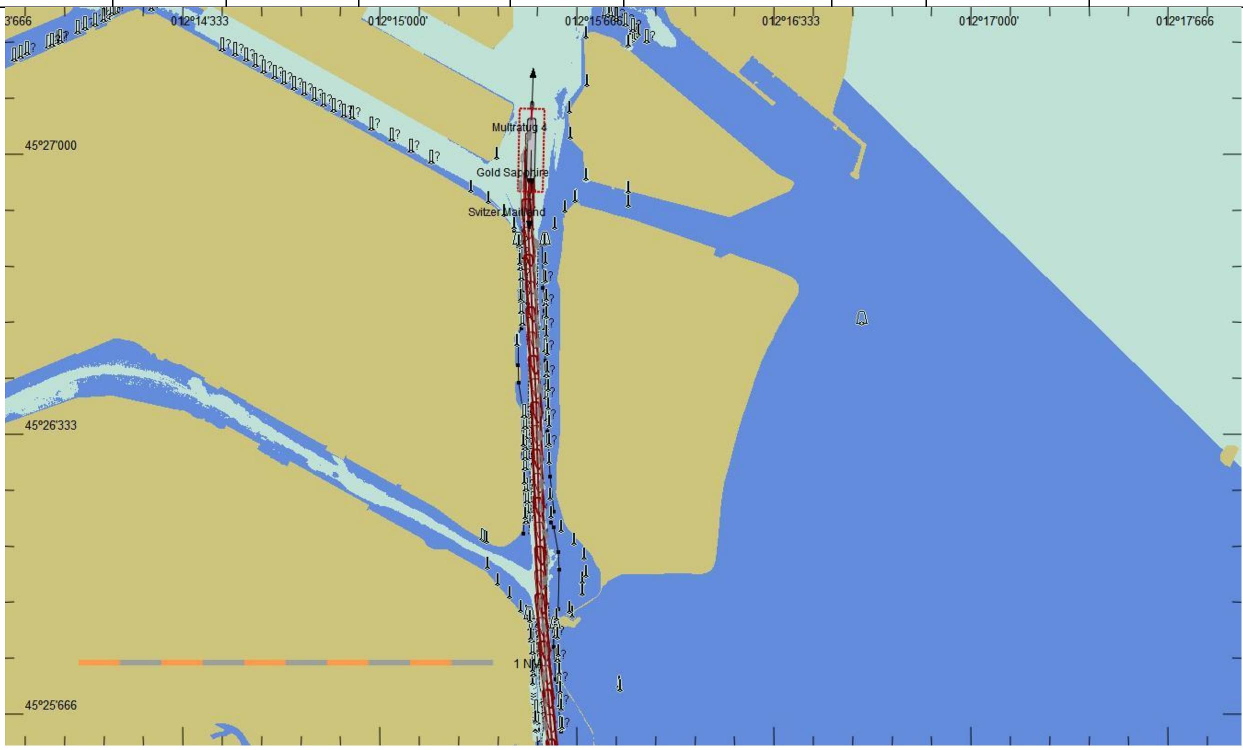


Figure 33 Run 202, departure from the basin, north of the channel.

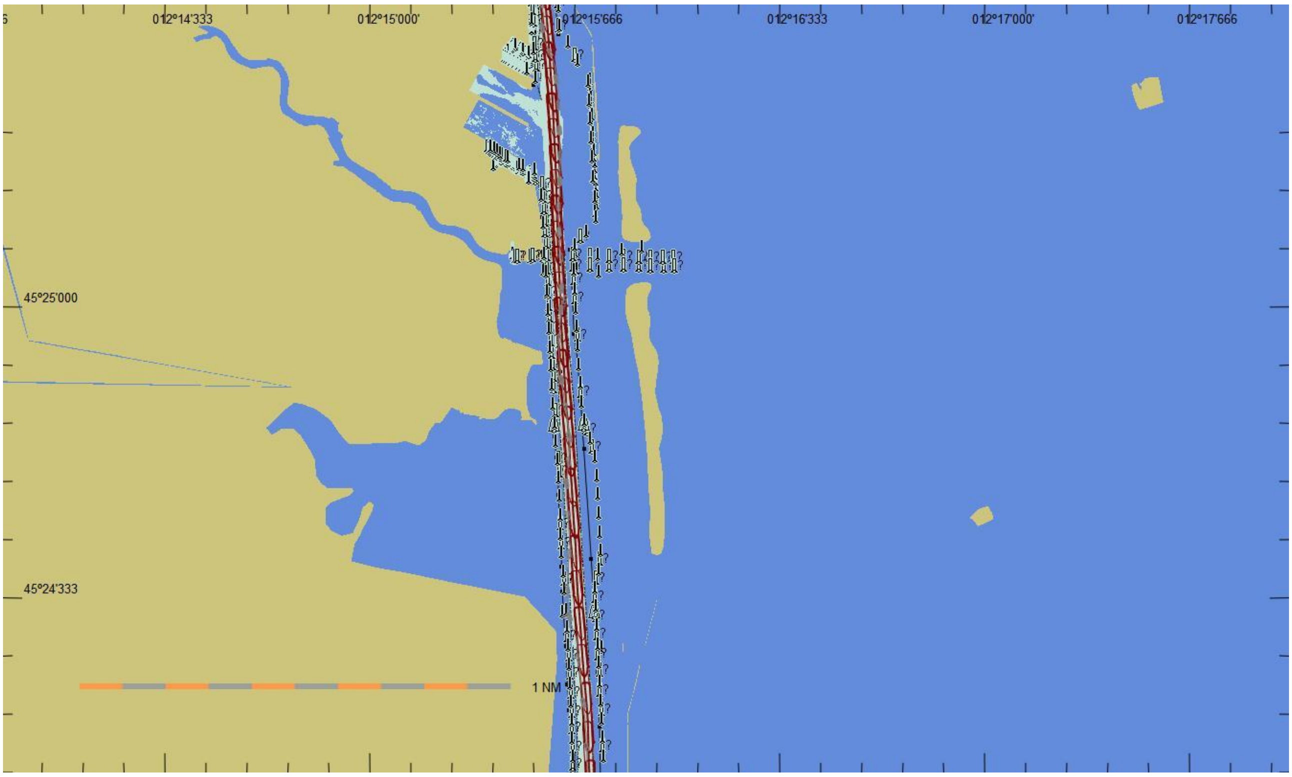


Figure 34 Run 202, track at the center part of the channel.

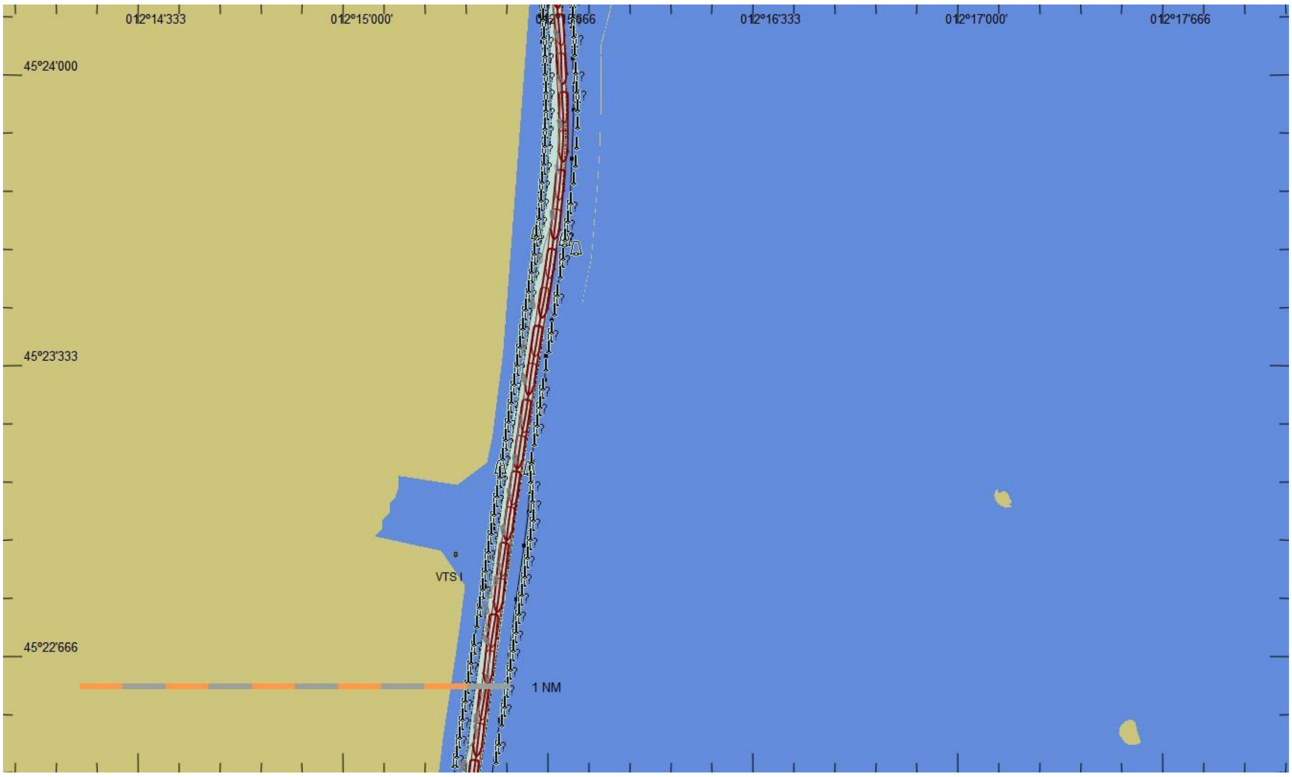


Figure 35 Run 202, track in the center part of the channel.

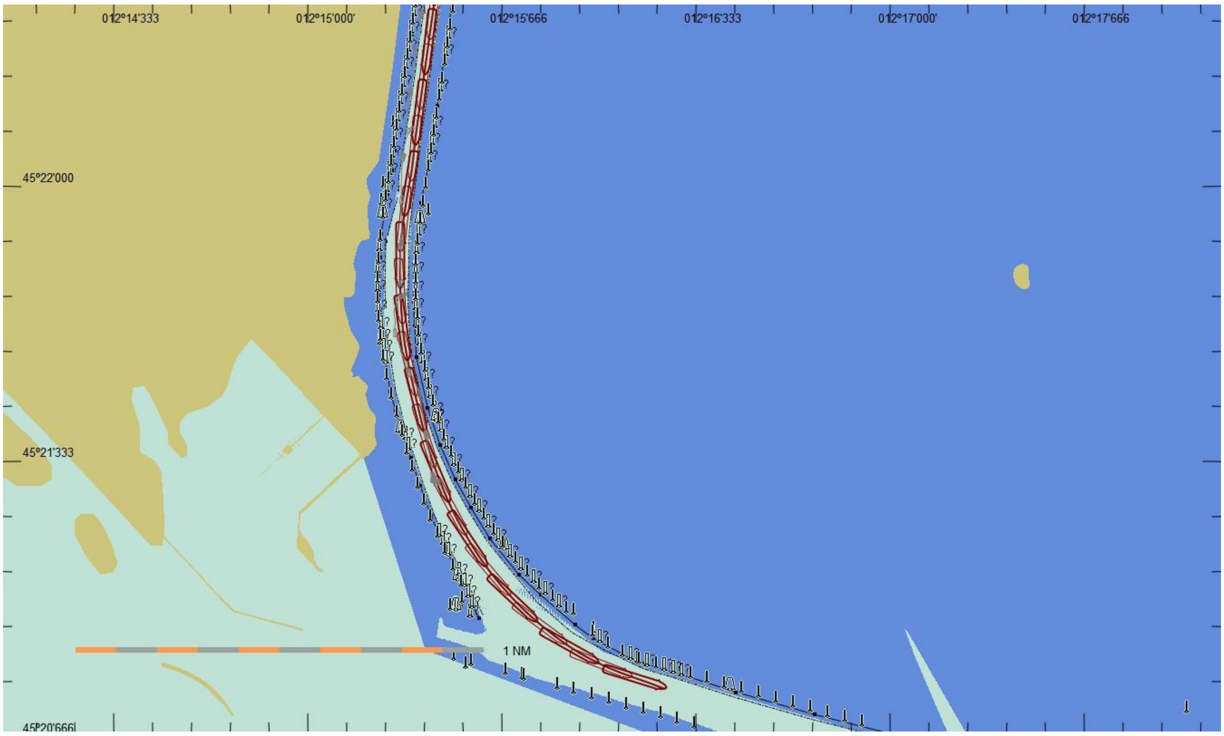


Figure 36 Run 202, ending of the track, after the curve in the south of the channel.

203	3644	Cruise	294 m	10	67	1	ENE	1

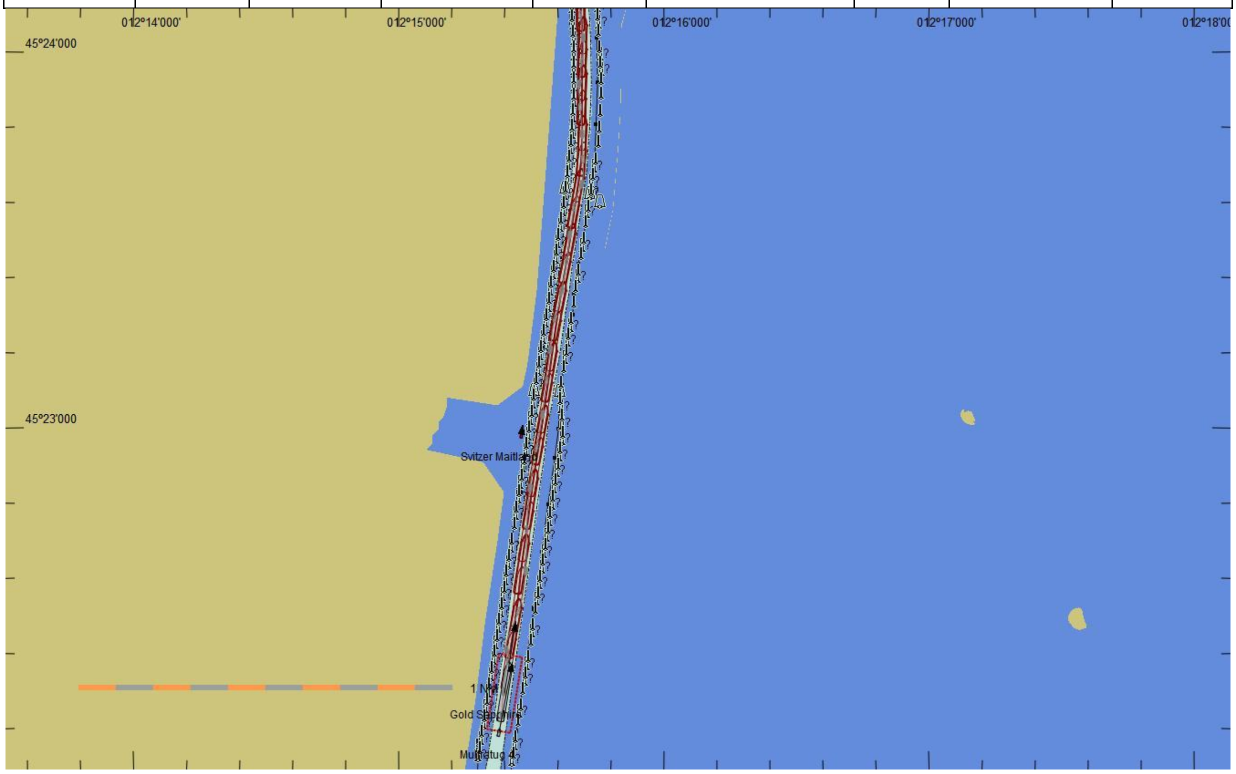


Figure 37 Run 203, arrival, track beginning after the south curve of the channel.

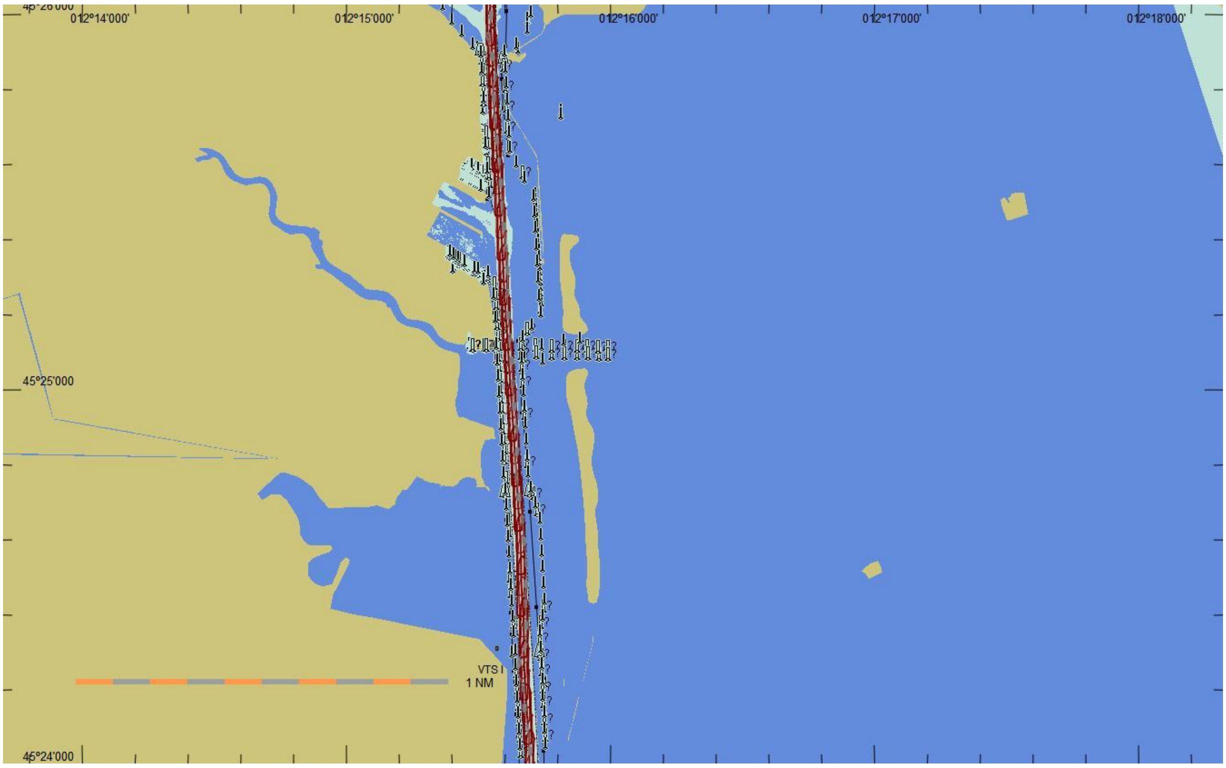


Figure 38 Run 203, track in the center part of the channel.

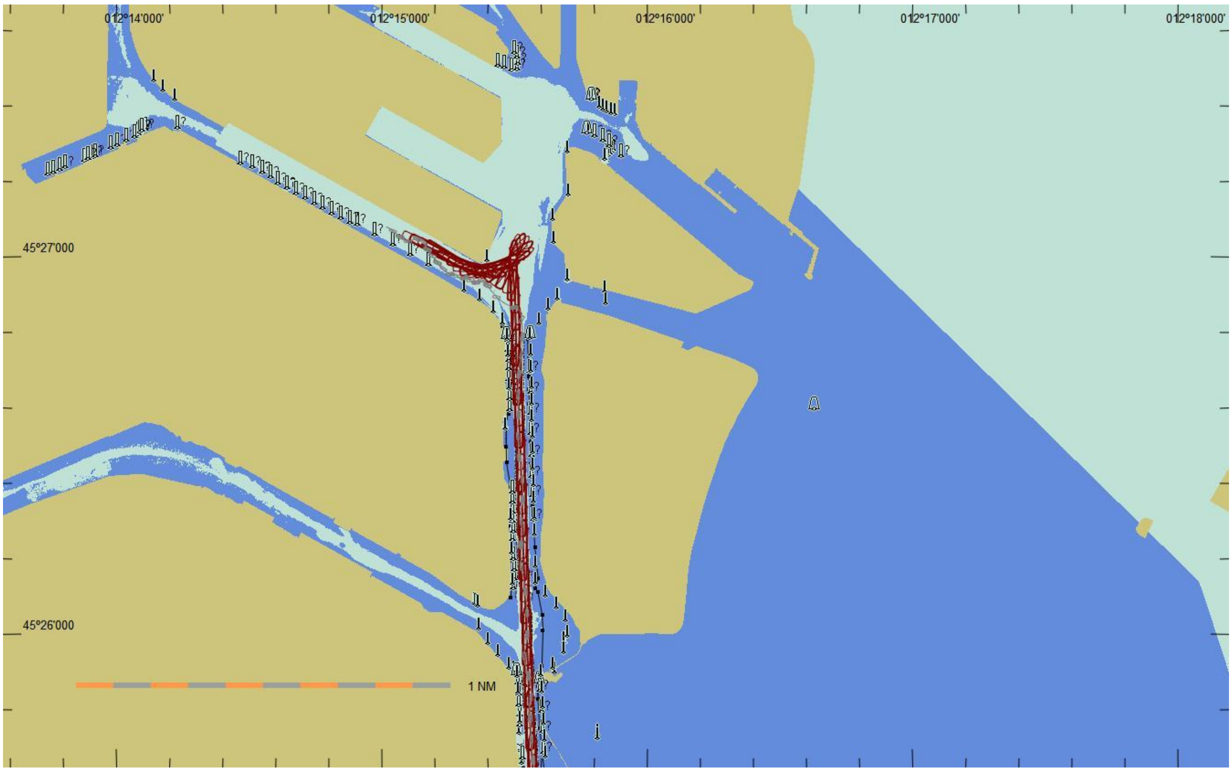


Figure 39 Run 203, end of the track, north part of the channel.

204	3481	Bulker	200 m	7.5	23	1	ENE	1

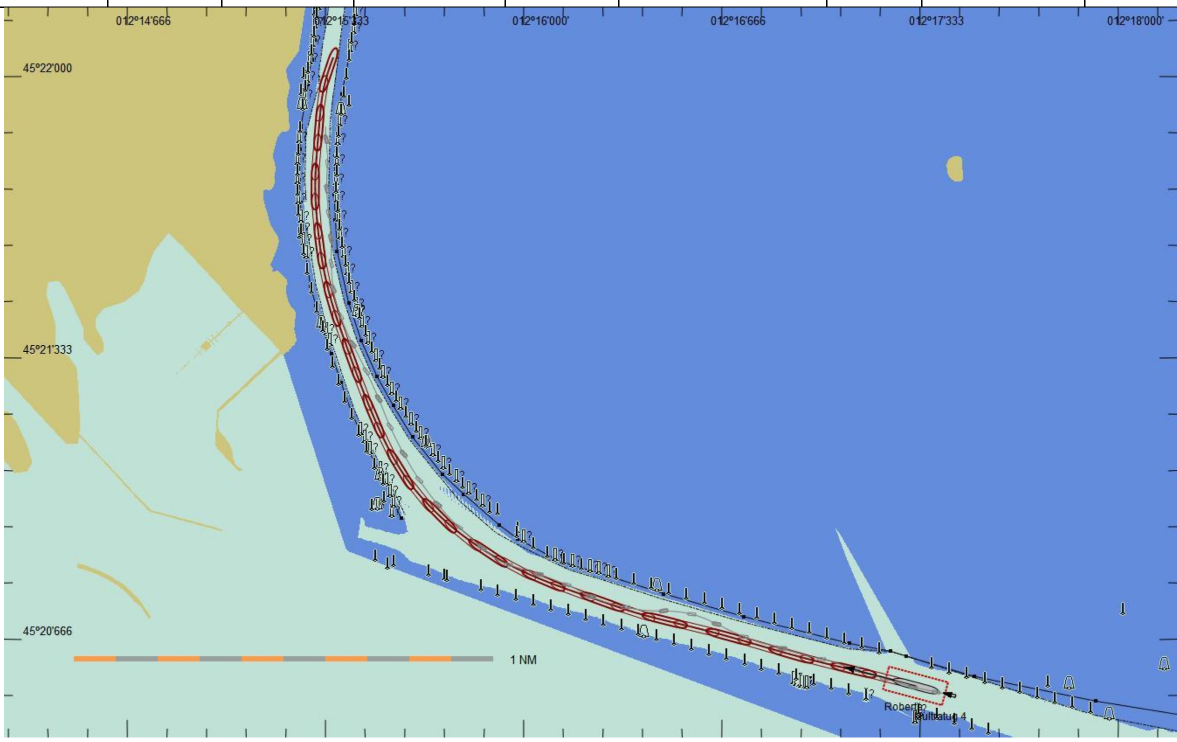


Figure 40 Run 204, arrival, beginning of the navigation before the curve, south part of the channel and grounding just after the curve.

205	3481	Bulker	200 m	7.5	23	1	ENE	1

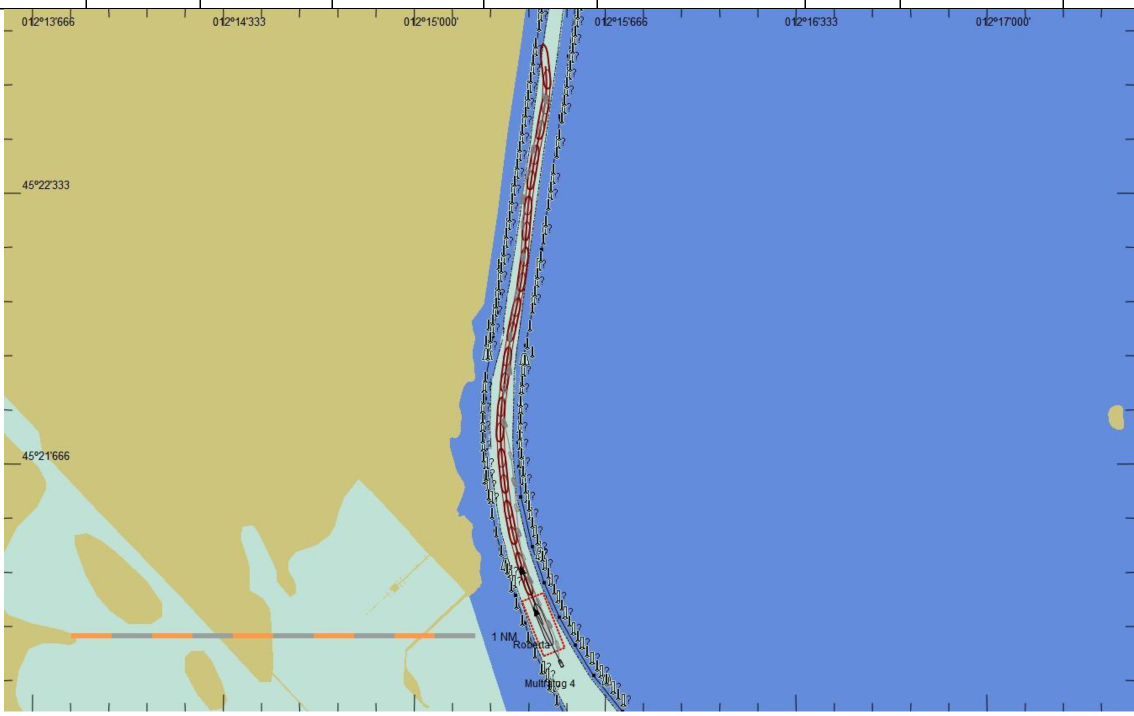


Figure 41 Run 205, arrival, begin of the navigation within the south curve, grounding just after that.

206	3481	Bulker	200 m	7.5	23	1	ENE	1

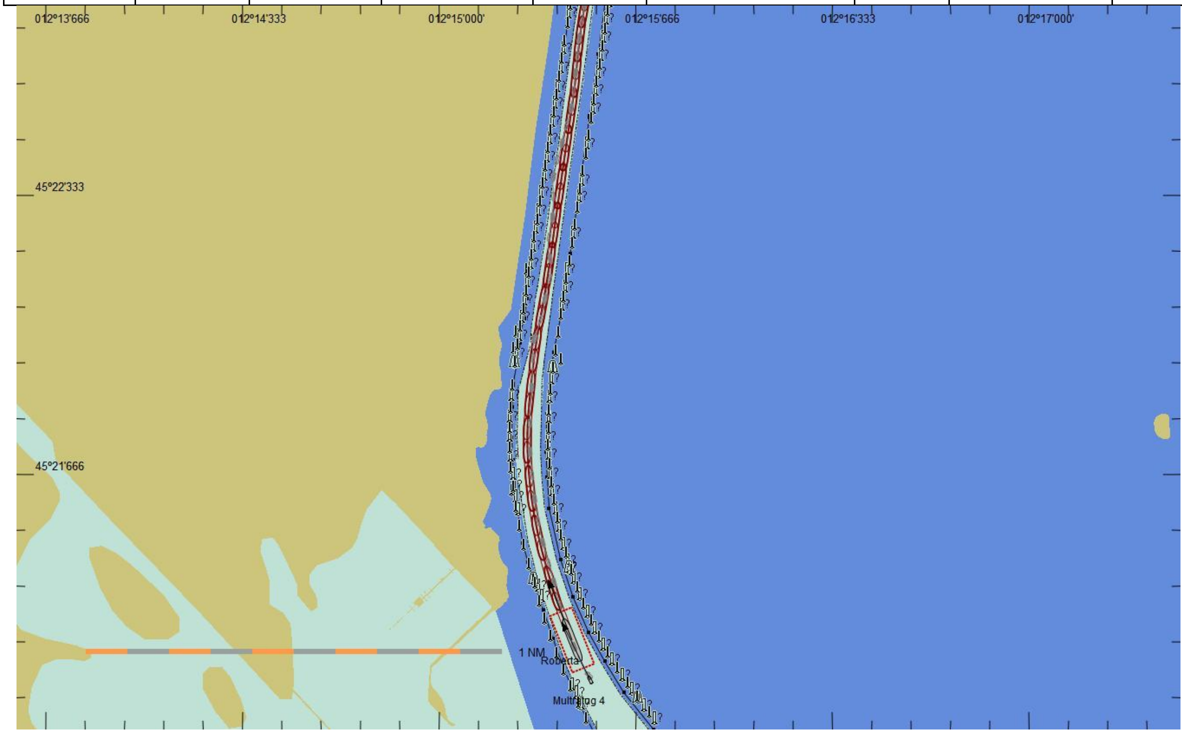


Figure 42 Run 206, arrival, track beginning in the middle of the south curve.

207	3481	Bulker	200 m	10	45	1	ENE	1

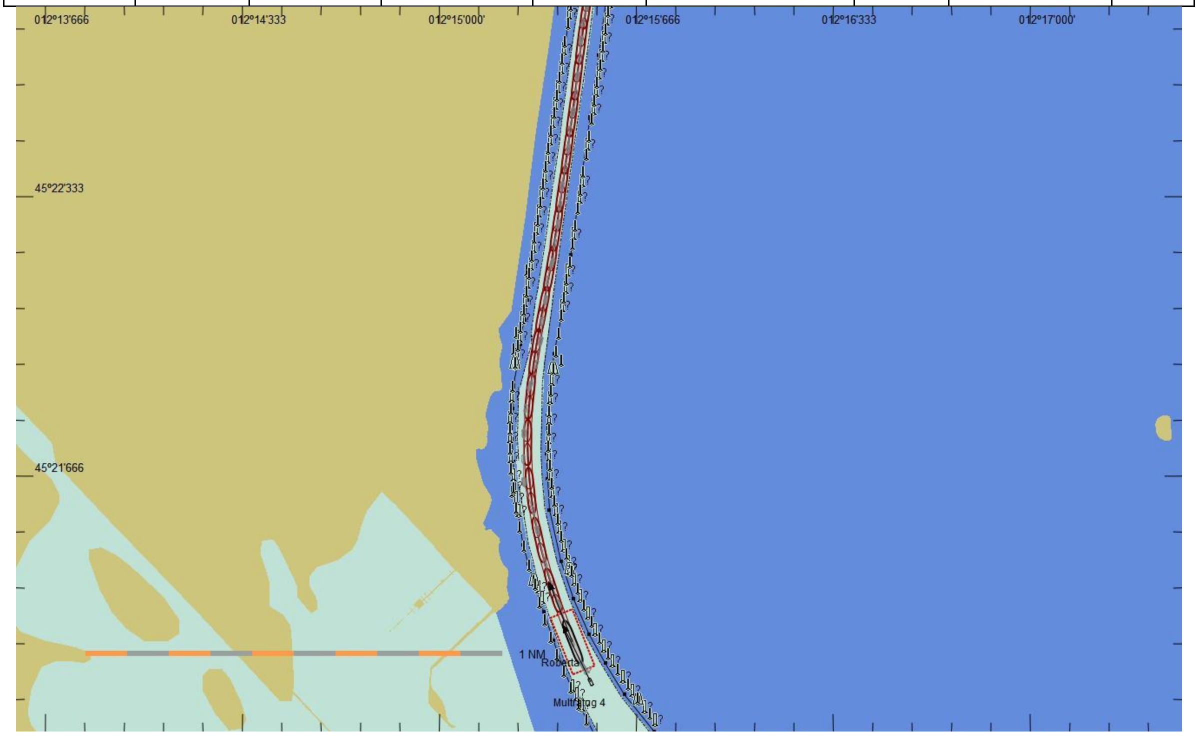


Figure 43 Run 207, arrival, track begins in the middle of the south curve.

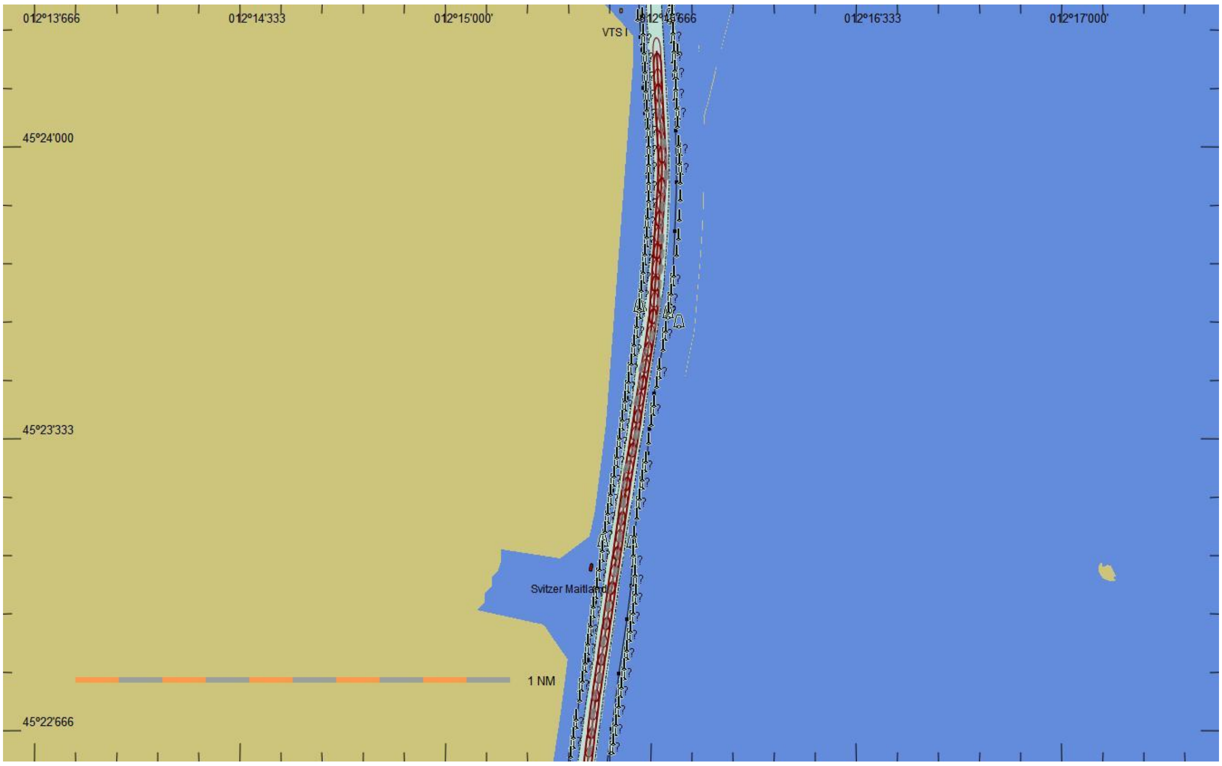


Figure 44 Run 207, end of the track in the center part of the channel.

301	3481	Bulker	200 m	12.5	67	1	ENE	1

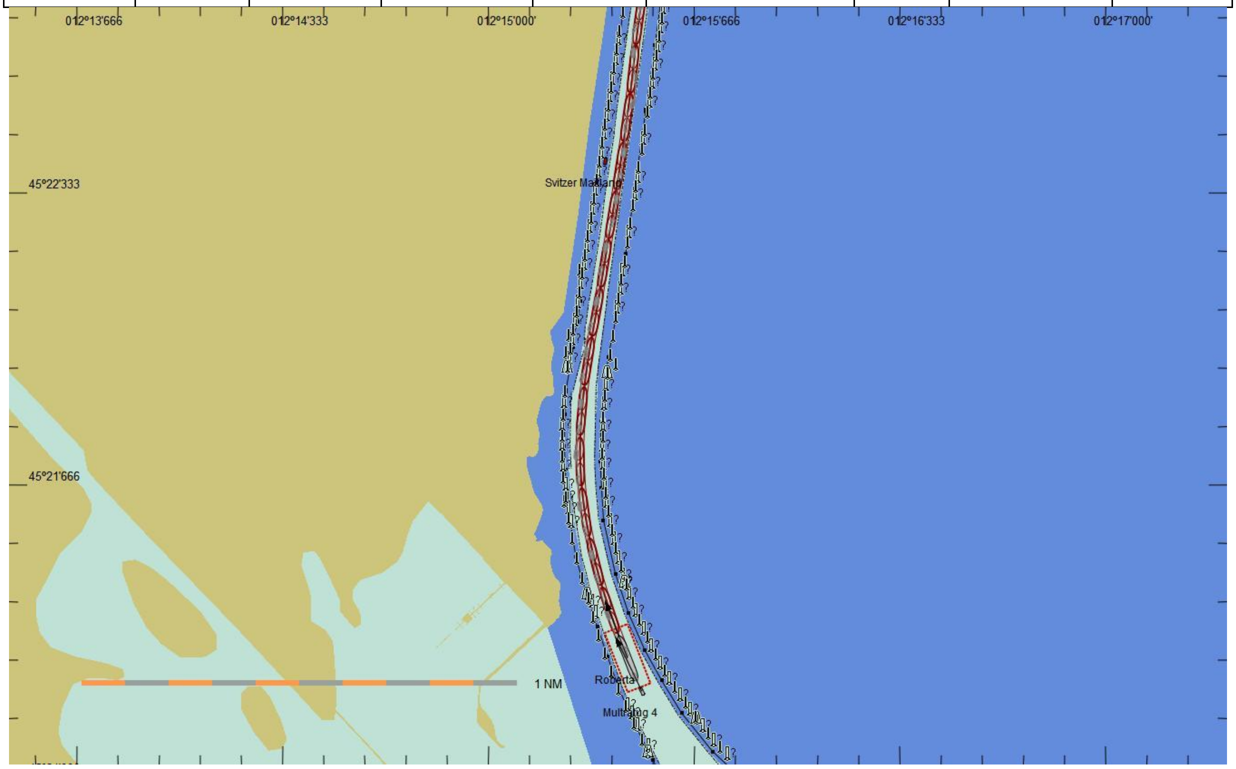


Figure 45 Run 301, arrival from the center part of the south curve.

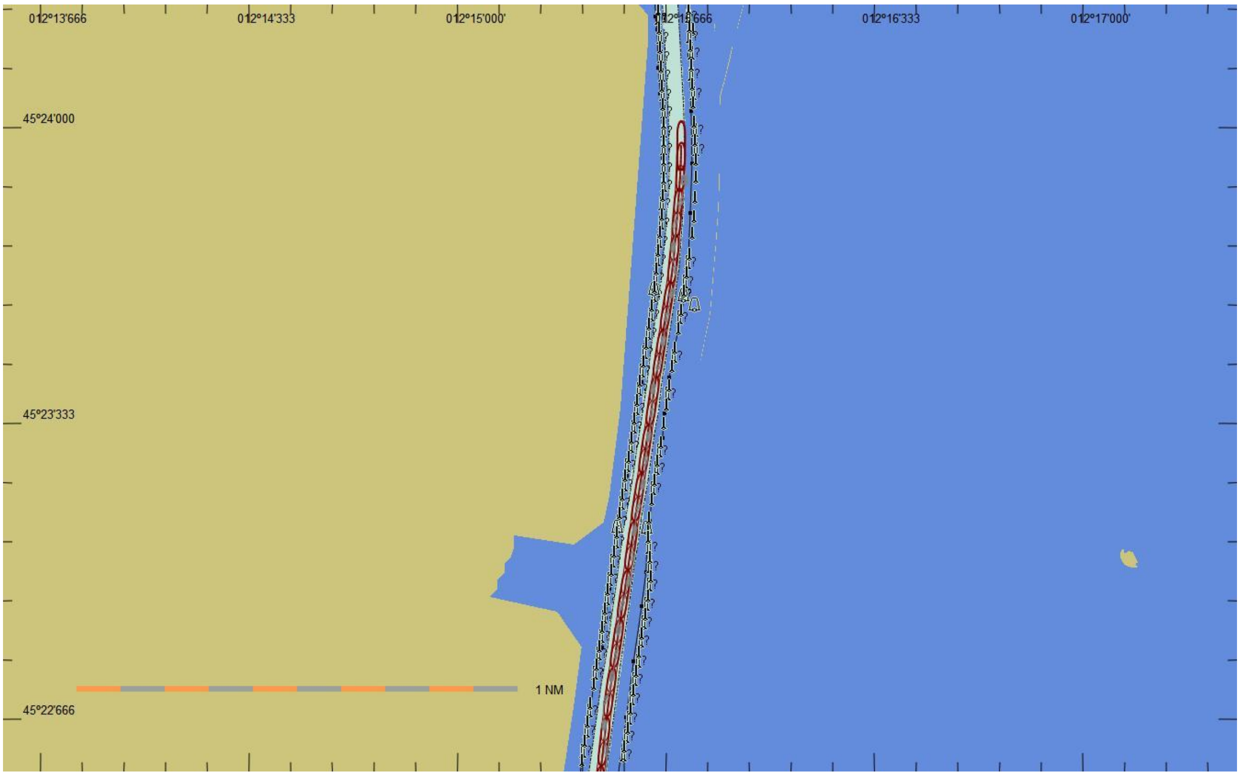


Figure 46 Run 301, end of the track in the center part of the channel.

302	3481	Bulker	200 m	10	67	1	ENE	1

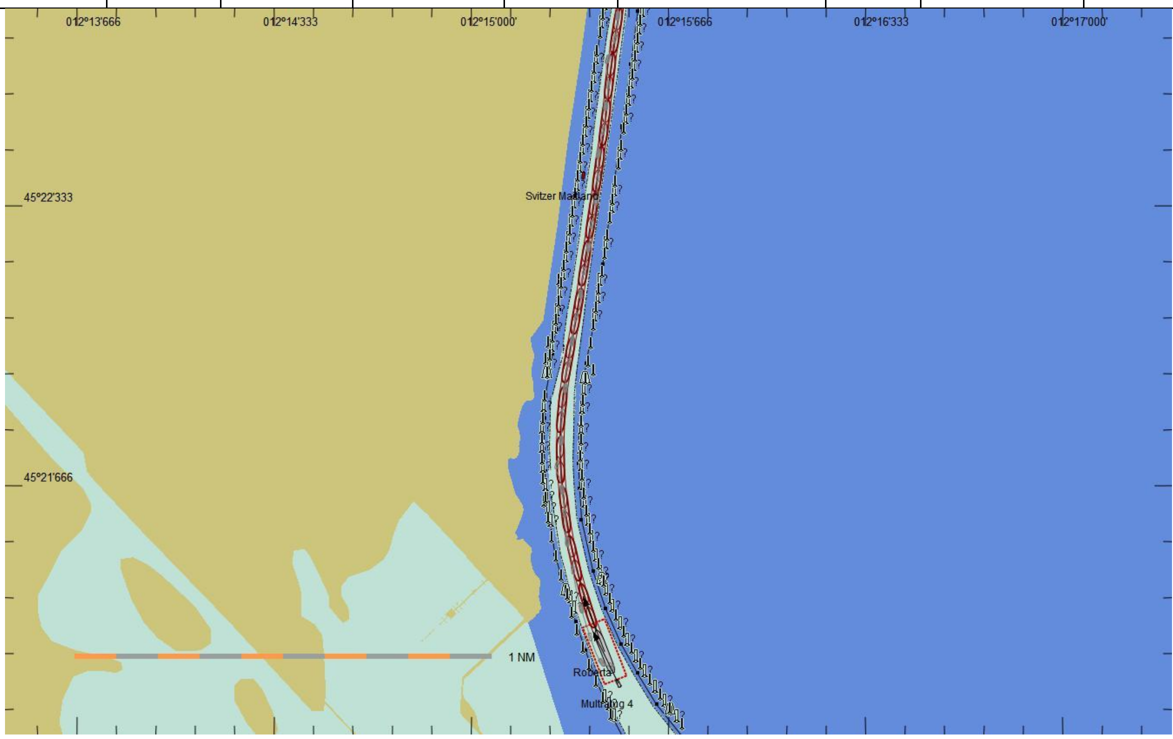


Figure 47 Run 302, arrival from the last part of the south curve.

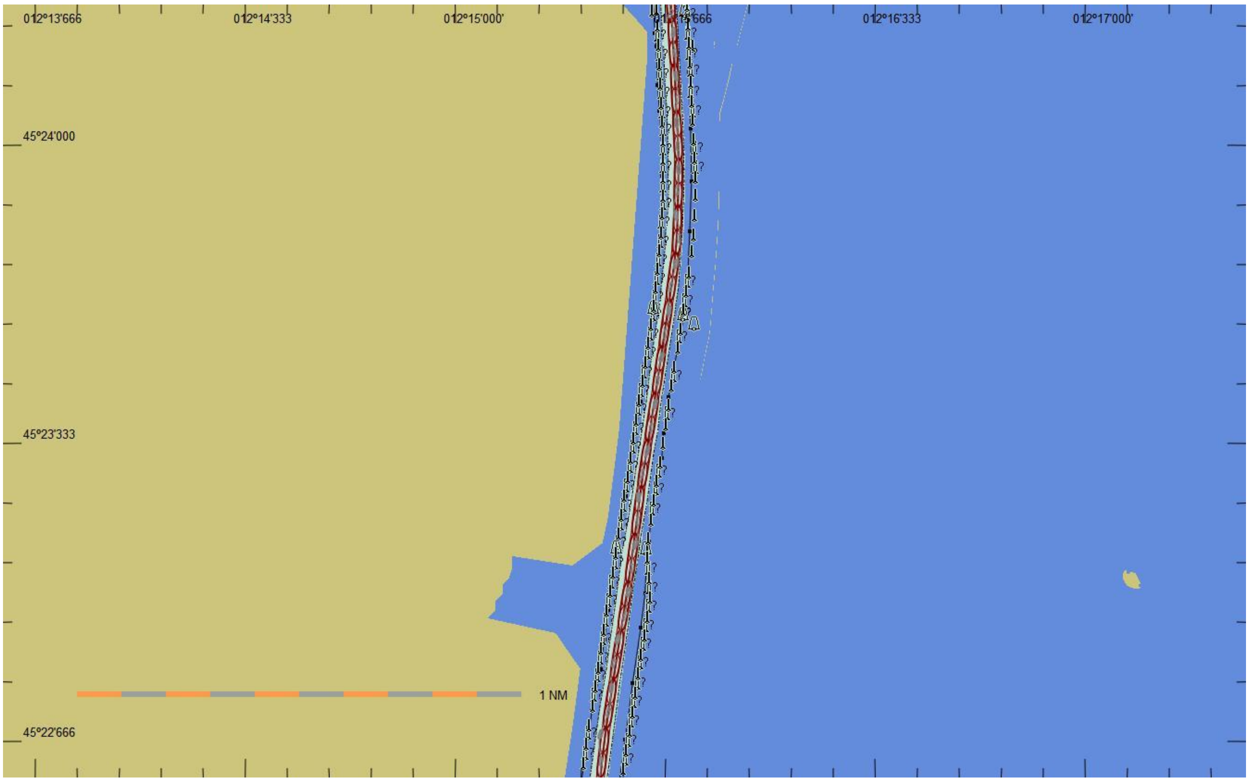


Figure 48 Run 302, track in the center of the channel.

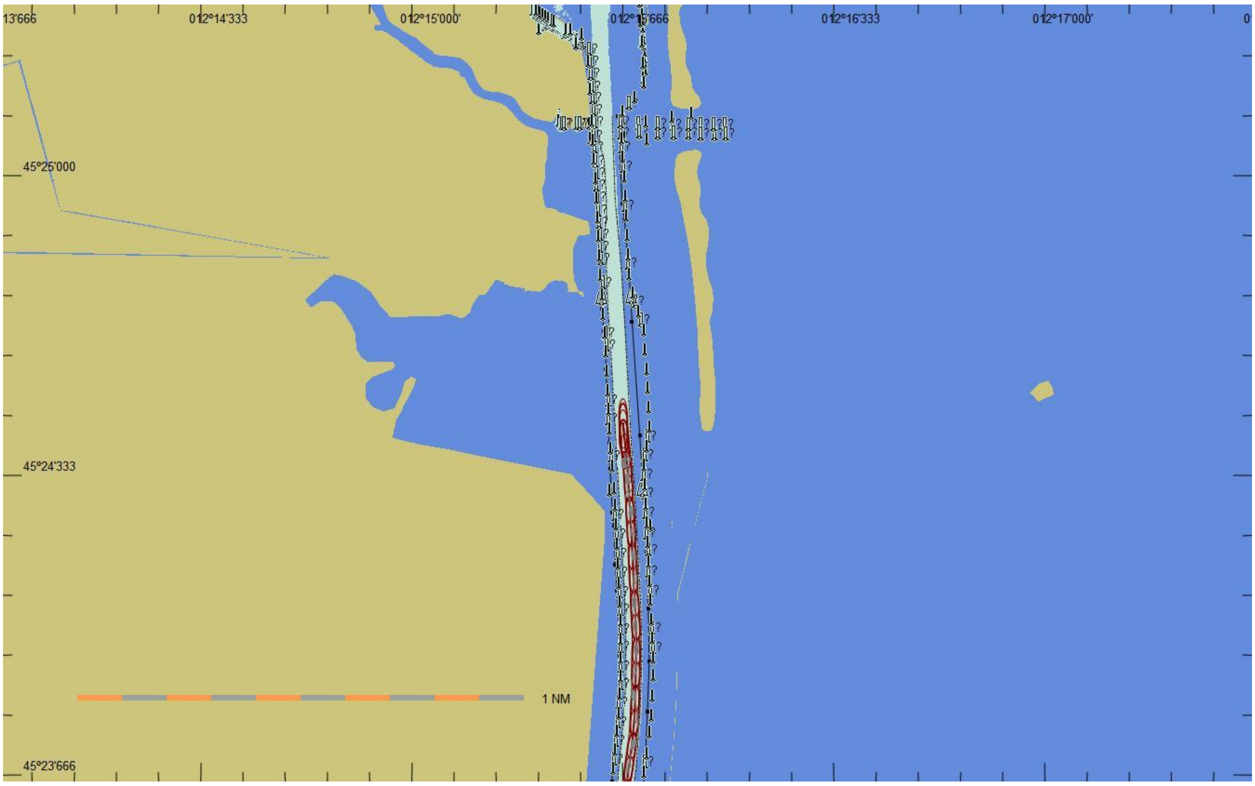


Figure 49 Run 302, end of the track still in the center of the channel.

303	3481	Bulker	200 m	7.5	23	1	ENE	1

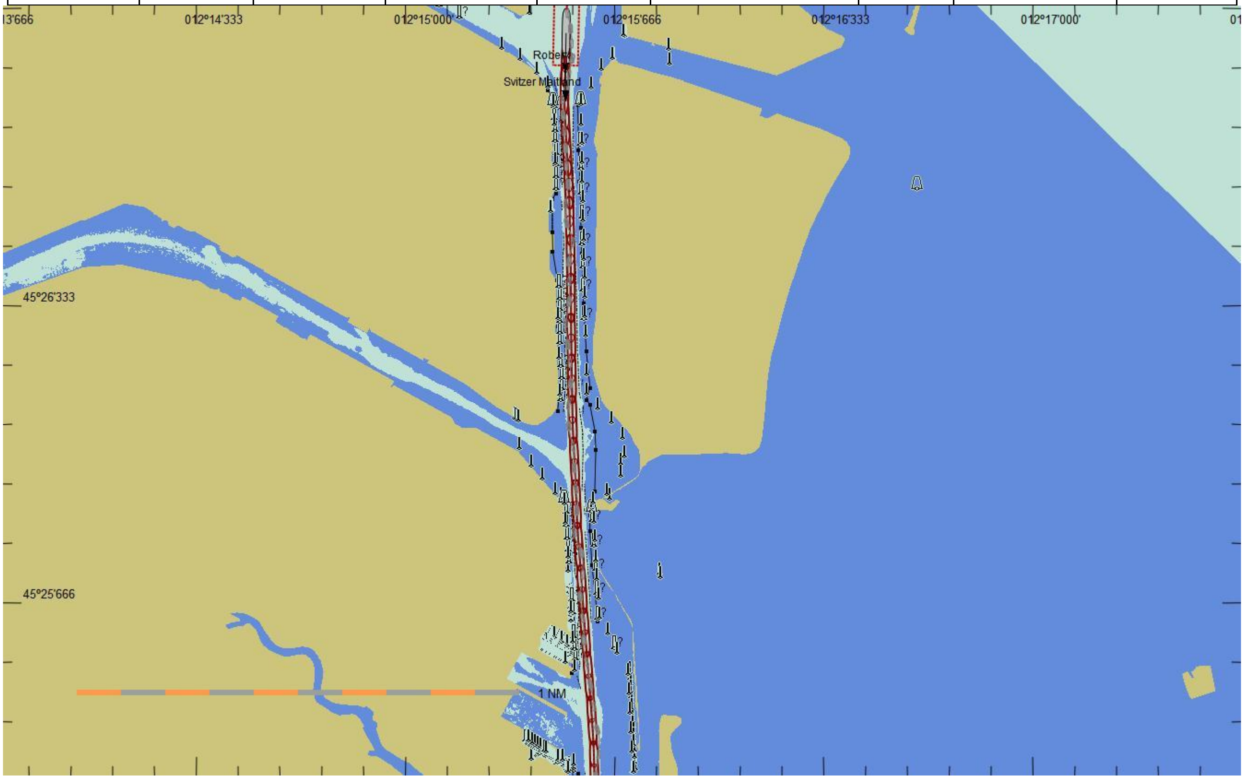


Figure 50 Run 303, departure from the basin in the north of the channel.

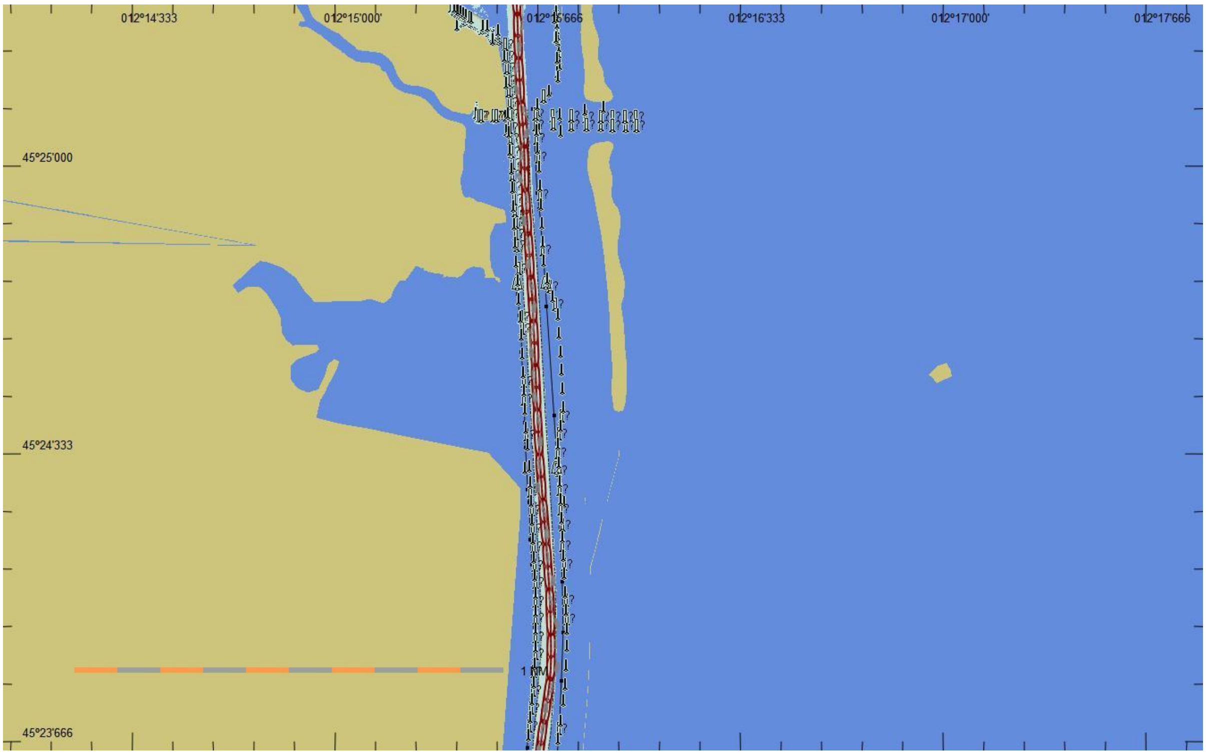


Figure 51 Run 303**,** track in the center of the channel.

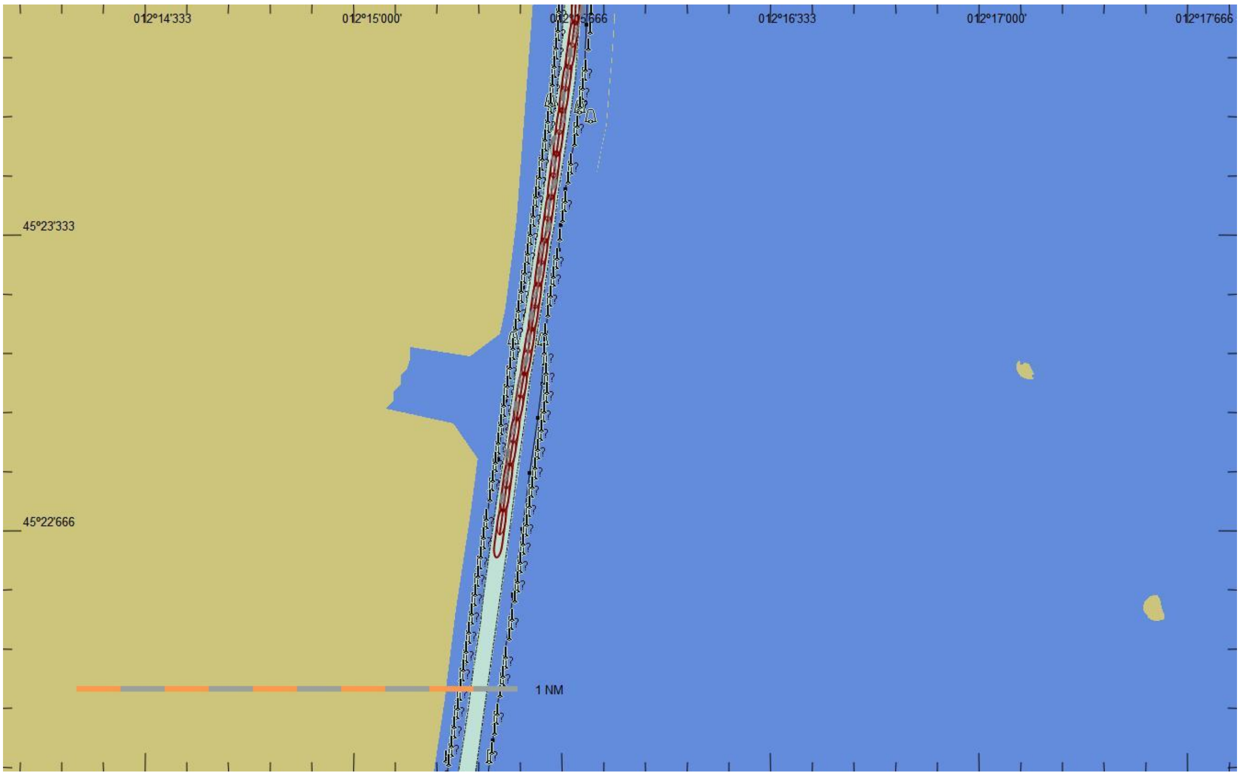


Figure 52 Run 303, end of the track in the center of the channel.

304	3481	Bulker	200 m	10	45	1	ENE	1

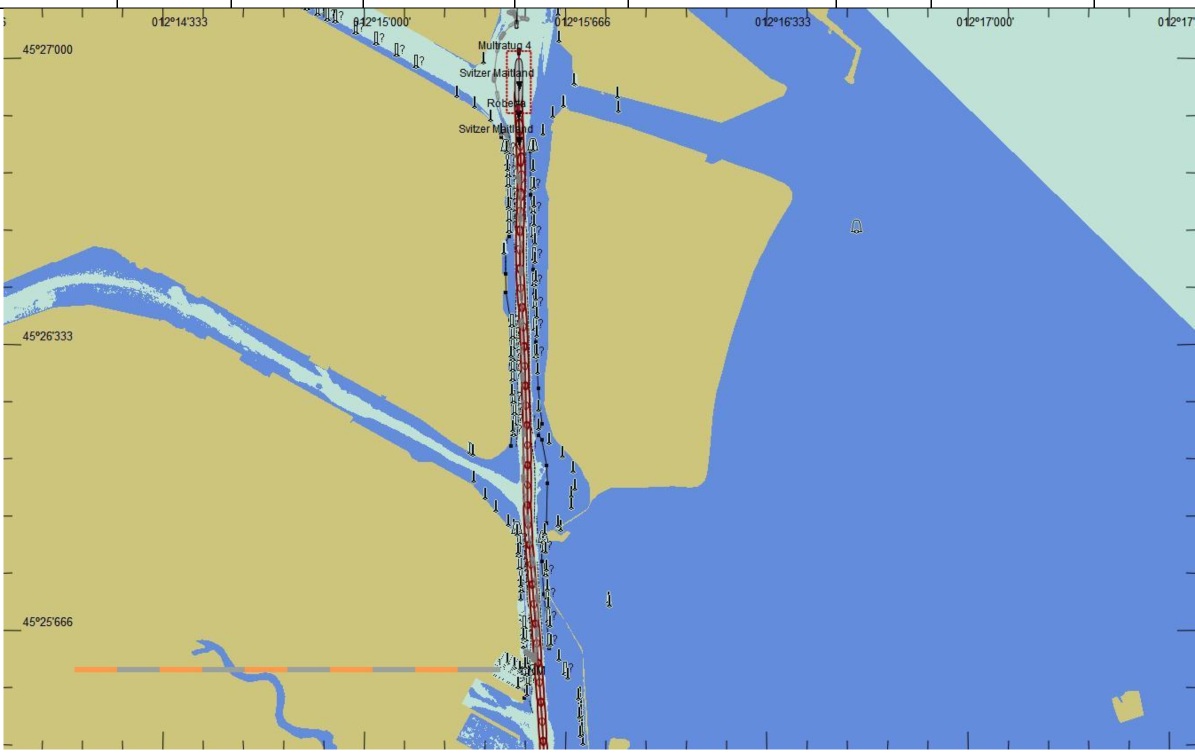


Figure 53 Run 304, departure from the basin in the north of the channel.

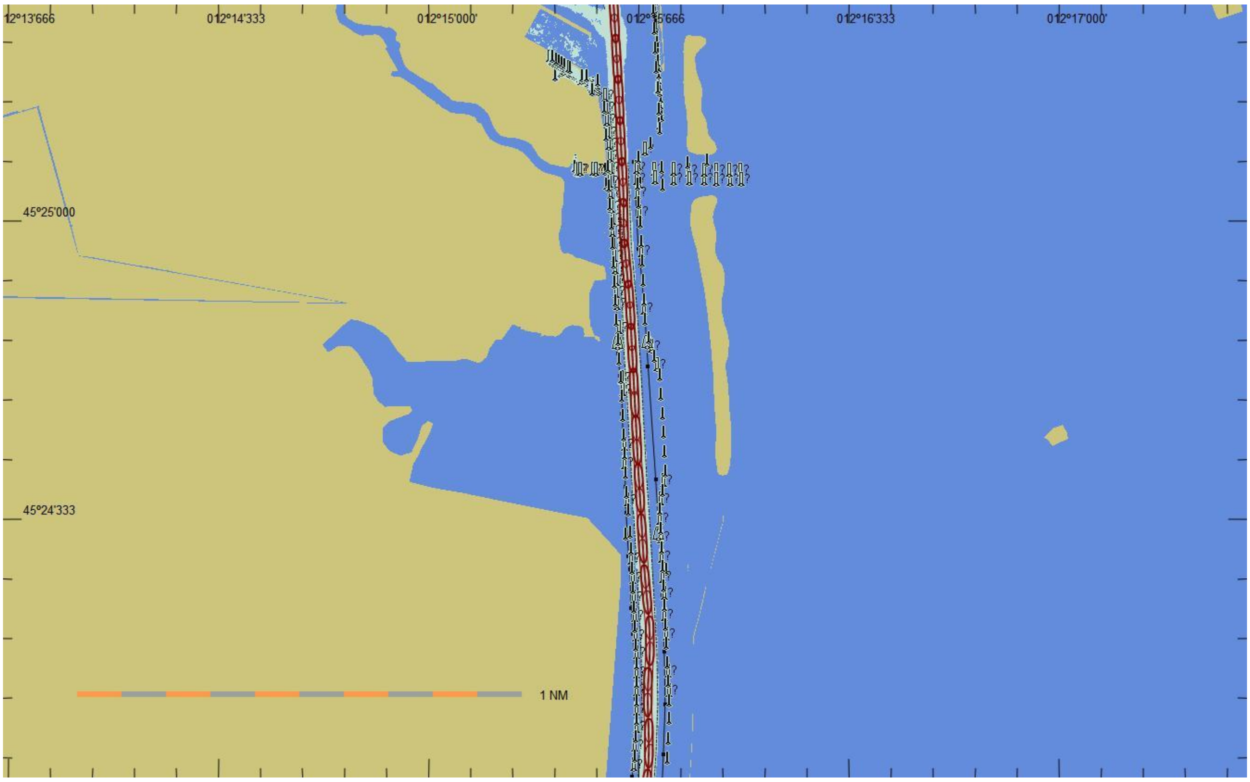


Figure 54 Run 304, track in the center of the channel

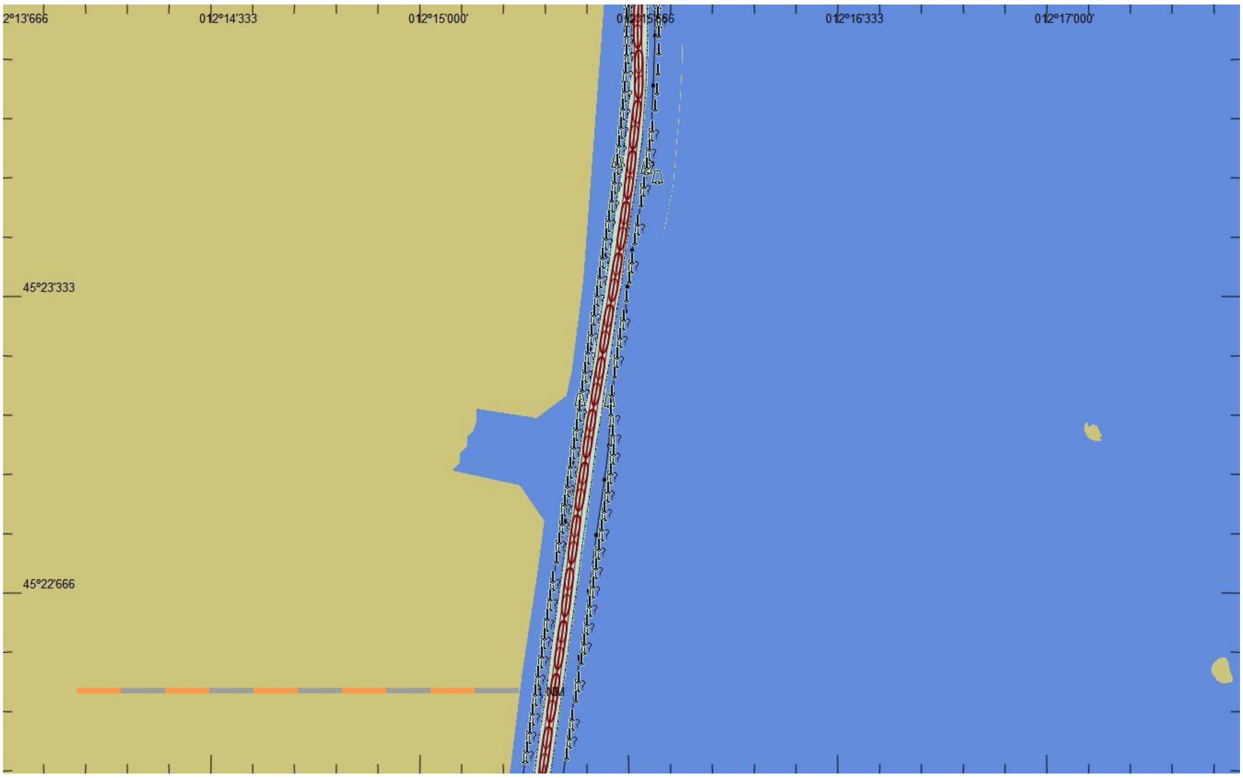


Figure 55 Run 304, track in the center of the channel.

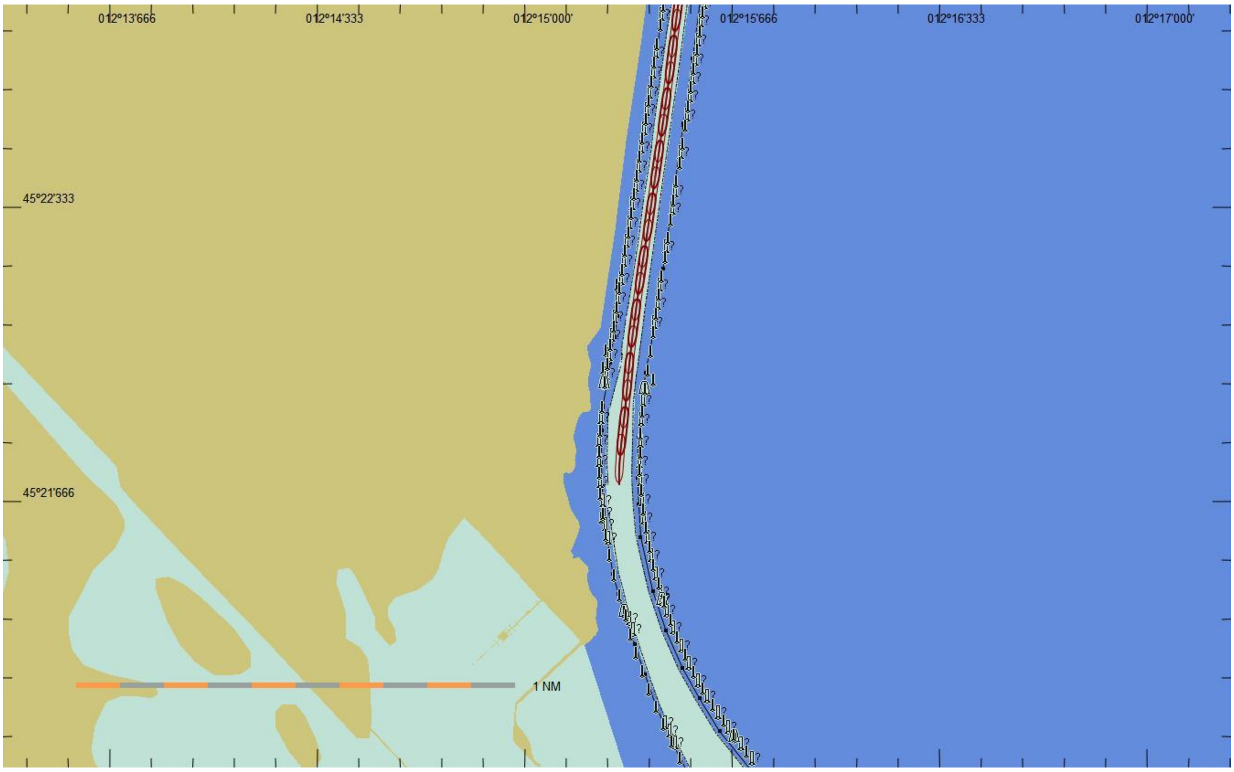


Figure 56 Run 304, end of the track approaching the south curve of the channel.

305	3481	Bulker	200 m	12.5	67	1	ENE	1

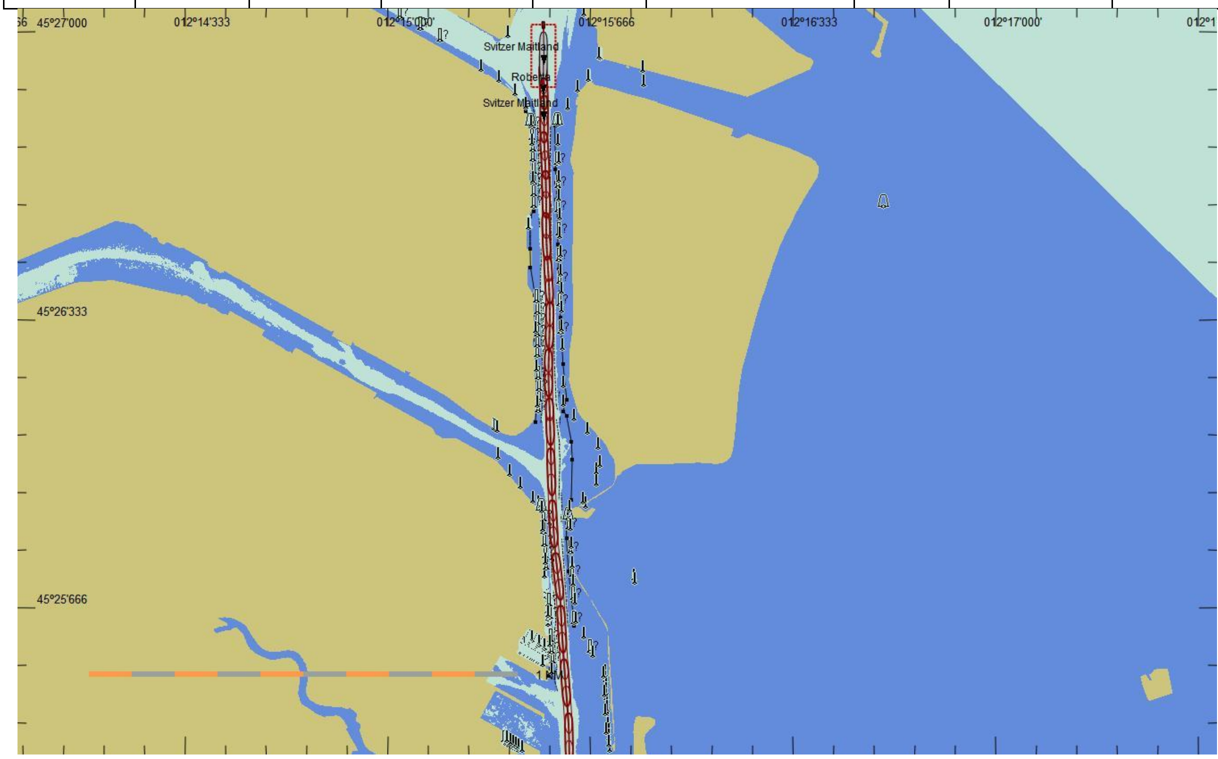


Figure 57 Run 305, departure from the north part of the channel.

Figure 58 Run 305, end of the track in the central part of the channel.

306	3481	Bulker	200 m	12.5	67	1	ENE	1

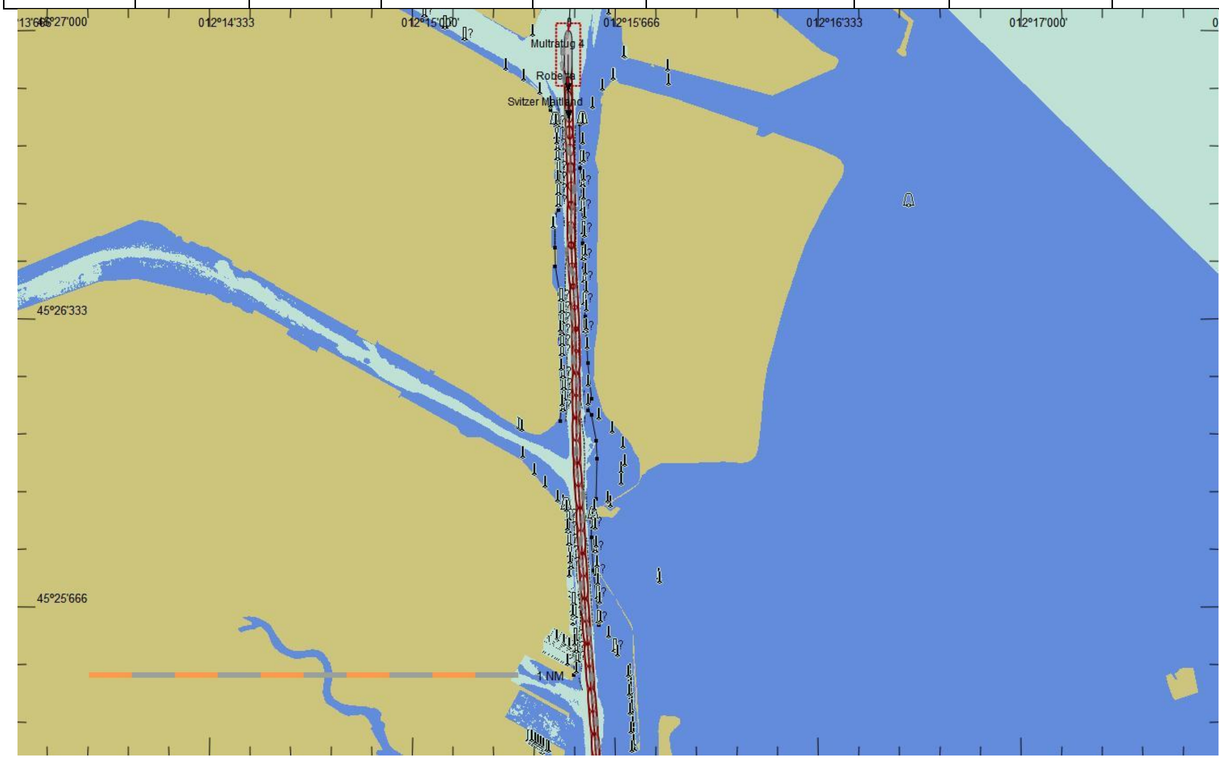


Figure 59 Run 306, departure from the north part of the channel.

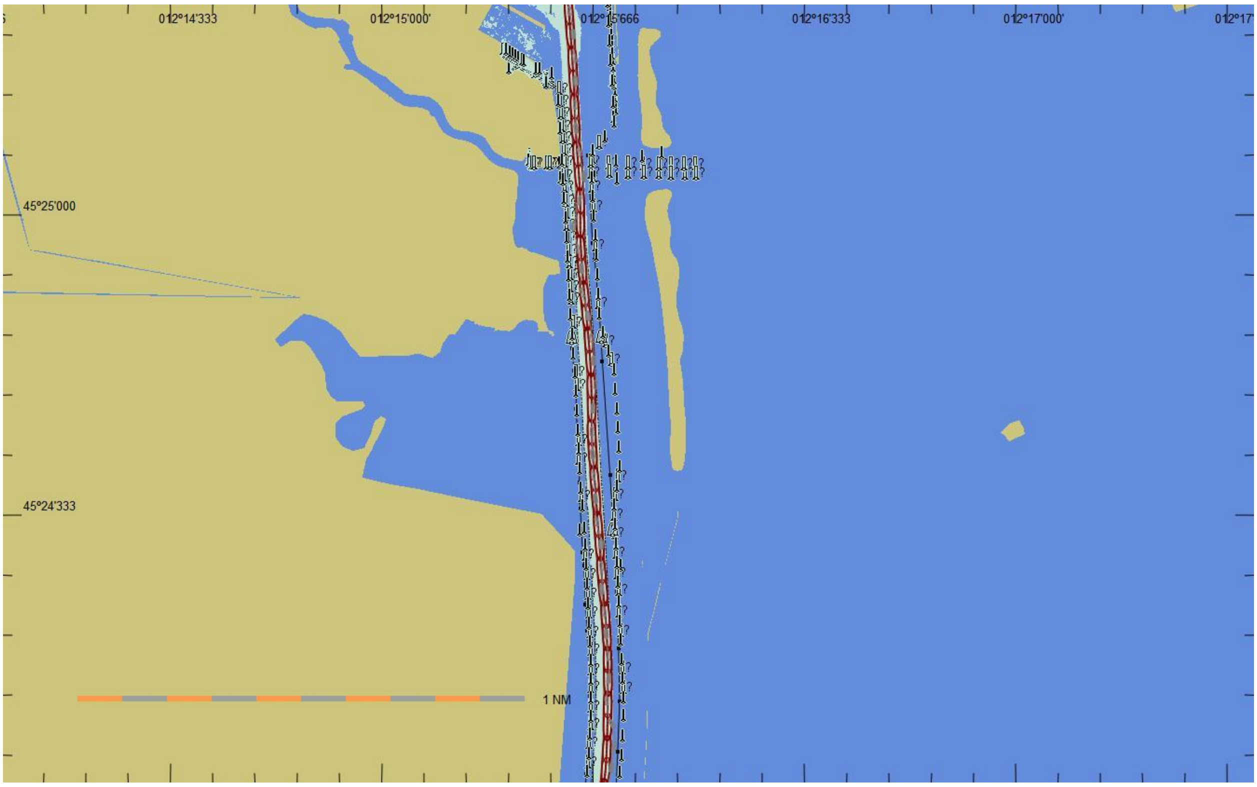


Figure 60 Run 306, center part of the channel.

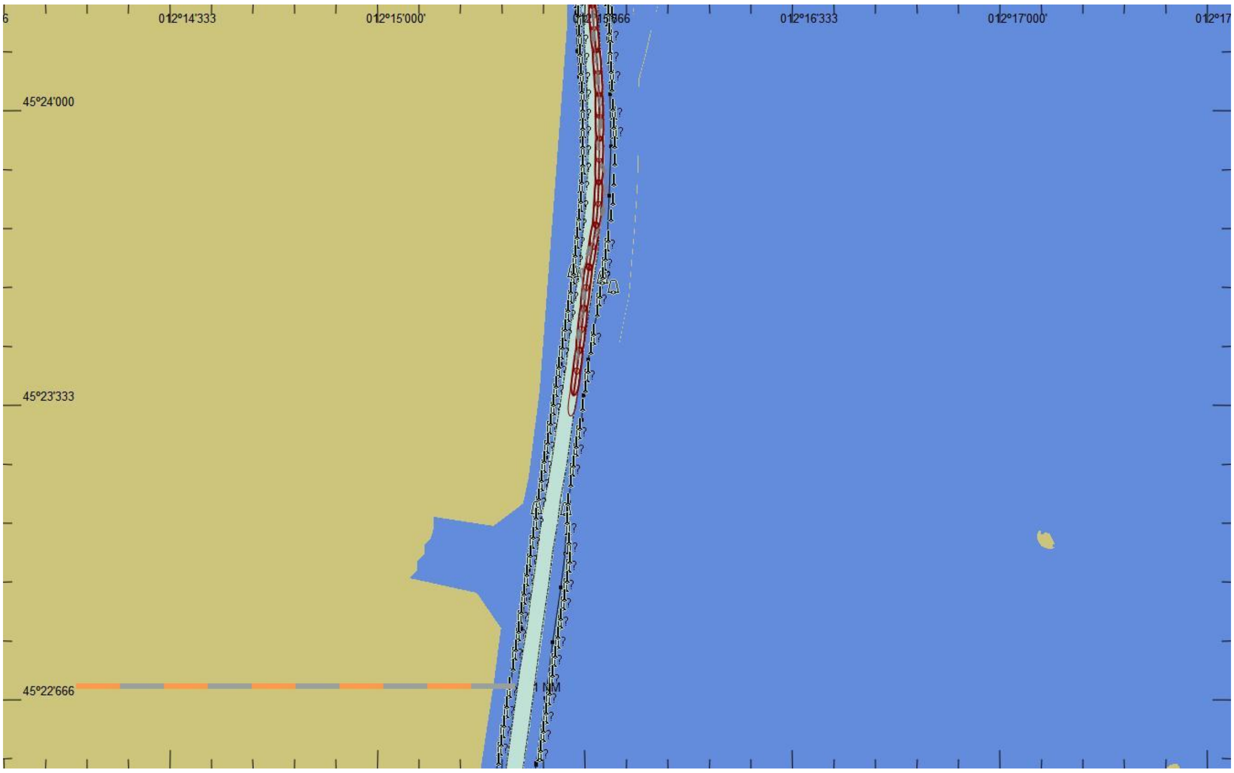


Figure 61 Run 306, end of the track, center of the channel.

401	3601	Container	294 m	7.5	23	1	ENE	1

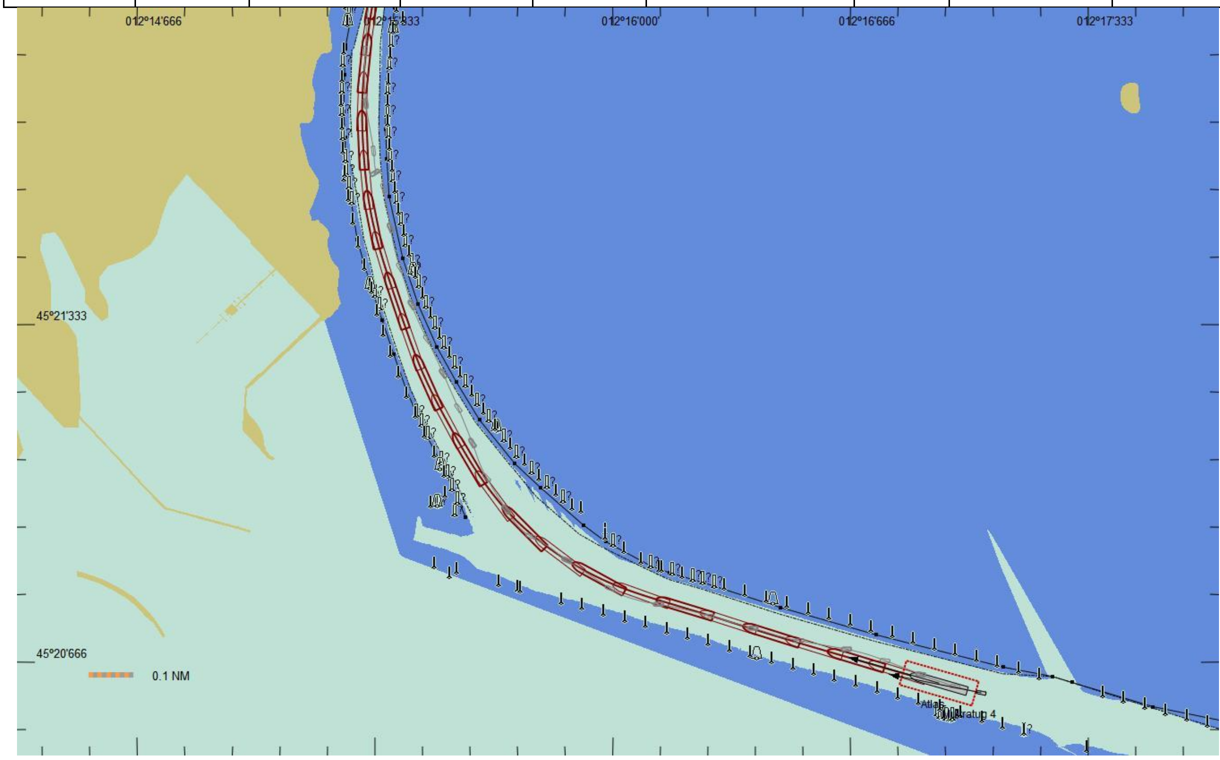


Figure 62 Run 401, arrival, view of the south part of the channel, before the curve.

Figure 63 Run 401, continue of the track in the center part of the channel.

Figure 64 Run 401, end of the track in the center part of the channel.

402	3601	Container	294 m	10	45	1	ENE	1

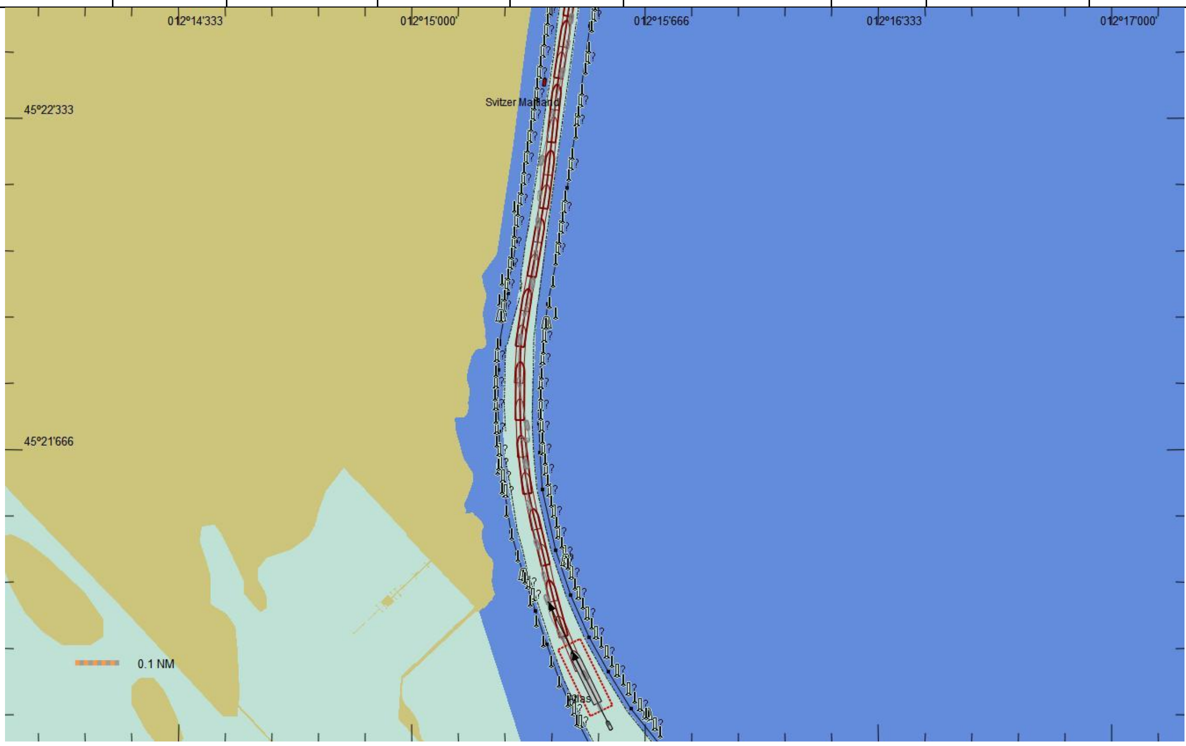


Figure 65 Run 402, arrival, track starting from the center of the south curve.

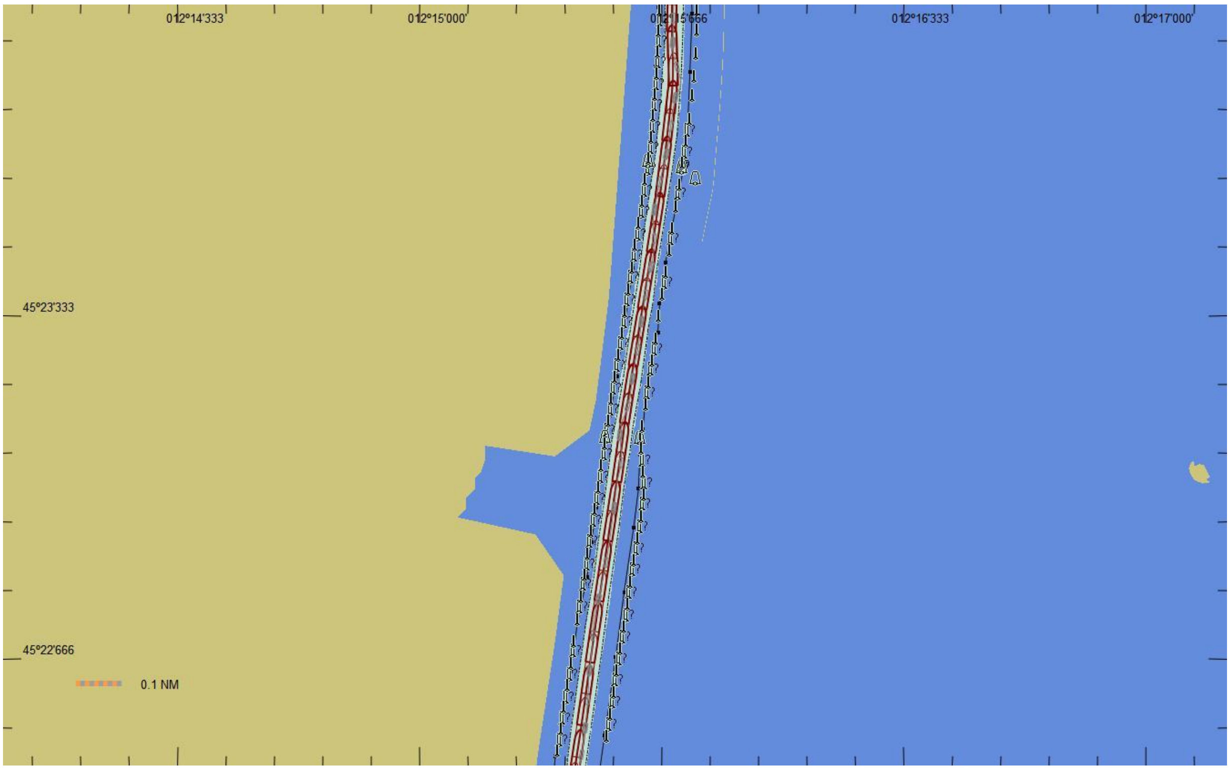


Figure 66 Run 402, continue of the track inthe cneter part of the channel.

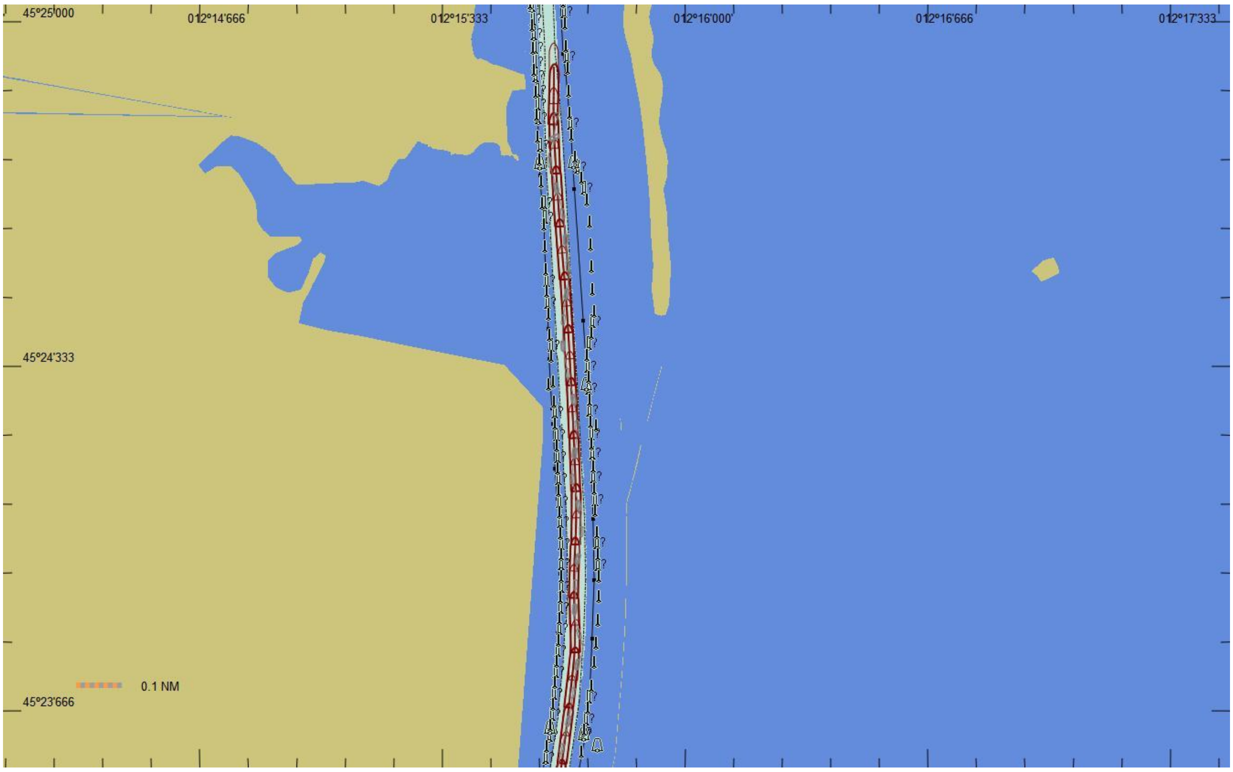


Figure 67 Run 402,end of the track, center part of the channel.

403	3481	Bulker	200 m	12.5	67	1	ENE	1

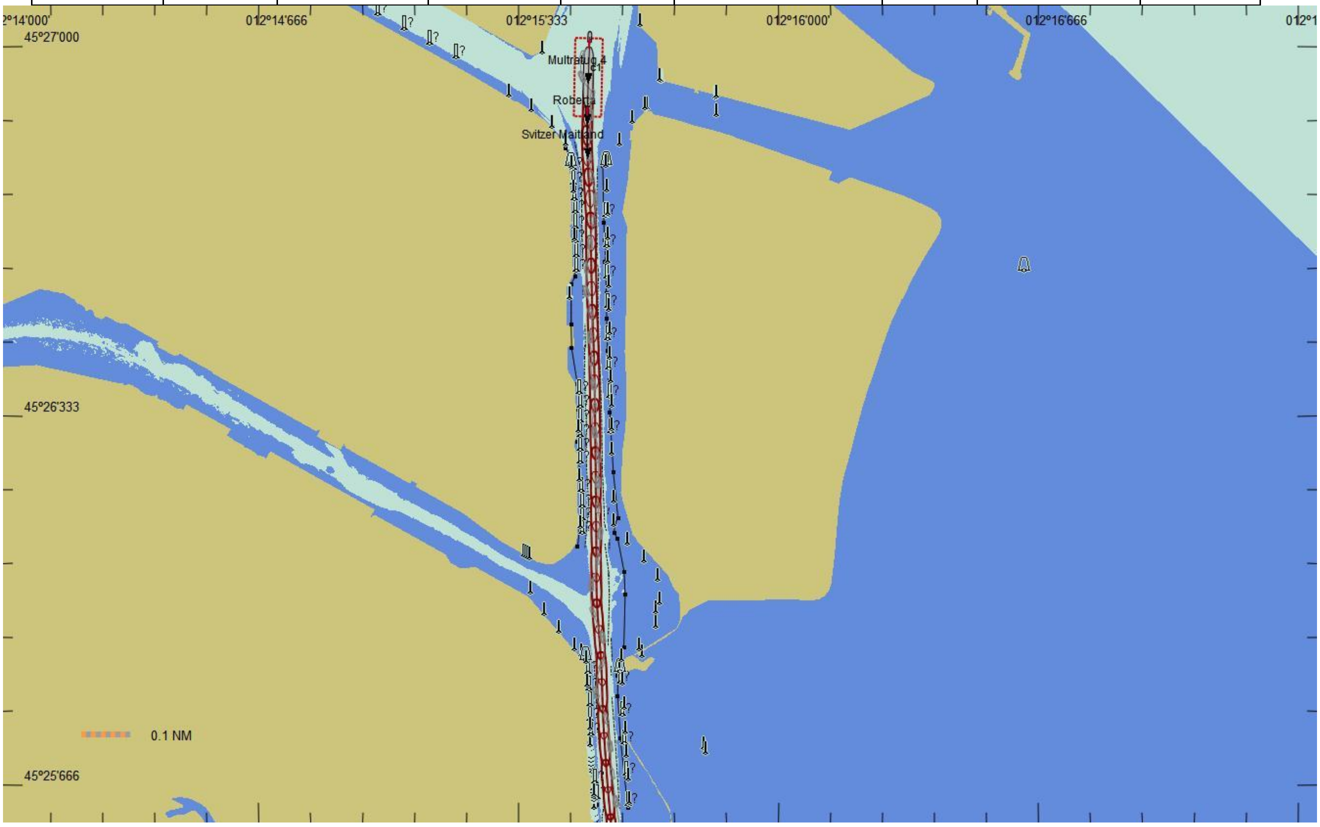


Figure 68 Run 403, departure from the north of the channel.

Figure 69 Run 403, track at the center of the channel.

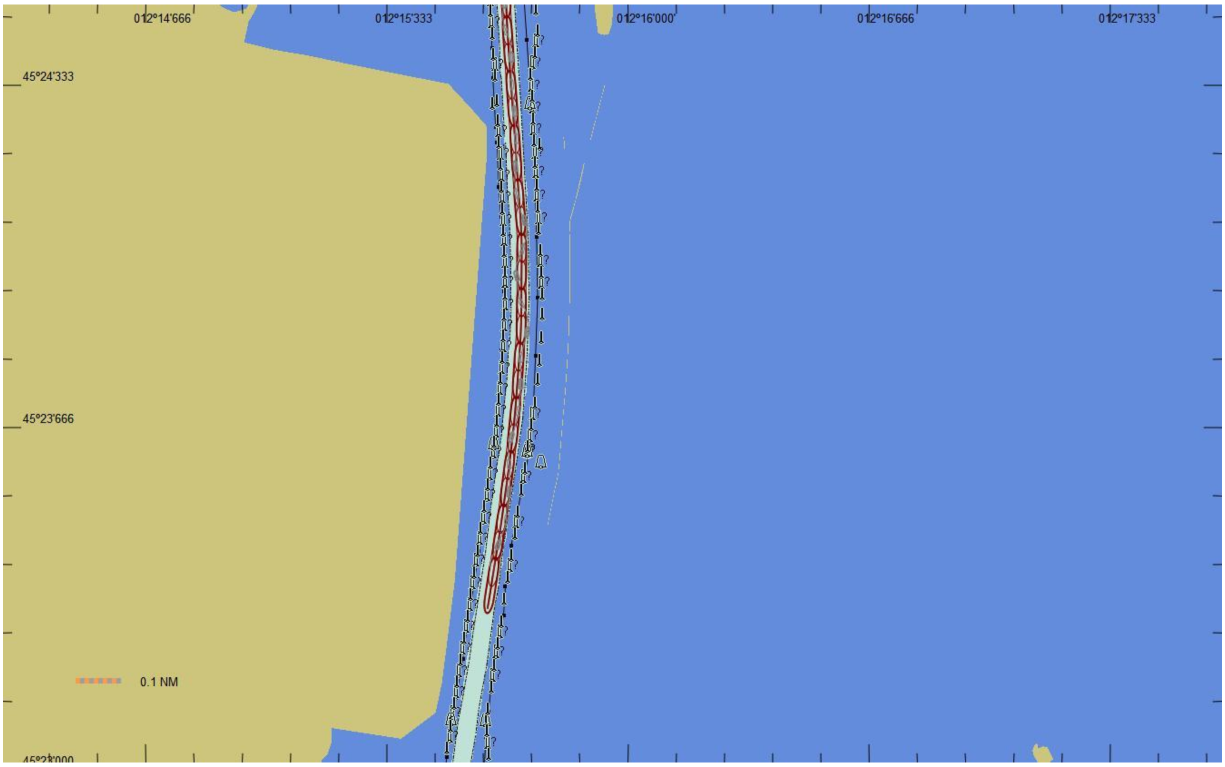


Figure 70 Run 403, end of the track, in the cneter part of the channel.

404	3601	Container	294 m	15	67	1	ENE	1

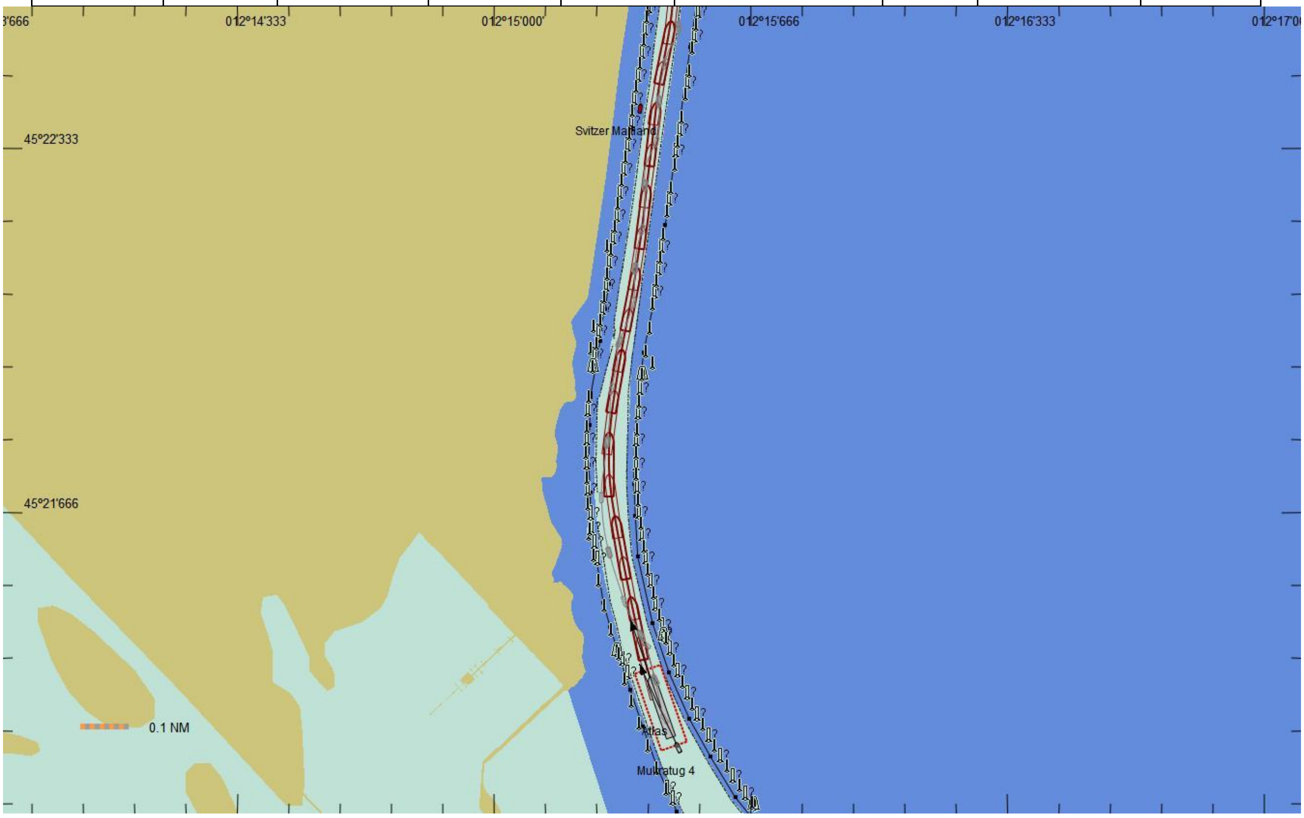


Figure 71 Run 404, arrival, from the end of the south curve

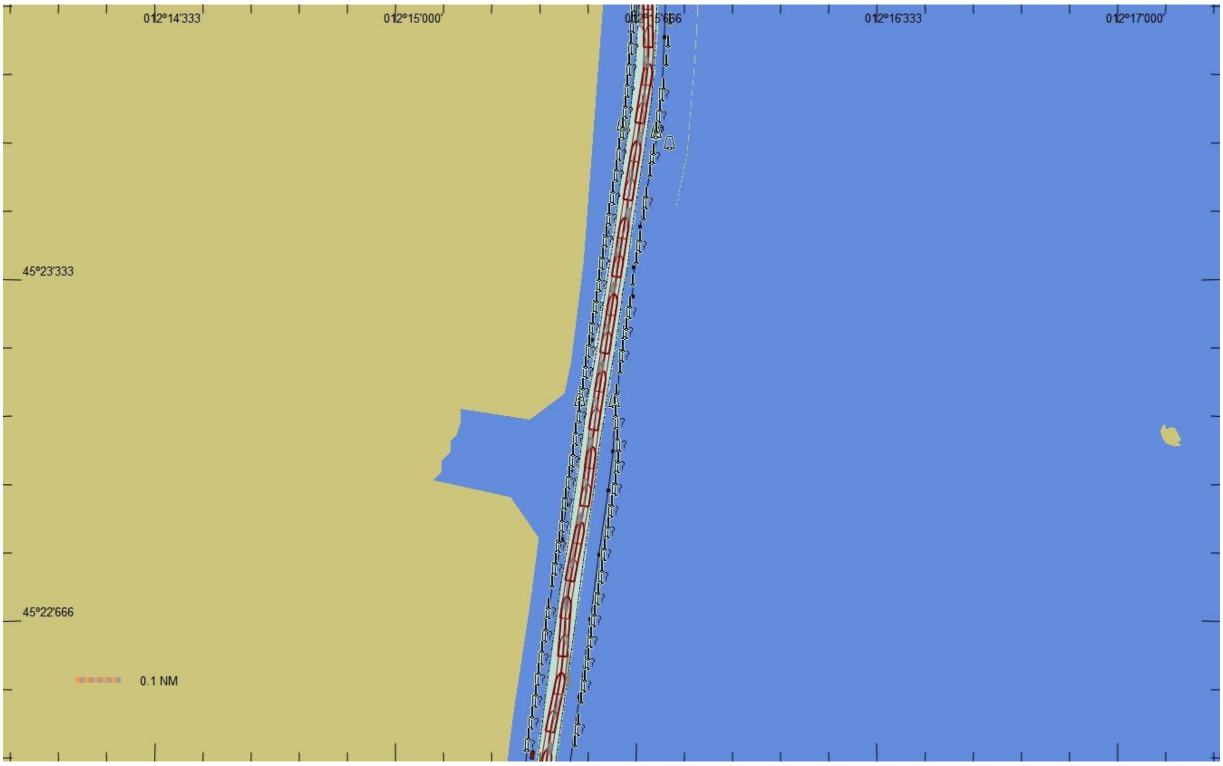


Figure 72 Run 404, track at the center of the channel.

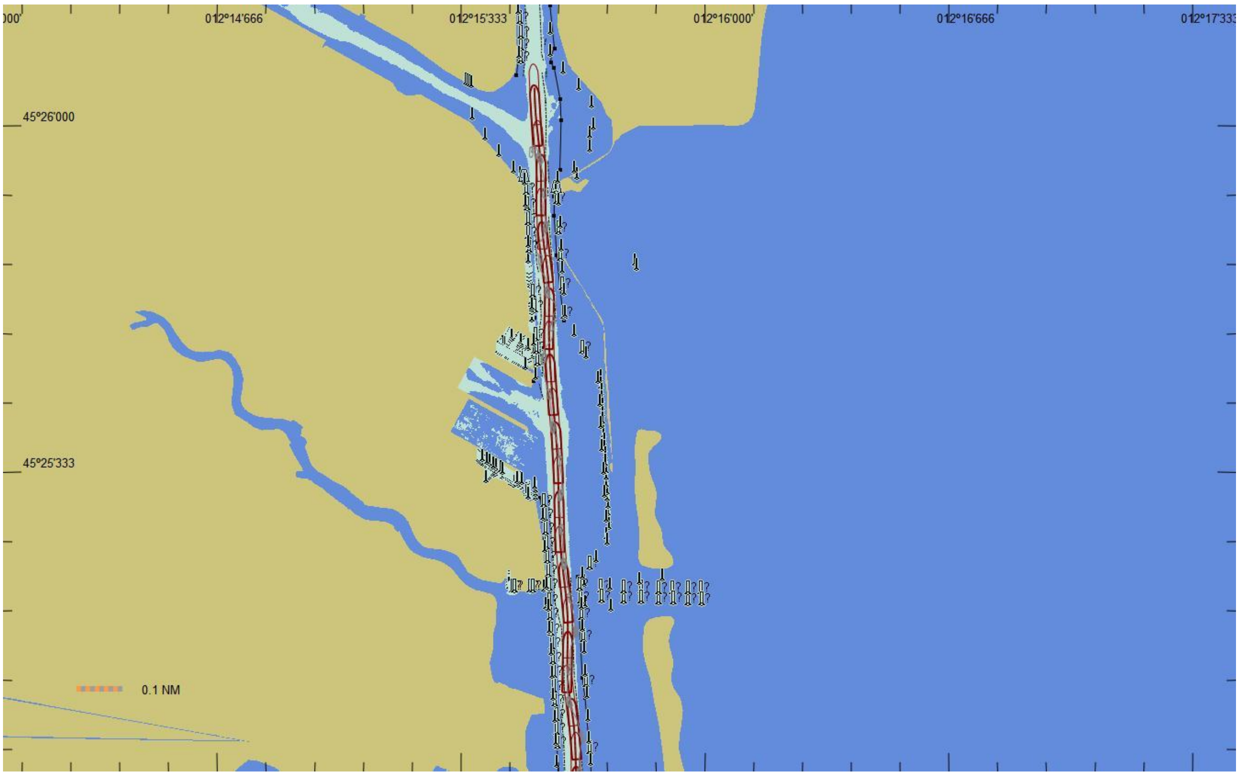


Figure 73 Run 404, end of the track, north of the channel.

405	3297	RoRo	200 m	12.5	45	1	ENE	1

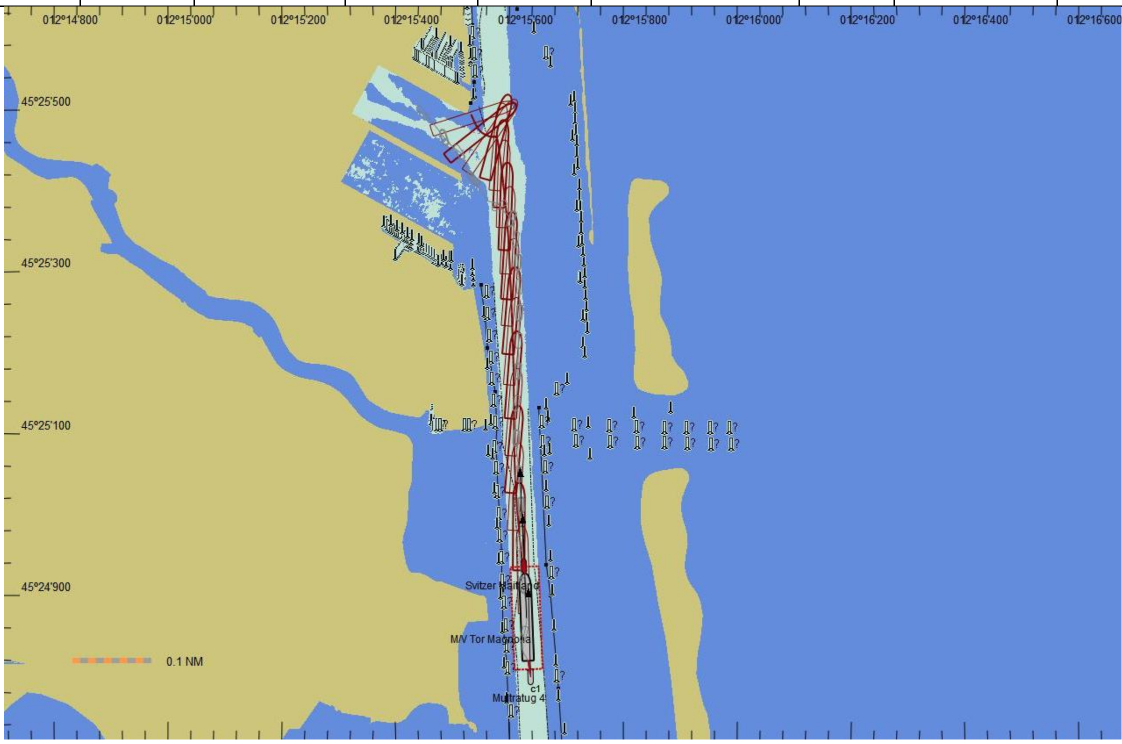


Figure 74 Run 405, arrival at the basin (Fusina) at the center of the channel

406	3297	RoRo	200 m	12.5	45	1	ENE	1

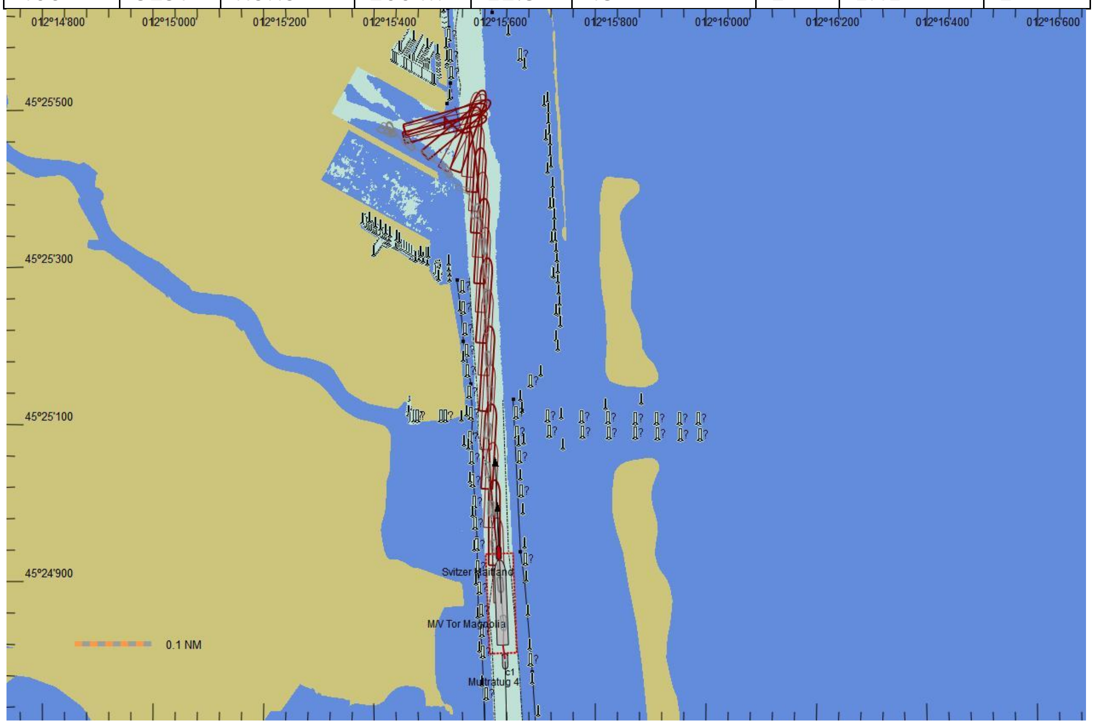


Figure 75 Run 406, arrival at the basin (Fusina)at the center of the channel.

407	3297	RoRo	200 m	12.5	45	1	ENE	1

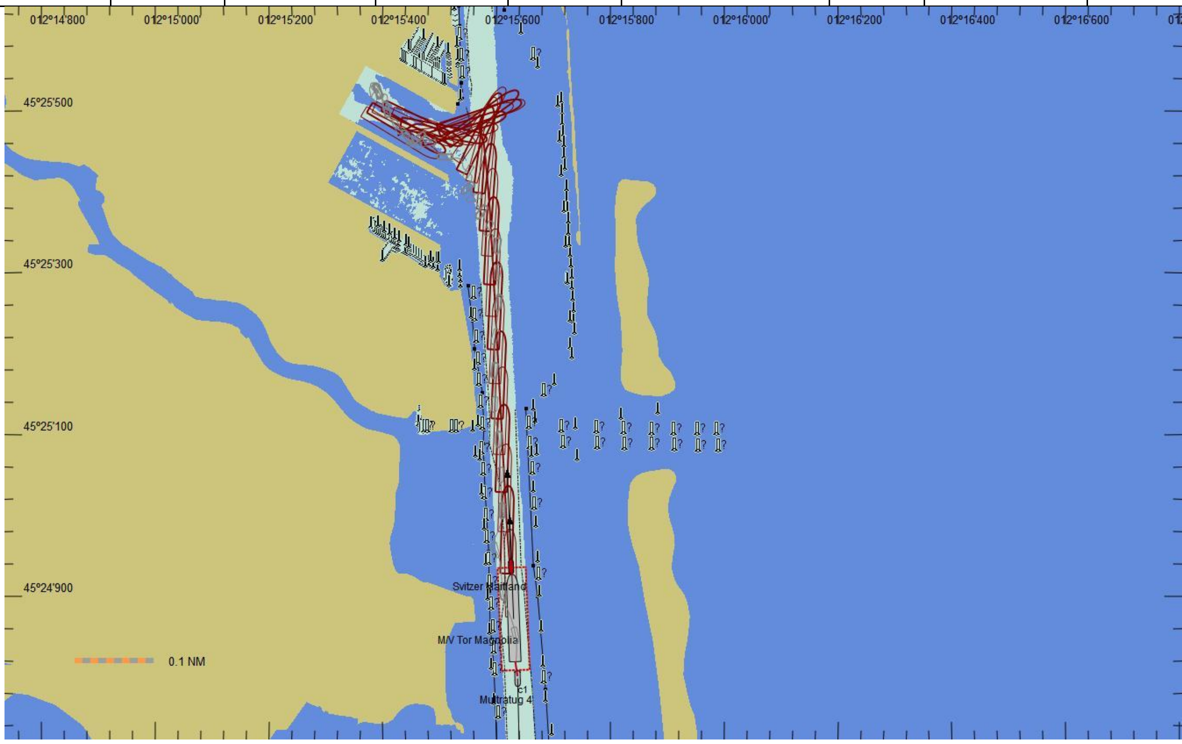


Figure 76 Run 407, arrival at the basin at the center of the channel.

408	3556	Cruise	295 m	10	45	1	ENE	1

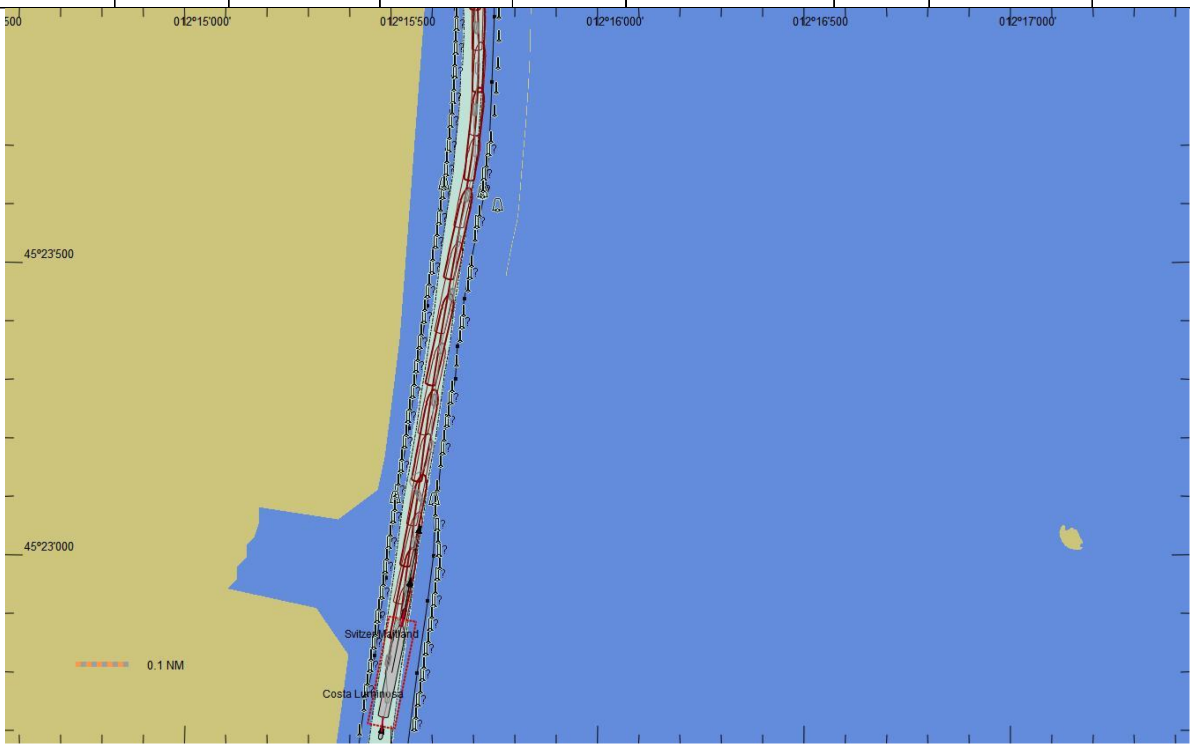


Figure 77 Run 408, arrival from the south of the channel, after the curve..

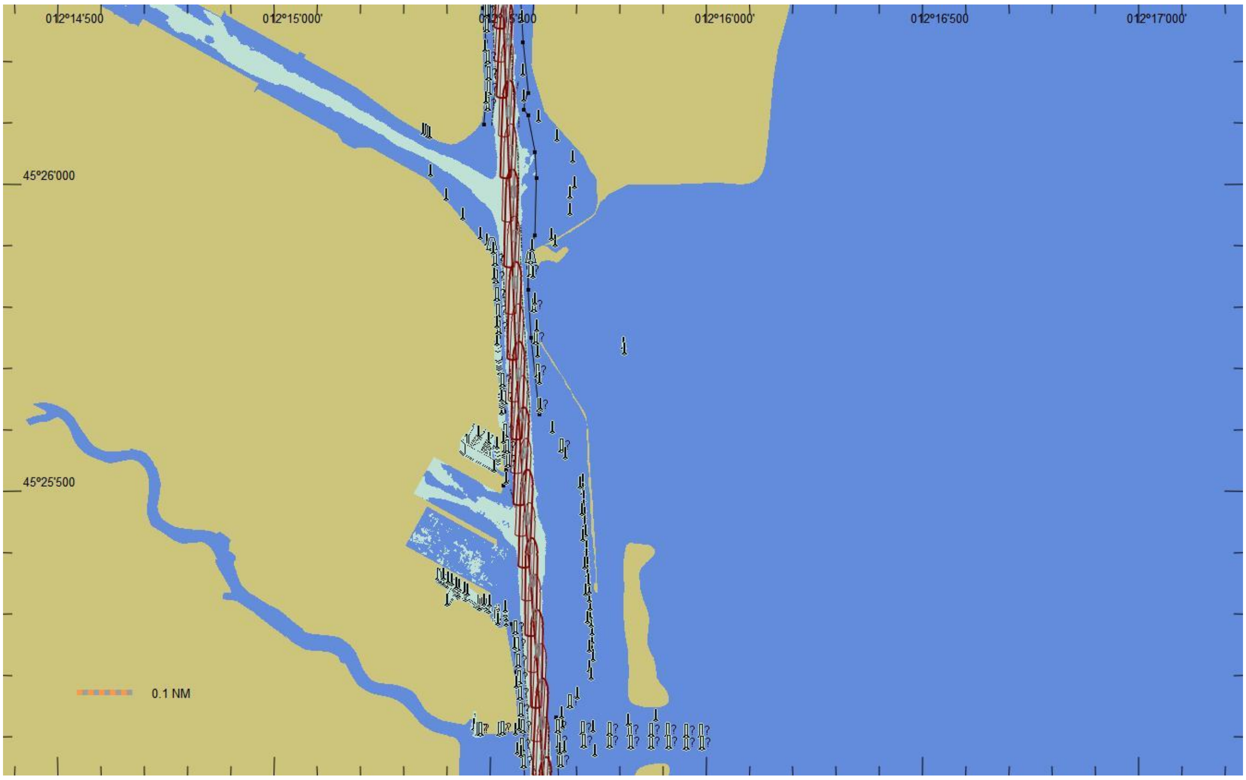


Figure 78 Run 408, track in the cneter of the channel.

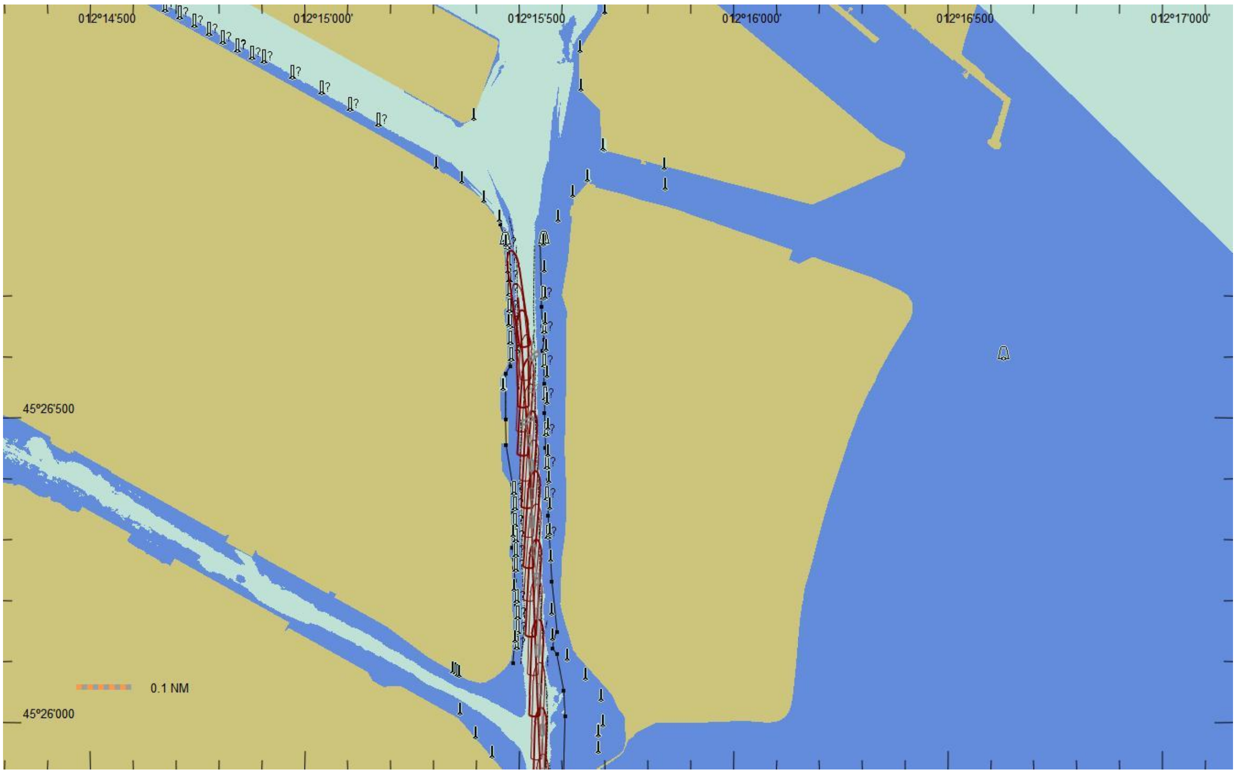


Figure 79 Run 408, end of the track, north of the channel.

409	3556	Cruise	295 m	10	45	1	ENE	1

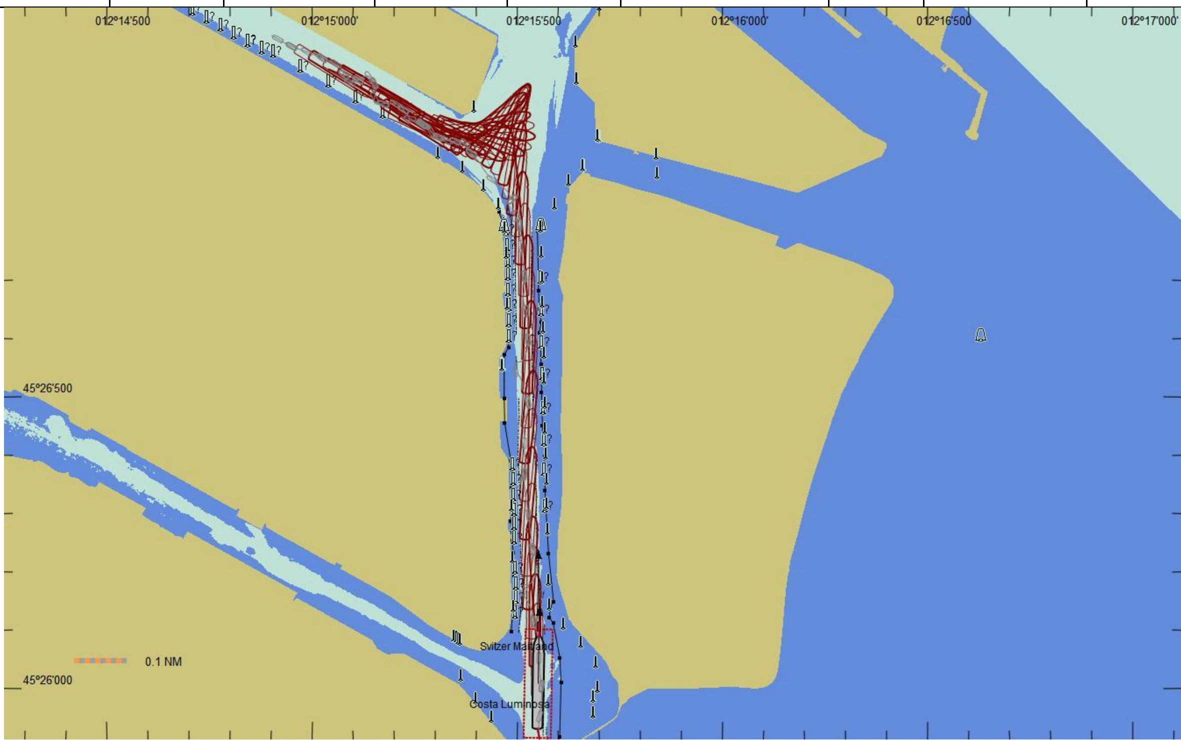


Figure 80 Run 409, arrival at the basin in the north part of the channel.

501	3297	RoRo	200 m	10	45	1	ENE	1

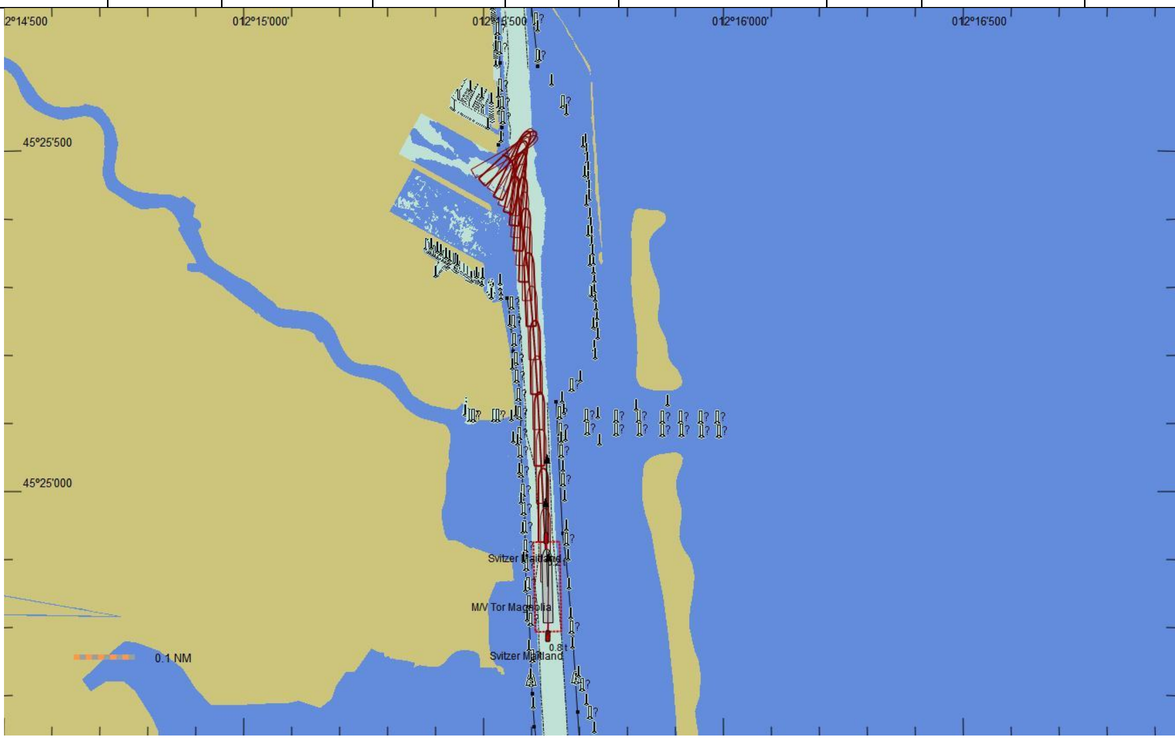


Figure 81 Run 501, arrival at the basin, center part of the channel.

502	3601	Container	294 m	7.5	23	1	ENE	1

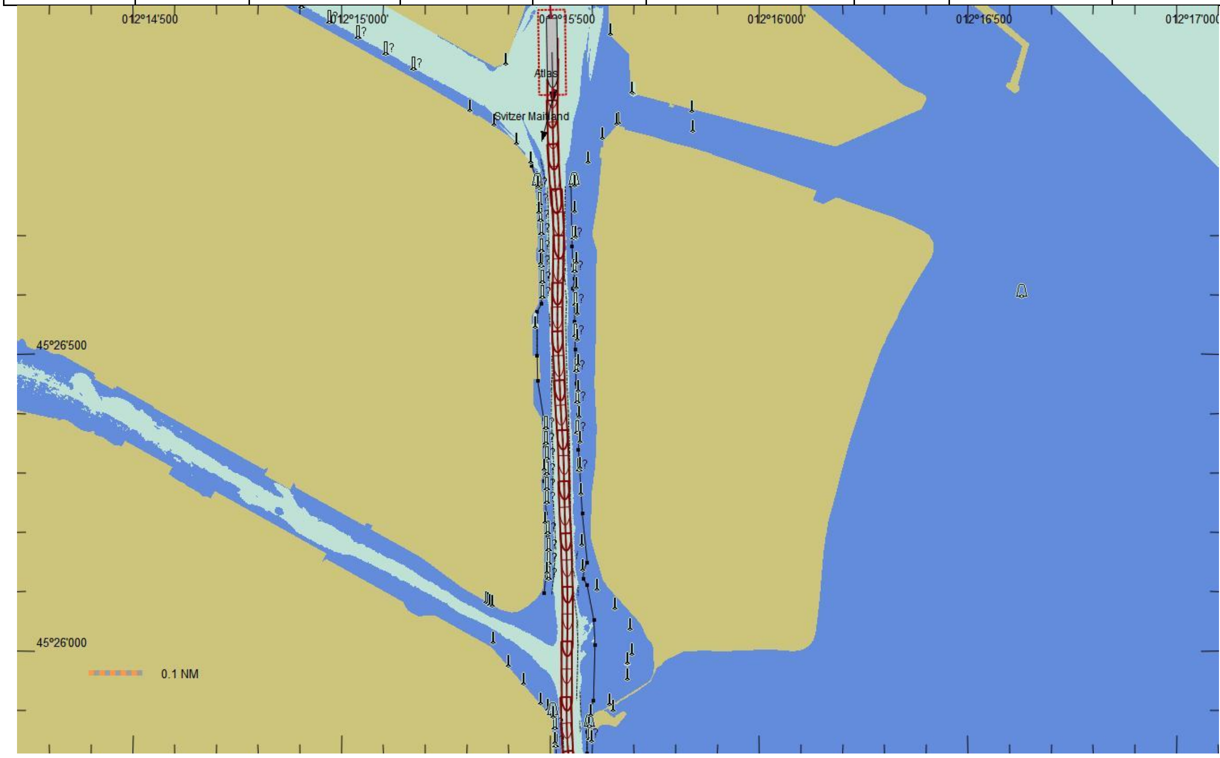


Figure 82 Run 502, departure from the north part of the channel.

Figure 83 Run 502, center of the channel.

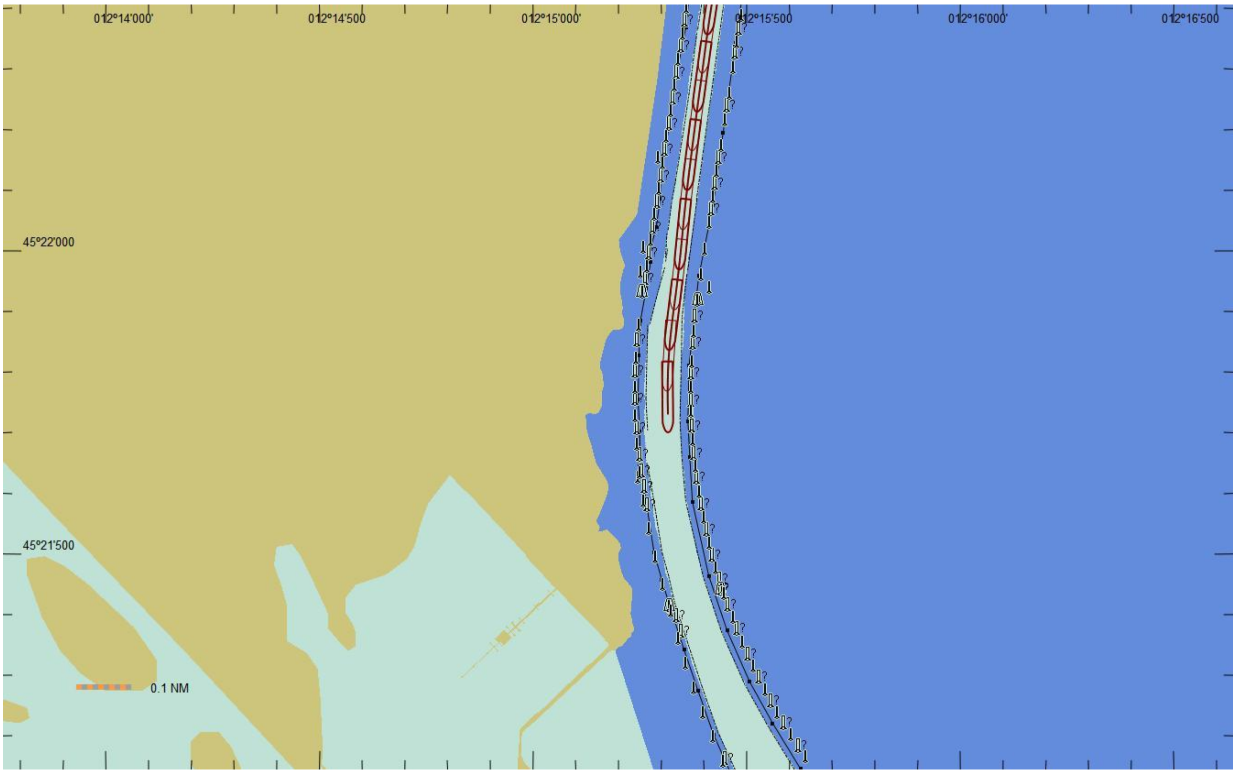


Figure 84 Run 502, end of the track, approachin the south curve.

503	3601	Container	294 m	10	45	1	ENE	1

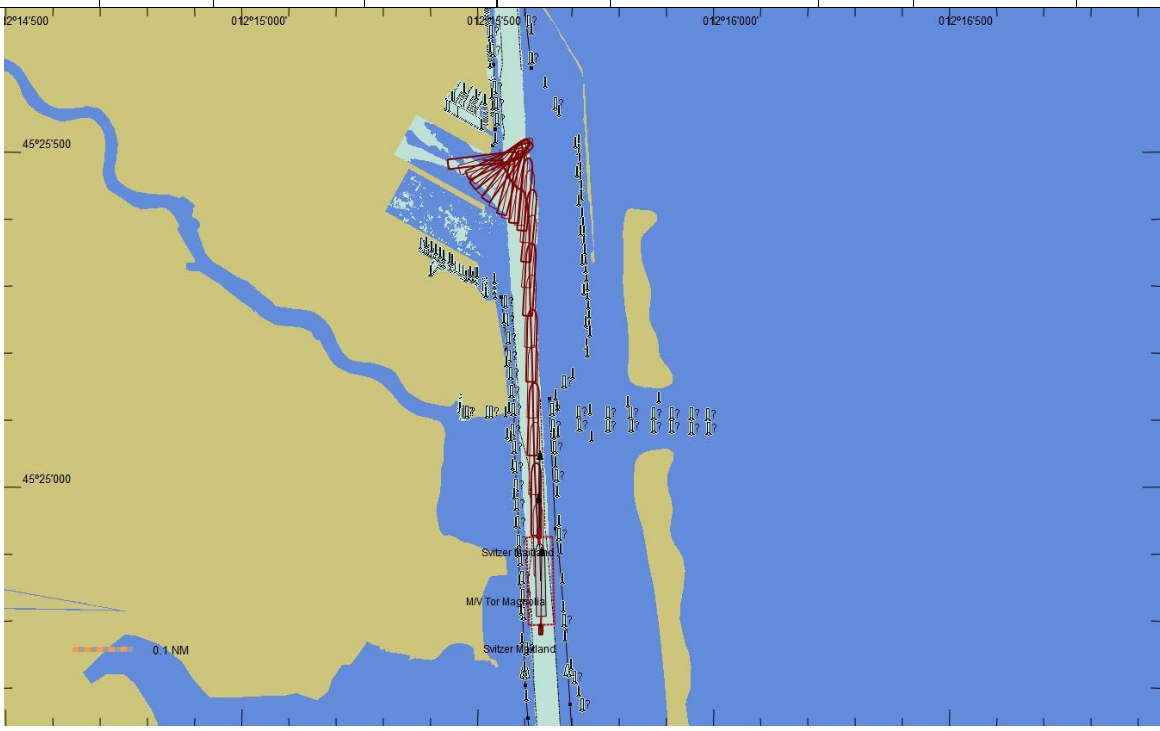


Figure 85 Run 503, arrival at the basin in the central part of the channel, bow-in.

504	3297	RoRo	200 m	10	45	1	ENE	1

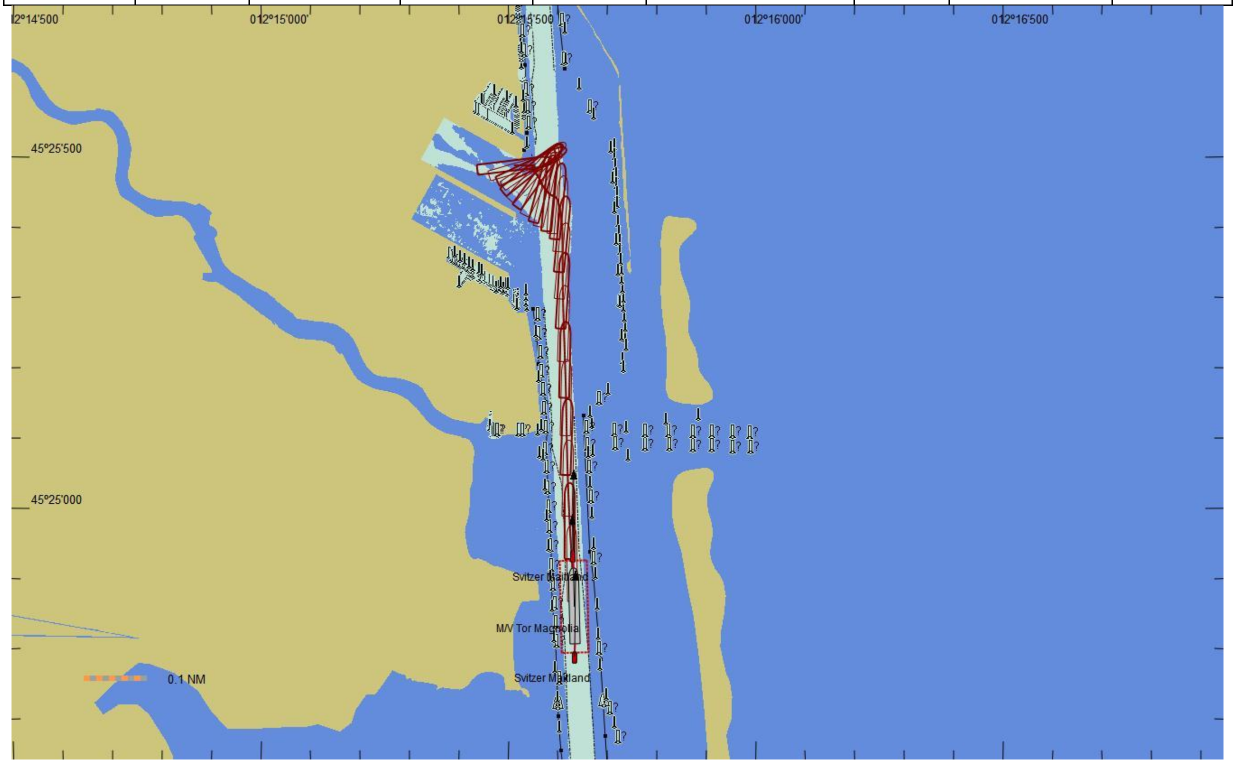


Figure 86 Run 504, arrival at the basin in the central part of the channel, bow-in

505	3601	Container	294 m	15	67	1	ENE	1

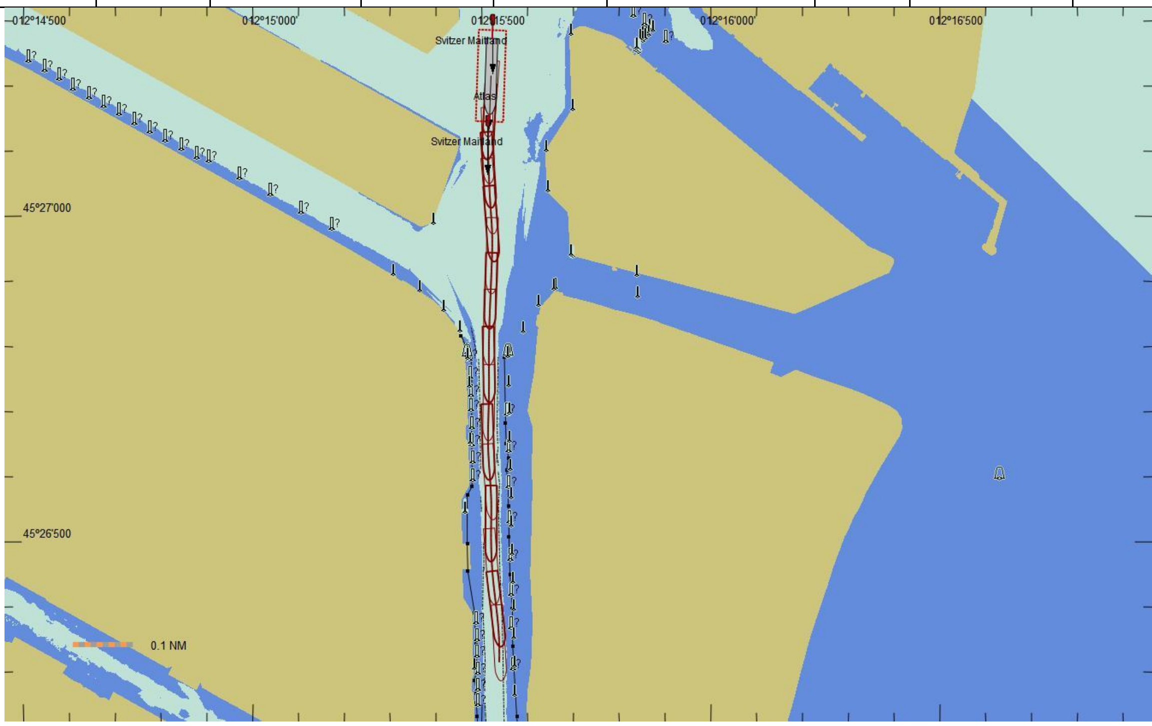


Figure 87 Run 505, departure from the north part of the channel and grounding just after the basin.

601	3297	RoRo	200 m	10	45	1	ENE	1

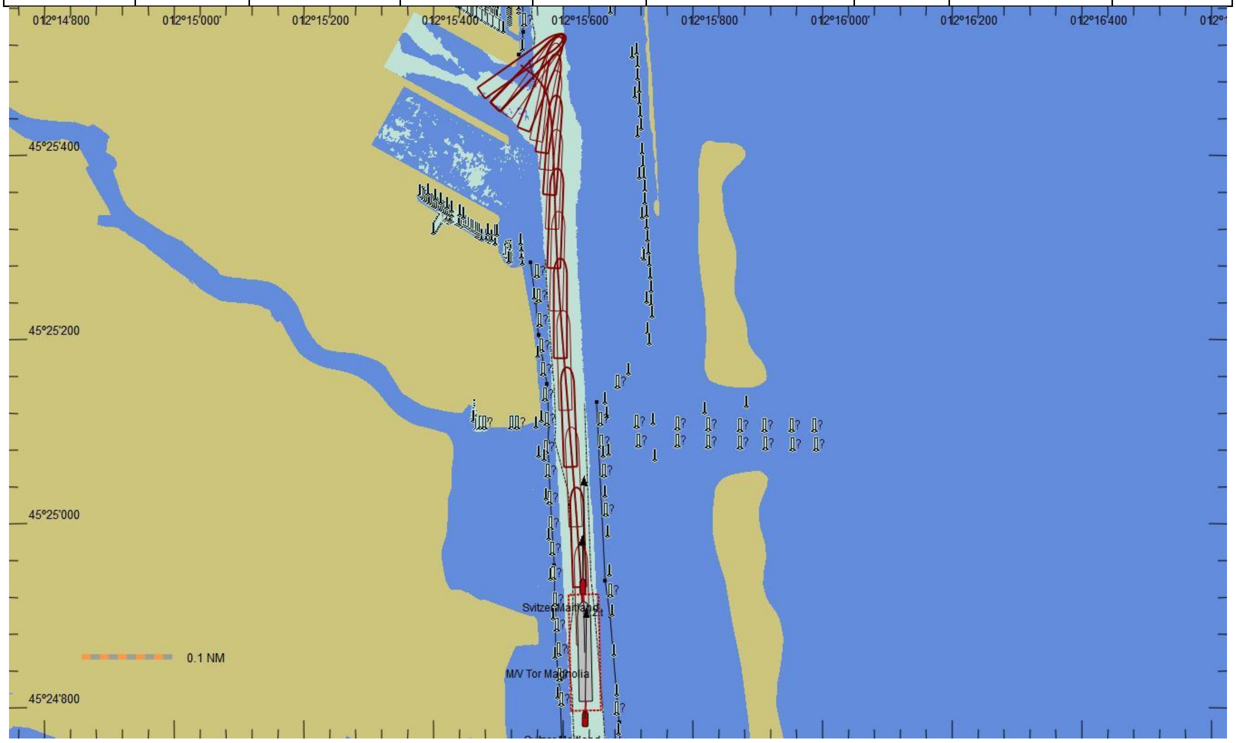


Figure 88 Run 601, arrival at the basin in the central part of the channel, bow-in.

602	3435	RoRo	220 m	10	45	1	ENE	1

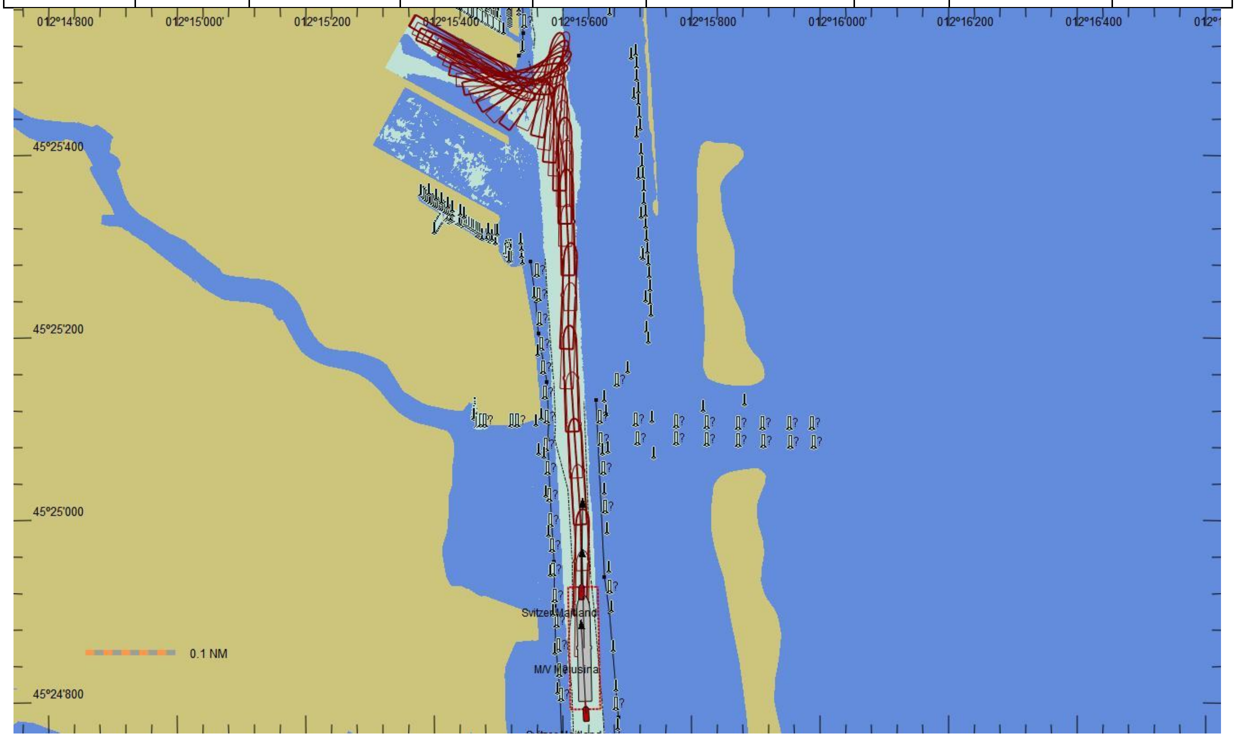


Figure 89 Run 602, arrival at the basin in the central part of the channel, bow-in.

603	3601	Container	294 m	12.5	67	1	ENE	1

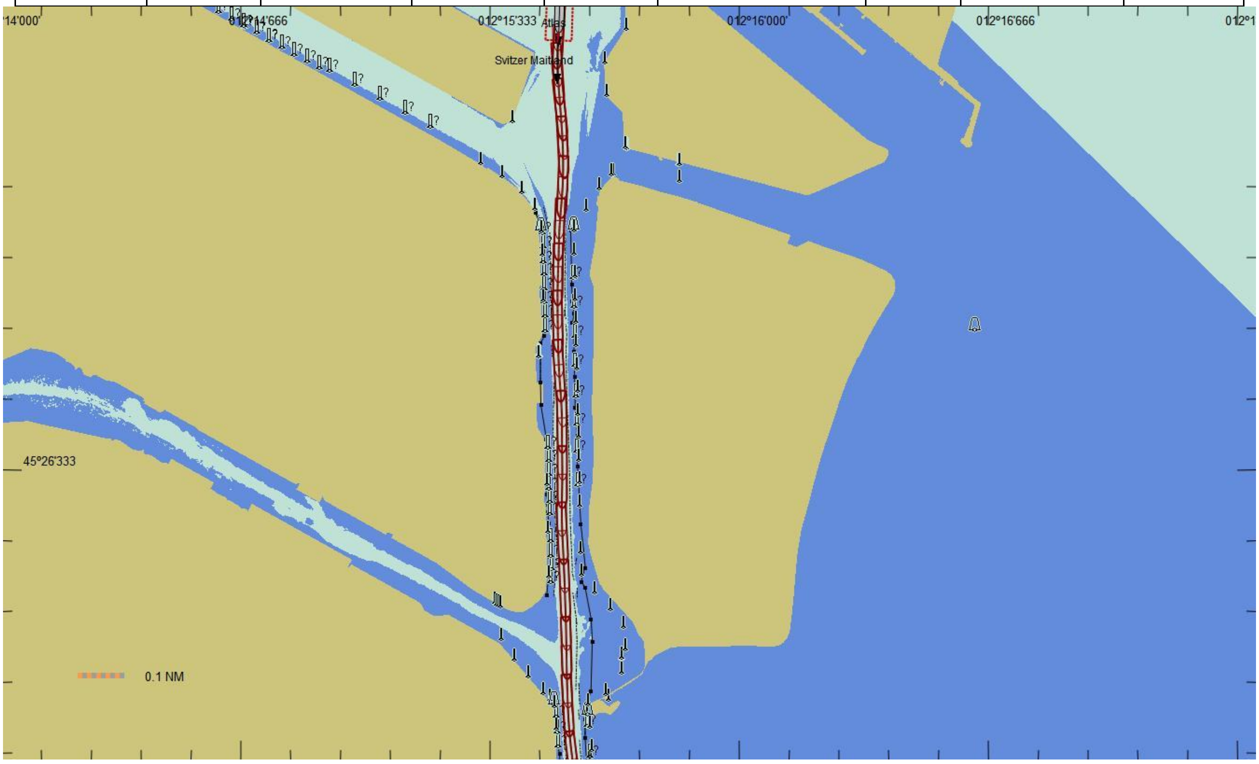


Figure 90 Run 603, departure from the north part of the channel.

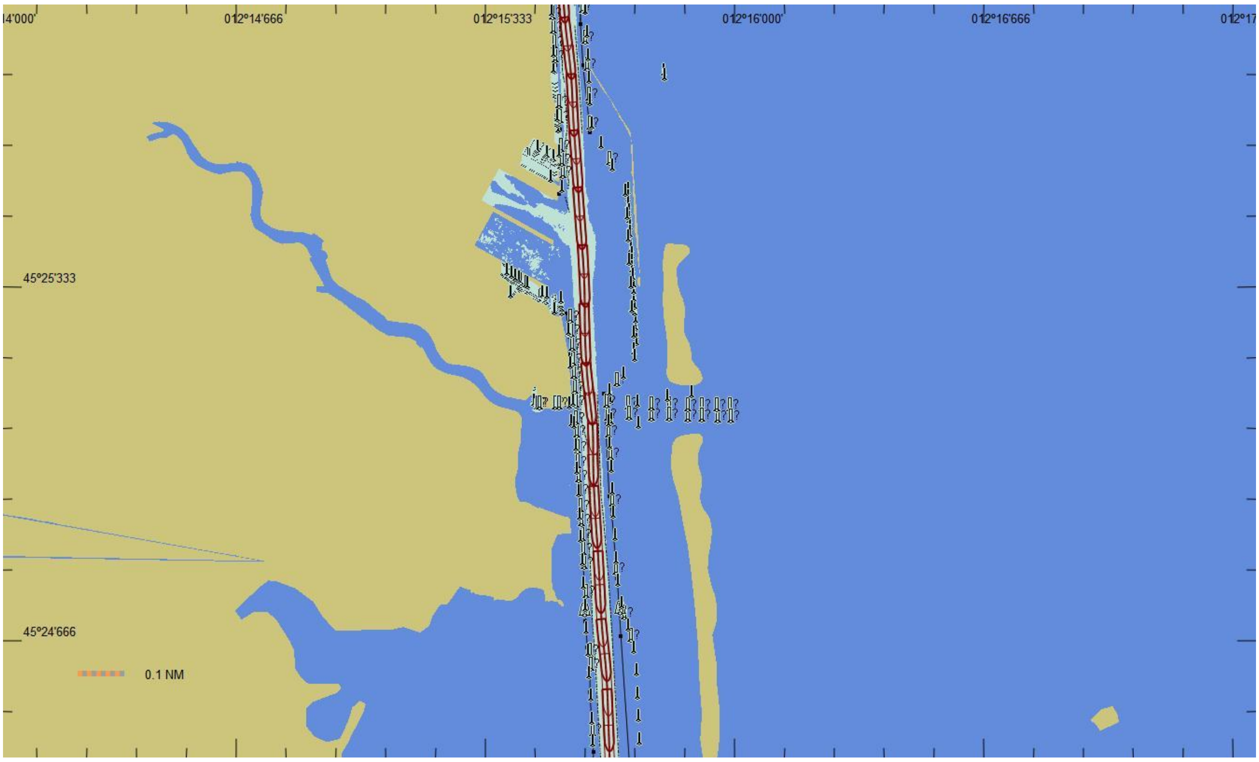


Figure 91 Run 603, track in the central part of the channel.

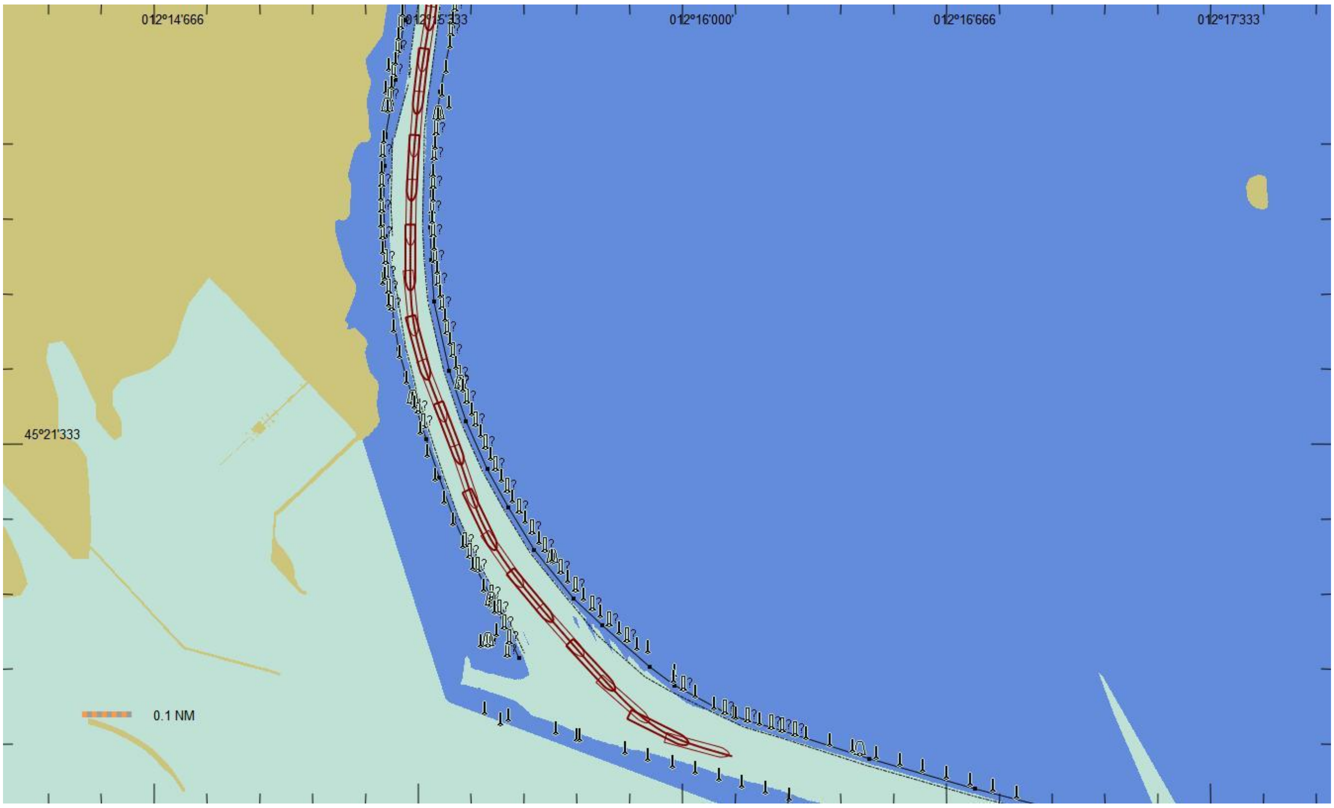


Figure 92 Run 603, end of the track in the south curve of the channel.

APPENDIX B

Bridge posters

Gold Sapphire Ship 3644

Manoevering Characteristics

Parameter	CRUISE	IMO limit
Turning circle, Advance	2.4 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.5 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	6.2 deg	15.4 deg
10/10 zig-zag, 2nd overshoot angle	9.5 deg	33.2 deg
20/20 zig-zag, 1st overshoot angle	12.7 deg	25.0 deg
Crash stop, Track reach	9.0 · Lpp	15 · Lpp

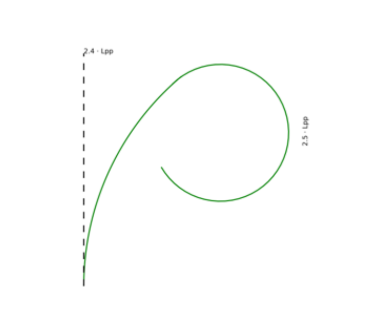
Rudder details

Parameter	
Number of rudders	2
Type of rudder	standard
Area of Rudder (movable part) [m^2]	2 x 21.6
Total rudder Area/(Lpp x T) [%]	1.99
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	45.0

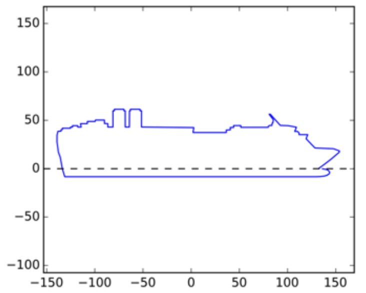
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	148	24.3	Grounded
Full Ahead	120	21.9	Grounded
Half Ahead	79	13.2	11.1
Slow Ahead	49	7.8	6.6
Dead Slow Ahead	35	4.7	4.2
Dead Slow Astern	-35	-2.7	-1.8
Slow Astern	-49	-4.1	-2.9
Half Astern	-79	-8.0	-5.9
Full Astern	-102	-10.8	-8.6

Turning Circle



Outline



Particulars

LPP	261.0 [m]
LOA	289.6 [m]
Beam	32.20 [m]
TA/TF	8.30 / 8.30 [m]
Disp	51714 [Tons]
WSA	11424 [m^2]
Propeller FP	CLOCKWISE
# Blades	6
Diameter	5.6 [m]
Engine Diesel kW	42000 [kW]
Bow THruster kW	6900 [kW]
Stern THruster kW	5100 [kW]
Air draft	61.41 [m]

Figure 93 Bridge poster Gold Saphire

#3481

Manoevering Characteristics

Parameter	BULK	IMO limit
Turning circle, Advance	3.4 x Lpp	4.5 x Lpp
Turning circle, Tactical diameter	3.2 x Lpp	5.0 x Lpp
10/10 zig-zag, 1st overshoot angle	6.1 deg	16.6 deg
10/10 zig-zag, 2nd overshoot angle	14.2 deg	34.8 deg
20/20 zig-zag, 1st overshoot angle	11.1 deg	25 deg
Crash stop, Track reach	18.9 x Lpp	15 x Lpp

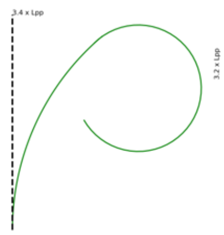
Rudder details

Parameter	
Number of rudders	1
Type of rudder	Normal
Area of Rudder (movable part) [m^2]	34.44
Total rudder Area/(Lpp x T) [%]	1.63
Rudder speed (two Pumps) [deg/s]	4.60
Max. rudder Angle [deg]	35.0

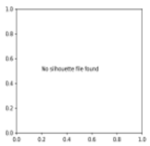
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	126	15.02	14.06
Full Ahead	87	10.61	10.12
Half Ahead	67	7.72	7.46
Slow Ahead	47	4.41	4.23
Dead Slow Ahead	33	2.70	2.56
Dead Slow Astern	-33	-1.98	-1.78
Slow Astern	-47	-2.80	-2.54
Half Astern	-67	-4.11	-3.74
Full Astern	-87	-5.47	-5.00

Turning Circle



Outline



Particulars

LPP	191.50 [m]
LOA	200.00 [m]
Beam	32.24 [m]
TF/TA	11.00/11.00 [m]
Disp	55689 [Tons]
Lateral wind area	2331 [m^2]
Propeller NA dir	0.0
# Blades	0
Diameter	5.8 [m]
Engine Diesel kW	9466 [kW]
Bow Thruster kW	2180.3 [kW]
Stern Thruster kW	- [kW]
Air draft	1.00 [m]

Figure 94 Bridge poster Roberta

Atlas Ship 3601

Manoevering Characteristics

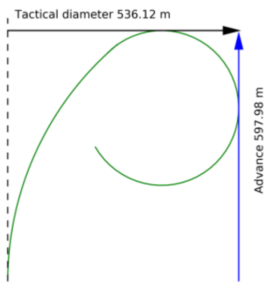
Parameter	Tanker	IMO limit
Turning circle, Advance	2.9 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.6 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	11.2 deg	14.8 deg
10/10 zig-zag, 2nd overshoot angle	34.7 deg	32.2 deg
20/20 zig-zag, 1st overshoot angle	21.4 deg	25.0 deg
Crash stop, Track reach	14.6 · Lpp	15 · Lpp

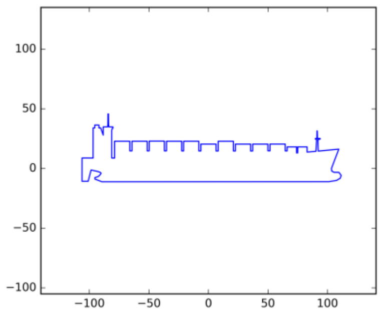
Rudder details

Parameter	
Number of rudders	1
Type of rudder	Semi Spade
Area of Rudder (movable part) [m^2]	39.84
Total rudder Area/(Lpp x T) [%]	1.76
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	35

Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Full Ahead	102	20.5	Grounded
Sea	71	15.9	14.1
Half Ahead	54	11.5	10.9
Slow Ahead	38	8.0	7.2
Dead Slow Ahead	27	5.0	3.2
Dead Slow Astern	-27	-2.3	-1.5
Slow Astern	-38	-4.1	-2.2
Half Astern	-54	-7.9	-4.7
Full Astern	-71	-10.5	-8.4





LPP	206.2 [m]
LOA	215.6 [m]
Beam	32.20 [m]
TA/TF	11.00 / 11.00 [m]
Disp	48523 [m^3]
WSA	8473 [m^2]
1 Propeller FP	Right Handed
# Blades	5
Diameter	7.00 [m]
Engine Diesel kW	20250[kW]
Bow THruster kW	735 [kW]
Stern THruster kW	-1 [kW]
Air draft	45.77 [m]

Figure 95 Bridge poster Atlas

Costa Luminosa

Manoevering Characteristics

Parameter	CRUISE	IMO limit
Turning circle, Advance	2.85 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.87 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	7.0 deg	20.0 deg
10/10 zig-zag, 2nd overshoot angle	9.6 deg	40.0 deg
20/20 zig-zag, 1st overshoot angle	16.9 deg	25.0 deg
Crash stop, Track reach	5.75 · Lpp	15 · Lpp

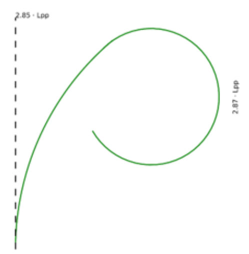
Rudder details

Parameter	
Number of rudders	2
Type of rudder	Azipods
Area of Rudder (movable part) [m^2]	N.A
Total rudder Area/(Lpp x T) [%]	N.A
Rudder speed (two Pumps) [deg/s]	2.82
Max. rudder Angle [deg]	360.0

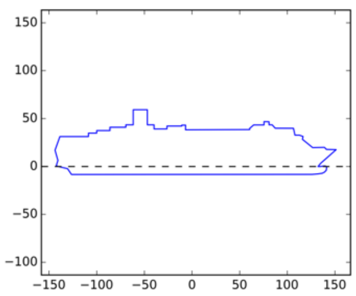
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	142	23.9	Grounded
Full Ahead	130	22.2	Grounded
Half Ahead	113	19.4	11.2
Slow Ahead	70	11.2	9.6
Dead Slow Ahead	50	7.3	6.3
Dead Slow Astern	-25	-2.2	-1.9
Slow Astern	-40	-3.8	-3.5
Half Astern	-60	-5.8	-5.5
Full Astern	-110	-11.3	-10.4

Turning Circle



Outline



Particulars

LPP	265.4 [m]
LOA	294.0 [m]
Beam	32.25 [m]
TA/TF	8.10 / 8.10 [m]
Disp	48837 [Tons]
Lateral Wind Area	10000 [m^2]
Propeller FP	Azipod, Inward
# Blades	4
Diameter	5.5 [m]
Engine Diesel kW	35200 [kW]
Bow THruster kW	5630 [kW]
Stern THruster kW	0 [kW]
Air draft	59.47 [m]

Figure 96 Bridge poster Costa Luminosa

M/V Tor Magnolia Loaded Ship 3297

Manoevering Characteristics

Parameter	RORO	IMO limit
Turning circle, Advance	2.67 Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.8 Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	11 deg	15.6 deg
10/10 zig-zag, 2nd overshoot angle	18 deg	33.4 deg
20/20 zig-zag, 1st overshoot angle	17 deg	25.0 deg
Crash stop, Track reach	4.5 Lpp	15 · Lpp

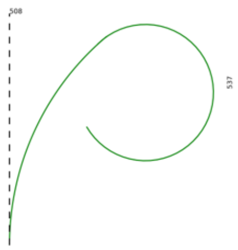
Rudder details

Parameter	
Number of rudders	1
Type of rudder	standard
Area of Rudder (movable part) [m^2]	19.2
Total rudder Area/(Lpp x T) [%]	1.31
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	45.0

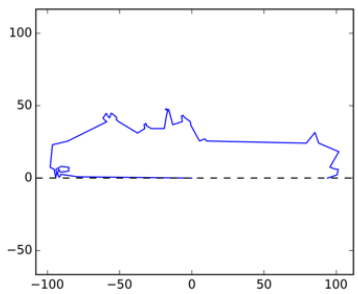
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	123	23.5	Grounded
Full Ahead	109	20.4	Grounded
Half Ahead	103	12.9	11.2
Slow Ahead	103	7.4	7.0
Dead Slow Ahead	103	3.4	3.2
Dead Slow Astern	103	-5.6	-5.1
Slow Astern	103	-8.6	-7.8
Half Astern	103	-13.0	-10.9
Full Astern	123	-14.4	-11.9

Turning Circle



Outline



Particulars

LPP	190.29 [m]
LOA	199.8 [m]
Beam	26.50 [m]
TA/TF	7.70 / 7.70 [m]
Disp	22884 [Tons]
Lateral Wind Area	4248 [m^2]
Propeller CP	COUNTER-CLOCKWISE
# Blades	4
Diameter	6.1 [m]
Engine Diesel kW	20070 [kW]
Bow THruster kW	2208 [kW]
Stern THruster kW	1766 [kW]
Air draft	40.00 [m]

Figure 97 Bridge poster Tor Magnolia

M/V Melusina Loaded Ship 3583

Manoevering Characteristics

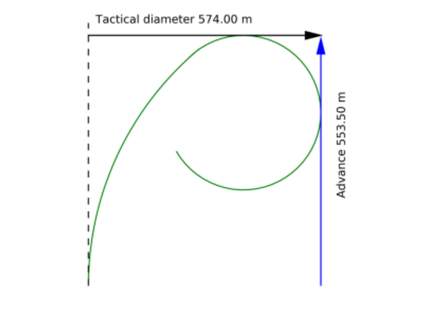
Parameter	Tanker	IMO limit
Turning circle, Advance	2.7 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.8 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	9.6 deg	13.3 deg
10/10 zig-zag, 2nd overshoot angle	17.5 deg	30.0 deg
20/20 zig-zag, 1st overshoot angle	16.6 deg	25.0 deg
Crash stop, Track reach	4.65 · Lpp	15 · Lpp

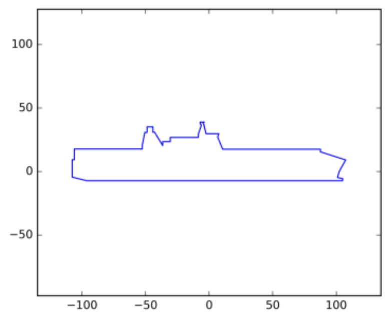
Rudder details

Parameter	
Number of rudders	1
Type of rudder	Flap (Becker)
Area of Rudder (movable part) [m^2]	18.24
Total rudder Area/(Lpp x T) [%]	1.156
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	45

Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Full Ahead	123	23.1	Grounded
Sea	109	20.2	Grounded
Half Ahead	103	12.6	11.1
Slow Ahead	103	7.2	6.8
Dead Slow Ahead	103	3.3	3.1
Dead Slow Astern	103	-5.7	-5.3
Slow Astern	103	-8.7	-8.0
Half Astern	103	-13.1	-11.4
Full Astern	123	-14.6	-12.1





LPP	205.0 [m]
LOA	215.0 [m]
Beam	26.50 [m]
TA/TF	7.70 / 7.70 [m]
Disp	25341 [m^3]
WSA	6200 [m^2]
1 Propeller CP	Counter-clockwise
# Blades	4
Diameter	6.10 [m]
Engine Diesel kW	20100[kW]
Bow THruster kW	2 x 1500 ~ 2 x 20.4 t [kW]
Stern THruster kW	2 x 1200 ~ 2 x 16.3 [kW]
Air draft	39.04 [m]

Figure 98 Bridge poster Melusina

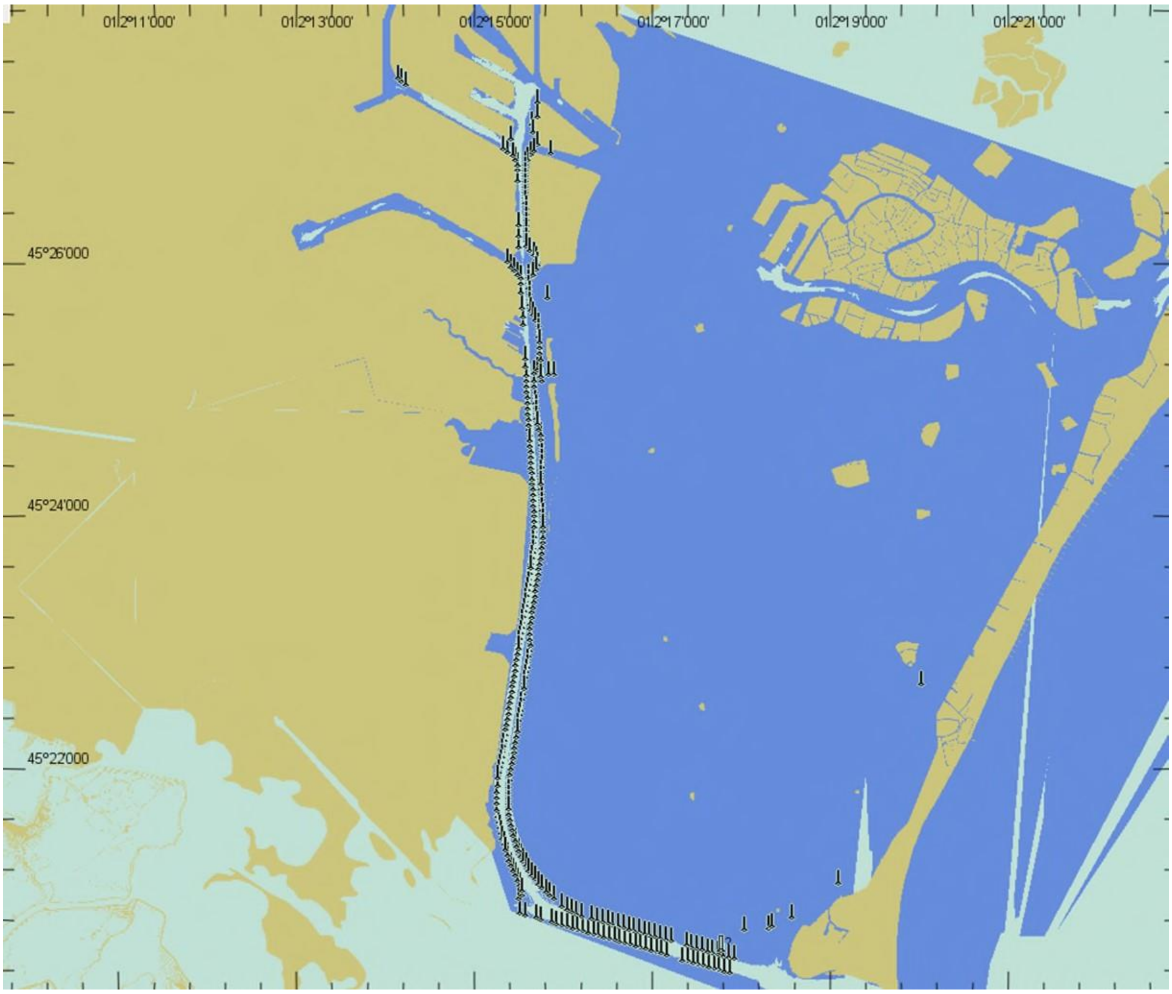
APPENDIX C

ENVIRONMENT DESCRIPTION

Area Model Generation

“Venice_2021”

Date: 2022-05-11



Introduction

The area "Venice_2021" is based on the following data

- Data provided from Port of Venice and received January- April 2022.
- Currents, waves and tide based on input from DHI srl.
- Banks are present along the channel
- Depths provided by DHI srl.

Area Geographical Limits

The environment model of "Venice_2021" have been developed to cover the area shown in Figure 2.1 below.

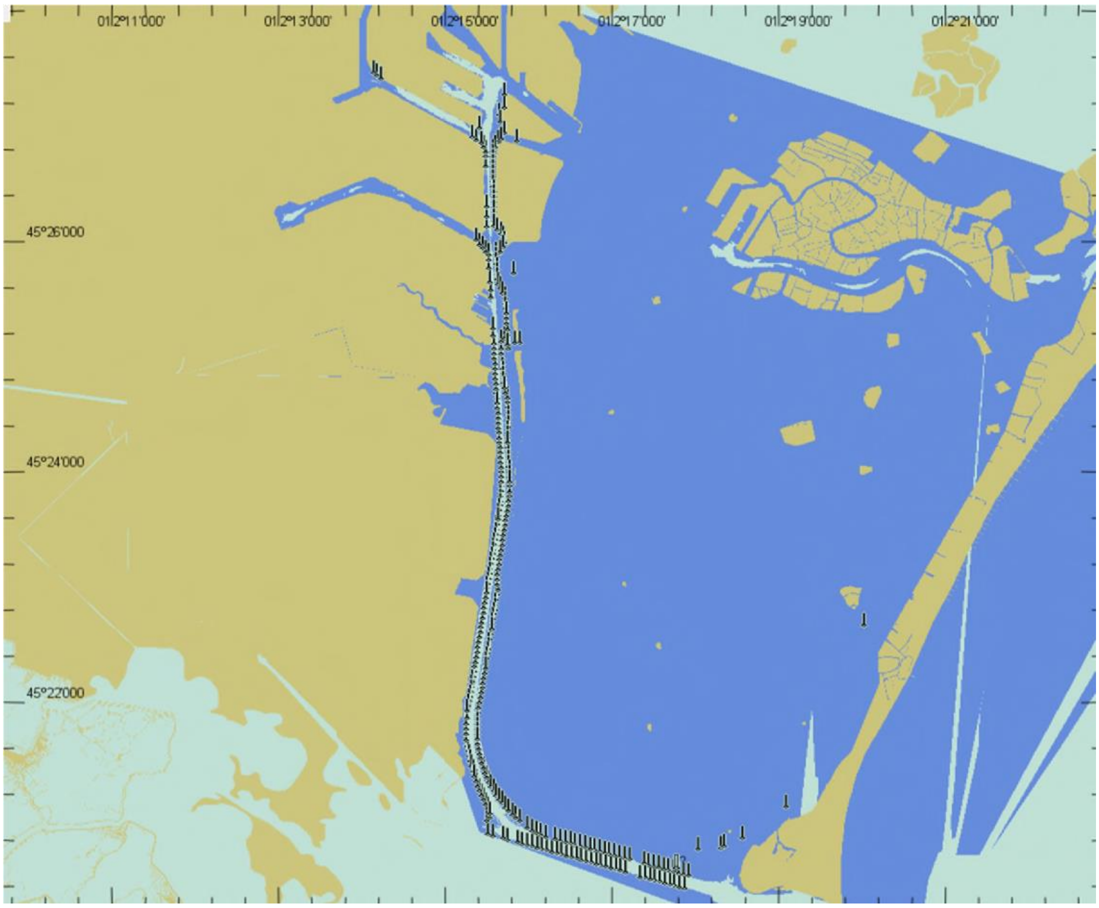


Figure 2-1 Area Coverage

The limits are:

SW: 45 08 000.000 N, 012 03 000.000 E
NE: 45 38 000.000 N, 012 37 000.000 E
Origin: 45 00 000.000 N, 012 10 000.000 E

Input Data

Bathymetry

Bathymetry were provided by DHI srl.

Existing layout

Below is shown the **10 m depth curve** for the whole passage from Malamocco entrance to the Cruise terminal for existing layout.

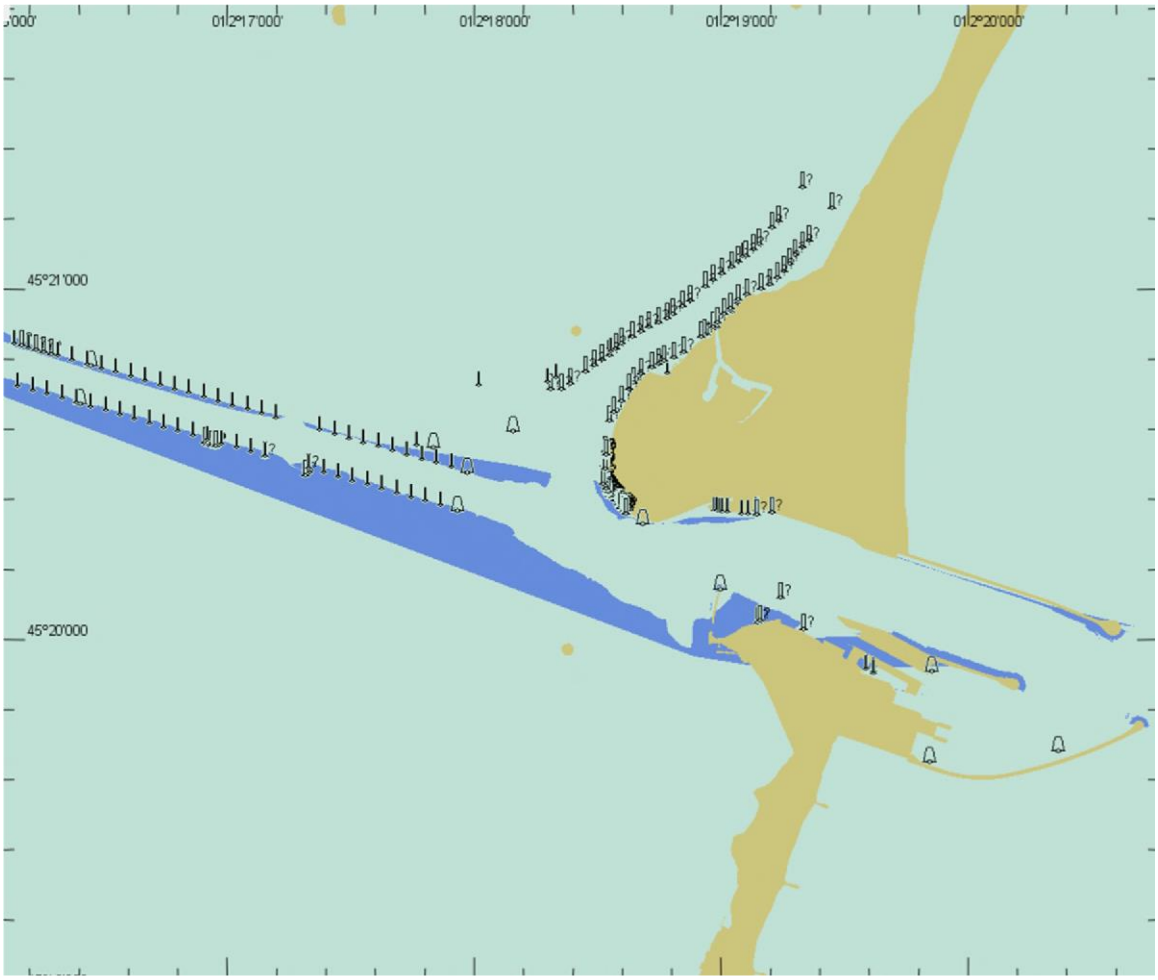


Figure 3-1 Depth curve 10 m

Figure 3-2 Depth curve 10 m

Figure 3-3 depth curve 10 m

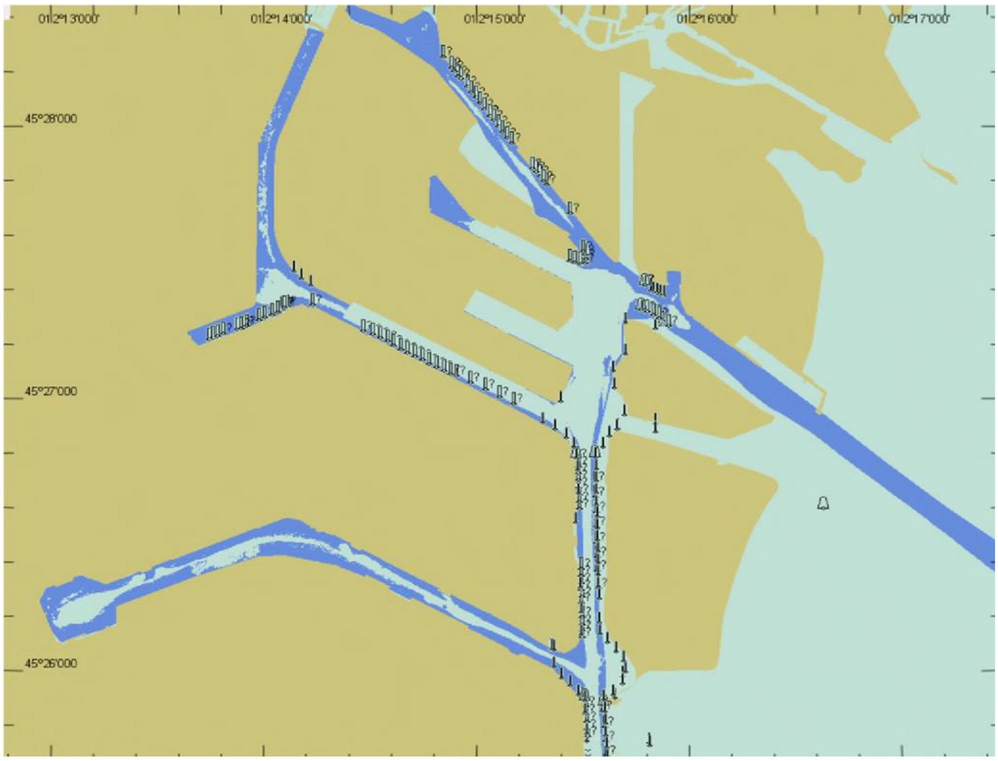


Figure 3-4 10 m depth curve

Figure 3-5 Depth curves at Fusina basins

Land Elevations

Land elevation were taken from Google and earth explorer.

Aids to Navigation

Aids to navigation was derived from the delivered data from Port of Venice. See section 1.

Figure 3-6 Markings Venice

Tidal Elevations

Tidal elevation was delivered by DHI srl.

Currents

Currents was delivered by DHI srl.

Waves

Waves was delivered by DHI srl.

Wind

Wind has to be set directly in the simulator.

Fenders

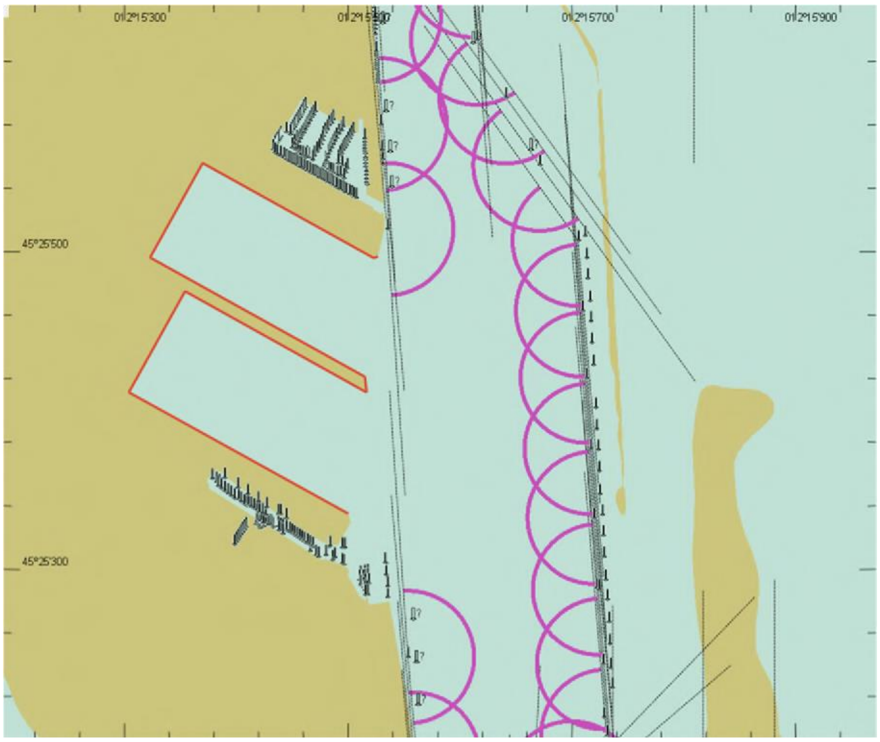


Figure 3-7 fenders in Fussina

Banks

Bank were implemented along the channel.

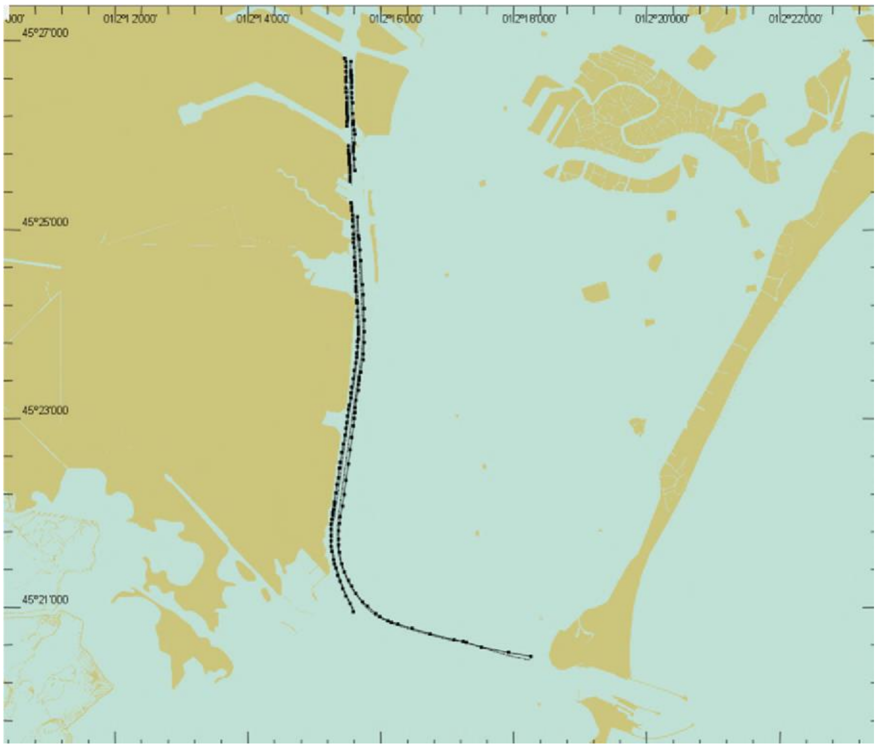


Figure 3-8 Banks Venice (black lines)

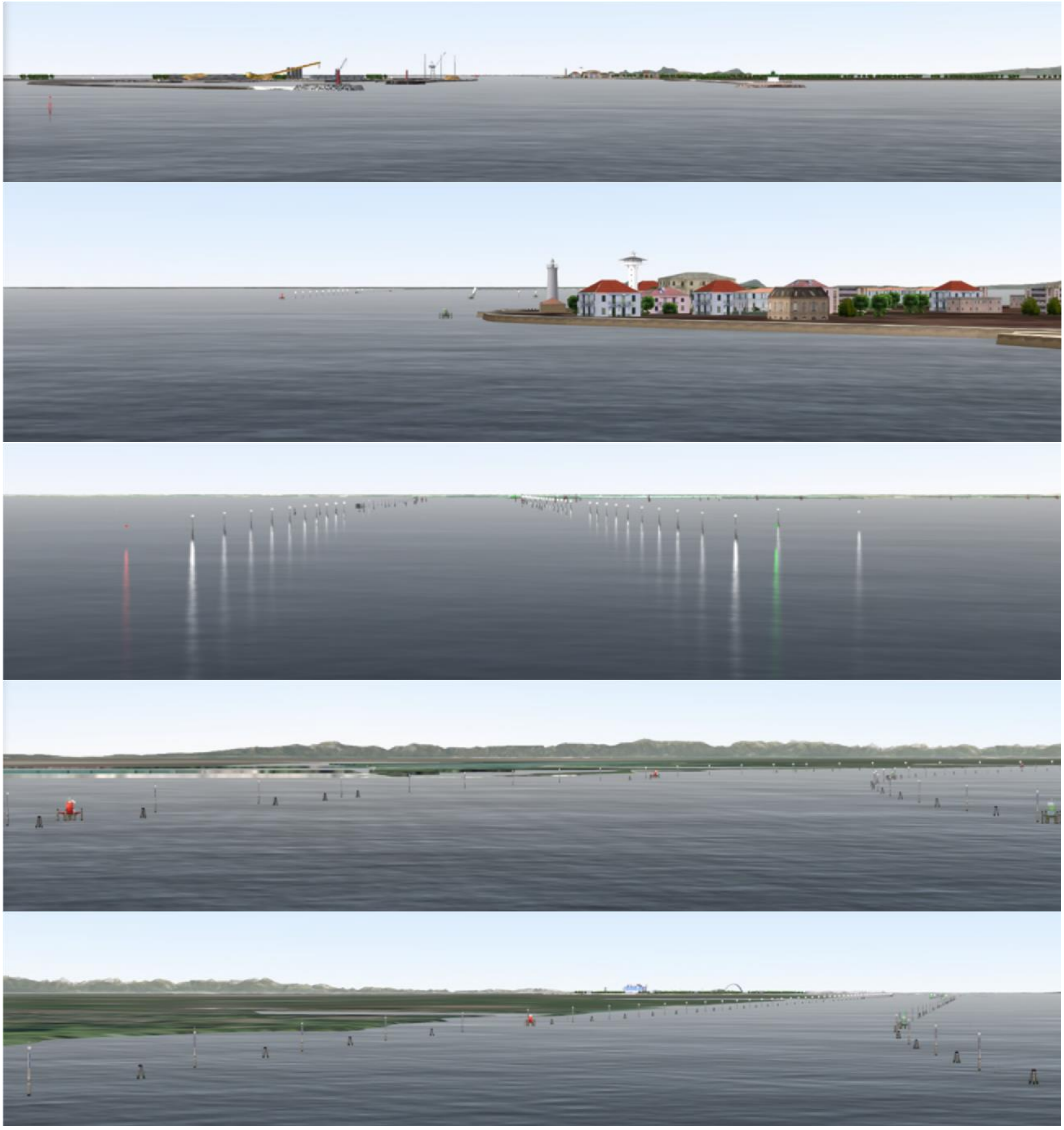
Level of Detail

No level was outlined. Level is I in the port.

Other Information

No other information was used as basis for the model.

Visual database Photos



APPENDIX D

WIND IN THE SIMULATOR

Wind definitions in the simulator

Wind definitions in relation to the simulators wind speed indicator versus the ships wind speed indicator.

In the simulator the wind speed is given in “meteorological wind speed”. This wind speed is not equal to the wind speed read from the wind indicator of the ship. As a tentative comparison the following facts and assumptions can be given:

Wind indicator registers the wind speed e.g. at 35 metres height.

Coefficient for calculating wind forces in the simulator refers to wind speed at 10 metres height and a mean value of a 10-minute sampling period.

Wind information from meteorological sources should refer to wind at 10 metres height.

Read-out from a wind indicator will typically refer to the mean value of a 5 second sampling period.

The variation of the mean wind in the height z above ground level is found by the formula:

$$u_z = u_{10} \times \left(\frac{z}{10}\right)^{\alpha}$$

u_z = Wind speed in a certain height

u_{10} = Wind speed at 10 metres height

α = Power constant (0,12 over sea, 0,16 over land, 0,28 over town).

z = Wind speed indicator height above the surface

Using Engineering Sciences Data Unit (ESDU) 72026 we find the following ratio between “Max 5 second wind” and “mean 10 minutes wind” equal to 1,25.

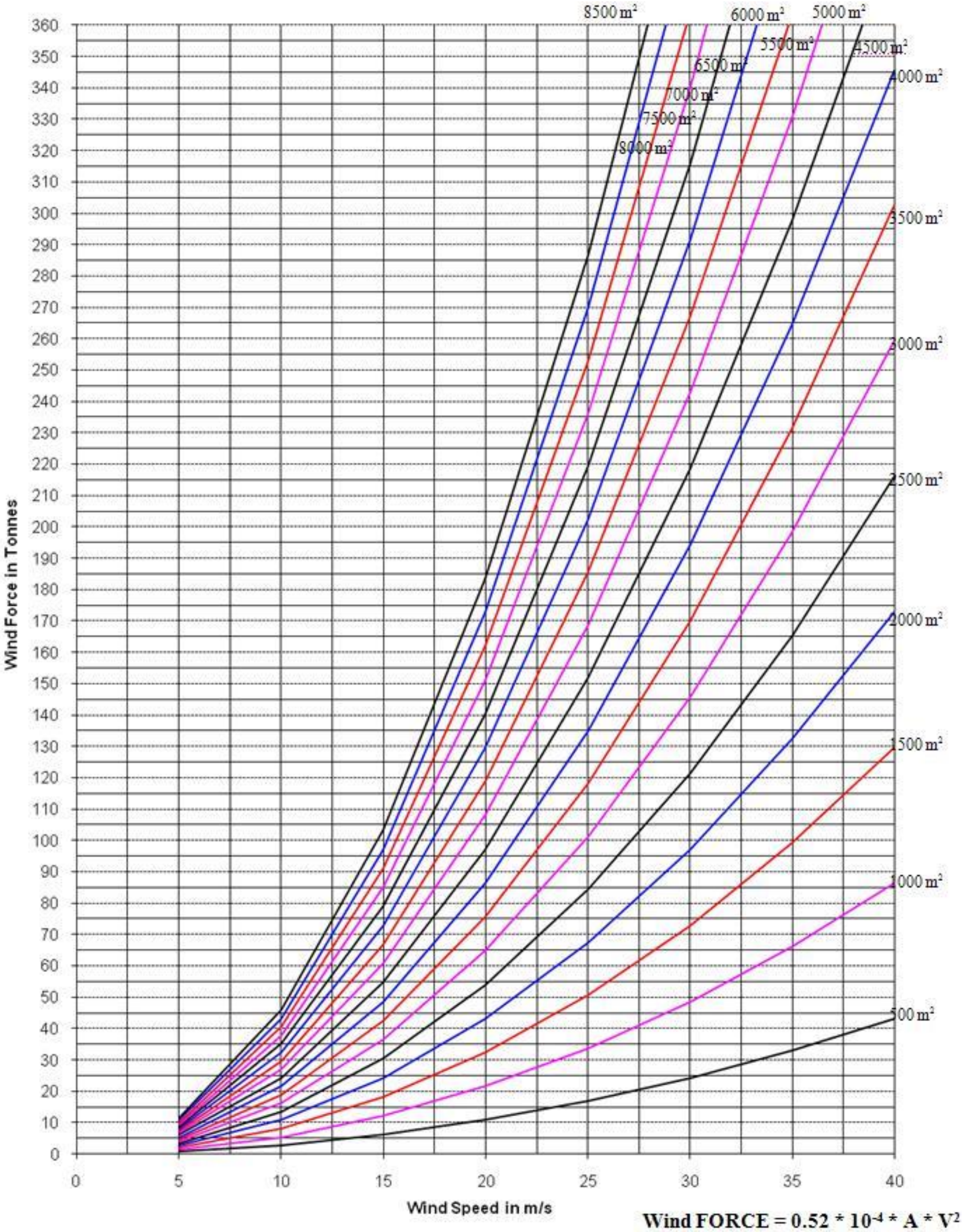
Example:

Wind read out on wind indicator (on ship, height 35 m) = 25 m/s

10 min. mean wind at e.g. 35 m height = 25 / 1,25 = 20 m/s

10 min mean wind at 10 m height = $20 / \left(\frac{35}{10}\right)^{0,12}$ = 17,2 ms

This means that what the navigator correctly reads as a wind speed of 25 m/s corresponds to a "meteorological" wind speed of 17,2 m/s.



Wind FORCE = $0.52 * 10^{-4} * A * V^2$
A = Beam Wind area in m^2
V = Wind speed in m/s

Approximate wind forces; standard formula used by navigators.